UNIVERSITY COLLEGE LONDON

Investigating Individual Preferences for New Mobility Services: the Case of “Mobility as a Service” Products

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Thesis Submitted to

The Faculty of the Built Environment, The Bartlett

University College London

In Candidacy for the Degree of

Doctor of Philosophy in Energy and Transport

2020

DECLARATION

I, Melinda Beatrix Matyas, confirm that the work presented in Chapters 1, 2, 3, 5, 7, 8 and 9 of this thesis are my own. Any information derived from other sources is clearly indicated in the thesis. In Chapter 4, the formulation of the idea for the four MaaS pillars originates from Prof. Maria Kamargianni, but the discussion and writeup is my own. The survey designs in Chapter 6 were done by me, however they were coded with Ruby on Rails by Sridhar Raman and the graphic design used for the presentation of MaaS in Case Study 2 was done by Cormac McGloin. In addition, the survey design for Case Study 2 incorporates feedback from several MaaS4EU project partners.

Throughout the thesis, where information has been derived from other sources, this has been acknowledged. My supervisors gave me guidance and feedback on all parts of the thesis.

Signature

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Date

04/02/2020

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ABSTRACT

In just a few years, the Mobility as a Service (MaaS) concept has gone from an idea discussed by very few, to being a prominent topic in any transportation related debate. However, within this time, there have only been few rigorous studies that explore the various aspects of MaaS. This thesis aims to contribute to existing knowledge by providing empirical evidence on individual preferences for MaaS plans and their components. In doing so, first desk-research is conducted to summarise existing MaaS schemes and outline the MaaS ecosystem. Next, MaaS surveys that are able to capture individual preferences for MaaS products are designed and specific challenges in the design process identified. The MaaS surveys, including MaaS plan stated preference experiments, are applied in two case study areas of London and Greater Manchester. Using the novel data collected, individual preferences for MaaS plans are examined using two distinct studies: (1) a mixed methods research conducted in London, which expands the survey by adding a qualitative (in-depth interview) element to examine user preferences for MaaS plans and the ways individuals choose between them; and (2) a latent class choice model based on data collected from Manchester to examine whether there is heterogeneity in preferences. Finally, implications for industry and policy stakeholders are discussed as well as interventions that can best support the widespread adoption of MaaS.

The results of this thesis show there is interest in the concept of MaaS among potential users as many see value in a single app that integrates different transport modes into a single service. In general, individuals are hesitant in purchasing pre-payed MaaS plans and would be more comfortable with a pay-as-you-go product option. While many people are reluctant towards MaaS plans, the results indicate that heterogeneity exists in preferences towards them and there are different user groups based on socio-demographic characteristics and current mobility habits. Smaller, less expensive plans including modes such as public transport and bike sharing can be used to target students or middle-income people with have high overall mode usage. Larger, more expensive plans that include modes such as taxi and car sharing in addition to public transport, will be attritive to individuals who are likely younger, male, well-educated, have higher income and already use many transport modes. Older population groups, individuals with low income and those that do not use any transport modes or are uni-modal are least likely to adopt MaaS plans.

The thesis also provides insights into individuals' preferences towards transport modes within MaaS plans. The analysis showed that respondents classify modes within MaaS plans into three categories: 'essential' modes that are pivotal to the individual and which

they most likely already frequently use; ‘considered’ modes are those that they would be willing to include but may not yet use; and ‘excluded’ modes are those that they definitely do not want in their plans and would eliminate any plan that included these. Public transport consistently proved to be an essential mode, while taxi, car sharing and bike sharing could be ‘essential’, ‘considered’ or ‘excluded’ depending on the characteristics of the individual.

The main contributions of this thesis are the novel data collected in two case study cities about individuals’ preferences for MaaS plans and the findings gained through the analysis providing insights into possible target audiences and product designs for MaaS plans.

IMPACT STATEMENT

The research developed through this thesis provides benefits both inside and outside academia. The MaaS concept is still in early stages of development and there is a limited number of academic works on the topic. As such, the methods and results presented in this thesis are pioneering in the study of individual preferences for MaaS.

As there are several uncertainties related to MaaS, researchers are finding it challenging to examine consumer preferences for MaaS and its products and the methods of this study are able to support future investigations in this area. The detailed demonstration of the MaaS survey design provides the first comprehensive 'prototype' that can be used, improved, adjusted and tailored for future studies in any type of city/area.

For researchers, the outcomes enrich the literature on individuals' preferences for MaaS products and enable further developments and a baseline for comparison. For policy makers and industry players the benefit is twofold. First, the detailed explanations and evaluations of the MaaS concept help improve the overall understanding of what MaaS entails and possible challenges that come with its implementation. As there is still wide confusion regarding what MaaS is, the work conducted through this thesis (and the dissemination activities below) contributed, and continue to contribute to better understanding of MaaS. Second, the results of the analysis of individuals' preferences provide valuable insights for any organisation wanting to implement MaaS systems, design and price MaaS products.

The research conducted through this thesis has contributed to the following dissemination activities:

Academic Journal Publications:

- Two papers published in *Transportation*
- One paper published in *Transportation Research Procedia*
- One paper in press in the *European Transport Research Review*

Academic Conference Presentations:

- 96th, 97th , 98th and 99th Transportation Research Board Annual Meeting (Washington, DC; 2017, 2018, 2019, accepted for 2020)
- 7th Symposium of European Association for Research in Transportation (Athens, 2018)
- Transportation Research Arena conference (Vienna, 2018, accepted for Helsinki 2020)
- 5th International Choice Modelling Conference (Cape Town, 2017)

- 20th EURO Working Group on Transportation Meeting (Budapest, 2017)
- Hungarian Transportation Research Conference (Gyor; 2017)
- Smart Urban Policy Futures Workshop (Greenwich, 2016)

Reports:

- One Practitioner Briefing prepared for the European Commission about Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning (SUMP) (2019)
- MaaSLab Dictionary (2018)
- One report commissioned by Transport for London (2018)
- One report prepared for the UK Department for Transport (2015)

Industry focused talks and public engagement (invited speaker):

- European Conference on Sustainable Urban Mobility Plans – SUMP (Groningen, 2019)
- Smart Transport for Sustainable Tourism Project Multiplier (London, 2018)
- Workshop on Mobility as a Service and Innovative Mobility Services (Bologna, 2018)
- 3 Revolutions workshop (California Davis, 2018)
- International Road Federation Congress, (New Delhi, 2017)
- Venturefest (Bristol, 2017)

A full list of publications and presentations can be found in Appendix A.

In addition, the work of this thesis has supported discussions with Regional and National transport bodies including, the Department for Transport, Transport for London, Transport for Greater Manchester and Transport for West Midlands. Further, a European Commission H2020 project has directly benefitted from the insights gained through this study for the surveys design.

Finally, collaborations with other academic research groups, such as the Institute of Transportation Studies at UC Davis, the Department of Economics and Business at the Central European University, the Institute for Choice at the University of South Australia, and the Department of Shipping Trade and Transport and the University of the Aegean have evolved as a result of this work.

ACKOWLEDGEMENTS

Undertaking this research has been a life-changing experience. It has been both more challenging and more rewarding than I would have ever expected. It pulled me out of my comfort zone and pushed me to work for longer and harder than I had ever done before. Coming out on the other side has made me a better, stronger and more confident researcher and person. This would not have been possible without the support and guidance from a range of people.

First and foremost, I would like to thank my supervisor, Dr. Maria Kamargianni. As Maria's first PhD student, we grew and learned together throughout the last years. She always pushed me to do more and be a better whole rounded researcher. Even though this regularly included giving me so many tasks that I would doubt whether it was physically possible to do all of them, she greatly widened my learning experience throughout my PhD. I would not be where I am without her and I will forever remain grateful for this.

My sincere thanks also goes Professor Andreas Schäfer for his support and to Professor Moshe Ben-Akiva, Professor Amalia Polydoropoulou and Dr. Athina Tsirimpa for their insightful comments and valuable feedback, during the survey design and modelling parts of my research. I would also like to thank my examiners Dr. Palacin and Dr. Kaparias for their constructive feedback that significantly improved the quality of my thesis.

I thank my fellow students and researchers from around the world for the stimulating discussions and for being comrades during the tough times over the past years. In particular, I am very grateful for Dr. Weibo Li, who was always there when I needed someone to discuss modelling issues with.

The development of the surveys and the data collection in this thesis were a very challenging tasks and I am very grateful for the help and support of several people during this process. First, I would like to thank Sridhar Raman for helping with the development of the survey tools. Next, I would like to thank Moshe Ben-Akiva, Bilge Atasoy and the MIT Intelligent Transport Systems (ITS) Lab as well as Fang Zhao and the Singapore-MIT Alliance for Research and Technology (SMART) for providing us access to the Future Mobility Survey. Finally, I would like to thank Exterion Media's Work.Shop.Play community panel and the RCUK Centre for Energy Epidemiology for supporting parts of my data collection.

Thanks are also due to the UK Engineering and Physical Sciences Research Council (EPSRC; Grant No. 1529045) for funding my PhD studies. In addition, I would also like

to acknowledge the EC H2020 funded project MaaS4EU (Grant No. 723176) for providing the data for parts of my research.

I would also like to express my heart-filled gratitude my family for all their love and encouragement. Mama, Papa, you raised Viktor and I to always be curious and ask as many questions as we can – I put it down to you that now both of us are pursuing PhDs! I would like to dedicate this thesis to you – mindent nagyon köszönök!

Finally, a special thanks is reserved for my fiancé and other half Dave, for everything he has done for me over the last years. Having gone through countless highs and lows - this man never stopped loving and supporting me. Bouncy, I am so excited to be spending the rest of my life being weird with you.

FOREWORD

Recent years have seen the emergence of a number of new mobility technologies, services and concepts, many of which have fundamentally changed the way mobility is provided. This thesis focuses on one of these, namely the Mobility as a Service (MaaS) concept. Looking more specifically at the demand for MaaS products, this research explores how to design surveys and analyse the results to gain insights into consumer preferences for MaaS plans.

During the inception of this thesis (Autumn of 2014), MaaS was not much more than an idea with very few practical implementations and a concept discussed by very few. Fast forward four years and MaaS has taken the transportation industry by storm. It is now being implemented in several areas around the world and is high on the agenda of most mobility related debates. One may say, that choosing MaaS as a topic of this thesis was both risky and lucky at the same time. The risk, and related difficulty, arose from the fact that MaaS was indeed just a concept, with several uncertainties when this research began (many of which still remain to date). It was a very real possibility, that it would not get further than a vision and would be overlooked by the industry. However, choosing MaaS as a topic so early on was also lucky, as this research could develop and grow together with the concept. The reader will notice, that several lessons were learned along the way, both with regards to the MaaS itself, and how to do research on such a complex and novel concept. The author hopes that these, alongside the results of the thesis, will prove to be valuable to academia, industry and the sector as a whole.

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List of Abbreviations

AAPOR	American Association for Public Opinion Research
AIC	Akaike Information Criterion
API	Application Programming Interface
ASC	Alternative Specific Constant
AV	Autonomous Vehicle
AVV	Aachener Verkedrsverbund GmbH
B2B	Business to Business
B2C	Business to Customer
BEV	Battery Electric Vehicle
BIC	Bayesian Information Criterion
BUD	Budapest
CAPI	Computer Assisted Personal Interview
CASI	Computer Assisted Self Interview
CATI	Computer Assisted Telephone Interview
DCM	Discrete Choice Model
DfT	Department for Transport
EC	European Commission
GHG	Greenhouse Gas
GSM	Global System for Mobile communications
HCM	Hybrid Choice Model
HSTL	Hayfield Sustainable Transport Ltd
ICT	Information and Communication Technology
IID	Independent and identically distributed
LCCM	Latent Class Choice Model
LMS	London Mobility Survey
LTDS	London Travel Demand Survey
LUX	Luxembourg
MaaS	Mobility as a Service
MAN	Manchester
MMNL	Mixed Multinomial Logit model
MNL	Multinomial Logit model
MO	MaaS Operator
MR	Mobility Record
MSP	Mobility Service Provider
PAYG	Pay as You Go
PAV	Personal Autonomous Vehicle

PE	Priority Evaluator
PT	Public Transport
RP	Revealed Preference
SA	Stated Adaptation
SAV	Shared Autonomous Vehicle
SLA	Sales-Lentz
SP	Stated Preference
UCL	University College London
UK	United Kingdom
VMT	Vehicle Miles Travelled
WTP	Willingness to Pay

CHAPTER 1: INTRODUCTION

1.1. CONTEXT AND MOTIVATION

Urban mobility is undergoing significant change. The increasing influx of people into cities and surrounding areas has resulted in rising levels of congestion and air pollution. At the same time, potential solutions are becoming available due to the emergence of the sharing economy, technological advancements and the extensive introduction of new mobility services. Jointly, they lead to the MaaS concept, which is at the heart of this thesis.

1.1.1 The problem: Urbanisation, congestion and pollution

A city's transport system plays a fundamental role in social cohesion, economic competitiveness and sustainable growth. In recent decades, urbanisation has caused people who wish to live in close proximity to business and commercial centres to flock to metropolitan areas. However, many cities have developed over centuries and were thus not engineered to withstand such increased traffic densities. The growth in population and the related upsurge of traffic has put mounting pressure on urban transportation systems and, in turn, has started to impact the economy and society (Bull and Thomson, 2002).

The United Kingdom (UK) serves as an illustrative example. In the UK's ten most congested cities, road traffic congestion has led to at least 30% added travel time (TomTom, 2017). Between 2014 and 2015, the total vehicle delay in London resulted in 10.9 million days (Intrix, 2017). According to the Department for Transport (DfT), this situation will exacerbate further, given a predicted 55% growth in traffic levels by 2040 (Local Government Association, 2017). This increase in congestion impacts the economy and public health. In 2016, the total direct and indirect cost of congestion in London was estimated to be in excess of £6 billion (Inrix, 2017). The estimated cost of congestion for the whole UK economy between 2013 and 2030 is £307 billion (Centre for Economics and Business Research, 2017). The associated public health impacts are also large. Traffic contributes to an estimated 40,000 premature deaths a year from air pollution (Royal College of Physicians, 2016). Exposure to outdoor air pollution has been linked to cancer, asthma, stroke, obesity and diabetes (Royal College of Physicians, 2016).

The problems that are caused by the increased traffic volumes are clear and governmental bodies and city councils are eager to find solutions. A pivotal area of

interest is the reduction of private vehicle ownership and use, which are well-documented contributors to congestion, air pollution and inefficient land use (Gärling and Steg, 2007; Jeekel, 2016; Stevenson, et al., 2016). One solution is fostering behaviour change by the promotion of transport alternatives, thereby decreasing private vehicle use and subsequently, their ownership.

However, as modern city dwellers' travel needs are diverse, dynamic and require flexibility, there is generally no single transport mode that can cater for them under all circumstances. In the absence of private vehicle use, multimodal options are thus needed to service the unique travel requirements of each individual.

1.1.2 The solution: Sharing economy, technological advancements and new services

The past decade has brought about a significant shift in the way goods and services are provided. As millennials are approaching their prime spending years, their progressive attitudes towards ownership have supported the evolution of the sharing economy and the emergence of related services such as Airbnb and Zipcar. Capitalizing on this shift in attitudes, technological developments and the widespread availability of information and communications technology (ICT) devices, recent years have seen the introduction of a number of new mobility services. Car sharing, bike sharing, on-demand transport, and ride hailing are now commonplace in many urban areas. Additionally, the next generation of innovations such as autonomous vehicles and drones are now being tested. All these new services, in combination with traditional public transport, could provide a viable alternative to private vehicle use.

Public transport on its own provides economic, environmental, health and land use benefits, such as more efficient road capacity utilisation, decreased long-term energy demand and increased walking thus contributing to public health (Rissel, et al., 2012; American Public Transport Association, 2018; Sustrans, n.d.; International Institute for Applied Systems Analysis, 2012). Car and bike sharing also offer several advantages over private vehicle ownership and use. Car sharing programmes significantly decrease vehicle miles travelled (VMT) (Martin, Shaheen, and Lidicker, 2010; Clewlow, 2016), while bike sharing can also shrink private vehicle dependence (Fishman et al., 2014). In many cases, those who use shared vehicles sell their own cars, delay vehicle purchase or do not even buy a vehicle in the first place, leading to an overall decrease in private vehicle ownership (Clewlow, 2016; Fishman, et al., 2014; Shaheen, Cohen, and Chung). Further, shared modes have shown to have a number of environmental and health benefits. For example, the fuel economy of shared vehicles is higher than that of private automobiles (Martin et al., 2010). In addition to reduced levels of VMT, car sharing can

lead to significant reductions in greenhouse gas emissions (Martin, et al., 2010; Chen and Kockelman, 2016). For example, Chen and Kockelman (2016) found that car sharing members reduce their transport greenhouse gas (GHG) emissions by approximately 51% when joining a car sharing service. In addition, bike sharing has a number of documented health benefits (Woodcock et al., 2014; Rojas-Rueda et al., 2011). For those situations where the above discussed public transport, car sharing and bike sharing alternatives cannot fulfil individual needs, other innovative travel solutions such as on-demand taxi, pooled taxi, demand responsive transport, and - in the future -autonomous taxis and drones can help fill the gaps. Although these modes do raise some potential concerns related to issues such as the efficient use of road space (the discussion on these is out of the scope of this thesis), overall the wide range of available solutions offer city residents a viable alternative for a private vehicle-free lifestyle.

With the assortment of travel options rapidly growing, the transport system is becoming increasingly complex. Users can find it difficult to navigate through the wealth of information sources, mobile applications, tickets and journey planners that are necessary for them to get around. This inconvenience can discourage them from choosing alternative options as opposed to their private vehicles. The need for a single, integrated, user-friendly system has led to the birth of the Mobility as a Service (MaaS) concept, which aims to decrease the pain points that result from multimodal journeys.

1.1.3 The research: MaaS and user preferences for MaaS products

There is no single, universally recognised definition of MaaS (a range of existing definitions will be discussed in detail in Chapter 2). The reason is two-fold. First, the concept encompasses several dimensions, including supply, demand and technology, which are difficult to summarise coherently in a single definition. Second, MaaS is still not at full maturity, and the definition is continuously evolving as the understanding of MaaS develops. As such, any definition needs to be fluid, and adjusted as necessary. In this thesis, the current definition of MaaS as provided by MaaSLab is followed (Kamargianni et al., 2018):

> *"Mobility as a Service is a user-centric, intelligent mobility management and distribution system, in which an integrator brings together offerings of multiple mobility service providers, and provides end-users access to them through a digital interface, allowing them to seamlessly plan and pay for mobility."*

A graphic representation of the concept is provided in Figure 1-1. The MaaS operator (MO) is the intermediate between the mobility service providers (MSPs) and the MaaS users. The MO aggregates the MSPs offerings, that can be transport services, mobility

supportive services or even services that advance traveller experience. While MaaS could include private transport, in this thesis it is assumed to encompass only public and shared mobility services due to their prominence in current market developments (see Chapter 4). Integral parts of the MaaS platform are multimodal journey planning, real time information, booking, payment and ticketing functions and a user account (MaaS Allience, 2017; Transport Systems Catapult (TSC), 2016). This means that the MaaS platform provides both information and planning integration and payment and ticketing integration to create a seamless user experience.

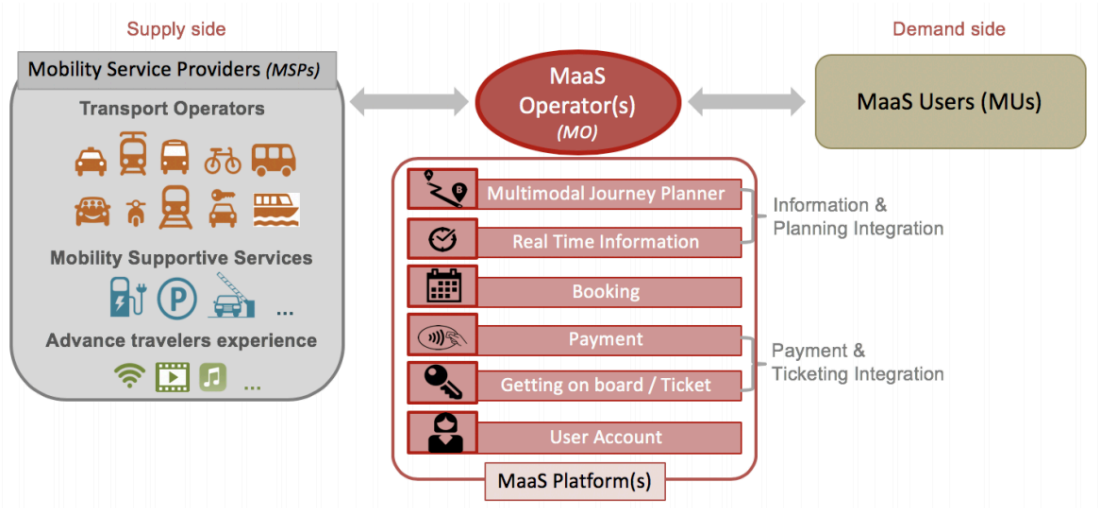

Figure 1-1: The MaaS concept (Kamargianni et al. 2018)

MaaS offers a single digital interface (e.g. an app) through which users can plan journeys, pay for and access all transport modes (Lyons et al., 2019; Atkins, 2015). Users can also have 'one-stop-shop' access to the transport modes directly through the MaaS platform. The MO offers users the option to purchase and use MaaS products, which include, but are not limited to pay-as-you go access to services and MaaS plans (Hensher, 2017; Jittrapirom et al., 2017). MaaS plans, which are a type of MaaS products, are bundled MSP products that are offered by the MO to its customers as an easy way to have one-stop-shop access to a variety of services (Hietanen, 2016; Hensher, 2017; Kamargianni et al., 2019). These are conceptually very similar to product bundles frequently used in other sectors such as the telecommunication industry.

MaaS is a solution that integrates many aspects of travelling and offers a unified platform to guide individual decision making (Atkins, 2015). However, there are several challenges in implementation, such as achieving commercial agreements between parties, opening up APIs (application programming interfaces) and data protection concerns (Polydoropoulou, et al., 2019).

One area where challenges are being faced is with regards to the preferences of potential end users and understanding how to create MaaS products that best fit their heterogeneous mobility needs. Without well-designed products, that actually provide tangible benefits to users, the concept may struggle to succeed. However, by conducting prior consumer analysis and careful product design, MaaS could have the potential to persuade people to choose transport modes other than their private vehicles. By looking at it this way, MaaS could be viewed as a potential mobility management tool, that aims to alter the way people perceive travel alternatives as opposed to physically altering the options themselves (Headicar, 2009; Bamberg et al., 2010). As stated by (Borg, 2004), whether travellers are 'able' to take a certain transport mode is determined by its availability and individual constraints; whereas whether they 'want' to take a certain mode is determined by information, perception and subjective preference. This means that there is potential to influence people's behaviour without physically changing the objective conditions – which is exactly what MaaS could deliver. In order to achieve this, there needs to be better understanding of the MaaS products that would be of interest to users.

As will be demonstrated in Chapter 2, empirical evaluations of MaaS, its potential products and user preferences are still limited (and were close to non-existent at the start of this research). As such, it is important to understand the concept itself and the options that could be available for MaaS products. The idea of MaaS plans (also called MaaS packages) is of special interest, as they fundamentally change the way services are provided. Since they package services from several transport modes into one product, they are a single mobility tool, which aims to cater for users' needs.

The concept of MaaS plans is not yet thoroughly developed. There are several areas of uncertainty including, but not limited to, whether public transport's role in MaaS is in fact as crucial as industry actors believe, what transport modes individuals want in MaaS plans and how much they are willing to pay for these, whether there are differences in the preferences between different user groups, overall what people think of the concept and whether there would be any interest for such plans at all. All the unanswered questions leave not just a small research gap, but rather a huge void that is looking to be filled. In order to start examining these topics, comprehensive consumer research should be conducted. Due to the novelty of both MaaS itself and MaaS plans, research methods need to be transferred and adapted from studies looking at other subjects.

1.2 THESIS AIM, RESEARCH QUESTIONS AND OBJECTIVES

Given the above background, the overarching aim of this thesis is to provide empirical evidence on individual preferences for MaaS plans and their components. In doing so, the following main research questions will be answered:

RQ1: What are the specific challenges of designing surveys that capture individual preferences for MaaS plans compared to choice situations regarding other products or services in the transportation sector?

RQ2: What are the identified user preferences for transport modes within MaaS plans and how do individuals choose between them?

RQ3: To what extent can the preferences for MaaS plans be explained by the characteristics of the decision maker and is there heterogeneity in preferences of different user groups?

RQ4: What policy interventions can best support the widespread adoption of MaaS?

To answer the research questions, the following objectives need to be met:

- Review literature, conduct desk-based research on existing MaaS applications and create an outline of the ecosystem of the MaaS concept;
- Review methods that are appropriate to examine user preferences for new products or services;
- Design MaaS surveys that are able to capture individual preferences for MaaS products and evaluate the process by identifying elements that are unique to MaaS;
- Collect data in the two case study cities of London and Greater Manchester using the MaaS surveys;
- Conduct a mixed methods study including discrete choice modelling, interviews and thematic analysis to examine individual preferences for MaaS plans and their components;
- Analyse the collected data using latent class choice models to examine heterogeneity among individual preferences for MaaS plans and identify MaaS user groups;
- Synthesise the results of the analyses and assess the implications of the results for industry and policy makers.

These objectives are tackled using a combination of both quantitative and qualitative methods. Literature review (both academic and grey literature), desk research, statistical analysis, modelling, focus groups and interviews are all employed during study. Combining such a wide variety of methods allows for rich insights to be gained on a topic that has not been extensively examined before. These approaches will be discussed in detail in the Methodology section.

1.3 THESIS CONTRIBUTION

Early documentations of the MaaS concept date back to only 2014. As such, this subject is comparatively under-researched, which includes the study of user preferences. Even the most recent (2018-2019) publications could not significantly increase our understanding on MaaS survey design and the evaluation of preferences for MaaS products. Also, the novelty of the service and the low rate of development mean that there are a large number of uncertainties in business models and product designs.

MaaS is a fundamentally different way of providing mobility services compared to individual services. As such, there may arise additional difficulties when studying user preferences for MaaS products compared to individual services. Even though there is a substantial number of studies focusing on consumer preferences for transportation services, these tend to narrow down on one specific service rather than a combination of modes. Studies that look at several items together as one product are more frequent in the marketing literature with a focus on product bundles (see Appendix A for details).

The main contribution of this thesis is the collection and analysis of novel data on user preferences for MaaS plans, which provide insights to industry and policy makers on what type of MaaS plans individuals would favour. The innovation of the thesis lies mainly in the following:

1. **The topic,** by focusing on Mobility as a Service and specifically examining user preferences for MaaS products.
2. **The survey design and related evaluation,** by creating a MaaS survey design, including stated preference experiments and identifying specific challenges of this process compared to choice situations regarding other products and services in the transport sector.
3. **The data collection,** by applying the MaaS survey to two case studies in different geographic areas, and gathering unique and valuable data.
4. **The analysis and results,** by applying both quantitative and qualitative research methods to analyse individual preferences for MaaS plans novel insights can be gained with regards to MaaS preferences.

5. **The findings,** by offering guidance to transport practitioners.

1.4 THESIS ORGANISATION

The remainder of the thesis is structured as follows:

Chapter 2 presents the literature review, which synthesises and compares evidence from studies on the MaaS concept and methods to study individual preferences for products and services. The chapter also identifies the research gaps that this thesis aims to fill.

Chapter 3 focuses on the methodology, which first discusses the research philosophy and approach and then details of the research design. The latter includes an outline of the research process and justification of the case study areas and the methodological choices, methods, techniques and procedures used to be able to answer the research questions.

Chapter 4 presents the desk research element of the research process. The two parts of this chapter are (1) a conceptualisation for the MaaS ecosystem and the role users play, and (2) mapping out of existing MaaS services and evaluation of their characteristics.

Chapter 5 includes the process of designing surveys that capture individual preferences for MaaS products. The presented survey design aims to be a guidance document for researchers examining this topic. In addition to survey foundations, it includes MaaS stated preference experiments for various MaaS plan types and possible extensions to the survey that allow for capturing in depth information. It also discusses the challenges of designing a MaaS survey and the limitations of the presented approach.

Chapter 6 uses the survey designs presented in Chapter 5 and applies them to the two case study cities of London and Greater Manchester. The survey design process is discussed. The data collection process is presented, with details about the sample as well as descriptive statistics of the collected data.

Chapter 7 studies individual preferences for MaaS plans, specifically focusing on the favourability of specific transport modes and features within MaaS plans. In doing so, a mixed methods study including both quantitative and qualitative approaches is used. For the quantitative aspect, data collected in London is modelled using a panel mixed logit model. For the quantitative element, the chapter presents the data collection, via interviews, analysis and results. The chapter concludes by bringing together the findings of both elements to culminate take-away points.

Chapter 8 addresses the question of heterogeneity within individual preferences for MaaS plans. A latent class choice model is adopted, which is able to capture differences in

preferences between different user groups. Using data collected in Manchester, the chapter identifies distinct classes of individuals with heterogeneous preferences for MaaS plans. The chapter concludes with additional insights on the reasons behind individuals not wanting to subscribe to MaaS plans.

Chapter 9 provides the conclusions of the thesis. It reviews the research objectives, methods and findings of each of the previous chapters. It also discusses the overall contribution and implication for industry and policymakers. Finally, the limitations and future research directions are also presented.

CHAPTER 2: LITERATURE

This chapter reviews literature on the MaaS concept and the methods that will be used in this thesis. It also highlights the gaps in knowledge that this thesis aims to fill. The chapter has two main sections. The first section focuses on the MaaS concept, including developments that paved the road to MaaS, characterisations of MaaS and the current academic literature on the topic. This section concludes with identifying the gaps in knowledge that literature has not yet sufficiently tackled. The second section reviews relevant methods to study end user preferences for new products and services, including both quantitative and mixed/qualitative approaches.

2.1 MOBILITY AS A SERVICE

2.1.1 Early MaaS developments

The phrase “Mobility as a Service” has only been used in the field of transportation since the pivotal works of Heikkila (2014) and Hietenan (2016). However, the building blocks and central ideas of the concept, such as integrating multimodal transport and offering on-demand solutions to cater for individuals’ needs, have been around for much longer. The following section will discuss key developments that have contributed to the existence of MaaS.

Multimodality is the notion of using multiple transport modes to complete a trip from origin to destination (Shaheen and Christensen, 2014). Historically, the transaction costs for using several transport modes were often prohibitively high (Willing, et al., 2017; Dijk and Montalvo, 2011). Gathering information about the best options, timetables and ticket prices, purchasing several tickets and the inconvenience of complicated interchanges are just some factors that would cause people to resort back to uni-modal travel (e.g. completing a whole trip by their private car). Solutions that aim to decrease these and other challenges associated with multimodal travel have been around since the first park and ride facilities were introduced in the first half of the 20th century (Dijk and Montalvo, 2011). More recently, technological advancements and digitalisation have brought new opportunities to assist people with using multiple modes of transport.

One opportunity is integrated smart ticketing, which allow travellers to use the same smart card to access a variety of different transport modes (Smart Card Alliance, 2003). Smartcards are most often used to provide ticketing and payment integration between different public transport options (i.e. bus, train, tram, metro). Studies have highlighted

several positive impacts of these solutions, such as growing rider throughput through stations (Prakasam, 2009), increasing the frequency of use of the participating transport modes (AECOM, 2011; NEA, 2003) and making passengers perceive easier and faster transactions and boarding (Blythe and Holm, 2002). Another tool that has been enabled by technological developments and the widespread availability of smartphones is multimodal journey planning. Multimodal journey planners aim to simplify travel with different modes by supporting travellers during pre-trip, wayside and on-bard stages of their journey (Eryilmaz, et al., 2014; Grotenhius, et al., 2007). According to Esztergar-Kiss and Csiszar (2015) there are four types of services: (1) solely information provision, (2) journey planning, (3) personal navigation and (4) personal navigation and location-based services. The more advanced developments include real-time information and personalisation, which help optimise the multimodal journeys for each individual (e.g. Kim, et al., 2005; Nadi and Delavar, 2011). Literature has shown that these tools are favourably viewed by users (e.g. Grotenhius, et al., 2007; Stopka, 2014). As discussed in Grotenhius et al. (2007) the pre-trip planning stages were most popular with travellers, however, it also helped them with stages such as “catching the right vehicle”. In another study, Stopka (2014) found that users showed significant interest towards personalized trip advice by the planning smartphone app, and they expected the app to offer optimal trip advice based on their personal data.

While technological advancements have led to solutions such as the smart card and multimodal journey planning, they have also enabled on-demand transport to reach new levels. Both Demand Responsive Transport (DRT) and other shared on-demand mobility services have benefitted from these technological developments. Demand Responsive Transport is defined as a public or private transport service with a low capacity vehicle that responds to demand with regards to its route and/or timetable and where the fare is charged by person (Davidson et al., 2014; Egan and Jakob, 2016). DRT has been used for several decades in situations where conventional bus and taxi services cannot cater for the passengers need (Mageean and Nelson, 2003). Traditionally, it was only used to serve areas of low demand or customer segments who were not able to use other transport services (e.g. dial-a-ride for elderly) (Mulley and Nelson, 2009). However, more recently, the purpose of DRT has broadened and is now used in a much wider range of cases (Mulley and Nelson, 2009). With widespread adoption of smartphones and improvements in software algorithms, these services are now more efficient and effective in being a complement to traditional transport modes (Davison, et al., 2014). They are also able to provide the flexibility and convenience of private transport but are less costly than private hires and taxis (Nelson, et al., 2010).

In addition to the widened scope of DRT, recent years have seen the introduction of several mobility services that enable travellers to gain short-term access to transport modes on an on-demand basis (Le Vine and Polak, 2015). With societal changes fuelling the emergence of the sharing economy and millennials craving access to transport modes rather than ownership of modes, shared mobility (including car sharing, bike sharing, ride hailing, scooter sharing, bike sharing etc.) has become a key element of the transport ecosystem (Shaheen and Chan, 2016). Compared to the previously discussed DRT, shared mobility tends to use smaller vehicles and is charged by vehicle (as opposed by passenger). It provides more flexible options to users and can be a protentional solution for first- and last-mile connectivity with public transport, bridge gaps in transport provision and offer alternatives to private vehicles and be able to better cater for individuals' needs than traditional transport modes (Shaheen and Chan, 2016).

In summary, the palette of new mobility services available to users has significantly grown over the past years. While developments such as multimodal journey planning and smart cards have improved the multimodal travel experience, these can be brought together and extended to further better users' experience. This is the background on which MaaS builds upon.

2.1.2 The MaaS concept and products

Early discussions that use the phrase "MaaS" in the field of transportation only date back to 2014. In these initial papers, MaaS is referred to as a scheme that brings together mobility service providers' offerings and supplies them to users through a single interface. One of the first MaaS documents defines this term as a "system in which a comprehensive range of mobility services are provided to customers by mobility operators" (Heikkila, 2014, p.8). In the same year, Hietenan described it as a "mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider" (Hietenan, 2014, pg. 2). Both studies build on earlier documents from the Finnish Ministry of Transportation and Communication in which the idea of providing transportation as a service can be found (Tuominen and Kanner, 2011).

Following these original MaaS discussions, there has been significant discourse around the interpretation of the concept. Some definitions provided by frequently cited works are presented in Table 2-1. Most dialogue originates from Europe, support is given from the ERTICO[1] backed MaaS Alliance that was formed with the aim to stimulate MaaS

[1] European network for ITS development. www.ertico.com

implementation in Europe (Holmberg et al, 2016). Examining the definitions provided in Table 2-1 some common themes emerge and highlight the most important elements of MaaS. In particular, three themes appear in all presented examples. First, all the definitions emphasize that MaaS integrates different transport options. Some even specify that this can be private or public (e.g. TSC, 2016; UITP, 2019; European Metropolitan Transport Authorities (EMTA), 2019). Second, the idea of MaaS having a single platform/digital interface/smartphone app that provides the gateway between service providers and users is present in all definitions. Some highlight that the platform combines and presents all options to users (e.g. Atkins, 2015; EMTA, 2019), while others focus on the fact that the platform offers integrated booking, ticketing and payment options (e.g. UITP, 2019; MaaS Allience, 2017). Third, all definitions place the users and the requirement for meeting their need on demand at the centre of MaaS. (MaaS Allience, 2017; EMTA, 2019).

Table 2-1: MaaS definitions

Source	Definition
Atkins, 2015	"MaaS focuses on providing a single platform for combining all transportation options and presenting them to the customer in a simple and completely integrated manner – the emphasis being on how to get from A to B rather than the individual transport modes and services. "
TSC, 2016 (based on a stakeholder workshop)	"Using a digital interface to source and manage the provision of a transport related service(s) which meets the mobility requirements of a customer. This definition of MaaS encapsulates the ability for the service to offer any type of travel experience using any form of transport service, public or private."
MaaS Alliance, 2017	"MaaS is the integration of various forms of transport services into a single mobility service, accessible on demand. For the user, MaaS offers added value through the use of a single application to provide access to mobility, with a single payment channel instead of multiple ticketing and payment operations."
UK House of Commons, Transport Committee, 2018	"MaaS could be thought of as offering truly integrated transport planning with the benefits of smart ticketing and through ticketing rolled-up into an easily accessible online service. Someone using MaaS could plan and pay for an entire journey, without the need for several transactions with different transport operators or multiple tickets using an app on their smartphone or other device. The service would use real-time data to optimise their journey and provide them with all the information they need to make it. Payment could be on a pay-as-you-go or subscription basis"
UITP, 2019	"Mobility as a Service (MaaS) is the integration of, and access to, different transport services (such as public transport, ride-sharing, car-sharing, bike-sharing, scooter-sharing, taxi, car rental, ride-hailing and so on) in one single digital mobility offer, with active mobility and an efficient public transport system as its basis. This tailormade service suggests the most suitable solutions based on the user's travel needs. MaaS is available anytime and offers integrated planning, booking and payment, as well as en route information to provide easy mobility and enable life without having to own a car."
European Metropolitan	"With Mobility as a Service (MaaS), customers fulfil and manage all their mobility needs on demand, based on their general preferences and journey-specific needs. The service

Transport Authorities (EMTA), 2019	is based on the seamless integration of all different public and commercial modes of transport and is delivered via a digital interface. The service must enable multimodal travel possibilities and thus allow for the planning and booking of multimodal journeys, support on the go and payment as well as alteration of the planned journey. MaaS also generates insights into demand, needs and travel behaviour for cities and authorities, allowing for more targeted and effective adaptations of services and investments in infrastructure".

Besides the core elements emphasised in these definitions, another aspect of MaaS, that has received a lot of attention, is its products. Several studies highlight that one of the unique selling points of MaaS is the payment of all services via the online platform (e.g. Holmberg, 2016; Lyons et al., 2019). These payments can be made through one of two products: either pay-as-you-go access or monthly mobility/MaaS packages (Hensher, 2017; Mulley, 2017; Sochor et al., 2017; Jittrapirom et al., 2017, Li and Voege, 2017, Giesecke, et al., 2016). This is also one of the featuring points from the MaaS Alliance (2017[2]), where a MaaS subscription service is described that offers single monthly or pay-as-you go options. While the concept of "pay-as-you-go" already exists in the context of travel (e.g. London's Oyster card), the notion of bundled mobility packages is less common. Packaging (or bundling) is defined as the sale of two or more products together for a single price (Guiltinan, 1987; Stremersch and Tellis, 2002). It is a frequently used method in many industries such as telecommunications, multimedia services, travel and tourism, food and beverage and consumer goods (Klein and Jakopin, 2014; Yang and NG, 2010; Nam et al., 2006; Carroll et al., 2007; Prasad and Hyma, 2014; Sheng et al., 2007). For a comprehensive review on the reasons behind bundling products into packages please refer to Appendix B.

In passenger transportation, the most similar concept to MaaS packages is public transport passes (or season tickets). These, in many cases, allow access to several public transport modes (e.g. bus, metro, tram) for a fixed pre-paid fee. They have been proven to have a significant positive impact on patronage of the included modes (Axhausen et al., 2000; Bandoe and Yendeti, 2007; Lathia and Capra, 2011). Looking at MaaS packages, these are frequently compared to telecommunication service bundles, as like those, they provide users pre-paid access to a variety of services (Hietenan, 2014; UITP, 2019). It has been noted, that tailoring mobility packages to user's needs is important for their success (Hensher, 2017; Ho et al., 2018; Nikitas et al., 2017). As stated by Strömberg (2015), the design of travel services should be flexible enough to be

considered as an available option for different types of travellers. For example, the availability of only a single MaaS plan will most likely not be appealing to every possible customer. This hypothesis is also supported by earlier research from outside the MaaS context, that states that service providers should adopt to the varying needs of customers (Walsh and Godfrey, 2000).

In summary, MaaS products are a reoccurring element in MaaS-related discussions. Packages are a frequently mentioned unique-type MaaS product and tailoring them to user needs is often stated as an important element to their success (e.g. Hietenan, 2014; Mulley, 2017). This thesis aims to contribute to the understanding of user preferences towards MaaS packages, thereby giving valuable insights which can be used to guide their market development.

2.1.3 MaaS literature

Due to the relative novelty of the MaaS concept, studies on the topic are limited. However, as the concept gains wider acceptance, the amount of both academic and grey literature getting published each year is constantly growing. The topics explored include business models (Ebrahimi et al., 2018), impacts on specific transport modes (Hensher, 2017; Smith et al., 2017), end user demand (Sochor et al., 2015; Ho et al., 2017), governmental role (Heikkilä, 2014), topology of services (Jittrapirom et al., 2017; Sochor et al., 2017) and impact on end user utility (Veerapanane, et al., 2018). Most literature consists of thought pieces and reviews. Some examples from the academic literature include studies that review MaaS services to highlight key characteristics (Jittrapirom et al., 2017). Others, take it one step further and attempt to classify these services based on the level of integration (Sochor et al., 2017; Lyons et al., 2019). There are also studies, which provide thoughts on one particular aspect of MaaS, such as the conditions of its implementation (Li and Voege, 2017) or the way various modes could be offered (Hensher, 2017). Grey literature also contributes a number of the available thought pieces and reviews (Datson, 2016; Cubic Transportation Systems, 2016).

In addition, a handful of papers explores the end user perspective (which is the topic of this thesis). Most studies use quantitative methods and examine aspect such as individuals' likeliness to adopt MaaS (González Alonso et al., 2017), individuals' preferences and willingness to pay (WTP) for MaaS packages (Ratilainen, 2017; Ho et al., 2017) and the difference between people's valuation of individual transport modes versus transport modes within MaaS packages (Guidon et al., 2019). All quantitative papers use stated preference (SP) experiments to collect data in which respondents are placed in series of hypothetical situations and are asked to make choices. Ratilainen

(2017), Ho et al. (2017) and Guidon et al. (2019) conduct SP experiments where respondents need to choose between hypothetical MaaS packages. Railainen (2017) and Guidon et al. (2019) present respondents a choice set including two MaaS packages and a no-choice option, while Ho et al. (2017) also include a pay-as-you go alternative. In contrast, González-Alonso et al. (2017) do not directly ask respondents anything about MaaS, rather infer respondent's willingness to adopt MaaS from proxy questions related their public transport subscription, mobility app usage and opinion towards payment via applications.

Quantitative studies examining preferences for MaaS packages use discrete choice models to analyse the collected data (Ratilainen, 2017; Ho et al., 2017; Guidon et al., 2019). Their findings vary with only few consistencies. Regarding the effect that individuals' characteristics have on their preference, Ratilainen (2017) concludes that respondents who are interested in purchasing MaaS plans were predominantly younger in age and have lower disposable income. Ho et al. (2017) support Ratilainen's findings regarding age, however they also find that number of children have a significant impact on MaaS product choice and that gender, car sharing membership, household structure and household size seem to have no impact on MaaS plan choices. Regarding the transport modes included in MaaS plans, there are discrepancies between the results of the different studies. The only consistent result is the respondents' preference for public transport, which always has a positive willingness to pay (WTP). Both Railainen (2017) and Guidon et al. (2019) find that public transport is valued higher when offered in a bundle than when it are offered on its own, showcasing the importance of this mode in MaaS plans. Looking at the inclusion of other transport modes, Ratilainen (2017) find that bike sharing, car sharing and taxi are all statistically insignificant in their models but less important in MaaS plans. In contrast, Ho et al. (2017) find positive WTP for taxi and Uberpool in MaaS plans although they also find zero WTP for car sharing, which supports the results of Ratilainen (2017). Guidon et al (2019) find that car sharing and park and ride are valued higher when offered in a bundle than on their own, while for bike sharing, electric bike sharing and taxi this is not the case. They also find that respondents' WTP was negative for bike sharing, electric bike sharing and taxi concluding that MaaS packages should only include public transport, park and ride and car sharing, while the other modes should only be included as a pay-as-you-go services.

A summary of the discussed quantitative work is presented in Table 2-2.

Table 2-2: MaaS user preferences studies using quantitative methods

Reference	Study area and sample size	Data collection and analysis method	Key results
González Alonso et al. (2017)	Amsterdam, Netherlands N= 797	Stated preference experiment about transport mode choice; basic statistical methods	- Multimodal users are most prone to adopt MaaS.
Ratilainen (2017)	Finland N=252	Stated preference experiment about MaaS package choice; multinomial logit	-Public transport is the only significant transport mode, while bike sharing, car sharing and taxi are insignificant - Average WTP for public transport is higher than the cost of the individual mode, while this for the other modes is significantly lower and even negative in the case of car sharing
Ho et al., 2017	Sydney, Australia N = 252	Stated preference experiment about MaaS package choice; non-linear random parameter logit	-Age and number of children have a significant impact on MaaS product choice, while gender, car sharing membership, household structure, household size have no impact. - Positive preference and WTP for all modes (are public transport, car sharing, taxi and Uberpool), although round trip car sharing has a WTP value of zero.
Guidon et al., 2019	Zurich, Switzerland N = 1000	Stated preference experiment about MaaS package choice; mixed logit model	- Public transport, car sharing and park and ride are valued higher when offered in a bundle than when they are offered on their own. - Bike sharing, electric bike sharing and taxi this are valued lower and have negative WTP

Besides these quantitative analyses, a few studies use qualitative methods to gain insights into the end user perspective. Research done by Stopka et al. (2018) conduct focus group discussions in Germany's Leipzig and Frankfurt areas. They discuss topics such as ease of access, flexibility and comparability of bundles. The study finds that many participants did not sufficiently understand the concept of MaaS packages and did not have a clear idea of the price they would be willing to pay for it. Also, the participants indicated a fear of losing money and flexibility when pre-paying for a package. Another study by Jiittapirom et al. (2018) use the Delphi method to gather experts' opinions about various MaaS-related topics. Their results show that experts agreed that youths, current public transport users and flexible travellers will be the early adopters of MaaS.

Other studies are based on pilot demonstrations. A number of papers have resulted from the UbiGo MaaS field trial (Sochor et al., 2015; Karlsson et al., 2016). In this trial, public transport, car sharing, taxi, bike sharing and car rentals were offered to users as subscription plans. 89 households, making up 195 users, subscribed for monthly plans

including a personalised combination of - and credit for - the various travel services. The prepaid tailored monthly plans were denominated in time or distance for each mode and the combined subscription was cheaper than each element individually. Credit could be topped up or rolled over and subscriptions modified. A mobility broker handled everything for the users to make it a seamless experience. As this was an actual trial, different provision structures/prices etc. could not be tested (as opposed to SPs). However, the project did result in a number of studies on various elements of MaaS. Sochor et al. (2015) examined user profiles and behaviour in relation to car ownership and use under a MaaS scheme. They identified four groups of participants: car shredders, car keepers, already car sharing and car accessors based on each groups' mode choices during the MaaS trial. Although each group had differences in their mode choice behaviour, they were all satisfied with the service provided during the trial (Sochor et al., 2015). In another study from the Ubigo trial, Karlsson et al. (2016) used a mixed methods data collection, which involved questionnaires, travel diaries, interviews and focus groups with participants of the trial. The study involved basic statistical analysis for the quantitative data and thematic analysis and selection of quotes for the qualitative element. The qualitative and quantitative data were analysed alongside each other. Their findings indicate an overall positive outcome from the trial, however, a number of barriers were also recognised.

2.1.4 Identification of research gap

While there have been increasing studies on the topic of MaaS packages and end user preferences, their number is still limited. In addition, some of the results are inconsistent, especially regarding individuals' preferences towards transport modes in MaaS plans, their WTP and the socio-demographic characteristics that are all significant factors in determining these preferences. With regards to the inclusion of specific modes, only public transport has recurring results, while the results for the other modes significantly differ. For example, while Ratilainen (2017) found that the inclusion of taxis is not a significant factor affecting an individual's decision between packages, Ho et al. (2017) found that respondents prefer more taxi in their plans, whereas Guidon et al. (2019) found that they prefer plans without this mode. Results also differ with respect to the personal characteristics that determine MaaS package preferences. However, there seems to be consistency with regards to younger population groups preferring MaaS packages (Ratilainen 2017; Ho et al., 2017; Jiittapirom et al. 2018), but not with regards to other individual characteristics. These inconsistencies suggest the need for further analysis that examines individuals' preferences for MaaS packages, the modes that are included and the effect that individual characteristics have on MaaS package preferences. In

addition, there seems to be a lack of studies that focus specifically on the heterogeneity of preferences and that identify MaaS package user groups. As discussed in the sections above, tailoring mobility packages to user needs is important for their success (Hensher, 2017; Ho et al., 2018; Nikitas et al., 2017). To do so, better understanding is needed with regards to the differences in preferences between potential user groups. This will also help identify who could be possible early adopters.

Even though there are only a few studies that look at individual preferences for MaaS products using quantitative techniques (surveys and modelling), there are even fewer that employ qualitative (or mixed) approaches. However, there are a number of benefits from conducting qualitative research, such as the provision of in-depth insights into the attitudes and perceptions of participants. In qualitative methods, individuals' own explanations of their thought processes can be collected, which can provide more detail than quantitative approaches (Clifton and Handy, 2003; Aicart et al, 2016). These methods can thus reveal the reasons behind people's preference towards certain modes, how they evaluate between the different elements within MaaS packages and what makes them hesitant towards the inclusion of certain modes in MaaS bundles. However, the few studies that do use qualitative techniques only cover specific topics, with only one of those reviewed gathering data directly from potential users.

The overall number of both quantitative and qualitative studies is still few and cover only a few areas. This leaves ample opportunities to expand to other countries, regions and cities and compare these results to those already in the literature.

2.2 EXAMINING END USER PREFERENCES FOR NEW PRODUCTS AND SERVICES

A large amount of literature exists that focuses on analysing user preferences for transportation related products or services. Studies most often use quantitative methods, while qualitative and mixed methods are less frequently employed. The following literature review will explore the different approaches and tailor them to the focus of this thesis.

2.2.1 Quantitative approaches: stated preferences and discrete choice models

Preferences for specific products or services that already exist are analysed using revealed preference (RP) data (e.g. the actual choices of customers in the market). However, this cannot be done for new products. A practical way to collect information about preferences towards currently unavailable products or services (such as MaaS packages) is by using stated preference (SP) techniques (Louviere, 2000). SP techniques

ask respondents to make choices in hypothetical settings, outside of the real market. On the one hand, SP has the advantage of allowing the researcher to manipulate the attributes of the choice options and thereby with great speed and statistical efficiency explore the effect of changes in attributes which could not be otherwise observed (Bonnel et al., 2009). On the other hand, SP experiments are susceptible to various response biases, such as anchoring-, inertia- and hypothetical- bias (McFadden, 2001; Thaler and Sunstein, 2009; Murphy, et al., 2005). Nevertheless, this data collection method is popular among the research community.

Since there are only a handful of studies that directly examine user preferences for MaaS products (as outlined above), this review will briefly draw upon papers that research other recent developments within the transportation field, such as autonomous vehicles (AVs) and shared services. In addition, it will also review studies that examine customer preferences for product bundles, as these can provide insights into methods to study MaaS packages (which are a case of product bundling).

Starting with AVs, a recent review paper found that most studies looking at individual preferences and acceptance of AVs use online surveys (Becker and Axhausen, 2017). Looking more closely at a few specific examples, Krueger, et al. (2016) use SP experiments to identify the characteristics of users who are likely to adopt shared AV (SAV) services and elicit preferences and WTP for the service's attributes. Collecting data from 435 individuals a mixed logit discrete choice model is used for analysis. Their results include insights into the socio-demographic characteristics of likely adopters as well as their preferences with regards to service attributes. A similar approach is taken in a study by Habucha, et al. (2017) who examine the choice between personal AVs (PAV) and SAVs by using a SP experiment (with 721 participants) and a logit Kernel model for data collection and analysis. This paper also provides insights into the characteristics of likely adopters and their preferences.

Turning to studies that look at shared services (e.g. car sharing, bike sharing), many of these use surveys to help determine which socio-demographic characteristics and mobility habits are important factors influencing individuals' preferences (Efthymiou, et al., 2013; Abraham, 2000; Yannis, et al., 2015; Prieto, et al., 2017). These papers use discrete choice modelling techniques to analyse the collected data. For example, Efthymiou et al. (2013) look at preferences towards vehicle sharing in Greece. They conduct a SP survey with 233 individuals to better understand who will join a bike or car sharing scheme. Using an ordered logit model to analyse their data, they are able to determine which socio-demographic characteristics and mobility habits are important factors in this decision. In another paper, Abraham (2000) conducted a survey with 50

people in Calgary, Canada analysing their choices between hypothetical car sharing services. Using a logit model, Abraham could provide insights into which characteristics of the car sharing service respondents preferred and how much, as well as the type of respondents that preferred these.

It can also be insightful to review studies that examine customer preferences for product bundles from other sectors than transportation. In such SP situations, an alternative is a composite good made up of a bundle of related components or features (Dellaert, 1995; Ben-Akiva and Gershenfeld, 1998). In order to analyse predetermined (fixed) bundles, studies usually prompt respondents to state their preferred choices among a number of proposed bundles (Fojcik and Proff, 2014; Hamilton and Koukova, 2008; Madden et al., 2002). For example, Madden et al. (2002) examined broadband delivered entertainment subscription packages based on an experiment where 1009 respondents were asked to choose from a list of package options. This study then uses a nested multinomial logit model to quantify the impact of service attributes and socio-demographic characteristics on preferences for the products. In some cases, respondents are first shown individual products and then the same products in a package to determine how packaging can change demand. Examples include Hamilton and Koukova (2008) who analyse students' perceptions of the relative importance of bundle elements; Fojic and Proff (2014) and Sheng and Pan (2013), who both test how bundling could increase product diffusions of a new product; and Janiszewski and Cunha, (2004) who focus on price discounts in the evaluation of bundles. However, it is not necessary to test respondents' preferences for individual product elements. A widely referenced study by Yadav (1993) examines students' choices of magazine subscription bundles based on pairwise comparisons of bundles.

In classic SP situations, the choice task is designed for each person by creating alternatives through a combination of attribute levels from the same finite list, and the respondent's task is to simply pick their preferred option. However, using solely this approach would not be sufficient to address the issue of flexible/customisable MaaS subscriptions. Studies that research customizable/flexible product bundles, which are found in the marketing literature, mainly resort to menu-based survey designs to determine consumers' preferences. Menu-based designs allow respondents to choose their own preferred attribute levels (Bharati & Chaudhury, 2015; Kamakura & Kwak, 2012). In some cases, the experiment is designed to include both pre-determine bundles and the choice to customize the elements within the bundle (Ben-Akiva and Gershenfeld, 1998; Liechty et al., 2001; Moore, 2010). Ben-Akiva and Gershenfeld (1998) for example, present three fixed packages and 12 individual features to respondents in a study about

custom calling product bundles. They allow respondents to choose among: 1. one fixed package, 2. one fixed package and any number of extra features, 3. any number of features, 4. none. Stated Adaption (SA) experiments are also useful to understand how people would customise their own bundles, such as the one described by Erath and Axhausen (2010). In this study, respondents are asked to choose the preferred bundle of mobility tools (e.g. car choice, public transport season ticket) given new prices for mobility costs.

Most of the works discussed above (both in terms of new mobility services and product bundles) use discrete choice modelling techniques to conduct the analysis of the collected data. The actual model specification takes a variety of different forms, such as simple logit (e.g. Abraham, 2000), nested logit (e.g. Ben-Akiva and Gershenfeld, 1998; Madden et al., 2000) or mixed logit (Krueger, et al., 2016). While the above only touched upon a handful of modelling techniques, more are available to researchers. As such, a review about the most often used models will be discussed below.

Discrete Choice Models (DCM) have contributed significantly to the understanding of individual choice behaviour in the field of transportation as well as a number of other areas. These models explain and predict choices between a set of mutually exclusive and collectively exhaustive alternatives (Ben-Akiva and Lerman, 1985). Their theoretical underpinnings contain elements of microeconomic theory of consumer behaviour (rational choice, preference theory) and are extensively documented in literature (e.g. Luce, 1959; McFadden, 1981; Ben-Akiva and Lerman, 1985; Anderson et al., 1992; Ben-Akiva and Bierlaire, 1999; Hensher et al., 2015). Since the choices made by individuals cannot be predicted with certainty, DCMs are based on the concept of random utility. In random utility models, the true utilities of individuals are considered random variables and the probability of choosing an alternative is considered the probability of that alternative having a higher utility than all other alternatives (Domencich and McFadden, 1975; Ortuzar and Willimsen, 2001).

In DCMs, the utility is decomposed into two additively separable parts, a deterministic component, which is a function of measured attributes and a stochastic error component representing unobserved attributes affecting choice (Manski, 1977). There is a large suite of choice models, in which the assumptions about the unobserved effects dictate the specific model to be estimated (Hensher et al., 2015). The most commonly used family of models is the multinomial logit (MNL) model, which due to its IID (independently and identically distributed) properties assumes constant variances and zero covariances. Its computational ease (closed-form mathematical structure) makes MNL models the workhorse of choice models and they have been applied and examined in a wide range

of studies (McFadden, 1978; Small and Hsiao, 1985). However, they rest on a number of simplifying assumptions which renders it unsuitable for many choice contexts (Bhat et al., 2016). One of these is the fact that the IID property also imposes an IIA (independence of irrelevant alternatives) assumption, which will not hold in many choice situations. As a result, most modern applications use more flexible structures which relax many of these assumptions (Ben-Akiva and Lerman, 1985; Hensher et al., 2015). Some commonly used structures will be briefly reviewed below.

The first approach is to use a more general model, such as the multinomial probit (MNP) that is based on a multivariate normal distribution random error component (Bouthelier and Daganzo, 1979). The MNP relaxes the IID and IIA assumptions and as such it is more flexible than the MNL model. However, due to its higher level of computational complexity, it is less frequently used than other model forms (Bolduc, 1999). It is estimated using simulation, rather than conventional numerical approaches (Louviere et al., 2000). Nevertheless, the MNP has been used to analyse a variety of topics such as mode choice (Van Cran, 2013; Kim, et al., 2003) and route choice (Yai, et al., 1997).

Another approach, the nested logit (NL) model, is able to accommodate interdependence between subsets of alternatives in a choice set (Hensher & Greene, 2002). Derivation of the NL model is based on the same assumptions as the MNL model except that correlation of error terms is assumed to exist among predefined groups of alternatives (Koppelman & Sethi, 2000). The model is set up with a hierarchical tree-like structure of alternatives, where behavioural relationships can be identified between choices at each level of the branch (nest). Within one nest, the IIA assumption holds, however it does not hold between nests (Hensher et al., 2015). The NL model's popularity is due to the fact that it offers noticeable gains in behavioural realism without much increase in the complexity of the estimation (Louviere et al., 2000). An extension of the NL model is the cross nested logit (CNL), which can be viewed as a generalisation of the nested logit model, allowing an alternative to belong to more than one group with different degrees of membership (Vovsha, 1997; Papola, 2004). CNL provide more flexibility than the NL model, however this comes as the cost of complexity in the model formulation (Bierlaire, 2006). Both NL and CNL models have been widely used in the literature to capture decisions such as mode choice (e.g. Lu, et al., 2015; Polydoropoulou and Ben-Akiva, 2001), location choice (e.g. Lee and Waddell, 2010), vehicle ownership choice (e.g. Berkovec and Rust, 1985), departure time choice (Lemp, et al., 2010; Ben-Akiva and Bierlaire, 2003), route choice (Vovsha and Bekhor, 1998; Mai, et al., 2015) and many more. Even though the NL model partially alleviates the IIA problem of the MNL, it retains

the restrictions that alternatives in a common nest have equal cross-elasticities and alternatives not in a common nest have cross-elasticities as for the MNL.

Mixed logit or random parameter logit models (MMNL) are another, more flexible approach, which are frequently used (McFadden and Train, 2000; Walker et al., 2007). Depending on how the model is specified it can allow for: (i) incorporation of preference heterogeneity and non-constant error variances across alternatives through relaxing the IID (Bliemer and Rose, 2010; Train, 2003; McFadden and Train, 2000) and (ii) for within respondent correlation across repeated choice observations (intra-respondent taste homogeneity) (Revelt and Train, 1998; Hess and Rose, 2007). Many researchers have opted to use these models, which can take either a random parameter or an error component specification, when they want to account for preference heterogeneity. While the incorporation of preference heterogeneity in MNL models is only possible though the inclusion of interaction terms, MMNL models allow parameters to vary across individuals. Some applications include Marcucci and Gatta (2012), who use this model when looking at heterogeneity with regards to airport choice decisions, and Kim et al. (2013), who investigate heterogeneity due to age and gender during vehicle crashes. MMNL models, by allowing tastes to be constant across replications for the same respondent, also allow for the panel effect to be accounted for. This is a key factor when working with repeated choices such as those that result from SP experiments. For example, Bliemer and Rose (2010) apply a panel MMNL model with random parameters, which takes into account the dependency between choice situations resulting from their stated choice survey data. MMNL can also be used to model 'traditional' (not instantaneous) panel data as in the case of Cherchi and Cirillo (2008) who used this specification on a six-week long panel. They are able to account for interpersonal variability (systematic and random heterogeneity over individual preferences and responses).

Moving on to another popular model, Latent Class Choice Models (LCCM) are frequently used to analyse individual heterogeneity. The early developments of LCCMs date back to the 1950s with the work of Lazarsfeld (1950), but have since been developed in terms of estimation methods, complexity of models and typed of data (Goodman, 1974; Haberman, 1979; Hagenaars, 1990; Vermunt and Magidson, 2000). Latent class models consist of two components: a class membership model and a class specific model (Green and Hensher, 2003; Vij et al., 2013). The class membership model formulates the probability that a decision-maker belongs to a particular class as a function of the characteristics of the individual. The people within a class share common characteristics, while those in different classes are dissimilar to each other regarding those characteristics (Coogan et al., 2011). Standard statistical tests are used to determine how

many segments should be used to classify the population. These latent classes (or segments) capture the heterogeneity within the population. Within the field of travel behaviour, LCCM are most frequently applied to mode choice decisions (Keskisaari et al., 2017; Prato et al., 2017; Vij and Walker, 2014; Atasoy et al., 2011) but have also been employed by studies on vehicle ownership (Hidrue, et al., 2011) and choice of number of trips (Kamargianni and Polydoropoulou, 2013). Looking at a more specific example, the effect of latent modality styles, which are sometimes referred to as lifestyle groups, have been previously used to study travel mode choice decisions (Keskisaari et al., 2017; Prato et al., 2017; Vij and Walker, 2014; Vij et al., 2013). These papers include unobserved heterogeneity by incorporating in their modelling framework a class membership model in which membership is a function of individual, household and mobility characteristics. Regarding individual and household characteristics, gender, age, income, employment, household composition proved to be significant factors in all the class membership models.

One of the more recent developments in DCMs are Hybrid Choice Models (HCM). HCMs aim to improve on the realism of DCMs by implementing a model system that encapsulates the endogeneity of 'soft' variables such as attitudes and perceptions alongside 'hard' variables such as socio-demographic characteristics (Ben-Akiva, et al., 2002; Daly, et al., 2013). The reasoning behind these models is that decision makers differ from one another in the way they make choices. This can be directly linked to the individuals' socio-demographic characteristics, but the underlying attitudes and perceptions may be equally as important (Walker and Ben-Akiva, 2002). However, while socio-demographic characteristics can be observed, attitudes and perceptions can only be inferred from proxies for the underlying latent attitudes. To measure these, psychometric scales (e.g. Likert scale) are used to create latent variables, which can be included in HCMs. Early literature on the topic dates back to the 1990s (Ben-Akiva, et al., 1997; Swait, 1994), but it is only in more recent years that these models have become widely known and applied. More recently, a number of researchers have opted to use these models to study various aspects of travel choice behaviour. They have been applied to studies on mode choice (Johansson, et al., 2006; Polydoropoulou, et al., 2013; Abu-Zeid, et al., 2011; Kamargianni and Polydoropoulou, 2013), vehicle purchase (Bolduc, et al., 2008; Kim, et al., 2014) and route choice (Tsirimpa and Polydoropoulou, 2007; Prato, et al., 2012) among others. With regards to the latent indicators that are used in the literature, these can vary significantly based on what the aim of the specific study is. For example, Daziano and Bolduc take into account latent environmental concerns during vehicle purchase behaviour (Daziano and Bolduc, 2013). Their latent

variables are about environmental consciousness and are constructed based on indicator variables about transport policies and problems. In another study, Prato et al. (2012) used latent constructs about memory, habit, familiarity, and spatial ability to help explain route choice behaviour. Like most studies, they use a seven-point Likert scale to collect information about the respondents' attitudes and perceptions. In another example, researchers examined teenager's mode choice decisions when commuting to school, taking into account latent variables regarding willingness to walk or cycle to school (Kamargianni and Polydoropoulou, 2013). Overall, these examples show that the effect of a wide range of latent attitudes can be examined using HCMs, however the appropriate data collected through psychometric scales is necessary in order to do this.

While the above review provided an introduction to some of the discrete choice modelling methods that are available to researchers, it is in no way comprehensive. Due to the sheer number of developments in the field, it was not feasible to include them all in this literature review chapter. Further details on the discussed models as well as others are available in Hensher and Johnson, (2018), Hensher et al. (2015); Greene, (2009); Ben-Akiva and Lerman (1985).

2.2.2 Mixed methods and qualitative approaches

Historically, quantitative and qualitative methods were seen as incompatible approaches. Researchers would frequently advocate one of the two methods and disparage the value of the alternative one (Johnson and Onwuegbuzie, 2004; Tashakkori and Teddlie, 2010). However, since the 1980s[3], studies have been applying these methods together with increasing frequency (Creswell, 2003; Creswell and Plano Clark, 2007). The pursuit of a combination of both quantitative and qualitative elements falls under the mixed-method approach, in which multiple research methodologies are combined in one study. Mixed-method approaches can provide significant added value to studies, especially when the phenomenon under study is complex (Morse, 2016). They are able to provide a more holistic understanding of the subject and enhance description and explanation. In many cases, there is a core component, that is supplemented with an additional component to improve the depth of the research findings. Using multiple methods to examine the same subject can also increase the validity of the findings (Hurmerinta-Peltomaki and Nummela, 2006). Even though mixed methods provide a number of benefits, its

[3] Mixed methods have been seen since the 1950s, but they are formally used since the 1980s (Creswell and Plano Clark, 2007).

popularity is limited by the fact that its implementation requires a large amount of resources, including time, financial means and skills (McKim, 2017).

A combination of quantitative and qualitative elements is frequently used in subject areas such as psychology, sociology and education. It is less common in the transportation field, which is still dominated by exclusively quantitative studies. However, since the pivotal reviews of Grosvenor (2000) and Clifton and Handy (2003), qualitative research, and as a result, mixed methods, have increasingly gained traction (Aicart et al., 2016). Qualitative elements can be used before the quantitative elements to examine how best to design the qualitative surveys; or after, to better explain the results that surface from the analysis (Hesse-Biber, 2010). Qualitative elements can bring a number of benefits to traditional qualitative surveys in the field of transportation. Grosvenor (2000) points out that quantitative and qualitative research should not be viewed as substitutes, but rather as complements that can add to the understanding of travel behaviour. Also, qualitative methods can be used to improve design and extend interpretation of quantitative surveys (Clifton and Handy, 2003). Looking at more recent viewpoints, mixed methods have been recognized as having the most potential to provide a well-rounded understanding of choices and behaviour (Clifton, 2013; Carrasco and Lucas, 2015).

Mixed-methods studies can be conducted using different respondents for the qualitative and quantitative stages (Baslington, 2008; Aarhaug and Elvebakk, 2015; Karndacharuk et al., 2016). For example, Baslington (2008) carries out a travel diary with children about their route choices to school and then conducts a follow-up interview with parents in the same areas. In a more recent study, Karndacharuk et al. (2016) carry out a survey measuring shared street space with residents, while also conducting interviews with transportation experts. Another family of studies use the same participants for both the quantitative and qualitative elements, thus allowing for follow-up questions to help understand the reasons behind the responses to the quantitative questions. A widely cited study by Handy and Clifton (2003) carries out a mail-out mail-back household travel survey about travel mode choice for shopping trips. Following the survey, they use a selection of respondents and through focus groups further explore the factors, motivations and attitudes behind the choices seen in the survey responses. Other studies use in-depth interviews with a sample of survey respondents to gain deeper insights into the outcomes of the quantitative results (e.g. Schneider, 2011; Pooley et al., 2013).

Looking more specifically at the qualitative elements, Aicart et al. (2016) provide a comprehensive overview of recent qualitative studies in the field of travel behaviour. They find that in-depth interviews are the most common method of qualitative data collection, followed by focus groups. Each of two methods has its merits depending on the situation.

Focus groups should be used when the researcher is interested in understanding the interactions between individuals (such as empathy or disagreement) or when the group setting may bring out more insights (Grosvenor, 2000; Lazar et al., 2017). However, individuals may be less keen to share their views when others are present, especially when they may contradict the general tendency of the group. Personal interviews remove the normative pressures and allows for flexible types of information to be collected (Clifton and Handy, 2003). In their review, Aicart et al. (2016) also examine the techniques used to analyse qualitative data. The most frequently applied method is thematic analysis, in which the data is explored to identify, analyse, organize and describe the themes and patterns that emerge (Braun and Clark, 2006; Nowell et al., 2017). The second most common approach is using Grounded Theory (Glaser and Strauss, 1967), which uses emerging patterns in data to generate theories, followed by the third, case studies, which studies a person or group over time.

2.3 CONCLUSIONS

This literature review in this chapter first focused on MaaS (concept) and then on studies that examine user preferences for new products and services (methods). The chapter started by outlining the developments that have led to MaaS, such as integrated multimodal transport, on-demand solutions, multimodal smart ticketing and demand responsive transport. This was followed by a review of the MaaS concept, including the most commonly used definitions and its key characteristics (transport services integration, single digital platform, meeting customers need on demand). MaaS products and MaaS packages were also introduced followed by a review of the MaaS literature with a specific focus on studies that examine the end user perspective. Based on the review, gaps in current MaaS-related research were identified. These include: overall limited number of studies available; inconsistencies in the results of existing quantitative studies with relation to individual MaaS package preferences; lack of studies specifically looking at heterogeneity and identification of user groups; very few papers using qualitative methods to collect data from potential users; lack of geographical coverage of existing works. These provide the gaps in the literature that this thesis aims to tackle.

The second part of this chapter explored relevant methods to study user preferences for new products and services. Among the quantitative approaches, stated preference data collection techniques were discussed as a useful method to collect data about services that currently do not exist in the market. Examples from AV and shared services as well as product bundling (marketing) literature were reviewed. Discrete choice models were introduced as a key analysis method with the most commonly used model specifications

(MNL, MNP, NL, CNL, MMNL, LCCM, HCM) presented. In addition, mixed and qualitative approaches were discussed and examples from the transportation field summarised. Focus groups and in-depth interviews were found to be the most common data collection methods, while thematic analysis and Grounded Theory were the leading analysis techniques.

Building on this literature review and the identified gaps, the next chapter will outline the specific approach that this thesis take. Aiming to reduce the gaps in knowledge, some of the methods presented in this chapter will be utilised to help better understanding user preferences towards MaaS products.

CHAPTER 3: METHODOLOGY

This chapter presents the overall methodological approach adopted in this thesis. It outlines and justifies the research philosophy, approach, design and procedures that enable the research questions to be comprehensively addressed.

3.1 RESEARCH PHILOSOPHY AND APPROACH

A research methodology is a system of rules and procedures that provide the foundations for conducting research and evaluating claims for knowledge (Nachimas and Nachimas, 2008). When developing an effective methodology a number of different stages need to be covered during the research process. Based on the concept of the 'research onion' (Saunders et al., 2015), this can be illustrated using six concentric ellipses representing a key phase of the process Figure 3-1. The research onion provides a clear and effective progression through which a research methodology can be designed. Its usefulness lies in its adaptability for most research methodologies and that it can be used in a variety of contexts (Bryman, 2012). When using the research onion framework one should go from the outer layers to the inner ones.

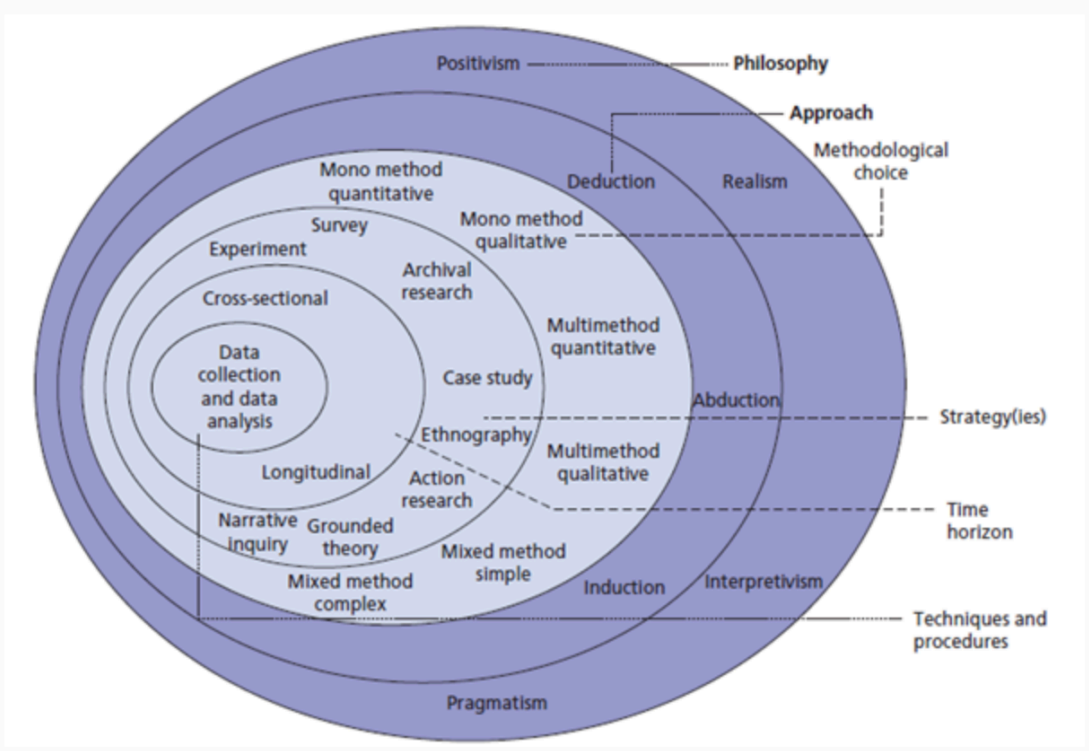

Figure 3-1: The Research Onion (Source: Saunders et al. 2012)

The research onion consists of six layers. The outermost layer of the framework represents the research philosophy, which is a system of beliefs and assumptions about the development of knowledge (Saunders et al., 2015). The assumptions created by a research philosophy provide the justification for how the research will be undertaken (Flick, 2011). The research philosophy underpins the methodological choice, research strategy, data and collection and analysis techniques that a researcher will choose. There are several types of research philosophies that differ on the goals of the research and the best approach to take to achieve these goals (Goddard and Melvillle, 2004). The two main philosophical frameworks are positivism and interpretivism (Saunders et al., 2015). Although they are sometimes described using different terminology (e.g. empiricism and constructivism) the underlying assumptions are principally the same (Bryman, 2012). Positivism argues that the social world exists externally and that its properties should be measured through objective methods, rather than being subjectively inferred (Easterby-Smith et al., 2012). The key idea behind interpretivism is that humans are different than physical phenomena because they create meanings, thus it is important to understand and interpret their beliefs and motives instead of only measuring these objectively (Myers, 2008). Positivism and interpretivism can be viewed as being on opposite sides of the scale. While positivism is associated with objectivity and is based on mainly quantitative statistical methods, interpretivism brings subjectivity by focusing on narratives and interpretations and consequently typically use small sample in-depth qualitative methods (Saunders et al., 2015).

This thesis does not clearly fit into one of these two philosophical streams. While the aim of the thesis ("providing empirical evidence of individuals' preferences for MaaS plans and their components") seems to tend towards a positivist philosophy due to the implied measurability, certain research questions (e.g. what are user preferences for transport modes within MaaS plans and how do users evaluate between them?) favour a more interpretivists philosophy as they require interpretation of the reasons behind people's decisions. As such, a research philosophy, pragmatism, that is a hybrid approach will be adopted. The pragmatist research philosophy is based on the rationale that both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question (Wilson, 2010). While positivism primarily focuses on quantitative and interpretivism on qualitative methods, pragmatism follows the research problem and applies whichever method will produce practical solutions and outcomes (Saunders et al., 2015). As such, the pragmatist research philosophy can yield better results for the topic of this thesis with the opportunity to use a mix of different research methods.

The second layer of the research onion is the research approach. Research approaches can be divided into three main types: deductive, inductive and abductive (Bryman and Bell, 2015). The main distinction between them is the relevance of the hypothesis to the study. A deductive approach starts with a theory and designs a research strategy to test that theory, whereas an inductive approach starts by collecting data to explore a phenomenon and use this to build a theory (Flick, 2011). An abductive research is a combination, where research starts with data collection to explore a phenomenon to generate a new theory, which is then subsequently tested through additional data collection (Saunders et al., 2015). This back and forth movement is frequently used to explain surprising facts identified during the research process. The deductive approach primarily fits with a positivist philosophy and is characterised as the development from general to specific (Sneider and Larner, 2009). It is criticized by followers of the induction because of its tendency to construct a rigid methodology that does not permit for alternative explanations of the phenomenon at question (Saunders et al., 2015).

The general stance of this thesis is an inductive research approach because it provides the flexibility to adjust and solidify the theories of MaaS plan preferences based on the outcomes of the data collection and analysis. As MaaS is an emerging field, there was not enough evidence to build strong theories to test, which would be needed for a deductive approach. While the primary approach of the thesis is inductive, there are elements of abductive approaches. As will be presented in Section 3.2, ‘surprising facts’ were uncovered during the analysis which resulted in subsequent data collection to explain these.

The four inner layers of the research onion will be presented in Section 3.2 as they are all parts of the research design. That section will provide the concrete tangible methods, strategies, time horizons and techniques and procedures followed in this research

3.2 RESEARCH DESIGN

Before detailing the elements of the research design, it is important to clarify the geographical scope. The thesis focuses solely on urban MaaS as most existing developments are in cities and suburban MaaS introduces additional layers of complexity because of the reduced transport network coverage (for details on these, see (Aapaoja, et al., 2017; Barreto, et al., 2018; Jittrapirom et., 2018). Due to the origin of most MaaS-related dialogue and market developments, this study focuses on Europe (see literature review and section 4.2). Within Europe, the United Kingdom (UK) has the highest

smartphone penetration[4] (Newzoo's Global Mobile Report, 2018), has large cities which are hubs of mobility services, and allows the research to be conducted without translation into English. The two largest UK cities, i.e., London and Greater Manchester, were chosen as the study areas as they both offer multiple transport options (public transport, bike sharing, taxi, car sharing etc.). Thus, both cities allow for flexibility in the design of MaaS plans and it can be assumed that there is higher awareness of the different transport modes than in cities where these do not exist.

The research design, i.e., the four inner layers of the research onion, is the overall strategy that integrates the components of the research in a coherent and logical way, thereby ensuring that the research questions can be effectively addressed (De Vaus, 2001). This thesis follows a mixed methods design, which fits well with the pragmatist research philosophy. As argued by Tashakkori and Creswelll (2007) this design not only combines quantitative and qualitative methods but also reflects an epistemological paradigm that integrates positivism and interpretivism. This design draws on the strength of both quantitative and qualitative data gathering and analysis techniques to formulate a holistic view and interpretation on the research questions (Creswell J., 2014). While the main research design follows mixed methods, it also has some characteristics of an exploratory design that is conducted during research problems where there are few earlier studies to rely upon (Stebbins, 2001). While exploratory designs tend to stop at gaining background information about the topic and evaluating what should be examined in future studies, this thesis goes further towards making conclusions based on rigorous data collection and analysis.

The thesis research framework includes seven main sections. The first three provide the background and foundations of the research, the second three are the central research processes, and the final is the conclusion and extrapolation. Details about the objectives, methods and purpose for each of the section are presented in Table 3-1 while Figure 3-2 provides the conceptual framework and how the different components within each section connect together to build a comprehensive study. The following paragraphs will provide more detail for each of the seven sections.

[4] MaaS platforms are mainly based on smartphone apps – see literature review and section.

Table 3-1: Thesis sections

Section	Thesis chapters	Objectives of section ("what?")	Methods used ("how?")	Purpose of section ("why?)
1.Framing of research	Ch. 1	– Review general field and provide a background – Provide the research questions and the objectives of the thesis.	Desk research Literature review	– Set the context and motivation of the thesis. – Clarify the focus and value of the research
2.Literature review	Ch. 2	– Synthesise and compare evidence from literature on concept and methods	Literature review	– Identify research gap that this thesis aims to fill. – Outline methods that could be used during the research
3.Research design (methodology)	Ch. 3	– Outline research design and procedure		– Justify choices of research methods and overall approach
4.Research process 1: desk research	Ch. 4	– Conceptualize the MaaS ecosystem – Map out existing MaaS services	Desk research	– Provide the rationale behind studying users – Support the design and provides the baseline of the MaaS surveys
5.Research process 2: survey design and primary data collection	Ch. 5 and Ch. 6	– Outline the steps to design a MaaS survey – Assess differences between MaaS and other surveys – Design surveys for London and Greater Manchester data and collect data	Desk research Surveys Focus groups	– Create surveys and collect data that will be used for the analysis – Identify specific challenges of designing surveys that capture individual preferences for MaaS plans compared to choice situations regarding other products of services in the transport sector **Answer research question #1**
6.Research process 3: data analysis	Ch. 7 and Ch. 8	– Create a model with data from London – Conduct interviews in London and analyse results – Integrate quantitative and qualitative insights from London – Create a model with data from Manchester that can capture heterogeneity and user groups – Interpret the results of the model for Manchester	Mixed methods, Discrete choice models, Interviews, Thematic analysis	– Evaluate user preferences for transport modes within MaaS plans and how do they evaluate between them – Analyses the effect of an individuals' characteristics on their preferences for MaaS plans and whether there is heterogeneity among preferences of different user groups **Answer research question #2 and #3**
7.Discussion and implications	Ch. 9	– Synthesise results and provide recommendations for policy and industry		• Translate the results into meaningful and easily understandable contributions. **Answer research question #4.**

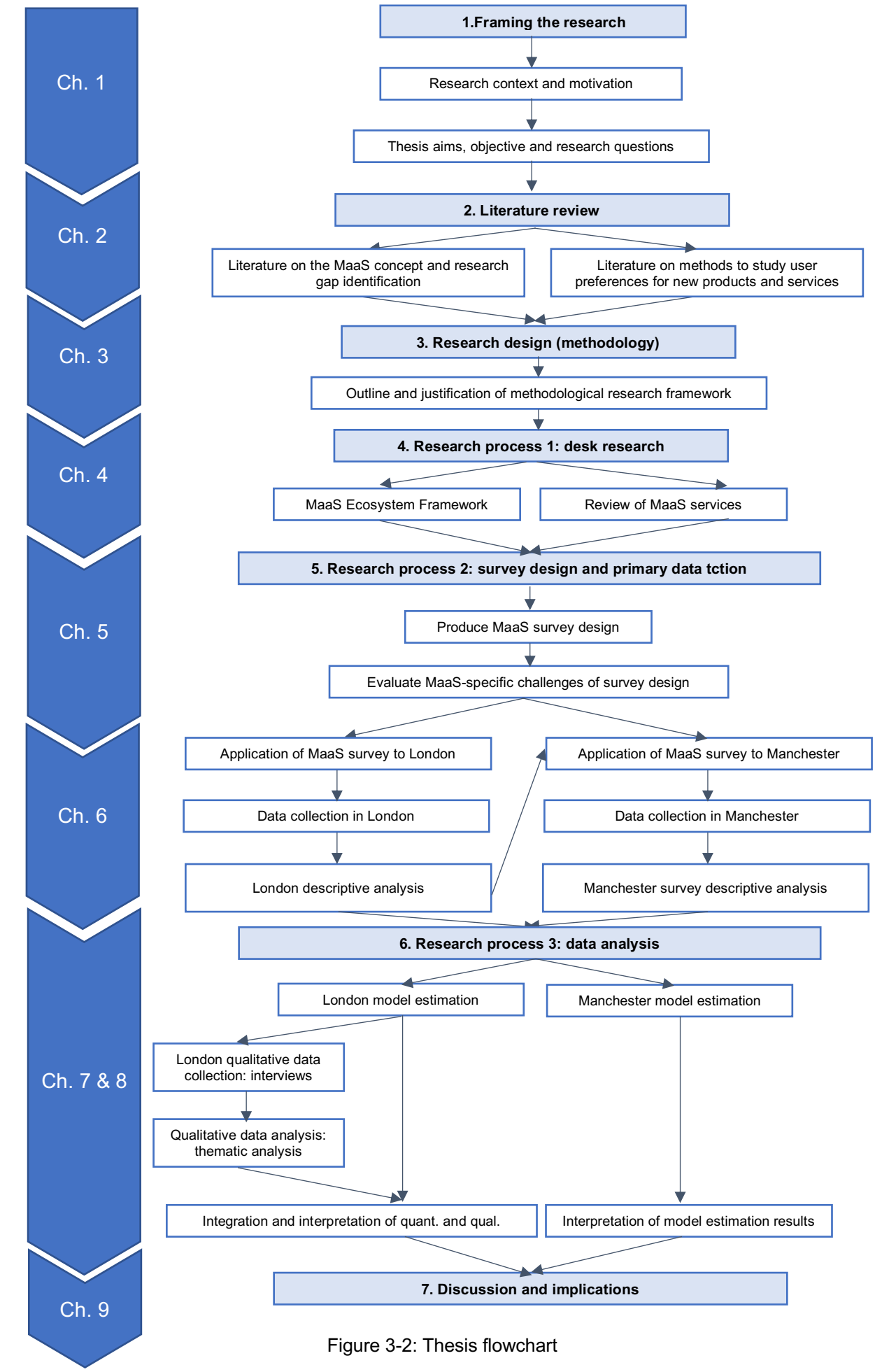

Figure 3-2: Thesis flowchart

The **first section** is titled 'framing the research' and was presented in Chapter 1. The objective of the section is to review the general field, provide a background to the study and outline the aims and research questions that this thesis intends to answer. In doing so, context and motivation are provided as well as the contribution and value of the thesis. The methods used in this section are desk research and literature review.

The **second section** (Chapter 2) is the literature review, which synthesises the existing work in the field and identifies the gaps in knowledge that this thesis will contribute to. By doing so, it justifies the research as one that brings something new to the cumulated knowledge. This section also provides the theoretical foundation by reviewing methods used to study individual preferences for new products or services and validates the methods and approaches used in this thesis.

The **third section** (Chapter 3) is the research design (methodology) which is the topic of the current chapter. The objective of this section is to outline and justify the research philosophy, approach, design and procedure and to ensure these are able to answer the proposed research questions.

The **fourth section** (Chapter 4) is the first research process, which focuses on the desk research stage of thesis. This section can be viewed as an exploratory and descriptive study, while the later research processes are the explanatory stages. The section has two main parts. First, a theoretical framework for the MaaS ecosystem is presented. This is based on desk research, literature review and unstructured discussions with stakeholders (transport operators, public transport authorities, researchers, potential users). The purpose of introducing this high level framework is twofold. First, it provides a more detailed explanation of what MaaS entails and, second, it highlights the central role that users play in this framework. By doing so, it supports the rationale of focusing the thesis on end users while also acknowledging the intricacy of the whole MaaS system and the fact that the users are just one element of this. The second part of this section is a review of real market MaaS applications. It examines each service model including the transport modes that are included, the type of actors involved, the platform, personalisation and products offered. This review provides the basis for the products that will be designed and tested during the MaaS surveys designed in the thesis and supports the validity of studying MaaS and its packages by presenting pilot studies and real market applications.

The **fifth section** (Chapters 4 and 5) is the second part of the research process encompassing the MaaS survey design procedure and quantitative primary data collection. The MaaS survey design is an outline of the sections that can be included in

a MaaS survey to enable data collection and analysis about individual preferences for MaaS products. The developed design includes a number of different approaches and sections that can be selected from depending on the aim and focus of the specific use case. A survey design usually does not merit its own thesis chapter and is frequently a subsection of the methods or data chapters. However, in this case, one of the thesis' research questions relates to whether there are any specific challenges of designing MaaS surveys that capture individual preferences for MaaS packages compared to choice situations regarding other products or services in the transport sector. To answer this, a detailed outline of potential MaaS survey designs is presented allowing for the challenges and its unique elements to be identified. The overarching design process is based on those frequently used in the transportation and marketing fields to evaluate individual preferences for products or services and include a questionnaire and stated preference (SP) experiment (Louviere et al., 2000). The process is then adapted to MaaS packages taking into account the knowledge gained from the literature review (research section #2), the desk research and MaaS pilots and services (research section #4) and multiple rounds of focus group testing (details of which will be presented in Chapter 5).

Taking the benefits and current state-of-the-art into account, this thesis works on the assumption that the survey designs will to be applied using computer or web-based tools. These data collection methods enable large sample sizes with relative ease and low marginal costs (Saunders et al., 2015). They also allow complex questionnaire design using features such as conditional branching (skip logic) meaning that questions could be adapted dynamically based on the respondents answer to a previous question. However, they are unable to represent the general population as those who are computer illiterate or do not have access to the internet will not be represented. This, in the case of MaaS, is not a major problem, as the main target audience for MaaS is those who have smartphones and are assumed to also be computer literate. The author acknowledges, that this in itself is a weakness of MaaS that needs to be addressed, but it is out of the scope of this thesis. Additionally, it is assumed that the surveys will be self-administered, thereby not allowing for an interviewer to answer any questions. With self-administered surveys, special care must be taken with how the questions are worded as there is no feedback from a trained interviewer (Lavrakas, 2008). Hover over pop-ups can be used to help respondents understand questions and concepts. These can be included in places where the focus groups indicate that further explanation would be helpful. Open ended questions should be kept at a minimum and made non-mandatory (Crawford et al., 2001). Radio buttons prevent multiple answers when only one is called for, and item non-response can be minimized by making the important questions mandatory.

The second part of the fifth thesis section takes the survey designs developed in Chapter 5 and applies them to the two case study cities. A sequential approach is taken, meaning that the London survey was developed first allowing adjustments to be made to the Manchester survey based on lessons learned. The discussion of both surveys starts with a description of the survey design. Both surveys include:

1. a questionnaire about individual and household characteristics, mobility tool ownership and use, travel habits and attitudes;
2. an introduction section to MaaS;
3. a stated preference survey (SP) experiment where respondents were asked to choose between hypothetical MaaS plan options;
4. follow-up questions and attitudinal statements regarding MaaS.

The questionnaire section of the surveys is important for later modelling purposes, market segmentation and allowing for context dependence in the SP experiment. Local and national household travel surveys (e.g. the London Travel Demand Survey and the National Travel Survey) were used as a basis for the questions and adjustments and extensions were made based on insights from the literature review, thought experiments and discussions with stakeholders.

While the questionnaire section of the two surveys (London and Manchester) are similar, the designs of the MaaS section and SP experiments differ, as they need to answer different research questions. The London survey was created with the main aim of collecting data that can answer research question #3 (“What are the identified user preferences for transport modes within MaaS plans and how do they evaluate between them?), while the Manchester survey was adjusted to be more appropriate for collecting data to answer research question #4 (To what extent can the preferences for MaaS plans be explained by the characteristics of the decision maker and are there distinct user groups?). The two surveys were conducted in different locations to provide a broader, UK-wide view on preferences for MaaS plans. Details of the differences in design as well as specific challenges of designing surveys that capture individual preferences for MaaS plans (research question #1) are presented in Chapter 6.

During the design of the London survey, three rounds of focus groups and interviews were conducted to test different design and wording options. The first and the third groups were smaller (five individuals) while the middle one was with around a group of ten individuals. The feedback was in the format of both email feedback and personal interviews and in some cases the combination of both. The feedback was carried over to

the Manchester survey where the focus groups were not repeated due to resource constraints.

Both surveys were deployed as a web application using the Ruby on Rails (http://rubyonrails.org/) open source framework based on the Ruby programming language. A web application built from scratch was used, rather than an already existing survey development tool, to provide more flexibility and customisation when creating the SP experiment. The data from the completed surveys were automatically verified and stored in secure servers in a MySQL (https://www.mysql.com/) database system. This structure was designed in a form necessary for choice modelling exercises, to enable seamless export into other bespoke analytical tools.

The final element presented during the discussion of both surveys is information about the sample, data collection and descriptive analysis. These focus on the samples that are used for modelling purposes in Chapters 7 and 8. Regarding the descriptive analysis, variables that can provide insights into individuals' preferences for MaaS but will not be used during later modelling exercises are focused on. These include responses to attitudinal statements about MaaS and individuals willingness to download the MaaS app. As the analysis in Chapters 7 and 8 centre around the SP data, all discussions on these are left to those chapters.

It has to be acknowledged that the data collected has a range of caveats as it suffers from survey-based threats to reliability. Response biases including participant error, satisficing and extreme responding, sampling biases and research biases due to phrasing and the way questions are presented are all possible in surveys. In addition, as paid research panels were used for sampling, self-selection bias is also likely.

The **sixth thesis section** encompasses the data analysis for both case study areas. Starting with London, the aim of this analysis is to examine user preferences for transport modes within MaaS plans and how do they evaluate between them. In doing so, a mixed methods study is used, meaning that the quantitative data collected in Chapter 6 is analysed and extended with qualitative data collection and analysis to help explain and enhance the results obtained through the models. The type of mixed method used is an explanatory sequential design, in which the quantitative phase is carried out first, followed by the qualitative phase to help explain the quantitative results (Creswell, 2015). This method is ideal for research with a quantitative focus, where the interpretation of the statistical results need additional refinements. By using qualitative methods to follow up quantitative results, participant views on critical areas can be explored in more depth.

Following the guidelines presented in Ivankova et al. (2006) and Creswell (2015), the visual model of procedures followed in this study is illustrated in Figure 3-3. The model portrays the research activities in chronological order, alongside the products (specific outcomes) resulting from each step. In the figure, boxes are used for data collection and analysis elements, while ovals indicate interpretation sections, where the quantitative and qualitative phases connect with each other.

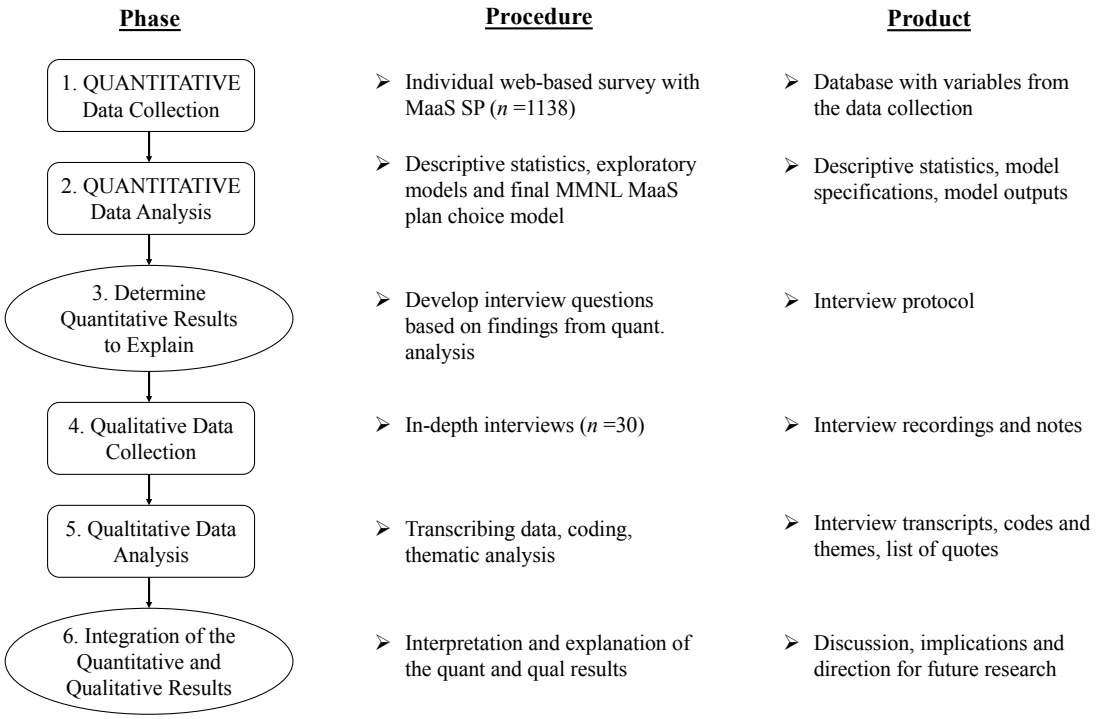

Figure 3-3: Visual model of procedures for explanatory sequential mixed method design

In the first, quantitative phase the data collected in the London survey was used. In the second phase, this data is statistically analysed and discrete choice models are estimated. A mixed logit model specification is chosen that can account for the panel effect that comes with stated preference data. Using the findings from the quantitative results, elements that need further, in-depth exploration are identified in step 3. This is one of the points of inference for mixing. Interview questions are developed focusing on key topics that are uncovered in step 2 and the interview protocol is finalized. Next, qualitative data is collected through in-depth interviews with 30 people. Unfortunately, the sample used for the quantitative data collection was not accessible (the panel was hired through a survey company; due to the GDPR standards access was not possible to the contact details of the participants), as such, a new sample is used. In step 5, the qualitative data is transcribed, and analysed using thematic analysis methods. Finally, step 6 integrates the quantitative and qualitative results and inferences are drawn about

how the qualitative outcomes help explain the quantitative results. The outcomes help answer research question #2 and offer insights into research question #3.

Turning to the analysis using the Manchester data, the aim is to examine the effect of an individual's characteristics on the preference for MaaS plans and whether there is heterogeneity among preferences of different user groups (research question #3). To do so, a latent class choice model (LCCM) is developed, which is able to capture individual heterogeneity by assuming that the population can be segmented into groups based on a combination of their characteristics. Through the analysis, MaaS plan user groups are defined as well as their willingness to pay for the plans. Descriptive statistics are also presented to provide reasons for people not being interested in MaaS plans.

Finally, the **seventh thesis section** synthesises the results of the previous sections and provides recommendations for policy and industry. In doing so it translate the results into meaningful and easily understandable contributions and answers research question #4.

CHAPTER 4: MOBILITY AS A SERVICE: ECOSYSTEM AND APPLICATIONS

The aim of this chapter is twofold. First a theoretical framework for the MaaS ecosystem is discussed, giving a high-level explanation of what MaaS entails and the different actors within the ecosystem. Second, a review of real market MaaS applications is presented, including their service model, the transport modes, the type of actors, the platform, personalisation and products offered.

4.1 MOBILITY AS A SERVICE ECOSYSTEM

The MaaS ecosystem encompasses a wide range of domains including business, technology, end users and policy. The 'ecosystem' phrasing is opted for as the concept is based on an intricate network of interconnected systems, which all interact and cooperate for the functioning of MaaS.

The MaaS ecosystem framework can be divided into four interlinked pillars, namely (1) business models, (2) technology (3) end user and (4) policy framework, which are illustrated in Figure 4-1. These pillars' interplay is what makes the MaaS concept unique. The business models include elements of financing, legal and, most importantly, organisational structures that bring together all public and private actors. This pillar also encompasses the next two pillars, as these are governed by decisions made through the business models. The technology domain is dubbed 'technology hub' as it is a centre that connects the front-end and back-end technologies in a unified, standardised manner. The end user is at the heart of the whole concept as creating seamless door to door mobility for customers is the motivation that led to the vision of the whole concept. Finally, the policy domain frames the other three, providing the protocols and regulatory foundations that enable successful MaaS schemes to emerge.

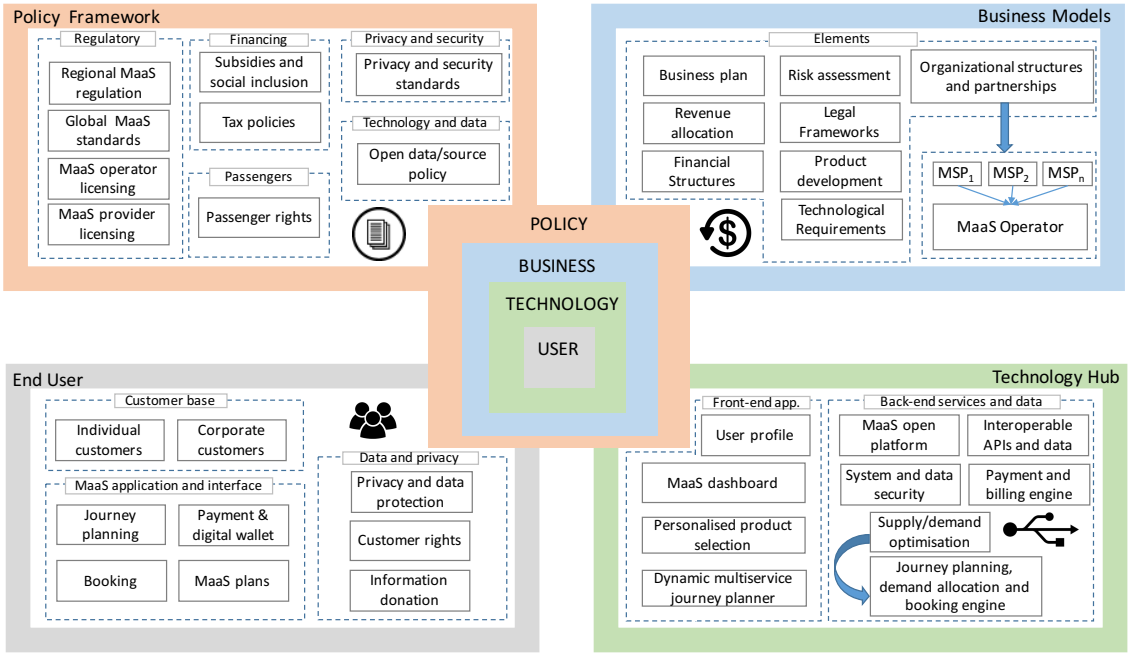

Figure 4-1: Mobility as a Service Ecosystem Framework

Before dissecting each element in the framework, the actors and their capacities within the MaaS ecosystem are identified. Starting from the top down, the *political actors* are the first agents to note. Their role is the most passive, as they just pre-specify the regulations and policies to enable the MaaS market, that cannot be altered dynamically. In an ideal situation, these actors would be proactive enough to re-evaluate the regulations periodically to adjust to the evolving concept. The second group of actors are the *mobility service providers* (MSPs). These agents provide the actual physical services, but besides that do not interact directly with the users. Instead, they interact with the *MaaS Operator* (MO) who is the new actor compared to traditional transportation service models. The MaaS Operator has been referred to in the literature in various forms such as combined mobility service provider and MaaS provider (Holmberg et al., 2016; TSC, 2016). Both the MSPs and the MO are active participants in the MaaS ecosystem and their partnerships significantly affect the success of the whole scheme. The final actors are the *end users.* Customers have a unique role in the ecosystem as they are both the users of the service as well as providers of information/data. The latter means that users have the ability to give information about themselves and their travels back to the providers so they can improve the service. In addition, they could also provide real-time feedback about the service (e.g. congestion on a transport mode) or disruptions along a route. Customers, of course, are active participants of the system. All these are described in the subsections below.

4.1.1 Business Models

The most vital part of the business models pillar is the above-mentioned new player, the MaaS operator, whose role is to integrate supply and offer the mobility services to the users via a single interface as a sole product. The MO's role is key to the ecosystem; it orchestrates the MSPs while interacting with the end users and providing the technical functioning of the system (although the technical element could be contracted to a third party). As there is no precedent to such an agent, there is no clear archetype of how the MO should come to existence. The emerging structures can be classified according to the ownership arrangements, that is, whether the MO develops as part of a public authority or a private company.

In the case of the former a transport authority takes over the role of the MO. Currently, in many cities (e.g. London, Budapest, Athens) the transport authority already acts as the integrator of all public transport modes (bus, metro, light rail, bike sharing etc.) and in some cases, allows access via a single smart card. In the MaaS business model, these public authorities could also include the other mobility services (such as car sharing, parking, on-demand modes). In the case of the latter, a private entity is in charge of the MO activities. Here, two options are possible, either an existing MSP can diversify and expand their offerings to include MO functions, or a completely new company can be created with a sole purpose of being the MO. Companies that diversify could be anything from small service provider to big multinational companies. With regards to the new company, one such example is MaaS Global, which was the first of a kind company created to be a MO.

It is not clear which of these models will surpass the others. It is possible that none will emerge as the preferred setup; rather each regional MaaS system will select the one that best fits its current level of centralisation, MSP availability and organisation and regional structure. Each structure has its benefits and disadvantages, which are summarised in Table 4-1.

Table 4-1: Benefits and disadvantages of MaaS Operator ownership arrangements

	Benefits	Disadvantages
Public MaaS Operator	• Existing strong role of transport authority has power to influence policy • Can ensure public transport is included in MaaS • Market has more trust in existing transport authority • Usually established communication channels with all modes	• Bureaucracy can slow operators and adaptability • May be difficult to diversify role • Usually non-profit: either constrained by law of lack of incentives to develop MaaS service
Private MaaS Operators	• Likely faster development due to profit maximising nature • Faster adaptability to change • Stand-alone MO enterprise (non-service provider) can remain impartial	• Lack of authority in influencing policy • May lack ability to handle responsibility of being MaaS operator for a larger area • Possibility of MaaS functions take over regular activities (e.g. service provision) leading to the region losing a mobility supplier • May be lack of trust in smaller/private operators

There are certain key factors that need to be evaluated in each situation in order to determine which structure should be applied. These include existing role and scope of the transport authority, the strength and reach of the potential private companies, the adaptability of the entities, the level of trust in the different potential MOs and whether the proposed MO can remain unbiased. A public-sector entity may be favoured in those areas, where the transport authority already has a strong role. This has the benefit that the authority has the power to influence policy, however it also raises some important concerns. The vision of MaaS systems is that a competitive environment is set up, where any mobility service provider can dynamically join the scheme if it satisfies the regulations and standards. With large transport authorities, bureaucracy may slow down the operations significantly, as they are not as adaptable as smaller organisations. To the contrary, private companies can be more adaptable. These entities may however struggle to handle the immense responsibility and strain that comes with being the MO for a whole region and lack authority in influencing policy. In the case of diversified existing private companies, there is also the possibility that the MO functions will take over completely and the rest of the original activities (e.g. service provision) will diminish – making the region lose a supplier. Companies created for the sole purpose of being the MO have one significant advantage over any alternative options in that their whole business model can be set to serve the needs of the MaaS system, instead of having to alter an existing business model that may turn out to be a patchwork setup.

Trust and unbiasedness are very important issues that need to be addressed as they appear in several instances. Since the MO, as the aggregator and integrator, needs to have access to all the providers' APIs and data (discussed further below), the providers need to trust the security of the MO's systems. This may be easier to achieve in the case of a transport authority MO, rather than a private company, especially if the latter is a completely new player. Further, the MO needs to remain neutral and equally promote products from all providers – even if this means services that are potentially competing with the MOs own products (e.g. if the MO is a part of a MSP). Being able to stay impartial is another advantage of a stand-alone MO enterprise as they can promote all services equally without any restrain.

While both MO types have benefits and disadvantages, it is not necessary for a city or region to only go with a single model. It is possible that multiple MaaS Operators will emerge in any given area who will be in competition with each other. Each area can only have a single MaaS operator which is public sector driven, but could have one or many private sector MaaS operators. It may also be the case that there is a public sector driven MaaS operator and several private operators. Market forces will drive prices and offerings and decide which and how many operators can survive in the specific market long-term.

Regardless of how the MO is created, it has a large part to play in the MaaS ecosystem. The MO will be responsible for product development, which will drive the concept forward. The products, for example the mobility plans offered, need to be carefully designed taking into account both the available supply and the end user. Pricing the products will be impacted by the status of the MO, as the public sector can only be non-profit and everything needs to be invested back into operations. Private companies are for profit, but as such, will need to pay taxes (this will be further addressed in the policy pillar).

The interactions and partnerships between MSPs and the MO; the end users and the MO and the authorities and the MO all need to be clearly established and the unilateral-bilateral-multilateral formal agreements need to be made. The agreements between the MO and the MSPs are probably the most critical. These will include detailed revenue allocation models, which are critical as the MO is now the body that sells the MSPs' services the users. The most efficient model has yet to be determined, but some of the potential options can be based on the online travel agency industry (e.g. Expedia) such as the merchant model, whereby the MSPs sell services to the MO in bulk at a discounted wholesale price and then the MO sells them on to customers at a mark-up price; or the agency model, where the MSPs give the MO commissions based on the services bought and the MO does not have to buy anything up front. The optimal revenue allocation model will be influenced by the MO structure as, for example, in the merchant model the MO

needs large upfront capital in order to pre-purchase in bulk, which a smaller private company may not have and may also be more risk averse and not want to be end up with potential leftover capacity. Each of these models and possible alternatives are an important area of future research. Another aspect of the MSP-MO interaction that will need to be clarified in bilateral agreements is whether the consumer will still be able to buy services directly from the MSP or will the MO have exclusive rights to sell these services. It is likely that there will be no exclusivity, especially while the MaaS operator in the market diffusion stage.

Finally, for the MaaS ecosystem to be commercially sustainable, there are countless additional elements that need to be further investigated. Some of these include: financing and the potential adaptation of public-private-people partnerships that could flourish under MaaS; exploring other relationships, such as alliances with payment and security platforms, energy companies, parking management businesses; and identifying a single consistent unit to allow for interoperable monetisation of all products. The combination of all these cross-company, cross-sector collaborations will build the social and economic infrastructure needed for Mobility as a Service systems.

4.1.2 Technology Pillar

The next aspect of the MaaS Ecosystem, the technology pillar, is embedded within the business model pillar, since the technological element is what enables the business models to work. This element provides the whole functioning of the system as it contains all the analytics that are necessary for the ecosystem to operate. It could be viewed as the ‘brain of the operations’. To provide the services to the users, a single interface needs to be available that combines planning, booking, ticketing and payment functions (front-end). In the back-end, the core is a dynamic multiservice journey planner, which relies on a real-time supply and demand optimisation engine. This system is connected with a demand allocation and booking engine, that automates these capacities. The users interact with a dashboard that includes their user profile and options for them to select personalised products. Finally, the billing and payment engine allows automatic fee settlement. The technological requirements are summarised in Table 4-2.

Table 4-2: MaaS technological requirements

	Requirements and Needs
Back-end	• Ability to synchronize data from different service providers and users • Ability to perform supply-demand optimization in real time • Stable and secure engines for user analytics and reporting (e.g. payment and billing) • Back-up systems in case of failures • Provide data management infrastructure • Good quality, real time data needed from MSPs

Front-end	• Smartphone app and web-based platform
	• Needs reliable internet connectivity
	• App elements:
	  ○ multiservice journey planner
	  ○ feedback options
	  ○ user profile and personalisation

Looking first at the back-end analytics, the MaaS platform needs to be able to synchronise data from the different service providers as well as the users in order to perform supply and demand optimisations activities in real time. The MaaS back office will need to have various engines for user analytics and reporting, demand and supply allocation (including journey planning) and user payment and billing. These engines will need to run dynamically in real time and be very stable and secure. Backup systems need to be in place in case of any failures, as if these do not exist and there is an emergency the whole system could crash. As available mobility resources are allocated in real time to fit the dynamic needs of users, a systems breakdown could be catastrophic.

In order for all of these engines to operate, the technology hub depends on fast, reliable and secure data. The essence of the necessary data is provided by the MSPs and an overview of these can be seen in Figure 4-2.

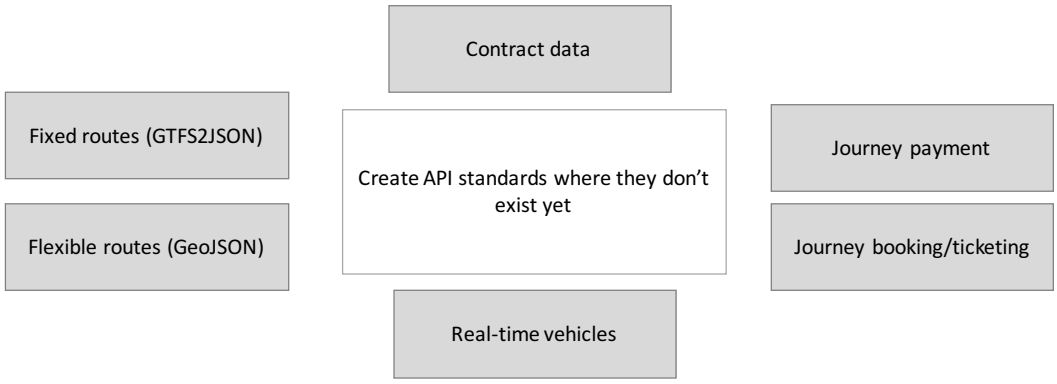

Figure 4-2: Data Sources

Most of the currently available MSP's APIs are for planning and are used by the variety of journey planners available at the disposal of today's travellers. In MaaS, however, besides APIs for planning, real time vehicle and route information as well as booking and ticketing information is required. The incoming API information needs to go through an API gateway, where the traffic is filtered according to access control and safety while the metrics are captured and logged. The traffic is then redirected and routed to the appropriate area of the MaaS platform. Open and compatible APIs for data provision and access as well as sensor data from services and the infrastructure are all essential - this latter aspect will multiply several fold with the widespread introduction of automated vehicles. Compatibility refers to ability of all devices, systems and infrastructure within a single MaaS scheme, as well as among the whole global MaaS ecosystem, to communicate information by being able to read, understand and translate each other's data. Data providers can play a key role here in making the data compatible, such as Transport API in the UK. However, once every player adheres data standards and protocols which are adopted on a central policy level, the role of data providers will become redundant. The MaaS platform could be an open platform that all the MSPs have access to and use the open libraries in order to develop their services; or it could be managed by a third-party operator. In the latter case, the MaaS Operator's job is simplified as the platform operation is contracted out, however, the MO becomes bound and reliant on the platform operator.

The back-end also has a critical role in providing the data management infrastructure of the ecosystem. The multi-dimensional, ubiquitous data capture with mobile devices and sensors about services, infrastructure and users' needs to be stored and retrieved in a fast, reliable and secure manner. The traditional technology architecture will not be able to accommodate such unprecedented levels of scale, speed and data variability. As such, advances in big data need to exploited in order to provide the technological foundation for large scale data collection, storage and analysis. Concepts that employ cloud computing, such as the NoSQL database technology will need to be explored to facilitate the agile and real-time data management requirements. Scalable data warehouses and large distributed file systems must be regulated by strict security and data policy requirements to ensure the latest encryptions tools and protocols are applied and followed.

Turning to the front-end, the program interface is what the users interact with directly. In this case it consists of the MaaS smartphone application and the web-based platform that the users see and communicate with. Since the front-end and back-end systems need to be in permanent interaction, the front-end devices need to be enabled by fast and reliable

internet connectivity in the forms of 3G and 4G network coverage as well as on-board and station Wi-Fi access. The main element of the application is of course the dynamic multiservice journey planner, which is powered by its back-end equivalent. This is where the users plan their journeys, book their vehicles and receive real-time updates about their travel. Further, this is through which users can provide feedback about services immediately when encountering any unusual service conditions. If promoted adequately, this social feedback mechanism can be a vast source of information and a tremendous advantage of MaaS systems. Finally, the application interface needs to have a user profile, where all the personalised elements of the MaaS service can be selected and altered. These include the MaaS digital wallet, which provides the overview of the financial standing of the user; the digital ticket, which the customer uses to access the services; the MaaS plan choosing platform, where they can select the type of monthly plan they want to use and many more.

4.1.3 End Users Pillar

Everything presented in the business models and technology pillars aim at providing the best possible experience for the end users, who are the heart of the ecosystem. The core business model is based around individual customers (B2C) however corporate customers can also be an important addition (B2B). In these latter cases, companies can subscribe to the MaaS platform's corporate mobility schemes and provide their employees and partners with travel allowances. The user needs for both these groups have to be taken into account when designing the service offerings.

Nowadays user needs are being reshaped and this has to be reflected in the way MaaS products are created and offered. User needs are increasingly heterogeneous and demand mass customisation where products are tailored to their requirements. The sharing economy is becoming more widely accepted, especially among the younger generations, fostering demand for shift from ownership to usership. The main product MaaS has to offer are mobility packages that serve the multimodal door-to-door needs of travellers. To optimally create these, many individual elements need to be considered on top of the societal changes mentioned above. These, depicted in Figure 4-3 can be grouped into individual mobility patterns, socio-economic status and attitudes and perceptions.

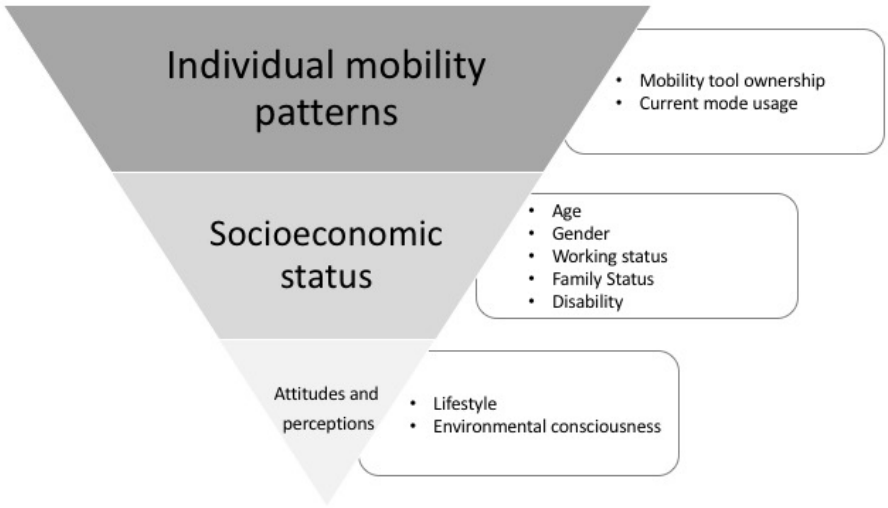

Figure 4-3: Elements to be considered when creating MaaS plans

Pre-MaaS individual mobility patterns include current mode usage and mobility tool ownership. These provide the basis for any post-MaaS travel behaviour due to status quo bias, commitments, sunk costs and cognitive dissonance. Current behavioural patterns need to be taken as a premise, which will be altered to a greater or lesser extent depending on other characteristics of the individual. These other characteristics include socio-economic status, such as age, family status and disability as well as attitudes and perceptions towards the environment, health etc. can greatly influence choices and behaviour change. MaaS has the potential to promote more environmentally and economically sustainable modes, which is an objective that also needs to be taken into account when creating the packages (Giesecke et al., 2016).

Users play a unique role within the MaaS ecosystem. They, of course, are mainly the customers of the service. Yet, they also play an important part in shaping the scheme via feedback mechanisms that should be included in the interfaces of the platform. Community feedback can provide real time customer experience responses about elements of the mobility network that may be difficult to collect information about otherwise (e.g. comfort). Further, users can be the source of ample amounts of data for analytics, including real time location, service satisfaction and choices just to name a few. One possible concept that can be tested is giving power to the user as to how much of their data they are willing to supply to developers and researchers. Obviously, some data is necessary for the system to function, but there is vast and untapped potential in a whole range of other data elements. Instead of systems automatically scraping users' data, through this approach, users would be empowered to decide what should be done to their data. For example, users could be given the option to 'donate' their data to science if they

wish. This could be a first-of-its-kind step towards open, automated and consentient transfer of data from users to research scientists.

There are many end user elements that need further investigation and will help shape the design of the products. User responses to the service should be tested in real life experiments, living labs and pilots. These should ideally be conducted in diverse environments, such as large urban centres, smaller cities, cross-border cases. This latter is important to highlight as frequent travel across borders are an everyday occurrence. In several cases, especially on continental Europe, even daily commutes can be cross-border, as workers may choose to live in a nearby country to save money. Real life experiments as well as stated preference experiments can help determine users' willingness to pay for products and potential modal changes resulting from MaaS.

4.1.4 Policy Pillar

The final pillar, policy, is the overarching umbrella that enables the system to operate in a fair, transparent and effective manner. For the whole MaaS concept and this framework to materialise policy, standards and regulation are needed to enable the market and protect the actors. As MaaS is based on integration and interoperability, which are only possible if there are regulations and standards governing them. The policy framework is made up of five cluster areas in which guidance needs to be provided. These are provided in Figure 4-1.

As expected, the regulatory responsibilities are the largest element in this pillar. The regional regulations will govern each regional MaaS system independently, every scheme will be unique depending on the conditions in each environment. These will need to be adjusted to fit with the local regulatory environments. As the ultimate vision is to have an Internationally Integrated Mobility as a Service system, global MaaS standards are included in the framework. This may seem very abstract and impossible to achieve, however, GSM (Global System for Mobile communications) networks are a prime example of how it is possible to make globally accepted and implemented technical standards (Mouly and Pautet, 1992). These standards initially will most likely only be implemented on a country level, but having standardised and interoperable MaaS systems all over a country is definitely a first step in the right direction. On a more local level, the part-taking service providers and the MaaS Operator will likely need to be licenced (touched upon above). This ties in with the concept of standards, as all the providers will need to abide to them and should only be able to receive and retain their operating licences if they accept and follow these. Furthermore, the regional MaaS Operator will need to meet certain criteria. One approach could be making a checklist of

characteristics and benchmarks (e.g. security standards, interoperability, sustainability of the system etc.) that MaaS Operators need to meet before they can be licenced to operate.

Financing corresponds to the second cluster included in the policy framework pillar is financing. As MaaS systems have the potential to be an environmentally and socially sustainable alternative to private vehicles (Giesecke et al., 2016), providing tax reliefs to these services can be a policy model that is worth exploring. Further, discounted MaaS packages – similar to current discounted public transport passes - should be offered to support social inclusion and overcome mobility inequality. There are many financing structures that need to be explored, including innovative ones like crowed funding, but these are out of the scope of this thesis.

Privacy and security policy are a critical element to the framework. The success of the MaaS concept relies on the real-time transfer of highly disaggregated information. If there are no proper privacy and security measures in place for both the demand and the supply sides, the system will break down. Further, the legal implications or any security breaches need to be outlined in policy, to make sure there is adequate enforcement of any privacy and security related violations. These standards/requirements also need to be made known to all affected parties. Fourth, passenger rights have to be addressed. As users will enter into legally binding contracts with the MaaS Operator, consumer protection regulations need to be applied. These are similar to those currently exercised for various transport service providers, for example flights or rail. Policies in this area can be adapted from those that currently regulate the individual services. These include, models for compensation if the service provided does not meet the expected standards, or if for any reason the user is denied access to any of the services. Further, users will only be willing to contribute significant amounts of information, if their privacy remains intact. Finally, technology and open data policy round out the pillar. The above discussed interoperability and open data play a crucial role. Both of these can be expedited by creating regulations, standards and policies.

The policy environment taps into every element of the MaaS ecosystem as such is an extensive topic for future research. Only through regulations, standards and policies can a safe, reliable and effective service be created that is available for all.

4.2 REVIEW OF SERVICES

Recently there has been a wide range of MaaS services appearing around the world. Building on previous reviews of services (Jittrapirom et al., 2017; Magoutas et al., 2017; Georgakis et al., 2018; Kamargianni et al., 2019),

Name (Area)	Short description	Status (Year)	Modes and Services	Types of actors (MaaS operator)	Functionalities
Optymod (Lyon, France)	Multimodal journey planner with booking for bike but no payment integration	Operational (2012-)	PT Bike sharing Regional train Parking	Public (Local authority)	Journey planning Real time info Congestio prediction Booking (for bike sharing Airplane schedules
TransitApp (143 cities worldwide)	Multimodal journey planner with payment for bike sharing (but no other modes) and booking for some modes	Operational (2012-)	PT Bike sharing Car sharing Taxi Ride hailing	Public and private (Private company)	Journey planning Real time info Booking (shared modes and taxi) Payment (Bike sharing) Departure alarms
Shift – Project 100 (Las Vegas USA)	Service where fleet of multimodal services owned by single company and users can pay, book and plan in one place	Ended (2013-2015)	Shuttle bus Bike sharing Car sharing Valet	Single private company	Journey planning Payment Booking Invoicing
Ubigo (Gothenburg, Sweden)	Small scale field operation test of a MaaS scheme	Ended, but larger deployment pending (2013)	PT Car sharing Car rental Taxi Bike sharing	Public and private (Private MaaS broker)	Journey planning Booking Ticketing Payment Invoicing 24-hour customer suppor
Smile (Vienna, Austria)	Small scale MaaS pilot	Ended (2014)	PT Bike sharing Car sharing Taxi Parking Charging stations Regional trains and ferry	Public and private (PT provider)	Journey planning Real time info Booking (shared modes Taxi / Regional train) Ticketing Payment Invoicing
Mobility Shop (Hannover, Germany)	Integrated ticketing and payment services	Operational (2014-)	PT including rail Car sharing Taxi Regional rail	Public and private (PT provider)	Real time info Booking Ticketing Payment Invoicing
Tuup (Turku, Finland)	Commercial multimodal journey planning app with integrated payment, booking and ticketing	Operational (2015-)	PT Bike sharing Car sharing Car rental P2P car rent Taxi Parking Freight service	Public and private (Private company)	Journey planning Real time info Booking Ticketing Payment Invoicing
WienMobil Lab (Vienna, Austria)	Pilot project based on earlier Smile project to test integration of transport modes	End of project (2015-2016)	PT Bike sharing Car sharing Taxi Parking	Public and private (PT provider)	Journey planning Real time info Booking Payment Invoicing
My Cicero Italy)	Commercial journey planning app with integrated booking and payment	Operational (2015-)	PT Taxi (planned) Parking Permit for urban congestion charging	Public and private (Private company)	Journey planning Real time info Booking Ticketing Payment Invoicing

			zone Regional rail and bus		Municipality services	
Moovel (Germany)	Commercial journey planning app with integrated booking and payment	Operational (2016-)	PT Bike sharing Car sharing Taxi Ferry Regional train	Public and private (Private company)	Journey planning Real time info Booking Payment Invoicing	App
Whim (Helsinki, Finland)	Commercial MaaS service, with application	Operational (2016-)	PT Car rental Taxi Regional rail Bike sharing Car sharing	Public and private (Private MaaS company)	Journey planning Real time info Booking Payment Ticketing Invoicing	App
CityMapper	Commercial MaaS application, created by a company with a journey planning app	Operational (2019-)	PT Bike sharing Taxi	Private and Public (Private company)	Journey planning Real time info Booking Payment Ticketing Invoicing	App

provides an overview of selected services. A number of other services could also be included, however the ones presented in table provide an overview of the current state of the market. All of the presented services have some key elements that make them be considered as MaaS including: multimodal journey planning, real time information, integrated ticketing and payment, the inclusion of a number of different transport modes, an integrator organisation who is in charge of providing the services to users through a single platform.

Table 4-3: MaaS Schemes

Name (Area)	Short description	Status (Year)	Modes and Services	Types of actors (MaaS operator)	Functionalities	Interface	Payment Options	Personalisation
Optymod (Lyon, France)	Multimodal journey planner with booking for bike but no payment integration	Operational (2012-)	PT Bike sharing Regional train Parking	Public (Local authority)	Journey planning Real time info Congestion prediction Booking (for bike sharing) Airplane schedules	App	No integrated payment option	Mode and address preferences and cycle ownership included in planning
TransitApp (143 cities worldwide)	Multimodal journey planner with payment for bike sharing (but no other modes) and booking for some modes	Operational (2012-)	PT Bike sharing Car sharing Taxi Ride hailing	Public and private (Private company)	Journey planning Real time info Booking (shared modes and taxi) Payment (Bike sharing) Departure alarms	App/ Web	Pay-per-use	Save regular and preferred routes and locations Set preferences (e.g. minimise walking etc.). Link with calendar and personal contacts
Shift – Project 100 (Las Vegas USA)	Service where fleet of multimodal services owned by single company and users can pay, book and plan in one place	Ended (2013-2015)	Shuttle bus Bike sharing Car sharing Valet	Single private company	Journey planning Payment Booking Invoicing	App	Pay –per-use and monthly packages	Optimised journey planner, Membership levels with different types of services
Ubigo (Gothenburg, Sweden)	Small scale field operation test of a MaaS scheme	Ended, but larger deployment pending (2013)	PT Car sharing Car rental Taxi Bike sharing	Public and private (Private MaaS broker)	Journey planning Booking Ticketing Payment Invoicing 24-hour customer support	App	Monthly plans	Personal mobility plans for each month where credit could be topped up or rolled over.
Smile (Vienna, Austria)	Small scale MaaS pilot	Ended (2014)	PT Bike sharing Car sharing Taxi Parking Charging stations Regional trains and ferry	Public and private (PT provider)	Journey planning Real time info Booking (shared modes / Taxi / Regional train) Ticketing Payment Invoicing	App	Pay-per-use	Optimised trip planning using information about user. Can set preferences based on cost time, CO2

Mobility Shop (Hannover, Germany)	Integrated ticketing and payment services	Operational (2014-)	PT including rail Car sharing Taxi Regional rail	Public and private (PT provider)	Real time info Booking Ticketing Payment Invoicing	App	Monthly membership for discounted tariff	Booking and payment cancellation. Personalisation of modes used
Tuup (Turku, Finland)	Commercial multimodal journey planning app with integrated payment, booking and ticketing	Operational (2015-)	PT Bike sharing Car sharing Car rental P2P car rent Taxi Parking Freight service	Public and private (Private company)	Journey planning Real time info Booking Ticketing Payment Invoicing	App	Pay-per-use	Optimised journey planning based on user's daily routines. Can set preferred modes based on cost and CO2
WienMobil Lab (Vienna, Austria)	Pilot project based on earlier Smile project to test integration of transport modes	End of project (2015-2016)	PT Bike sharing Car sharing Taxi Parking	Public and private (PT provider)	Journey planning Real time info Booking Payment Invoicing	App	Pay-per-use	Have personal mobility profile in which you can: store car and bike sharing membership, set preference based on mode, cost, time, CO2 footprint
My Cicero Italy)	Commercial journey planning app with integrated booking and payment	Operational (2015-)	PT Taxi (planned) Parking Permit for urban congestion charging zone Regional rail and bus	Public and private (Private company)	Journey planning Real time info Booking Ticketing Payment Invoicing Municipality services	App	Pay-per-use	Stores different tickets; record and share journey
Moovel (Germany)	Commercial journey planning app with integrated booking and payment	Operational (2016-)	PT Bike sharing Car sharing Taxi Ferry Regional train	Public and private (Private company)	Journey planning Real time info Booking Payment Invoicing	App	Pay-per-use	Favourite routes stored in system, personalised notifications in case of disruptions, can link with social media accounts
Whim (Helsinki, Finland)	Commercial MaaS service, with application	Operational (2016-)	PT Car rental Taxi Regional rail Bike sharing Car sharing	Public and private (Private MaaS company)	Journey planning Real time info Booking Payment Ticketing Invoicing	App	Pay-per-use and monthly plans	Calendar synchronisation, personal info sharing, Profile where you can change subscription
CityMapper	Commercial MaaS application, created by a company with a journey planning app	Operational (2019-)	PT Bike sharing Taxi	Private and Public (Private company)	Journey planning Real time info Booking Payment Ticketing Invoicing	App	Plans	Plans for personalisation – still under development

The geographic location of the schemes is very much European oriented, with only two of them operating (or operated in the case of Shift) in other locations. This shows that Europe is the pioneer when it comes to MaaS systems. Looking at the structure of the services, there seem to be two common approaches with regards to what type of entity is operating the integrated service. First, there are those services where a private company is in charge of the integration (e.g. TransitApp, Moovel, Whim). In a number of examples, a commercial journey planning app is extended to have booking and ticketing functionalities, and the company owning the app naturally evolves into being the operator (e.g. My Cicero, Moovel). It is also possible that the private company is created with the sole function of being a MaaS operator as in the case of Whim (the MaaS product of MaaSGlobal). The second common approach is that the public transport provider broadens its scope and offers the other functionalities (e.g. WienMobil Lab, Mobility Shop).

Turning to the transport modes included in the services; public transport is part of every single service except Shift. However, Shift is different than all the other services, in that all the different transport modes were owned and operated by the same company. There is no integration of different mobility service providers meaning it is questionable whether this can be considered MaaS or even MaaS-like. Either way, its operation was not successful and the service was stopped in 2015. Circling back the public transport point, the inclusion of public transport in all of the services seems to indicate that it provides the foundation of a successful integrated service. This raises an important question: is public transport the backbone of MaaS?

Moving on to the core functionalities of the services, all but one rests on a multimodal journey planner. This makes sense, as one of the easiest ways to integrate services is at the planning stage, where, besides timetables and schedules no other information sharing is necessary. Real-time information is also a prominent feature, which goes hand in hand with multimodal journey planning. Payment (and invoicing), booking and ticketing functions are part of some, but not all services. In order to successfully achieve these for multiple mobility services, sharing of detailed information and APIs is necessary. This in some cases is further complicated by the fact that some services may not have, for example, electronic ticketing and payment systems, meaning it is very difficult it integrate them into such an ICT intensive system. A number of cases exist (e.g. Optymod, TransitApp) where certain transport modes are part of the payment, booking or ticketing systems but not all. It may be, that initially only a few are integrated into the system, and as time passes, and technology improves or agreement are made, the other

modes/service providers will also join. Some of the services also include some ad hoc functionalities, such as municipality services (MyCicero) and Airplane schedules.

Next, turning to the user, all of the services are available on smartphone applications. This shows the power that these new ICT technologies have in the transport sector, but also raises some questions regarding its accessibility to certain population segments (elderly or technologically illiterate). With regards to the payment options, most services only provide pay-by-use options. However, Shift, UbiGo and Whim also provide monthly subscriptions. Focusing on the latter two, in the case of UbiGo trial, households subscribed to monthly plans including a personalised combination of- and credit for- the various travel services. The prepaid tailored monthly plans were determined in time or distance for each mode and the combined subscription was cheaper than each element individually. Credit could be topped up or rolled over and subscriptions modified. A mobility broker handled everything for the users to make it a seamless experience. In the case of Whim, their product offerings have changes a number of times during their time of operation. Initially, their publications indicated that they support plans that were based the characteristics of socio-demographic groups, such as families or students (Hietanen, 2016). The proposed approach included prespecified amounts of certain transport modes in each plan which are determined by the needs of each group. They also included some more innovative ideas, such as ‘guaranteed 15-minute pick up by taxi’, ‘child seats provided in cars’, and the inclusion of shared taxis. However, more recently their MaaS products designs are not segmented according to socio-demographic groups, but rather by the size of each plan. All of them have local public transport as their core, and then have a certain amount of points that can be used freely among other modes (taxi and car sharing).

Finally, all the services have some level of personalisation or customisation options available to users. In many cases this allows users to have a personal profile where they can set their preferences in terms of mode choices or optimisation algorithms. Some even allow users to connect with their calendars or their social media accounts.

4.3 CONCLUSIONS

Section 4.1 first presented a holistic approach to describe and evaluate the various elements of the MaaS ecosystem. In the development of the ecosystem, four pillars were identified - business, technology, end users, policy - whose interplay creates the complex networks and interactions between the part-taking agents. It has to be noted, that the presented reference architecture is no way exhaustive. The demonstrated building blocks

could each be the catalyst for further detailed research on them individually as well as the interactions and interplay between and across them. For future research (on the ecosystem – which will not be discussed in more detail in this thesis), the author advocates the value of a systems approach, where the synergies can be incorporated into the analysis. Second, this section presented a review of current MaaS applications. A wide variety of services were presented, all at varying levels of integration and functionalities. From this evaluation, it is clear that the MaaS concept itself as well as its applications are still in their infancy. Even though the idea has been around for years now, its complexity means that there are still a large number of unanswered questions. The list of MaaS-like integrated services (which does not intend to be exhaustive) shows both that there is growing interest in the concept and that no one service or business model has risen among others. This also includes the type of products they offer – there is an assortment of product offerings made up of different monthly membership options, subscriptions/packages and pay-per-use choices.

CHAPTER 5: SURVEY DESIGNS FOR MAAS PRODUCTS

The aim of this chapter is to present the process of designing surveys that are able to capture individual preferences for MaaS products. The developed design includes a number of different approaches that can be selected from depending on the aim and focus of the specific use case. The chapter also discusses the specific challenges of designing surveys for MaaS products and how these differ from surveys regarding other transport services.

5.1 MAAS SURVEY FOUNDATIONS

A survey that will allow for analysis on individual preferences for MaaS and its products can include four distinct components. The word *can* is used, as not all elements are necessary. However, to ensure that the survey is as comprehensive as possible, this thesis describes and advocates for all four elements. These are depicted in Figure 5-1.

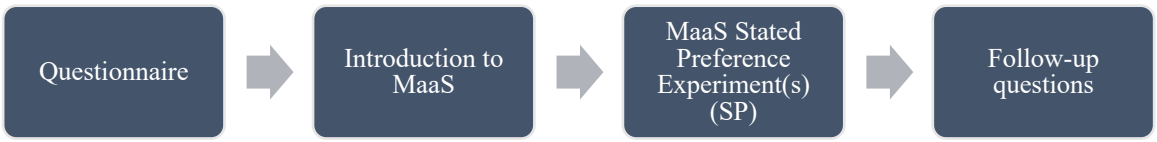

Figure 5-1: MaaS Survey Components

The first element of most surveys is a questionnaire section collecting information about the respondents characteristics and mobility habits. This background information allows for user segmentation and provides variables in later modelling and analysis efforts. Second, MaaS is introduced to respondents. This is a critical part, as survey participants will most likely not have any prior knowledge about the concept (at least in most cases; this of course may be different in those areas where MaaS is operational e.g. Helsinki). Third, MaaS product stated preference (SP) experiments are presented. These can take various different forms and designs, which will be extensively discussed later in this chapter. Finally, follow-up questions can be presented to respondents about MaaS. By this section of the survey, respondents should have a working understanding about MaaS and its products and should be able to better answer specific questions.

5.1.1 Questionnaire

The first section of the survey is the questionnaire during which information about the respondents' socio-demographic characteristics, current mobility tool ownership and mobility habits should be included. These are important not only for later modelling purposes and to allow for market segmentation, but also some elements of the SP can be dependent on these (context dependence). Local, regional or even national household travel surveys, e.g. the London Travel Demand Survey or the National Household Travel Survey for the US, can provide great building blocks for the RP questions. By matching up key questions and response options with these surveys and the census, the sample collected through survey applications can be compared to the population of the studied location. The questions included should be carefully selected and as thorough as possible, to collect any information that may explain preferences for MaaS. This will allow minimization of missing variable bias during modelling.

Thought experiments, literature reviews and discussions with stakeholders can also help determine which questions should be included. The amount of questions should be kept large to collect enough information, while also trying to keep the response burden as low as possible. This trade-off should be studied with focus groups before any survey is implemented, as ones that are too long, risk lower engagement and fatigue, that can lead to a decrease in the quality of response and survey abandonment (Galesic and Bosnjak, 2009; Callegaro et al., 2015). Based on the author's a-priori evaluation, Table 5-1 presents some categories with indicative questions. The list is not exhaustive, rather it provides a preliminary resource that researchers can use, add to or delete from for each application.

Table 5-1: Questionnaire sections

Topic	Questions
Socio-demographic	Age, gender, residential location, education level, employment status, household income and composition, health conditions/disabilities
Current mobility characteristics and mobility tool ownership - private	Vehicle ownership including types, usage, average monthly vehicle related expenses; bicycle ownership, license holding; scooter etc.
Current mobility characteristics and mobility tool ownership – shared and taxi	Car club awareness and membership (costs, usage), bike sharing usage and membership, taxi usage broken down by taxi type (Taxi hailed off street or ordered via phone; ordered through app), monthly spending on taxi, ride sharing awareness and use, electric scooter sharing awareness and use etc.
Current mobility characteristics and mobility tool ownership – public	Public transport usage, first-last mile modes, public transport passes, discounts, contactless payment usage (e.g. contactless bank card, Apple pay)

Travel patterns and characteristics	Frequently visited locations, mode, duration, factors in choosing mode for commute – grocery shopping – leisure activities, number of trips conducted with various modes per week, satisfaction with regular travel
App based mobility	Smartphone mobility apps and usage, attitudes towards mobility apps
Attitudes and perceptions	Towards innovative products and services in the transport sector, car ownership, car sharing schemes (the latter two for current car users and non-car users)

Looking at each row in Table 5-1, first questions regarding the socio-demographic characteristics of the respondent are included. These are necessary for segmentation and will assist with generalizing the results to the wider population. If there are any concerns about collecting residential location, this can be asked only to a ward level (first part of post code) and made optional, in order to ensure anonymity and the privacy of the respondent.

The next three sections are about the respondents currently mobility characteristics. Looking at private mobility, this includes information about private vehicles and the licenses that would enable to use of these, bicycles, and also any other private mobility tools that could be of relevance. For example, if a researcher was looking into MaaS schemes in an area where scooters/Vespas were frequent (e.g. Italy) questions should be tailored to include these. Next, questions regarding the use and awareness of shared modes is included as most MaaS schemes involve one or more of these modes. This, again, should be carefully tailored to the area of the study, and prior analysis of the modes (and their business models) that could be included in a MaaS system should be examined. In many cases the general knowledge about shared modes is patchy, as such the definitions of these should be included. For example, car sharing could be explained as a service where “you can rent a vehicle to drive for a short period of time, usually hourly”, to ensure that it is not confused with car rental or ride sharing. Taxi services and the respondents use of them is also important as these are frequent modes in MaaS systems. As many urban areas have a wide variety of taxi services and taxi business models (ones hailed off the street, Uber/Lyft, shared taxi options etc.), it needs to be clear to the respondent what each question is referring to. Questions can be broken down by these taxi types to allow comparisons between the uptake and popularity of the different types and focus mainly on usage and costs. The final mobility option is public, which is at the heart of all MaaS schemes. Public transport pass ownership and usage, payment methods are important indicators of their commitment to this mode and their willingness to subscribe for long-term (monthly) mobility tools.

Next, a number of questions can be added that focus on the respondent's weekly travel patterns and their characteristics. This section asks questions regarding most frequently used transport modes and trip duration for the most common trip types, commute – grocery shopping – leisure. It can also include questions regarding the factors that affect an individuals' choice of transport mode, for example: comfort, travel time, ease of use, price, reliability and safety. Additionally, this section can include details about respondents' weekly usage of all the different transport modes, giving thorough quantitative data about current mode usage. These could provide valuable insights when analysing preferences for MaaS products and they can indicate a respondent's habitual behaviour.

The penultimate section is around app-based mobility. Nowadays, journey planners and other mobility related mobile phone applications that help users get around a city. As these applications have characteristics that are similar to those that a MaaS application would have, it is important to understand not only the use of journey planners, but also the use and attitude towards other mobility apps of the respondents. Statements regarding the respondents' attitudes and perceptions towards the usefulness of- and dependence on- mobility related apps can be added. These are statements with 7-point Likert scale answer options. Carrying on with attitudes and perceptions, statements regarding the 'innovation adoption', specific to transport options, can be shown. These can later be used to construct latent factors that can help explain openness to MaaS.

As mentioned above, the questions can be adapted to any area and can be lengthened/shortened based on the needs of each study. It is important to do extensive a priori analysis on the area to be studied with regards to: (1) the existing transport modes / any that will be introduced in the near future (2) the type of MaaS system that wants to be examined, including what modes will be included (3) any existing travel survey in the region to use as a basis.

5.1.2 Introducing MaaS-Specific Survey Sections

Before survey participants can be shown SPs related to MaaS products, they need to be introduced to the MaaS concept itself. As MaaS is new and unknown to the wider community, it has to be explained in terms that are easily understood. The difficulty comes from doing this in a short and concise manner, while making sure all the key MaaS characteristics are included. There are three overarching methods by which MaaS can be introduced to respondent – all with benefits and disadvantages.

The first method is using a simple description to explain the MaaS concept. When writing this, the text needs to be short and to the point, to ensure that the respondents actually

read this. Various methods such as only having the ‘next’ button pop up after a certain amount of time can be employed to aid this (although this in itself could cause survey abandonment, however, arguably for those that click through the definition very quickly would not be able to adequately answer the questions and would cause biased results). The description should be written from a user’s point of view and the wording should be context dependent and tailored to the study area and target audience. Also, relating the description to other services, such as journey planners or travel passes that they may use can be helpful. In either case, the wording should be carefully tested with focus groups to ensure that the interpretation is correct.

The second method utilises visualisation techniques to explain the MaaS concept and its core functions. As the MaaS app is what users would see and interact with in real applications, screen shots mock-ups can be provided as illustrations with short descriptions to complement this. Icons can be used for transport modes that are included. Using pictorial representations makes users’ perceptions of modes more homogenous, makes the task more interesting and easily understandable (Morikawa, 1989). Using pictures also increases the chance that respondents will look at this and the text around it, thus leading to overall a greater fraction of respondents understanding the concept. Further, in the industry, currently many products are explained using illustrations, so these are probably more familiar to respondents.

The third method involves creating a short video clip demonstrating the MaaS concept. Again, the video would need to be short and to the point, which is very challenging with such a complex concept. It is also important that the video remains unbiased and does not overly emphasise certain aspect of MaaS. The video should also be rendered small, so that it can be easily stored and played on any kind of device.

There are benefits and disadvantages to all three approaches. The first one is the simplest to implement, as no graphic designing or video creation are necessary. It is the most viable one when there are resource constraints. However, it has the highest risk of people getting to the SP without understanding MaaS. The other two methods are more likely to engage respondents and ensure they have a working understanding of MaaS, they are also much more resource intensive. This is especially true for the video one, as creating a high quality video requires a large amount of time and either skills or financial investment. Taking this into account, the pictorial method can be a middle-ground solution. This also has the advantage, that, if done well, is able to convey the necessary information to the respondents in the shortest time. Another aspect to consider is which method is able to provide the most balanced and neutral view about MaaS. If MaaS is presented in a way that makes it sound very exciting, researchers will not be able to get

respondents impartial view as they will be biased by the presentation. Biasing is possible with all three methods, although may be more likely with the description and the video where the narration could include words and phrases that have a positive connotation.

An important thing to add is that before implementation, the presentation should be carefully be mocked up and tested with focus groups. It is especially important to ensure that the concept is well understood and there are no biases introduced though the explanation. These can be teased out by presenting the focus groups with the concept and then asking them to explain what they understood by this. In an ideal world, all three methods could be mocked -up and tested, keeping in the end the one which is best received. However, this is very resource intensive, and in most cases will be infeasible.

5.2 MAAS STATED PREFERENCE EXPERIMENTS

5.2.1 MaaS SP Overview

Designing MaaS SP experiments are not a straightforward process. This is mainly due to the fact that MaaS itself is not yet well defined, and the interpretation of what MaaS entails can differ from one area to the next. Also, MaaS products themselves, which are what would be under investigation during an SP experiment, are not clear and there are many possibilities of how these could look like. Nevertheless, some of these challenges can be overcome by following a detailed process when designing MaaS SPs. These are outlined in Figure 5-2, which provides a flowchart of the different elements.

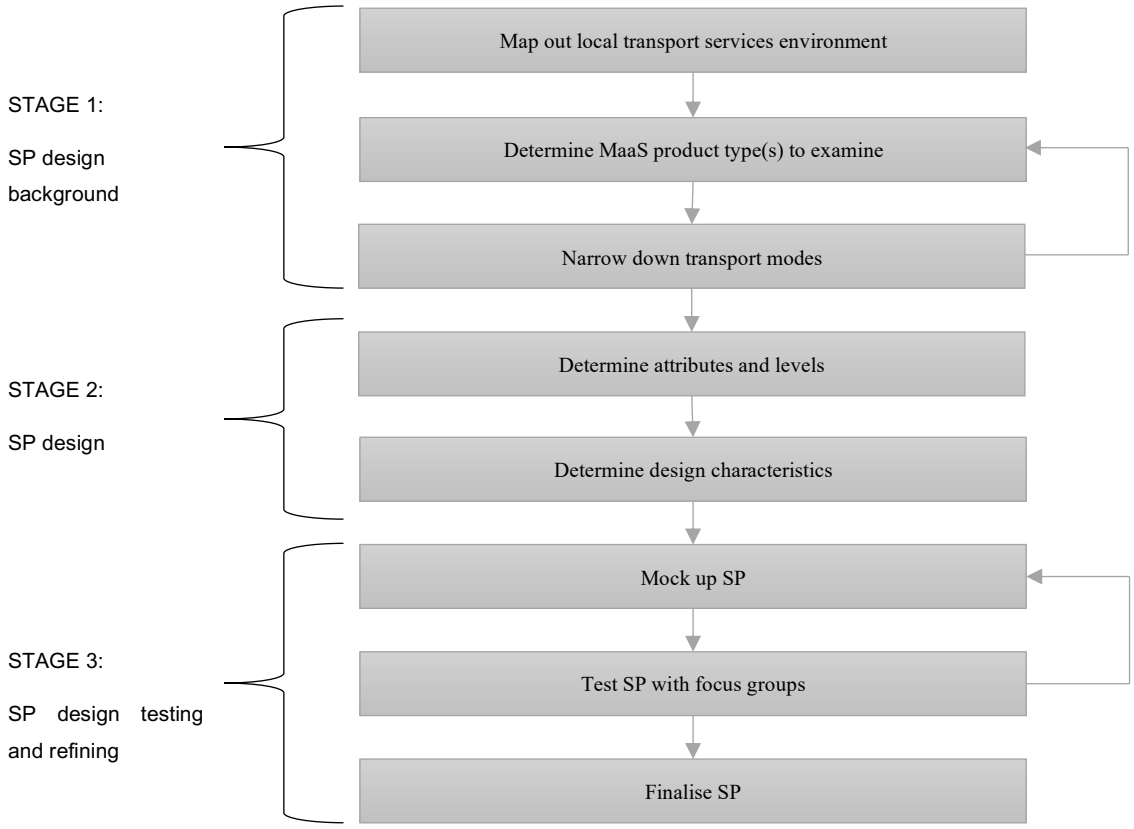

Figure 5-2: MaaS SP Design Flowchart

Stage 1 of the design process involves background research and decisions regarding the exact MaaS product type that will be examined. This stage can involve desk research, discussion with industry actors and thought experiments. Stage 2 is the core SP design, which includes determining the SP attributes and levels and other design characteristics. This stage is clearly fed from the earlier stages and takes many factors from there. The final stage is the testing and refining of the design. This stage, although it seems less important, is actually critical in the process. There are several feedback loops during the process, which help perfect the final survey.

5.2.2 MaaS SP Design Background

Local transport services environment

The first step of the MaaS SP design process is mapping out the local transport services. As MaaS is not a new transport mode per se, rather a new way of integrating and providing already existing services, in depth knowledge is needed about the available service provisions in the study area. The available modes, their business models and pricing structures can be thought of as the building blocks of any MaaS service and its products. It should be noted, that this can also include modes that may not yet be available in an area, but they are looking to be introduced. Especially at initial stages of

the design, it is worthwhile having information about everything that *is* and *could* be included in a MaaS service.

In order to ease later stages of the design, it is good practice to create a dataset with all the services available. This could include multiple service providers for modes which are not a monopoly (e.g. there are usually several taxi operators in an urban environment). If there are too many operators, the most prominent ones or the ones with the highest market shares will suffice. For each service, the dataset should include details regarding the products they offer, their business models and pricing structures. Any additional characteristics of the service, such as special features or products, can also be noted down, as these can be contenders to include as attributes in MaaS plan SPs. The pricing structures, including unit prices and how a unit is defined are critical elements of this database, as they will provide baselines for determining the pricing of MaaS plans / products during the SP.

When designing MaaS plan SPs, there is a significant flexibility-complexity trade-off. While it would be desirable to include and test all possible modes, service options and innovative concepts, this would be too complex of a cognitive task for the respondents, especially since the whole concept of MaaS is new and needs to be understood. As such, all of these aspects need to be narrowed down to create a viable group of services to include in the study. The aim of each study, the MaaS product(s) under investigation and the study area will help determine which services/features to keep and which to drop.

Defining MaaS product types

Before diving into the design of SP surveys to study MaaS products, it is important to understand what MaaS products are and how they may look like. In some survey areas, it may already be clear that a certain specific MaaS service is about to be introduced and researchers will aim to match the survey with that business model. However, in most cases, it is unclear what MaaS service, business model and product types could be introduced. As such, this section outlines some key product types that could be studied. Figure 5-3 provides an overview of these.

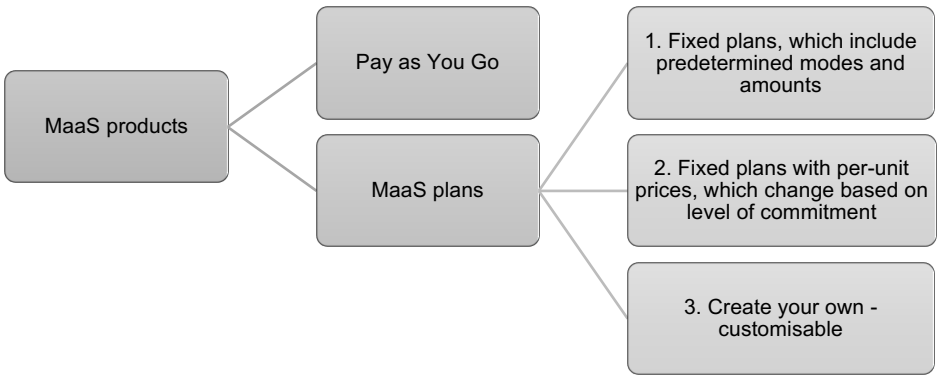

Figure 5-3: MaaS product types

There are two main categories based on whether commitment is required from the user. The first one in the fully Pay as You Go (PAYG) option, which does not demand any level of commitment from a customer. This product would mean that a user downloads the MaaS app, creates a profile and then just uses the app to plan, book and pay for each trip on a per use basis. If they do not use MaaS at all, they do not pay anything. This is conceptually very similar to the public transport smart cards, such as the Oyster Card in London, with which travellers pay per use. The MaaS service Whim, also has a pay as you go option. This product type has the advantage that it can be seen as less daunting to people who are unfamiliar with the MaaS service.

The second main category of products are those that require some level of commitment from the user. These are realised though subscription plans, where the user pays a certain amount even if they do not use the service at all. Subscription plans, in exchange for the commitment, provide benefits to users (see Appendix B for details). This can be either in terms of price discounts and/or by adding value though the integration itself. Subscription plans are very frequent in other sectors – the most obvious being telecommunication service bundles. However, when it comes to MaaS, these are a very contradictory areas of discussion. Most MaaS application opt for the more straightforward PAYG option, but Shift, Ubigo, Mobility Shop and Whim all have various subscription options (see Chapter 4 for details).

There are three core models that MaaS subscription can take. The first one is the concept of ‘fixed bundles’. These include a pre-specified amount of each transport mode, for a fixed price, which can be used up over a certain time horizon (e.g. a week or a month). The fixed amounts can be denominated in number of trips, distance, time or anything else, depending on each mode and their business models. The second subscription type is those with fixed unit prices that change based on the level of commitment. This, in a way, is similar to the PAYG option in that users would need to pay by use for each mode. However, the difference lies with the actual per unit prices and the fact that these plans

would have a subscription fee attached to ensure commitment. To explain more clearly, by paying a subscription fee for certain fixed time horizon the user is guaranteed lower per unit usage costs of various modes. The final subscription plan type is the 'create your own' plan. This is a special case of the fixed bundles, during which users actually create their own fixed bundles to which they will subscribe to. This subscription type is based on the concept of mass customisation, by which choice menus are offered to users to ensure personalisation and increase consumer satisfaction (Fogliatto and Da Silveira, 2012).

For all three subscription plan types, the duration can vary from anything as long as a day to a year or more – although as with most subscriptions, weekly or monthly are most likely. Another aspect that can be considered is who the target audience for the products are. MaaS service offerings can be customised to fit to a variety of users. The most obvious group are local residents to an area. Plans could be designed to fit different groups of people, such as commuters, students, families, all who are regular travellers in a city. An alternative target group could be tourists who are visiting an area for a short period of time. This latter group could really benefit from the simplicity of having every transport option neatly bundled at their fingertips. Finally, it should be mentioned, that it is possible to combine multiple MaaS plan types in one SP experiment. This can either be in a single SP, for example having each of the choices be different plan types, or with the SPs for each plan type being one after the other.

Currently, it is not clear from the industry which of these MaaS product types works best. It is most likely the case, that not any one will be superior in all cases, but rather different MaaS services in different areas with different modes included will have different product designs and for different target audiences. As such, in the following section, SP designs for each of the designs will be discussed.

5.2.3 SP Designs for MaaS Subscription Plans

Attributes and levels

Once the transport modes and service features that will be included in the SP are concluded upon, the SP attributes and their levels need to be determined. Regardless of which product type is examined, in choosing attributes and their levels, certain considerations need to be taken into account. One important aspect is that the number of attributes presented in each experiment should not be too many so that the respondent is able to comprehend the task and make appropriate trade-offs (Hensher, 2006). Another critical part of designing any SP is that the factors included should create a realistic choice situation for the respondents (Hensher and Greene, 2003; Train and Wilson, 2008; Rose

and Hess, 2009; Huang et al., 2015). For example, if the attribute levels are too far off reality, the respondents will not take this seriously and will not be able to relate to the choice situation. As such, a popular development in stated preferences are pivot-style SP experiments that use the existing knowledge base of the respondent or real life product attributes when creating the experiments (Rose and Hess, 2009; Train and Wilson, 2008).

Using the above discussed MaaS developments as a basis, attributes fall under two categories: transport mode specific attributes and non-mode specific attributes. The former includes the actual modes included in the plans as well as any additional transport mode specific features that the researcher may want to include (e.g. 10-minute taxi guarantee[5], is part of certain plans). The latter includes characteristics of the plans such as price or subscription duration, that are features of the product as a whole.

Looking at the attribute/level considerations for each of the three MaaS plan types, first ixed MaaS plans with pre-determined modes and amounts are examined. An example of a fixed MaaS plans with pre-determined modes and amounts is presented in Figure 5-4. The example is a very simple SP page with plans, including only transport modes, their amounts and the cost of the plan.

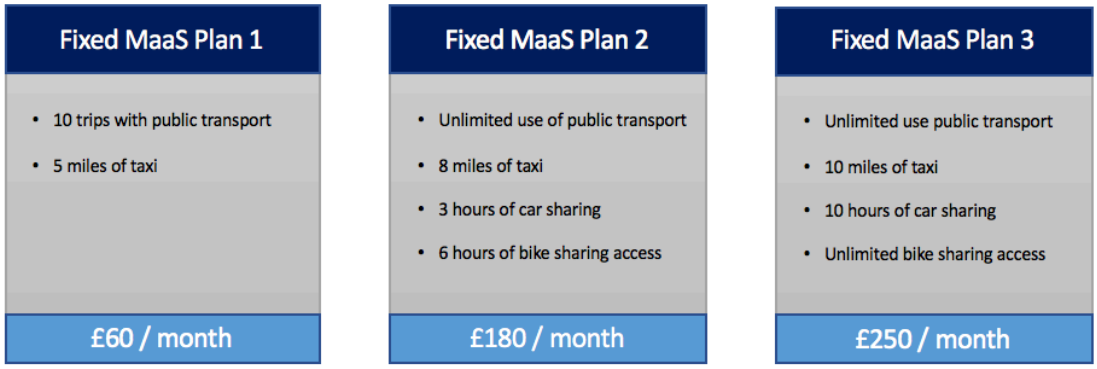

Figure 5-4: Example of fixed MaaS plans with pre-determined modes and amounts

For all MaaS plan types, the central element are the modes that are included. With this specific type, the amounts of each mode that are included are also critical. There are various ways to define what an 'amount' of a transport mode is. The possible options for all transport modes are: (1) distance (e.g. miles); (2) duration (e.g. minutes, hours); (3) number of trips (e.g. finite number, or unlimited in a certain time period). Regardless of which approach is used to denominate amounts, the geographical and time duration boundaries need to be clearly established. Further, it is advisable to make the service

[5] This means that a taxi will always be available within 10-minutes of ordering.

denominations match up with the local context, to make it clearly understandable to respondents. For example, if a city offers transport passes that allow for 10 trips on a bus, residents of that area will clearly understand what a 'trip' is. The cost attribute is also specific to this plan type. Only the total cost of the plans is presented, not the individual price of each element. This is done so that the respondents evaluate their willingness to pay for *all* the elements included in the plans, rather than try to compare each individual unit price. This provides a more realistic approach to how these types of plans would be shown in a real market setting as this is how bundled products' prices are shown. To determine the actual prices presented to the respondents, a 'base price' for each mode-specific attribute (e.g. amount of a mode) is taken from the dataset outlined above. The 'base price' for those modes where only a single provider exists, or is dominant over the others, their price was taken. For those modes where multiple service provides exist, either averages can be taken or the most prominent one with the highest market share. The levels for the price attribute are pivoted around the sum of the base prices of those modes that are included in the plan. One final, but important, element to ensure that there are no strictly dominating alternatives. Dominating alternatives are those that clearly outweigh all other alternatives. For example, in a simple mode choice situation with time and cost attributes, this would be an alternative which is both cheaper and faster. Having strictly dominating alternatives may lead to substantially biased estimates (Bliemer et al., 2014). In a MaaS plan context, determining what a dominating alternative is can be quite difficult as it is not clear how much people value each transport mode. However, certain conditions can still be imposed to constrain certain pairings, such as taking into account the actual prices of the modes included.

Turning to the second type of MaaS subscription plans, these are bundles with fixed per-unit prices. An illustration of a simple SP with this plan type is presented in Figure 5-5.

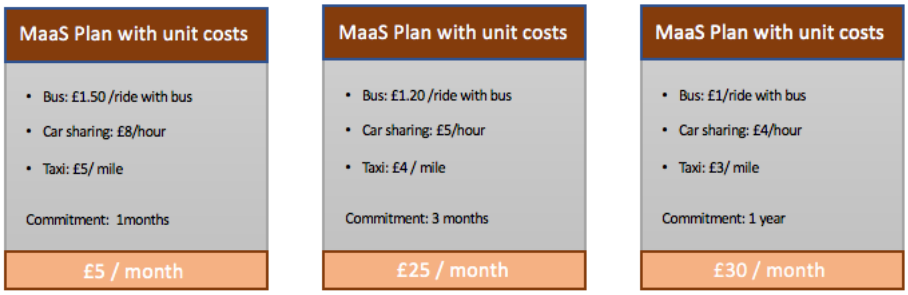

Figure 5-5: Example of MaaS plans with fixed unit prices and varying levels of commitment

Regarding the attributes and levels associated with this MaaS plan type, the attributes themselves are similar to the previously discussed plan type. However, the levels are conceptually different. While previously, the levels were amounts of transport modes,

here, they are per unit prices. These should be based on actual market values and can be pivoted around them. Similar to above, the discussion on what a 'unit' is can be complex, as this can be distance, time or number of trips. As shown in the illustration, there is an additional attribute called commitment, which shows how long a user would need to subscribe for in order to benefit from accessing the modes at the presented prices. This commitment attribute can also be applied to the other MaaS subscription plans. The final attribute of this plan is a subscription fee, which is a per month cost in the example. However, this fee could be a one-time fee, it does not necessarily have to be a reoccurring one. It is up to the researcher to define what the exact business model of the tested plans will is. With this plan type it is important to consider the trade-offs made between the different plan attributes and levels, that is, to ensure that there are actual trade-offs and there are no dominating alternatives. Longer commitments and higher subscription fees should be rewarded with lower per unit costs for the modes. These can be implemented in SPs via conditions imposed on how the levels for each plan are chosen.

Finally, looking at the 'create your own' plans, an example is presented in Figure 5-6.

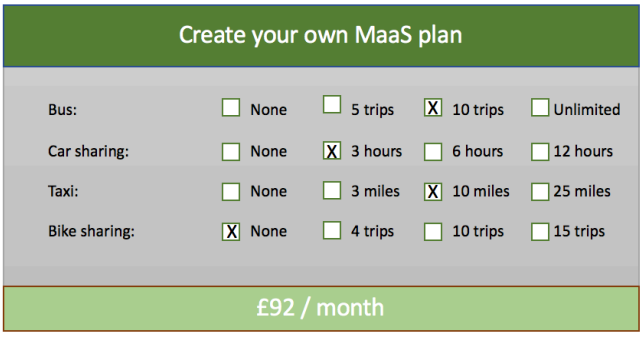

Figure 5-6: Example of 'create your own' MaaS plan

During this approach, the respondents can determine which and how much of each mode they would like (Stated Adaptation element). Regarding attributes and levels, this type of MaaS plan SP is actually conceptually similar to the fixed bundles approach, as respondents will end up with a fixed bundle in the end. The only difference is that here respondents actually create their own combinations of items. There are different approaches to how the levels for each attribute are presented. These can be shown as the illustration, whereby there are a finite number of choices to choose from. They can also be shown on a continuous scale, where the respondent can tailor it even more to their needs - although this may not work for all modes. It is important to note, that the method for presenting the levels to a respondent will have direct modelling and analysis implications as the each possible combination that is a participant can choose is actually

an element of the choice set (this will be discussed in more detail later in this chapter). The other important attribute is price. Again, there are different ways that this can be presented. In the example, the final price of the chosen plan would only be shown once the respondent selected an option from each row. This approach allows various complex pricing schemes to be tested, which do calculations in the background depending on what the respondent has chosen. These calculations are not shown to the respondent, they can only see one final price. Another approach could be to include details about how much each unit would cost for each mode and then a final price would be shown once all of them are selected. Some additional attributes could also be various discounts depending on how many items a respondent selected. The 'create your own' approach can be quite interesting when it comes to examining MaaS as it allows researchers to examine exactly what combinations of modes respondents want. However, it does bring some challenges when it comes to analysis, as will be discussed later.

A final element to mention about attributes and their levels is that the choice of what to include can be made context dependent. This means that information collected during the RP section of the survey can be used to narrow down the presented attributes and levels. For example, if a respondent stated that they do not have a driving license, researchers may choose to exclude any modes (e.g. car sharing or car rental) that would require the user to drive. Another case could be if a respondent stated that they have a disability that prevents them from cycling, bike sharing could be excluded as an attribute (aka the level would be fixed to 'none' or 'zero').

SP design considerations

After determining the attributes and levels of the MaaS SPs, there are several design considerations to decide. Some will influence (e.g. constrain) the above-discussed attributes and levels, as such there will be feedback loops between the various stages of the design process (as indicated in Figure 5-7). Please note, not all considerations mentioned below are applicable to the 'create your own' product type, as this is a menu choice, thus a special case of an SP experiment. Nevertheless, many of the items still apply to that case as well. Figure 5-7 provides an overview of all the different elements that need to be examined.

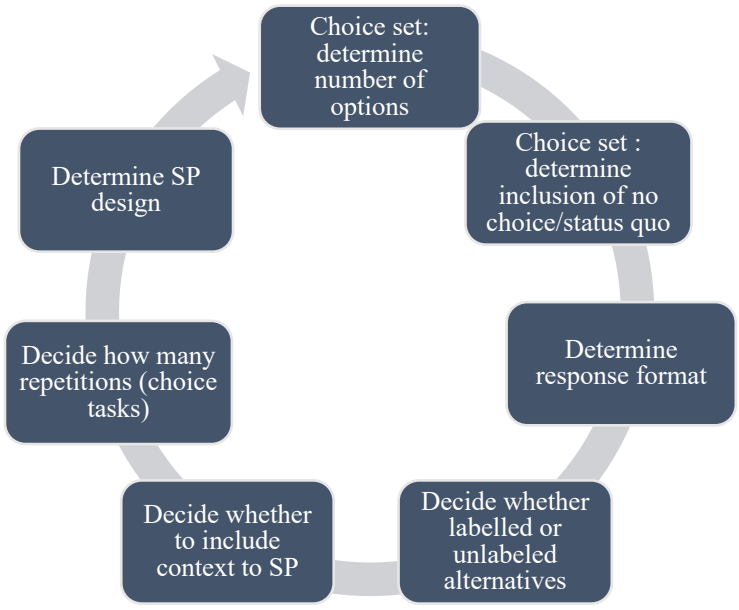

Figure 5-7: MaaS SP Design Considerations

Starting from the top, researchers need to make some key decisions when it comes to the choice set. First, the number of options (plans) shown to users from which they can choose from can range from as low as two to as high as ten or more (Louviere, 2000). Similar to many other elements of the MaaS SP design, there is a trade-off here. The larger the choice set, the more information can be gained through each choice that a respondent makes. However, when survey participants are faced with a large number of options, they begin satisficing or speeding through the alternatives without proper evaluation. This is exacerbated in the case of MaaS, where the concept itself is already quote complicated and understanding even a single MaaS plan may be quite difficult. In order to help provide some insights into optimal number of plans, focus groups and interviews were conducted. 10-12 people either in small groups of two to three or individually were presented with different approaches. The tested approaches included showing each MaaS plan one at a time on its own page and then a final page asking respondents to choose, and presenting two to four MaaS plans on a single page and asking respondents to choose on that page. The feedback received showed that presenting each plan one at a time was too slow for respondents and they lost interest much quicker than if multiple plans were presented at once. While this approach made people feel like the process was being dragged out and they got bored much quicker - they did note that this was the easiest way to understand each individual plan. Those experiments where two to four MaaS plans were presented at once generally received positive feedback, although there were few participants who found this a bit difficult to understand. Four was the maximum number of plans that were tested on a page, as it become difficult to clearly display on a single page without scrolling.

The second decision about the choice set is with regards to the availability of a no-choice or status quo option. Researchers frequently add a 'no-choice' or 'none' option, which allows respondents to demonstrate if in a real-world situation, they would most likely not choose either of the available choices. This can also help understand if there would be any interest in plans or whether individuals would not be willing to change their current travel tools (due to the offering not being right, status quo bias or psychological inertia). The alternative is to not include this, and have a so-called 'forced choice' in which respondents have to choose one of the presented MaaS plans in order to move on with the survey. In these cases, it is important to adjust the question frame to ask participants to choose the MaaS plan that they are 'most likely to choose' or 'prefer most'. The benefit of this approach is that it can capture a preference in all cases and can have more insights into the trade-offs *between* plans. As MaaS and MaaS products are largely unknown and may, at first, seem like a big change to respondents' current habitual travel behaviour creating a forced choice can protect against cases where the sample size is small and potentially not enough respondents pick one or more of the plans causing problems during modelling. However, in these cases, the results should not be used to draw conclusions about the market share that MaaS plans could have as that would be incorrect and biased.

Third, the response format needs to be decided. These are also called 'dominance measures' and indicate any form of numerical assignment of preferences between different objects (Louviere et al., 2000). There are many types of dominance measures, but only mention the most relevant ones to MaaS plan SP situations will be mentioned. The first, and most straightforward, is the discrete choice option. This approach allows respondents to indicate their most preferred option relative to the others, but it does not give any information about the relative preferences among the non-chosen ones. The second, is a complete ranking of the presented alternatives from most to least preferred. The degree of preference is not included, just the order, as such providing an ordinal scale. The third approach is to allocate a fixed set of resources (e.g. chips) which respondents can allocate to each choice depending on how much they like them. This could include allocating all to a single one or spreading them out among several. When it comes to MaaS plan SPs, the choice task is already quite complex, as such, it is most preferred to make the choice itself simple. However, as with all aspects of survey creation, there is a trade-off between the simplicity of the task and how much information is gathered.

The next aspect to determine is whether the presented MaaS plans are named/labelled alternatives or not. For example, in an experiment where three MaaS plans are

presented, the plans could be titles Plan 1, Plan 2, Plan 3, which do not carry any meaning, or be called Little Plan, Medium plan, Big plan, which do carry an underlying meaning. The choice of whether to choose labelled or unlabelled alternatives needs to be reflected in conditions on attributes and levels and later during modelling exercises. If, for example the above little-medium-big plan names are used, conditions should be imposed that ensure that the medium plan is larger than the small plan and the big plan is larger than the small plan. What is exactly meant by 'larger' is up for debate. This can be in terms of price, amount of modes or anything else – as long as there are no dominating alternatives created in the process.

Another aspect to consider is whether to add an experimental context These contexts are completely hypothetical measures which are included to gain some insight into the preferences for MaaS plans under various scenarios. It is widely known that travel is a habitual behaviour and is driven by repetition rather than conscious deliberation (Schlich and Axhausen, 2004; Friedrichsmeier et al., 2013). There has been a number of studies that examine what measures are necessary to break these habits, and many of those that are successful are strong habit interrupting policies such as free public transport passes (Thøgersen and Møller, 2008; Redman et al., 2013). Keeping this in mind, two main types of contexts can be shown: carrots and sticks. Carrots aim to provide motivation for individuals to try MaaS plans. These are especially focused on providing incentives for starting to use MaaS plans, since the most difficult element of any subscription service is getting people interested in the first place. Sticks on the other hand provide a disincentive for respondents to use their own private vehicles and instead shift to MaaS plans. Such situational elements can be added to all three MaaS plan SP types, including the create your own ones.

An additional decision that needs to be made is with regards to how many pages are presented to respondents, that is, how many choice tasks they are faced within a single SP design. This can greatly range. During the focus groups and interviews discussed above, participants indicated that they started to get bored and not pay attention after the first three-four choice situations (click throughs). The first one took them the longest time to complete as that was the first time they were confronted with such a choice. During later ones it was easier to understand, but after a few pages they would start rushing through and miss critical differences between the plans.

The last aspect that needs to be performed is that SP design itself. Combining all the attributes and levels that are possible when testing different MaaS plan options becomes very large. This means that it is impossible to show a respondent every possible combination. There are several methods to choose between these, and these are heavily

discussed in academic literature (e.g. Rose et al., 2008, Walker et al., 2015, Bliemer et al., 2014). The approaches include random designs, orthogonal designs and efficient designs. Nowadays, the most advocated designs are efficient designs, however, according to Walker (2015) the random design performs as well as any other design and as all designs, will perform even better if it is cleaned to remove choice tasks where one alternative clearly completely dominates the others (hence there is no real trade-off for the respondents).

5.2.4 SP design testing and refining

The final element of the MaaS SP design process is testing and refining. As outlined above, there are many different elements to consider during the various steps of the design. There are most definitely other business models or product designs that could be designed which would also bring with them other elements to consider. As the MaaS concept is still largely unknown to the general population it may be hard for them to grasp the essence of a MaaS plan SP if it is not well developed. It is very easy to create SP experiments that are not understandable or unrelatable to respondents. In those cases, the results would be meaningless, because it would mean that respondents most likely just clicked though without properly evaluating and considering the different options. As such, it is critical to mock up the full design (including the description of MaaS) and test this though either focus groups or interviews. The visual presentation of the plans, including how they are placed on a page, what colours to use, font size etc. should also be properly mocked up and can also be evaluated during this phase. It is important that enough time is left for this stage of the design process, as several elements may need to be updated and refined based on the feedback from focus group/interview participants. If several aspects are changed, it may also be necessary to do a second or third round of testing (as indicated by the feedback loop in Figure 5-2). Once the survey has been extensively tested, the SP can be ready to apply.

5.3 MAAS SURVEY EXTENSIONS AND ADVANCEMENTS

5.3.1 MaaS-related questionnaire enhancements

Starting with the questionnaire, there are two extensions to the above-described survey sections that could add value (but also length) to any MaaS survey. The first is related to the ‘core’ MaaS product – the MaaS application. As discussed in Chapter 2, MaaS consists of a planning, booking and ticketing platform, all accessible from a single digital platform, usually a smartphone app. These are the ‘core’ MaaS functionalities; the MaaS

products are additions. As the MaaS application is the base of all MaaS products, users would not be able to purchase and use MaaS plans without having this on their phones. As such, it is crucial to understand people's willingness to download the application as this may be one of the barriers to MaaS adoption. This can be done as part of a MaaS survey, by presenting respondents with a mock-up of a MaaS app which describes its features and ask them whether they would be willing to download the application if it was available to them. The question and answer frame can take different forms including ones with discrete or ordinal responses. Additionally, the various features that the MaaS application can have can be examined. Respondents can be asked to rate or rank the importance of these or add anything they think is missing.

The second questionnaire extension collects information about participants' attitudes and perceptions towards MaaS. After the respondent has completed the SP pages, they can be presented with some final questions regarding their deeper, latent attitudes and perceptions towards to MaaS. To gauge these, statements are presented and participants are asked to state their level of agreement or disagreement with these statements on a five- or seven-point Likert scale from strongly disagree to strongly agree. Such statements can help with understanding those reasons behind individuals preferences for MaaS and its products that may not be directly observable. They can also be used during later modelling exercises to construct latent variables.

Turning to the extensions/advancements to the SP experiment, there are a few different elements to mention. The first is with regards to those cases when there is a forced choice (that is no 'none' option is presented). In these cases, the respondent needs to select which plan they prefer the most, even if they would not actually select any of them had there been the option to do so. In these cases, a researcher can choose to include an additional follow-up question asking a respondents whether they would actually purchase their chosen plan. This approach creates an additional question after each SP, thereby increasing the burden to the respondent, but allows the researcher to capture more detailed preferences. For those cases where there is a no choice/status quo option (or the above mentioned follow-up question is included), an additional question asking respondents why they would not choose any of the presented options can be presented. This can have pre-specified answer options, or can be left open-ended to allow respondents to give more detail about their disfavour of all the MaaS products thereby adding a qualitative aspect to the survey.

Another SP aspect that can be considered is whether the preference between different MaaS product types is an important concern in each case study. Shorted, more compact surveys can focus on a single MaaS plan type. This is preferred as they create less

burden to the respondents, thus ensuring higher completion rates and better response quality. However, if testing different MaaS product types is important, it is possible to have multiple SP experiments regarding the different product types and then a final question asking respondents their preference between them. This can also include the pay as you go element. There are a couple of considerations with doing this. First, respondents should be told beforehand that they will be faced with several different product types (this can be phrased as coming from different companies if that makes it easier for respondents to follow) and that they will be required to indicate their overall preference at the end. Second, the choice between the MaaS product types will be strongly influenced by the attributes and levels of each specific SP that the respondent is faced with. Thus, this needs to be taken into account during the analysis of this section.

A final addition to the SP is that inclusion of optional add-ons. In some cases of marketing, users are allowed to include supplementary elements to their products. This could well be the case in MaaS, where there is a core product, such as a MaaS plan, and various other modes/items can be added on top. This could even be additional amounts of a certain mode, or an additional feature. These could be part of any MaaS plan SP as part of the choice.

Another extension to the MaaS survey is addition of questions regarding impact that MaaS can have on mode choice and mobility tool ownership. Both these areas have high industry and policy relevance. Although this thesis does not focus on the impact that MaaS can have, some simple additions to the MaaS survey can be introduced that capture some initial insights. However, it has to be noted, that this in itself is a huge topic, and these additional elements are not meant to be extensive and in detail.

There are a few approaches through which initial insights into the impacts on mode choice/modal shift can be captured. The first one involves questions that can pop up directly after the SP experiments and would involve asking them what impact they foresee that the plan of their choice (if they chose one) would have on their usage of various different modes. Without making this part specific to a mode choice situation, the most straightforward way is to ask them whether it would, overall, increase, decrease or not impact their use of each transport mode. Even though this method will not result in precise information about the potential impacts MaaS plans can have on mode choice, it would give some preliminary indication of the directionality (e.g. increase in the use of one mode and decrease in another). Another approach is that statements are presented pertinent to possible affects that MaaS could have on the use each transport mode and respondents are asked to either rank these or rate them on a Likert scale. Again, this approach would only allow for some initial insights into impacts. It would be possible to

go further in depth on this topic and place respondents in hypothetical situations where they have a MaaS plan and would be asked what mode they would choose for a certain trip. However, this would create a very complicated choice task, where respondents are put in multi-level hypothetical situations. The cognitive burden of this would be extremely high and the results would be very unreliable. As such, steering away from such approaches are advocated for, unless other innovative survey designs are used (further discussion on more advanced methods to examine MaaS's impact on mode choice is out of the scope of this thesis).

Another important impact of MaaS is the potential effect it can have on vehicle ownership and use. This is again of high importance to the industry and policy makers, as it is frequently expressed that one of the key aims of MaaS is to decrease private vehicle ownership and use. The most straightforward approach is again to ask simple questions regarding impact, or to again involve statements. Some of these can be identical for all respondents, while others can be tailored based on whether the respondent is a car owner/driver or not. All responses to these questions should be interpreted with caution, as personal vehicles are a big investment, with high fixed costs, and there will probably be high survey biases. For example, a respondent may very easily say that they would sell their car in a survey, but in reality this is much more difficult.

5.3.2 Integrating the MaaS survey into a smartphone based survey

With the increase of smartphone penetration over the last decade, researchers have been increasingly using these to collect detailed and precise mobility information about individuals. Smartphone based GPS travel surveys usually come in the form of a downloadable application (Vacca and MeloniI., 2015; Carrel et al., 2017). To reduce the burden to the respondent, recent developments have focused heavily on transport mode detection and activity recognition (Gonzalez et al., 2010; Stenneth et al., 2011; Ghorpade et al., 2015; Nitsche et al., 2014; Hemminiki et al., 2013). These studies aimed to automate the survey process as much as possible and in many cases so that respondents only have to check and correct trips and modes rather than putting it all in themselves.

Data from such collection tools can provide valuable insights into people's mobility habits and decision-making process. To better understand MaaS and its possible effects, it can be valuable to know in greater detail peoples' current mobility habits and how these may influence their MaaS preferences. As such, the SP experiments and the whole survey can be adapted as an extension to a smartphone based prompted recall travel survey. Having access to information gathered through state of the art smartphone based travel surveys provide a great opportunity to use this tool to enhance the quality and quantity of

data collected and available for analysis. Another tangible benefit of such a survey method is that it is able to provide feedback to the user. This can both engage the respondent more but also add an element of clarification to the status quo alternative.

Even though there are several advantages of using this type of data collection, there are also a number of challenges. As these tools are still under development, even the most advanced ones still require high levels of respondent involvement. Respondents are usually required to provide or verify information regarding their daily activities and travels for multiple days. Although the ultimate goal is to minimize the input necessary from participants, the current developments are not yet at the highest level. Also, this collection method requires respondents to have a smartphone, however, in the case of research pertinent to MaaS, this is not an issue as the target audience is those that have smartphones already (as mentioned above). Although the response burden may currently still raise too many concerns, in the future, when these tool are more mature and better developed, utilising them tools may significantly enhance MaaS surveys.

5.4 DISCUSSION

5.4.1 Challenges

One of the main challenges of creating MaaS surveys, and specifically MaaS plan stated preference experiments, is that so many aspects of MaaS are still unknown. Many of these come from the lack of clarified business models, specifically the products, the positioning and the pricing of these (Tsirimpa et al., 2018). The value proposition and the financing and revenue allocation models that could be viable are not yet clear, which leave a big gap in the background that is necessary the determine the exact attributes and levels in an SP experiment. To look at a more concrete example, it is not clear whether MaaS plans are able to offer price discounts to users (as it frequently happens in other industries with bundled products – see Appendix B). This very clearly depends on whether the MaaS operator is able to acquire the various mobility services for a discount and what their profit margin is. However, this is not yet clear, and only recently have studies started to examine this aspect (e.g. Tsirimpa et al., 2018). As such, researchers need to make assumptions regarding this, and need to set a range of prices. This problem is not necessarily unique to MaaS, as many new transport services start with undefined business models. However, due to the complexity of the MaaS concept, the lack of clarity is present on several dimensions that will most likely take longer to resolve. This increases the amount of assumptions that researchers need to make when creating MaaS surveys compared to any other new transportations service.

Another challenge is the determination of what modes to include in MaaS plans. Again, this is up to the researcher to decide, as only some level of guidance is currently given from the industry. It is not yet examined in detail under what circumstances and business models each specific mode is willing to join a MaaS scheme. From discussions with industry actors, it is clear that it is much more difficult to get transport operators involved and committed to MaaS schemes than was initially foreseen. The real-life MaaS applications can give some indications of those modes and specific operators that are more open. For example, it can already be seen that not many ride hailing services, where individuals share rides with people going the same way, are included. Although it is not clear whether this is because they are not interested, because their integration is too difficult, or they have not been invited to join.

The discussion around modes also brings up another challenge, and that is with regards to having multiple operators for a single mode. Larger cities frequently have multiple competing operators, who offer the same of very similar services (e.g. taxi services). Hypothetically, a MaaS service should be able to include different service operators and offer users the best possible one in each situation. However, including this concept in a MaaS SP is very difficult. First of all, it is unclear whether this for the area under study would in fact be possible. It may well happen, that providers will not want to join a MaaS scheme where one of their direct competitors is already taking part. Even if this was possible, on the one hand, explaining this to a respondent is very difficult, but on the other hand leaving it out may be completely unrealistic for the study region. If the researcher sticks to a single operator (when there are multiple competing ones around) also raises other concerns, including how these will be defined. If a service is identified as a specific company, will that bias the results and make them interpretable for only that specific case? There is no straightforward solution for this problem, each specific study will need to evaluate this on a case by case.

A further difficulty related the modes arises with regards to their characteristics. Individual preferences towards certain modes, such are car sharing, highly depend on the exact traits of the service under consideration. For example, quality and type of vehicles, proximity, coverage, included features all are important factors besides price when determining whether someone would be interested in using this service and are frequently used attributes in mode choice SPs or ones focusing solely on subscription to car sharing. However, including details on every attribute of every mode included in a MaaS plan is infeasible and would create a choice task that is way too complex for a respondent to understand and answer. This is a big difference compared to surveys about individual transport modes as there more space can be dedicated to explaining the details

and characteristics of the service. A possible solution could be to give details of each mode prior to the SP, potentially at the same time as the MaaS concept is introduced. These still would need to be kept very short and to the point and there is always the risk that respondents would forget it by the time they get to the SP. Another approach could be to use hover over explanations (as discussed above) but again, these would need to be short and there is a risk that respondents would not use them. This is a significant challenge when it comes to MaaS SPs. Assumptions can, and will be made about the respondents knowledge of each mode and their common understanding of what each of them actually entails. This could be exacerbated in those cases where new services are included in the MaaS plans, where the participants' prior knowledge is limited.

Still staying with the modes, an additional dilemma is how to determine the amount of each mode to include and the unit of measure. This is similar to problems faced when determining the amount and unit of a service to include in a subscription service, as such it is not unique to MaaS. The only difference is that certain modes, such as taxi, do not usually have subscription services so there are not many examples to take as a basis. As there are not many MaaS products available in the market (and at the start of this thesis there were none), there are minimal cases that can be examined for guidance. While this makes MaaS SPs that much more important to do, they also add an extra level of uncertainty. The scale on which each mode can be measured is quite large, and it can be very difficult to narrow down the focus. For example, someone may be interested in using 100 miles of taxi, while another person may not be interested in any at all. This is where context dependence comes into play, and understanding more about the individual before they get to the SP can help tailor each experiment.

5.4.2 Limitations

One key limitation of the discussed survey design need to be mentioned. Using the word 'limitation' may not be correct, as this is a question of focus, rather than constrain. Nevertheless, the presented approach only grazes the surface of understanding the potential impact that MaaS can have. The effect of MaaS services and products on mode choice, the ownership and use of mobility tools including private vehicles and even, in the long run, residential choice are important demand-side considerations that need to be examined. However, they are not adequately covered in this survey design. Including these in a SP scenario would be very difficult as the researcher would need to place respondents in one hypothetical situation to choose a MaaS plan, and then another one on top of that to choose a mode. That approach would be too difficult to get reliable data from. As such, the impact on mode choice and other aspects should be studied thought

pilots and real life applications, where participants can truly react and researchers can capture robust data. Before-during-after studies can be especially useful, where participants' behaviour is evaluated before the introduction of MaaS, while they use MaaS and after they stop using MaaS.

The presented design focuses on the mid-term choices associated with buying a MaaS plan. These decisions will then enable the mode choice and other impacts to happen. One may view this at the top level, or first choice in the decision making process associated with MaaS.

CHAPTER 6: CASE STUDIES AND DATA COLLECTION

The aim of this chapter is to uses the survey designs presented in Chapter 5 and apply them to the two case study cities of London and Greater Manchester. The survey design process is discussed and the data collection process is presented, with details about the sample as well as descriptive statistics of the collected data.

6.1 CASE STUDY 1: GREATER LONDON

The first application of the MaaS survey design is for Greater London. The MaaS London survey, called the London Mobility Survey (LMS), was created with the aim of gathering data on travel behaviour and user preferences for MaaS and its products. The following sections will present the survey design, sample and descriptive analysis of this case study.

6.1.1 Survey Design

Survey Foundations

Starting with the questionnaire, information regarding the respondents' socio-demographic characteristics, current mobility tool ownership and mobility habits are collected. These are important not only for later modelling purposes to allow for market segmentation, but also some elements of the stated preference experiment (SP) will be dependent on these responses (context dependence). Prior analysis was conducted on the London Travel Demand Survey (LTDS), in order to evaluate the information that currently exists about travel demand in the city and possible gaps that LMS could fill. The more fundamental questions are matched up with those in LTDS to allow for later comparison between the two data sets. The details of the questionnaire including the exact questions can be found in Appendix C.

After the questionnaire, the MaaS concept is presented. The decision was made to use the description approach due to the financial and time implications of using graphical or video approaches. To help determine the exact wording to use, three waves of testing were performed with individuals. The first and the third groups were smaller with only five individuals while the middle one was with a group of ten individuals. These took the format of both email feedback and personal interviews, and in some cases the combination of

both, about preferred wording, terminology and length of description. The groups included individuals from a range of socio-demographic backgrounds and were chosen based on a convenience sample. The same groups of people were also used to test later stages of the survey.

All three focus groups provided a vast amount of feedback that were taken into account to arrive at the description presented in Figure 6-1. The wording in the description (and then throughout the SP) was put into context. Everything was phrased using London terminology and analogies after previous wordings did not resonate with respondents. The description was phrased from the point of the journey planner function as this is one of the most relatable features of the service. This approach greatly increased the overall understanding of MaaS as a concept and how it would be relevant to a user.

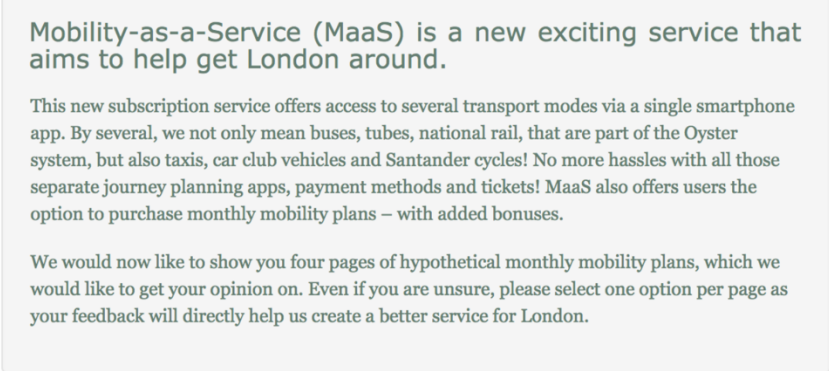

Figure 6-1: Introduction to MaaS in Case Study 1

While the description presented in Figure 6-1 helped respondents gain a better understanding of what MaaS is, it also introduced biases as the phrasing is not objective. This limitation needs to be acknowledged, and should be taken into account during the interpretation of any results.

Before turning to the MaaS SP design, the MaaS plan type needs to be determined. When this case study was implemented (2015) the available knowledge about MaaS plans was very limited. As such, the decision was made to study both fixed bundles and ‘create your own’ bundles alongside each other. This meant that a respondent would be presented with a certain number of fixed plans (with a pre-determined amounts of each mode) and a create your own menu in every choice situation.

Stated Preference Design

Turning to the SP section, there is a significant flexibility-complexity trade-off; while it would be desirable to include and test all possible modes, service options and innovative concepts, this would be too complex of a cognitive task for the respondents, especially

since the whole concept of MaaS is new and needs to be understood. As such, the assumption was made that if MaaS were introduced it would include only existing transport modes. A dataset was created that included all non-private modes available in London, covering characteristics for each mode and supplier such as their business models, pricing structures, subscription possibilities, booking and payment options if applicable and ICT availability (booking apps etc.). This dataset was used to determine the attributes used in the SP. Below, each considered transport mode and the determined attributes and levels are discussed. These are also summarised in an attribute-level table in Table 6-1.

First, public transport in London includes bus, tube, overground, Docklands Light Rail (DLR), tram, rail and riverboat. Due to the high number of public transport options in the city, it is clear that presenting all of them individually would overcomplicate the public transport attribute. As the transport modes are already integrated with the Oyster card ticketing and payment system they were aggregated and used as “public transport” in the SP. Three public transport levels were chosen: none, unlimited bus and unlimited public transport. These follow the currently existing bus pass and oyster travelcard (unlimited travel) options available in the city. The unlimited pubic transport level had an additional complication. The London travelcards (unlimited public transport) have a zonal aspect to them. Thus, the level had to be ‘unlimited public transport in your zones’ where the zones were fed from earlier elements of the survey. This tailoring to respondents was crucial as there are huge differences in the prices depending on which zones are included. If the respondent stated that they had a travelcard in the pre-survey, the travelcard zones were fed through from there. Further, two other elements had to be taken into account and fed from the pre-survey. Both eligibility for discounts / free travel and disabilities were questions included in the pre-survey and fed into the public transport – and associated price (to be discussed below) – levels.

The next mode to examine is bike sharing. In London, there is one main bike sharing scheme the Santander Cycles. The two levels are none and unlimited access for 30 minutes use at a time. This matches up with the current operation of the service. An additional feature was included that allowed for increased bike sharing rental time to 60 minutes at a time. Similarly, to the public transport mode, if the respondent stated in the pre-survey that they have a disability that prevents them from cycling, this mode was excluded.

Moving on, London has a vast amount of taxi services, including the London black cab, ride hailing services (i.e. Uber) and hundreds of minicab companies. A base dataset was created including a selection of these and containing information about their availability,

business models and pricing. After evaluating the extent of the taxi provisions, the decision was made to lump all these together to reduce the complexity of the task. Before determining the levels for the taxi attribute, an analysis was conducted on data from the London Travel Demand Survey (LTDS) to get an idea about the ranges people tend to travel using taxi. The analysis showed that there are huge differences in these amounts, and it is very easy to have levels that are quite far off of what respondents would like to see (this was also tested with focus groups). In order to create more tailored levels, which will result in improved information gained through the SP, a pivot style design was used. Information from the pre-survey about taxi distance travelled on an average month was used as a baseline from which the attribute levels were pivoted off of. This approach had to be slightly altered as respondents with low or null amounts of taxi would have little or no variation (or even negative values) in their levels. Analysing some test simulations, 10 miles per month was chosen as the threshold under which pivoting was not used and fixed attribute levels were adopted. There are also some additional feature attributes for taxi, out of which at most one was presented by alternative. These attributes are presented Table 6-1.

The next mode is car sharing. Car sharing (called car clubs in the UK) is assumed to be short term car rental services, where users can pay by the day, hour or in some cases even minute. When mapping out the offerings, differences in the setups were identified. There are two main types of car sharing services available in London: where company owns fleet and when individuals do in community or peer to peer car sharing (or peer-to-peer car rental). The decision was made to focus on the first type as the business models of the former tend to be based on individual agreements between the supplier and the customer, thus would be difficult to include in MaaS plans. Six main car sharing operators (based on the size of their fleet) were identified all with varying geographical coverage. Similarly, to the taxi case, pivoting was used here except for those people who do not use car sharing at all, and as such they were assigned predetermined levels. A report on car clubs in London stated that 80% of car club members use their car less than 6 times a year and that the average hire is 6.9 hours. As these values are quite low, the levels for car sharing were also kept low (Steer Daviews Gleave, 2016). Driving license possession and disabilities were excluding factors of this attribute. Car sharing also has some additional features, which can not only provide insights into MaaS plans, but also to some characteristics that would encourage more people to use this mode.

Other modes, such as car rental, ride sharing and demand responsive transport were also considered but were excluded in the final design. Car rental was excluded, because the thesis only focuses on short term, city trips and in London for urban trips car rental is

very similar to car sharing. However, it is not as flexible for seamless door-to-door mobility since car rental points are usually in a specific area and users need to travel there to collect and return to the cars. Car sharing is much more flexible; even with round trip car sharing, the pick-up points are much more dispersed around the city allowing for more options. With the more novel models, such as free-floating car sharing which already exists in parts of London, users have even more flexibility. To include longer term hiring, the SP includes car sharing attribute levels on a daily besides the usual hourly levels. That being said, in other cities / areas where car sharing is not available, car rental could be included instead. Ride sharing, falls under the same category as peer to peer car sharing by which they are based on individual agreements between the customer and the supplier. Further, peer to peer as well as demand responsive services are not as well known in the case study area and in a SP experiment, they would need to be explained in much more detail for respondents to understand what they are asked to choose about. It needs to be noted that these modes could be integral part of MaaS schemes and future SP experiments should also aim to include these into them.

It has to be pointed out that there is a focus on the features of taxi and car sharing in this SP plan designs. The reason for this is that these modes are provided by private companies and can offer several innovative features to advance customer experience. These features can be important elements to customise the MaaS user experience.

Table 6-1: London case study attributes and levels

	Attribute levels for fixed plan	**Attribute levels for the 'create your own' plan**
Mode-specific attributes		
Modes		
Public transport	Unlimited bus Unlimited public transport in your zones	Unlimited bus Unlimited public transport in your zones None
Bike sharing	Unlimited access + 30 min use None	Unlimited access + 30 min use None
Taxi	If *current taxi usage* >10 miles -> None, *current taxi usage**0.8, 1, 1.1, 1.3, 1.5	0-200 miles in increments of 2 miles
	If *current taxi usage* < 10 miles -> None, 5, 8, 10, 12, 15 miles	
Car sharing	If *current car sharing time* >0 -> None, *current car sharing time**0.8, 1, 1.1, 1.3, 1.5	0-20 hours in increments of 1 hours; 0-7 days in increments of 1 day
	If *current car sharing time* = 0 -> None, 1 hour, 2 hours, 4 hours, 6 hours 1 day, 2 days, 3 days + 2 hours	

Features		
Bike sharing rental time up to 60 minutes at a time	Yes No	NA
Floating car sharing anywhere in London	Yes No	
Car sharing includes minivan access	Yes No	
Can use any back to base car sharing company in London	Yes No	
Pay for car sharing by the minute	Yes No	
Add an additional driver to car club plan	Yes No	
10-minute cab guarantee	Yes No	
Only luxury cabs	Yes No	
Pooled taxi an option	Yes No	
Non-mode specific attributes		
Cost	(Sum of base prices) * 0.5, 0.6, 0.65, 0.75, 0.8, 0.9, 1, 1.1	
Transferability	None of your credits can be transferred to the next month	NA
	All of your credits can be transferred to the next month	
Special Present	None	NA
	Free luxury car for a weekend	
	Free grocery delivery for a month	
	Free food delivery for a month	
	Free dinner for two	
	Free dinner for two (up to the value of £50)	

Turning to the non-mode specific attributes and levels, the ones included in the SP are cost of the plans, transferability and special prizes. Regarding price, only the total cost of the plans was presented, not the individual price of each element. This was done so that the respondents would evaluate their willingness to pay for *all* the elements included in the plans, rather than try to compare each individual unit price. This, as discussed above, also provided a more realistic approach to how these plans would be shown in a real market setting. To determine the actual prices presented to the respondents, each mode-specific attribute had a 'base price' that was established through the dataset of all non-private modes in the city. The price of the presented plan is pivoted around the sum of base prices for each included mode. The base value for each mode was chosen after detailed evaluations of the current market offerings of transport service providers. For those modes where only a single provider exists, or is dominant over the others, their

price was taken. These modes are public transport and bike sharing (the author acknowledges, that now there is more than one bike sharing services offered in the city, however when the survey was designed and carried out, these were not yet available). The public transport fare system in London is very intricate. For bus passes discount levels need to be taken into account, while for travelcards (season ticket) there is also a zonal dimension. As such, the base price for public transport used Transport for London's price table, but it was tailored to each respondent based on answers provided in the RP survey. For bike sharing, Santander Cycles only offers annual subscriptions, not monthly. Doing research on historical prices (where other subscriptions were also offered) a base price of £25 was decided upon. Moving on, taxi and car sharing are the two modes where multiple service providers exists. For both these services, the top six to ten providers' payment models were collected and average values were taken for the base prices. The resulting base price for taxi is £4/mile. For car sharing, this depends on the amount included in the plan: for under 8 hours of usage, the base price is a fixed cost £10 with an additional usage fee of £6.5/hour; for over eight hours of usage, the fixed cost is £20 with £5 for each hour and £45 for each day. Even though the base price calculation method is quite complex, mimic the market prices were mimicked as closely as possible to have realistic values. Using the sum of the transport mode base prices, each plan base price is calculated. These are then multiplied by a cost attribute level to arrive at the plan costs in each SP scenario. The cost attribute levels were chosen based on examination of cost related levels used in the literature and discussions with experts.

In addition, it is important to acknowledge the differences between the first three bundles (fixed) and the fourth, customisable menu. It has been widely examined in the literature, that both from a producer and a customer point of view, there is value in allowing users to create their own products (Fogliatto and da Silveira, 2012). From the supply side, a premium price is charged to offset the potential additional costs of (Piller et al., 2004; Chen and Wang, 2007; Zhang and Tseng, 2007). On the demand side, the additional value to consumers from being able to design their own products the way that they want, increases their willingness to pay (Fiore et al., 2004; Schreier, 2006; Franke et al., 2010). As such, the price level for the 'create your own' menu option was set higher in each experiment to test whether this holds in the case of MaaS plans.

Transferability refers to whether left over credit from one month can transferred over to one month or not. It has two levels "none of your credits can be transferred to the next month" and "all of your credits can be transferred to the next month". The special present incentive attribute was included to see whether they can be used as motivational techniques for people to subscribe to certain plans. The hypothesis is that if someone

subscribes to a plan that includes public and shared modes that they may have not used before, there is a chance they will try it and start using it. Transferability and the special present were not included in the menu as through the focus groups it became clear that the menus had to be kept very simple or respondents will not comprehend the task and will just randomly click through.

Once all the attributes and levels are determined, the other design elements needed to be resolved. First, the choice set, including the number of options presented and the inclusion or exclusion of no choice/status quo alternative was finalised. Initially, various SP presentation designs were tested, including placing each plan on separate pages and then on a final page asking them to indicate their preference. Even though some people preferred this as it was easier to understand, overall, this significantly lengthened the survey process thus was less favoured to showing all the plan options on one page. In the final design, during each scenario task the respondents were presented with a single choice between four different hypothetical plans. The four alternatives were: three fixed plans and one menu option where the users can determine which and how much of each mode they would like (Stated Adaptation element). These were presented alongside each other, but only one of them can be chosen. Thus, the outcome of a choice made from the options is either one of the three fixed plans *or* any combination of the individual attributes in the menu option. The menu option is presented alongside the others to allow analysis of the flexibility-complexity trade-offs. Further, the flexibility of the menu option is priced, meaning that the price attribute of the menu is always greater than that of *all* the other plans. This approach was chosen to allow for analysis of peoples' willingness to pay for flexibility within MaaS plans. Regarding the inclusion of a no-choice alternative, the decision was made to exclude this. This created a 'forced choice' but also allowed for a fail-safe way to ensure that enough data is collected to model preferences between MaaS plans. When interpreting the results of the models run with this data, this needs to be taken into account.

Next, the response format, labelling of alternatives and context needed to be concluded. Discrete choice was chosen to simplify the already complex survey and later modelling. Regarding the labelling of the alternatives, the fixed bundle alternatives were unlabelled and were differentiated only by calling them Plan A, Plan B and Plan C. The menu choice was labelled 'create your own' thereby also indicating what the respondent needed to do with this specific choice. In this case study, no context was included.

Each respondent was presented with four SP tasks, in which levels were chosen based on a cleaned random experimental design. According to Walker (2015) the random design performs as well as any other design and as all designs, will perform even better

if it is cleaned to remove choice tasks where one alternative clearly completely dominates the others (meaning there is no real trade-off for the respondents). Hence, a condition was imposed on the scenarios such that each has to be internally consistent while making sense with regards to the research topic. If the sum of the base prices of plan A is greater than the sum or the base prices in plan B, then in the presented alternatives this also has to be true.

An example of a stated preference experiment presented to the users is depicted in Figure 6-2. Icons for the travel modes, hover over explanations and colours were used to provide a visually stimulating presentation for respondents. During the focus groups, understanding and acceptance of all the information increased as these elements were included in the design.

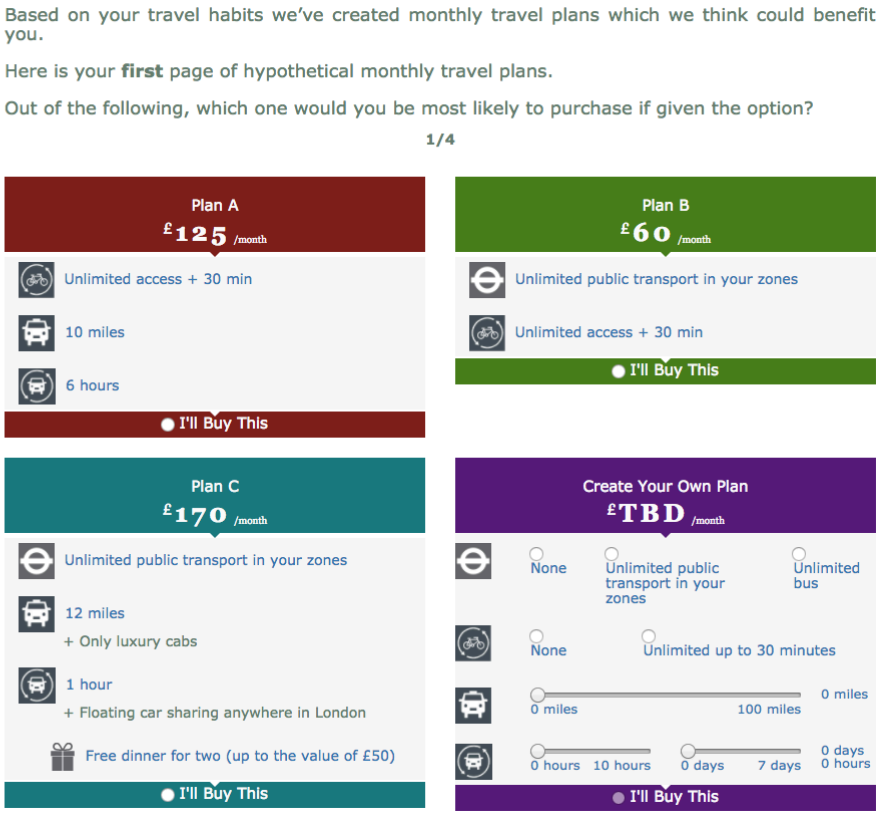

Figure 6-2: Case Study 1: SP visual

During the refinement stages of the survey design, a number of conditions were imposed on each page in order to focus on the research objectives of this study. First, maximum of two 'none' level among the mode-specific attributes was allowed. This had to be imposed as the whole point of MaaS plans is that it offers users a combination of transport modes and if there is only one in the plan the aim is lost. This meant, that for example if a respondent did not have a driving licence and had a disability where they could not cycle, the other two modes (public transport and taxi) had to be included. Another element

that was of interest is how additional features affected the choice of plans. Hence, a differentiation was made between two different types of plans: a basic which did not have any additional features and a premium which had additional features. However, even in the premium plans only one additional feature per mode was allowed in order to decrease the cognitive load on respondents. In the first two scenarios, there were two basic plans and one premium, in the second two scenarios there were two premiums and one basic. The respondents did not know this distinction. Further, some special features were limited to the premium plans (as presented in Table 6-1).

Detailed testing coupled with the review of transport services described above lead to a design that is both relevant for MaaS plan research and understood by respondents. Feedback from the tests though interview/focus groups were taken into account and implemented wherever possible.

Survey Extensions

Four main survey extensions were adapted in this case study. First, after each SP task, respondents were asked if they would actually buy their chosen plan if it were available today. The response options were: (1) Yes, I would definitely buy this plan, (2) Yes, I would consider buying this plan, (3) No, but I would use MaaS as pay-as-you-go, and (4) No, I would not use MaaS at all. This additional question was important, to better understand respondents' willingness to purchase MaaS plans. The pay as you go option was included to capture those individuals who like the concept of the integrated service with a single payment and ticketing option, but they would not want to commit to monthly plans. It differentiates between people who would not want to subscribe to their chosen plan and those who are not interested in MaaS at all. However, as no further information was given to respondents about how much the pay as you go options would cost them, these responses cannot be used for detailed analysis. In order to do that, a separate SP should be created just for the pay as you go option, which would have significantly increase the length of the survey and the burden to respondents.

The second extension is with regards to the impact that MaaS plans could have. After each MaaS plan, respondents indicated whether they believe their chosen plan would increase, decrease or have no impact on their current modal split. The question responses are presented to users by transport mode, where they have three radio buttons to choose from. The transport modes are shown as icons, the same ones that were used in the SP to ease understanding. The impact that MaaS could have specifically on public transport and private vehicle use. The possible impact on these two modes were identified as being of high importance to the industry and policy makers (this was

identified through regular discussions with these actors during meetings and various events – please refer to an extensive list of these attended by the author of this thesis in Appendix C. To reduce the response burden, respondents were split into either frequent public transport users or car users. Those who were identified as car users, were asked to indicate the top three ways that MaaS would impact their private vehicle use, while the same question is asked from public transport users.

The third extension includes questions about individuals' attitudes and perceptions towards MaaS. These are questions relating to MaaS in general and are presented on a separate page after all the SP tasks are complete. These first half of these questions relate to the attitudes respondents have towards certain elements of MaaS. These are all statements with 7-point Likert scale responses. The exact questions included in the survey extensions can be found in Appendix C.

The final extension of LMS is its integration into a smartphone based survey tool. While this design of this extension and the associated data collection provide interesting insights into using state-of-the-art smartphone based travel survey tools to study MaaS, they are out of the core focus of this thesis. As such this extension and the discussion on the associated data collection can be found in Appendix D.

6.1.2 Sample and descriptive analysis

Two waves of data were collected. The first wave in December 2016 - February 2017 using and the second wave in April 2017 via an opinion panel. For both data collection waves, market research panels[6] were used. Two different panels were used due to availability constraints. While using market research panels eases the data collection process, they also introduce biases due to the fact that the respondents are used to taking surveys and may not take the time to fully evaluate the question at hand. Both panels proved appropriate for this data collection as they were able to carry out the designed survey, fulfil the eligibility criteria set out for the research in this thesis and have respondents from all socio-demographic backgrounds. Only people living in London over the age of 18 were eligible. Incentives were awarded to participants in terms of "currency points" that are used by the market research company. These points are accrued over time and be cashed in for vouchers. Unfortunately, the exact monetary value of the points could not be obtained nor the overall number of people who were invited to participate in the survey.

[6] For wave 1 Exterion Media's (www.exterionmedia.com/uk) community panel and for wave 2 Research Now's (www.researchnow.com) panel was used.

For the purposes of this thesis, a sample of the collected data is used. During the stated preference experiment, respondents were asked to choose among three fixed plans and a 'create your own' options. For the 'create your own' alternative, respondents had to physically interact with the experiment and only then was an actual alternative created and presented to them. However, 92% of the sample did not touch this option. For these respondents, the create your own alternative was out of their consideration set – they did not consider this option as part of their choice set. Based on this presumption, the analysis in this thesis solely focuses on the three fixed MaaS plans and takes as a sample the 1,068 respondents in 3,769 choice situations where the create your own plan was not considered. This approach was followed for two reasons. First, to allow the analysis to focus only on one MaaS product - the fixed plans with predefined amounts of each mode; and second, to temporarily bypass the complexities of modelling menu choice data (as discussed in Chapter 5). The following descriptive analysis will be based on the dataset that will be used for modelling in Chapter 7.

The characteristics of the sample are presented in Table 6-2. The statistics are compared to the 2011 Census and information available from the Greater London authority (ONS, 2011; GLA, 2015). For the Census data values, only those who were over 18 were taken into to make it comparable to the LMS values. By comparing the two columns, it can be seen that the sample is not representative of the wider London population. Caution should be exercised when interpreting the results with the current sample, or it should be weighted if the results are to be generalised.

Table 6-2: Descriptive statistics of Sample

Variable	Survey N=1,068	Census /GLA N=3,266,173
Gender		
Male	47%	51%
Female	53%	49%
Age		
18-29	22%	24%
30-39	24%	24%
40-49	18%	19%
50-	36%	35%
Household Income		
Up to £19,999	20%	22%
£20,000-£35,000	22%	30%
£35,000-£50,000	17%	21%
£50,000-£75,000	15%	17%
£75,000-£99,000	9%	6%
£100,000 or more	7%	4%

Prefer not to say	10%	-
Children in household		
No children	71%	70%
Have children	29%	30%
Household vehicle		
Has household vehicle	73%	58%
Does not have household vehicle	27%	42%

Chapter 7 will present the results of the stated preference experiments, including analysis on the factors affecting MaaS plan choices and individuals' preferences towards each transport mode within MaaS plans. Besides the SP experiments, other data was collected related to MaaS that will not be included in the analysis in Chapter 7 – these will be presented below. While the descriptive statistics discussed below will not provide rigorous analysis on each topic, they will indicate initial insights and suggest further areas of research – areas which are however out of the scope of this thesis.

As described above, the SP placed respondents in a forced choice, meaning that they did not have the option to choose none or opt out. Therefore, after each SP choice situation, respondents were asked whether they would buy their chosen. Presented in Figure 6-3, 10% of respondents stated that they would definitely buy their plan, 12% chose that they would consider buying their plan, while 32% stated they would not. 45% of respondents stated that they would not buy their chosen plan, but would use MaaS as a pay-as-you-go service.

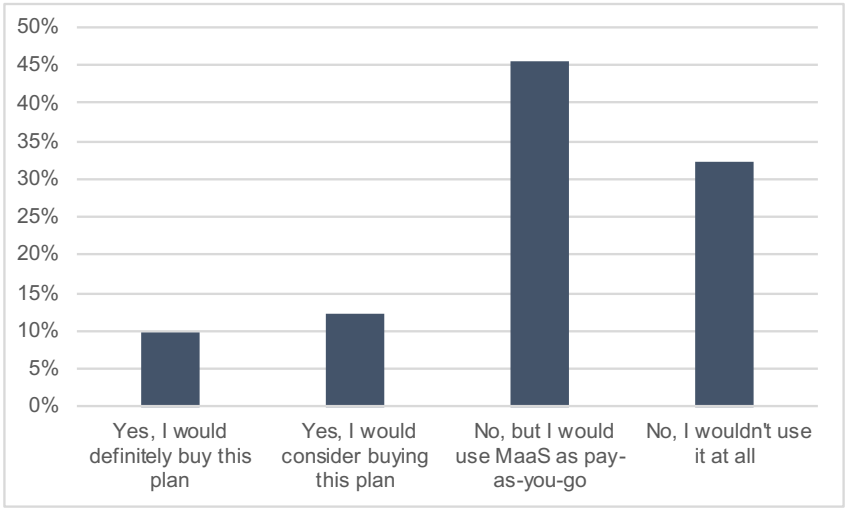

Figure 6-3: Responses to "Would you buy your chosen plan if it were available today?"

These results indicate that there is a fraction of the population who, under certain conditions, would be interested in MaaS, either though packages or by using it as pay-as-you-go. Only 32% of the sample would not want to use it at all, however this number

may be biased due to the survey or the positive description of MaaS. It is important to note, that these results do not provide the full picture, and rigorous analysis including information about each chosen plan would be needed to be conducted. While this is not part of this thesis, it is further work to be considered.

After the whole SP experiment, respondents were prompted to respond to attitudinal statements on a 7-point Likert scale. The results of these are presented in Figure 6-4.

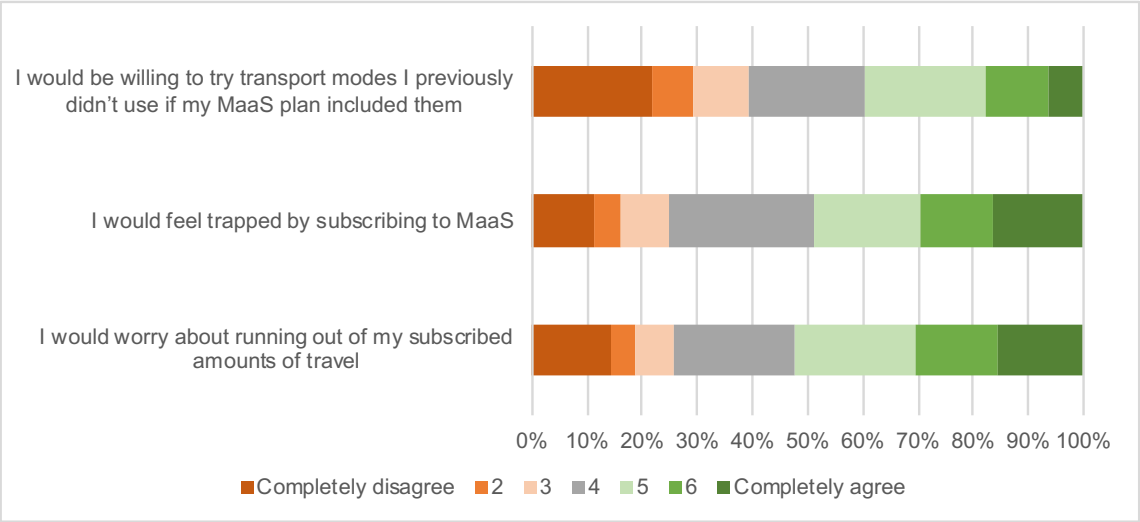

Figure 6-4: Case Study 1: attitudes towards MaaS

The first statement "I would be willing to try transport modes I previously didn't use if my MaaS plans included them" provides some insights into MaaS's potential role as a mobility management tool. 40% of respondents agreed to some extent with this statement, indicating that MaaS could have a role in promoting the use of non-private transportation modes. Mobility management or demand management, commonly referred to as soft measures, aims to alter the way people perceive travel alternatives as opposed to physically altering the options themselves (Headicar, 2009). While hard measures modify the objective environment, for example through infrastructure improvements or prohibiting the use of cars of certain streets, soft measures seek to change people's perceptions of the available choices (Bamberg et al. 2010). The responses to this statement indicate that MaaS could have a role to play, and this should be further researched to evaluate the conditions under which MaaS could have the largest impact in shifting users away from private vehicles and towards more environmentally sustainable transport modes.

The second and third statement provide insights into factors that may deter people from subscribing to MaaS plans. Approximately half of the respondents agreed that they would feel trapped by subscribing to MaaS or would worry about running out of the amount of

travel that they purchased in their plans. These should be addressed to aid the uptake of any MaaS service that includes participants pre-paying for services.

6.2 LESSONS LEARNED AND IMPROVEMENTS

Designing SP experiments is always challenging, especially when this involves services not yet available in the market. In the case of MaaS, this is further complicated, because the MaaS concept is still immature and the MaaS products are constantly evolving (see Chapter 4 for a review of existing MaaS products). The following paragraphs will summarise the most important lessons learned during case study 1:

Present a single price for each plan: Initially, SP designs were tested where the price of each individual service were presented alongside the plan price. However, the focus groups and personal interviews revealed that this is not well received by respondents. Several individuals stated that this was "too much effort" for them to read and understand, and they would rather just have the plan price as it is currently presented to them when purchasing telecommunication plans. As the MaaS concept is new, the focus group participants were more comfortable with plans that were shown similarly to services that they are familiar with.

Concept of roaming too distracting: The concept of being able to use MaaS in various geographic areas (i.e. in different areas/zones of Greater London, and in other cities/the concept of MaaS roaming) was also tested. However, the focus groups revealed that adding this additional attribute was too much additional burden to respondents and ended up drawing attention away from the core MaaS product.

Less modes means better comprehension: The number and levels of modes presented had to be changed several times throughout the design process. Even though MaaS plans could include other modes and service designs, including these create too much of a burden to respondents. The focus groups showed that including less modes increased comprehension of the overall idea of MaaS plans. It has to be noted, that the survey was carried out at a time when most respondents were unaware of the MaaS concept. Once the service matures and awareness increases, it may be possible to test more complex plans. Until then, simpler plans are preferred.

Presentation should mimic other product bundles: a number of presentation methods were tested during the focus groups. These include: (1) presenting each plan on an individual page and then a final summary page where respondents are asked to choose; (2) presenting the plans in a table format, where the modes are in one column, the prices

in another, (3) including the pay-as-you-go option in the experiment itself as a 5th choice. Regarding (1) a couple of focus group members liked this approach, as it was clear and easy to understand. However, the overwhelming feedback was that presenting it page by page was too long and that they did not want to have to click so many times. This approach would probably result in increased survey abandonment. Options (2) and (3) were better received as they were shorter, however, they were still less preferred to when the plans were presented like product bundles are in the market. Option (3) caused some unnecessary confusion, and presenting the pay as you go choice next to the plans ended up drawing away too much attention and respondents did not spend cognitive effort on the plans. As the MaaS market matures, there may also be other MaaS SPs worth exploring. For example, having a base MaaS plan and then having add-ons may also be a viable approach.

There are several areas in which the survey design of case study 1 can be improved.

Due to the sequential nature of the case studies improvements could be taken into account when designing the surveys for case study 2. The following paragraphs will present the key areas where the survey design of case study 2 is improved based on insights gained from case study 1:

Efficient design: Due to the time pressure of the case study 1, a random survey design was applied. Literature states that if sample size is large enough, the experimental design may not matter (Walker et al., 2015; Rose and Bliemer, 2009) and any design will perform well. However, this in most cases will not hold, and using random design may compromise the ability to retrieve statistically significant parameter estimates (Rose and Bliemer, 2009). Thus, more advanced designs should be applied. In these, a fraction of all the possible different choice situations is selected methodologically, so that the best combinations of attributes from the SP experiment will be used for estimating the model. Orthogonal designs are frequently used in the literature however, the current state-of-the art is the efficient design, which aims to find the fraction of the choice situations that are the most statistically efficient in terms of predicted standard errors of the parameter estimates (ChoiceMetrics, 2018). In simpler terms, the efficient designs try to maximize the information that can be collected from each choice situation. One important caveat of efficient designs is their need to have prior information about the parameter estimates (which is why it would have been very difficult to use this design for the first round MaaS SP design). Priors can be obtained from existing literature, pilot studies or even expert judgement (Bliemer and Collins, 2016; ChoiceMetrics, 2018) and can be as little as the sign of a few parameter estimates. Using insights gained from the case study 1 SP design as well as discussions with experts, case study 2 is able to use an efficient design.

Using pictorial presentation to introduce MaaS: The section introducing the MaaS concept can be improved. Looking more closely at the commercial MaaS services that have become available since the case study 1 survey design (e.g. Whim's commercial introduction – see Chapter 4) these services use pictorial representations of smartphone phone screens to explain the concept of MaaS to users. It is important for respondents to understand the full benefits of using MaaS, including the integrated journey planner, ticketing and payment platform. As such, for case study 2 the section introducing MaaS is updated and pictures are used.

Introducing questions about willingness to download MaaS app: A gap was identified in the questions regarding users' willingness to download the MaaS application and their preferences and attitudes towards the core MaaS services. Even though MaaS plans are an important MaaS product, the base of all MaaS products is the MaaS application with journey planning, ticketing and payment. Without this, users are unable to access the MaaS plans. Understanding potential users' preferences for the core MaaS product and their willingness to download the app, is step zero in being able to create a user-oriented successful MaaS product. As a result, questions relating to respondents' preferences and attitudes towards the core MaaS services can be added to improve the survey.

Including 'none' choice: In case study 1, respondents were faced with a 'forced choice' in which they had to state their preference between MaaS plans. It was only as a follow-up question that they were allowed to state if they would not sign up to any of the plans. In order to capture a true[7] choice, in the case study 2 design, a 'none' option is added to the choice set. This way respondents are able to compare the offerings with their current travel and can evaluate the trade-off that come with each of the MaaS plans.

Splitting bundles and create your own plan SPs: While the reason for having the fixed plans and the 'create your own' plan alongside each other in the first-round SP is that it allows us to examine the trade-offs between fixed vs flexible options; it is also possible to separate these two options into two different SPs. Having the fixed plans independently can simplify the choice task significantly for users. Also, having the menu on its own, permits more flexibility in design, such as the inclusion of clearer levels for the menu, such as discrete amounts rather than a continuous toggle. In addition, creating discrete choice models with data from menu choices is very complex. While it is out of the scope

[7] Please note, that no choice is fully true, as in SP experiments all choices are made in hypothetical situations, this a number of survey biases can occur.

of this thesis to address this question in full, a discussion on the difficulties stemming from choice set generation associated with menu choice is presented in Appendix E.

Names MaaS plans: To make the choice options more similar to those seen in the real life, the MaaS plans can be given names and can be presented in order of increasing service offering. When examining service packages offered in telecommunications industries, tourism or even the existing MaaS plans they very frequently have names for their plans and tend to have a low-, a mid- and a high-level plan that caters for different user groups. By following the same approach, the MaaS SP will be more relatable to respondents, as it looks more similar to choice situations they are used to seeing in everyday life. In addition, the additional features that were presented in the case study 1 were removed. Initial modelling exercises revealed, that these do not significantly influence respondents' decisions with regards to MaaS plans. The reason behind this is that at this stage of MaaS, the concept of MaaS plans itself is still new and unknown to respondents. Even just combining transport modes into one product may be difficult to completely comprehend, and including the features at this stage may seem irrelevant at this stage. As such, it is recommended that examining these if left to a later stage, when respondents are more familiar with the base concept.

6.3 CASE STUDY 2: GREATER MANCHESTER

The second application of the MaaS survey design is for Greater Manchester. Similarly to the London survey, the Manchester survey was created with the aim of gathering data on user preferences for MaaS and its products. The lessons learned during the London survey were taken into account during this second case study. The following sections will present the survey design, sample and descriptive analysis of this case study.

6.3.1 Survey Design

Survey Foundations

The questionnaire section of the survey is very similar to Case Study 1. Certain elements were added or removed to collect all the important information necessary for analysis, while trying to keep the response burden as low as possible. The details of the questionnaire including the exact questions can be found in Appendix F.

Next, the MaaS concept is introduced. In this case study, due to the availability of more resources the static visualization technique was used. The aim of this first MaaS page is to familiarise respondents with the core MaaS service. Based on the reviews presented in earlier chapters, the core MaaS service consists of a multimodal journey planner and an integrated ticketing and payment function, all which are available through a

smartphone application. As such, these core functions of MaaS were presented on smartphone screens, with very short, bullet points describing these functionalities. The descriptions are presented in Figure 6-5. While the presentation enables respondents to gain an understanding of MaaS and its functions, it may also introduce biases due to the presentation. All results and interpretations need to take this into account.

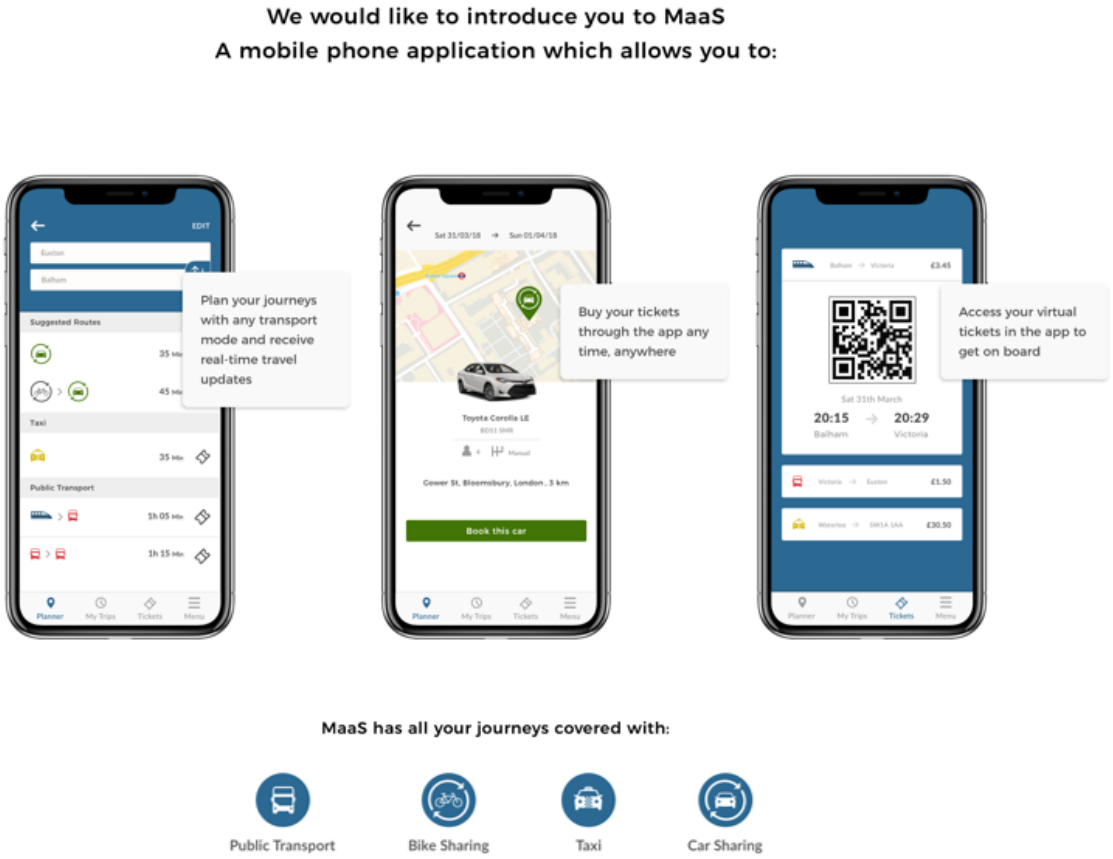

Figure 6-5: Introduction to MaaS with Smartphone Images

Stated Preference Design

The first step of the SP design is to map out the transport services environment for each of the three areas. Similarly to the London case, a dataset was created, which provides the background to the choice of transport modes to be included. The same four transport modes were chosen as in London: public transport, taxi, bike sharing and car sharing. The only difference is that while in the London case study, the transport modes were kept generic, in the Manchester case study company names were included for two of the transport modes. Bike sharing is specified as being Mobike[8] and car sharing as Enterprise Car Club, to aid respondents understanding of what these modes entail.

[8] At the time of the survey development, Mobike was still in operation and were planning on being part services offered through the project. Mobike has since completely withdrawn from Manchester

Looking at the attributes and levels for this MaaS product type, to simplify the design only transport mode amount and price were included. A design element that was determined early on in the process is to have labelled alternatives that actually carry meaning. This had a direct impact on the attribute levels. The plan types were chosen mimicking industry, where there are usually a small, a medium and a large product which users can choose from. Assumptions were created to ensure that the plans are adequately differentiated. These are presented in Table 6-3.

Table 6-3: Plan types and characteristics

Play type	**Basic**	**Urban**	**Extra**
Core elements	This plan focuses on public transport and/or bike sharing. This is the simplest plan with only those two modes in them, and are also the cheapest option.	This plan always includes unlimited use of public transport. On top of this, some level of bike sharing and taxi is also included.	This plan always has unlimited use of public transport and bike sharing. On top of this taxi and/or car sharing is also included.
Price levels	Always the cheapest option	Always the middle option	Always the most expensive option

All plans are monthly and each of the three plan types, Basic, Urban and Extra, have certain characteristics that remain consistent throughout the experiments. The core elements of the Basic plan are public transport and bike sharing and is always the cheapest option. The Urban plan always includes unlimited use of public transport and on top of this, some level of bike sharing and taxi. The Extra plan always has unlimited use of public transport and bike sharing, and on top of this some level of taxi and/or car sharing. The Extra plan, as indicated by its name, is always the most expensive. The remaining attribute is the price of the plan, which is calculated using a similar method as in in the London case study, using the sum of base prices and the multiplier from the design.

A number of conditions are taken into account when creating the plans that ensure there are no dominating alternatives presented. In addition, the experiments were personalized based on the characteristics of the respondent. For example, if the respondent indicated that they do not have a driving license, car sharing was excluded as an attribute. Also, if a respondent has discounted or free public transport passes, this was taken into account when calculating the cost of the plan.

The exact attributes and levels can be seen in Table 6-4 and a visual of a MaaS plan choice situation for Greater Manchester is presented in Figure 6-6. Colours and icons

(with hover over explanations) were used to make it easier for respondents to visually differentiate between the presented plans.

Table 6-4: Manchester SP attribute levels

	Basic plan	Urban plan	Extra plan
Public transport	1 month unlimited bus within Greater Manchester	N/A	N/A
	1 month unlimited public transport within Greater Manchester	1 month unlimited public transport within Greater Manchester	1 month unlimited public transport within Greater Manchester
Bike sharing	No (not shown)	No (not shown)	N/A
	Free access to Mobike bike sharing	Free access to Mobike bike sharing	Free access to Mobike bike sharing
Taxi	N/A	N/A	No (not shown)
		1 taxi trips within Greater Manchester	N/A
		2 taxi trips within Greater Manchester	N/A
		3 taxi trips within Greater Manchester	3 taxi trips within Greater Manchester
			4 taxi trips within Greater Manchester
			8 taxi trips within Greater Manchester
			10 taxi trips within Greater Manchester
Car sharing	N/A	N/A	No (not shown)
			1 hour car sharing with Enterprise car club
			3 hours car sharing with Enterprise car club
			5 hours car sharing with Enterprise car club
			8 hours car sharing with Enterprise car club
			12 hours car sharing with Enterprise car club
Price	(sum of base prices) * 0.8	(sum of base prices) * 0.8	(sum of base prices) * 0.8
	(sum of base prices) * 0.85	(sum of base prices) * 0.85	(sum of base prices) * 0.85
	(sum of base prices) * 0.88	(sum of base prices) * 0.88	(sum of base prices) * 0.88
	(sum of base prices) * 0.95	(sum of base prices) * 0.95	(sum of base prices) * 0.95
	(sum of base prices) * 1	(sum of base prices) * 1	(sum of base prices) * 1
	(sum of base prices) * 1.05	(sum of base prices) * 1.05	(sum of base prices) * 1.05
	(sum of base prices) * 1.12	(sum of base prices) * 1.12	(sum of base prices) * 1.08
	(sum of base prices) * 1.15	(sum of base prices) * 1.15	(sum of base prices) * 1.15
	(sum of base prices) * 1.2	(sum of base prices) * 1.2	(sum of base prices) * 1.2

Figure 6-6: Case study 2 SP visual presentation

Besides the three labelled alternatives, a no-choice ('none') alternative is also included to avoid the 'forced choice' situation used in case study 1. For the response format, discrete choice is used. The SP included context, that is, asking respondents to imagine themselves in hypothetical situations (e.g. where certain policies are implemented) and choose MaaS plans keeping that in mind. Two main types of contexts are shown: carrots and sticks. Carrots aim to provide motivation for individuals to try MaaS plans. These are especially focused on providing incentives for starting to use MaaS plans, since the most difficult element of any subscription service is getting people interested in the first place. Sticks on the other hand provide a disincentive for respondents to use their own private vehicles and instead shift to MaaS plans. Sticks were only shown to people who are frequent vehicle drivers (defined as driving a vehicle at least once a fortnight). The list of possible carrots and sticks are presented in Table 6-5. Each experiment can only have a single carrot or stick presented or none of them.

Table 6-5: List of contexts used in case study 2

	Measure	Duration
Carrot	First month free*	If you like it stay with us, if not, no commitment
	£50 gift voucher with first month subscription	With each 3-month subscription
	£25 gift voucher with first month subscription	With each 6-month subscription
		When you subscribe for first time
		When you bring a friend
		None
Stick	A congestion charging zone is implemented in the centre of Manchester, so that anyone driving in the centre with a private vehicle has to pay £5 / day	NA

	A congestion charging zone is implemented in the centre of Manchester, so that anyone driving in the centre with a private vehicle has to pay £8 / day	
	Fuel prices increase by 50%	
	Parking places in the centre of <Manchester> are converted into green space resulting in 50% less parking available in the city	
	Private cars are banned from the centre of Manchester	

The final two aspects to determine are the number of repetitions and the design. Regarding repetitions, 5 choice situations were presented to respondents, where the first two did not include context and the second three did. Behind the SP experiment are four D-efficient designs (Rose et al., 2008). The designs were assigned to respondents based on their ownership of a driving license and whether it is a non-context or a contextual (carrot-stick) SP experiment. The choice experiment was designed using NGene (ChoiceMetrics, 2018). Not all conditions were possible to include within the software, as such, some designs were ruled as ineligible in post-analysis. The designs were blocked into 100 sets. The priors were determined from the London survey together with expert judgement.

The full survey also included two other SP designs: a stand-alone 'create your own' MaaS plan scenario an SP based on another MaaS product type. However, as this thesis focuses on MaaS plans when they are packaged product bundles, data from these other SP designs will not be used for analysis. As such, these two designs can be found in Appendix G.

Survey Extensions

The first extension is an additional section presented right after the MaaS concept and MaaS app are presented to respondents. Following the description, respondents are asked whether they would download the application if it was available to them, and if they answered no, what are the reasons for this. In addition, respondents were asked to rate the importance of various core MaaS features. As there is a large number of possible features, the most relevant ones were selected (see Table 6-8). These can provide insights into the elements that are essential for the different sociodemographic user groups and can help guide MaaS product development.

Table 6-6: Importance of MaaS app core functions

MaaS app: Journey Planning	
Proposing routes that combine public and private transport modes	1=Not at all important to 7=Extremely Important
Proposing the fastest routes based on network conditions	
Proposing transport mode combinations to save money	
Sending real time updates when there are delays along my route	
Showing the waiting time for the mode to arrive	
Showing the location of the vehicles I am about to use	
MaaS app: Other functionalities	
Being able to see my travel statistics for every week/month/year	1=Not at all important to 7=Extremely Important
Being able to download an invoice for every trip	
Being able to share my journey with friends and family while travelling	
Being able to order food delivery while travelling	
Allowing me to set targets for reducing my travel expenses	
Rewarding me when I choose green transport modes	

The second extensions relates to the fact that the SP has a no-choice option. An additional question is included as a follow-up that collects information about the reason that the respondent are not interested in the presented MaaS plan. This has some pre-specified options they could choose from, but also had an open ended section where respondents could include more detailed descriptions or other reasons that were not included in the presented options. For the unit price SP, an additional question was included to grasp the approximate number of trips that would be conducted with each of the modes.

After the respondent has completed the SP pages, they are presented with some final questions regarding their deeper, latent attitudes and perceptions towards to MaaS and car ownership/use. To gauge these, statements are presented and participants are asked to state their level of agreement or disagreement with these statements on a seven-point Likert scale from strongly disagree to strongly agree. The statements are broken into two sections: one focusing on the attitudes and perceptions towards MaaS; and the other one focusing on car ownership and use. The first set of statements is identical for all respondents, while the second is tailored based on whether the respondent is a car owner/driver or not.

6.3.2 Sample and descriptive analysis

The data collection for case study 2 was supported by the European Commission (EC) H2020 funded research project, MaaS4EU (www.MaaS4EU.eu). The data collection took place during June to July 2018 and the sample was recruited through a market research company. The collected sample is not representative of the population of Manchester,

and this should be taken into account when interpreting analysis results. Table 6-7 shows the characteristics of the sample.

Table 6-7: Sample characteristics

Variable	Survey N=475	Census (2011)
Gender		
Male	52%	49.4%
Female	48%	50.6%
Age		
18-29	23.8%	36.8%
30-39	31.3%	19.9%
40-49	16.9%	15.4%
50-	28.0%	27.9%
Household Income		
Under £15,000	7.8%	-
£15,000 - £24,999	14.1%	-
£25,000 - £34,999	15.8%	-
£35,000 - £49,999	22.5%	-
£50,000 - £74,999	14.3%	-
£75,000 - £99,999	13.1%	-
£100,000 or more	5.9%	-
Prefer not to answer	6.5%	-
Children in household		
No children	60.4%	65.5%
Have children	39.6%	34.5%
Household vehicle		
Has household vehicle	80.8%	-
Does not have household vehicle	19.2%	-

Similarly to case study 1, the following paragraphs will present descriptive statistics about MaaS-related variables that were gathered during the data collection. The stated preference experiment and related analysis will be presented in Chapter 8, therefore it will not be presented here.

First, in case study 2, respondents were asked questions relating to their willingness to download the MaaS application. This question was not included in case study 1. The results of this question are presented in Figure 6-7 which shows that 27% would definitely download the app and 37% would probably download the app – meaning that almost two thirds of respondents stated that they would download the app. While these results do have the caveat that they may be biased due to the survey or the description of MaaS, they still indicate that there is interest in such an app.

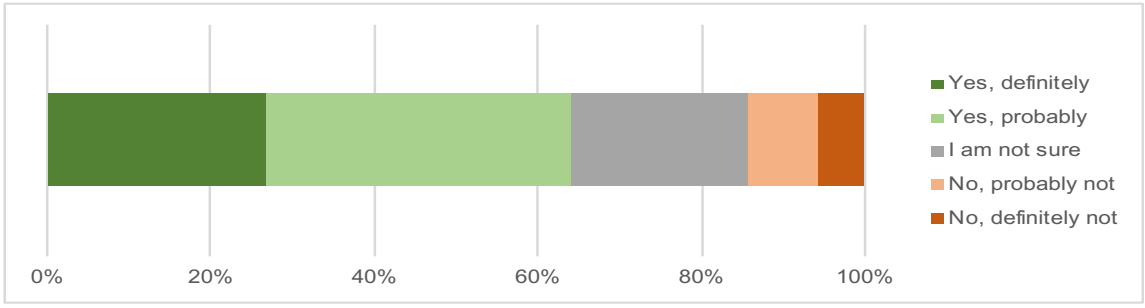

Figure 6-7: Willingness to download MaaS app

Those respondents who answered not sure or no to the whether they would download the app were asked a further question regarding the reason behind their response. The descriptive results are presented in Figure 6-8. The most common reason that participants chose was that they do not see how this would benefit them, while the second one was that they already have too many apps on their phones. These two results have implications for marketing MaaS apps. Nowadays, individuals already have a lot of transport applications to choose from, many of which they already have on their smartphones. The motivation to download yet another app is decreasing as the options available increase. It needs to be made very clear how a MaaS app differs from all the other apps and how it would benefit users. Marketing strategies should focus heavily on the benefit it provides users, and why it is worth for them to download this specific application.

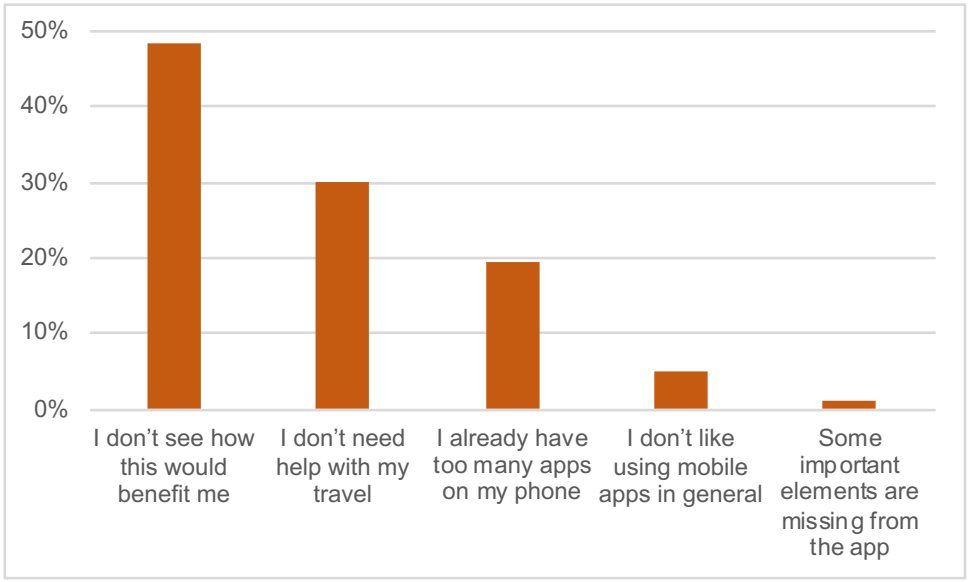

Figure 6-8: Reasons for now wanting to download app

Following the SP experiments, respondents were asked to respond to attitudinal statements, similar to case study 1. Some statements remined that same as case study

1, however others were added to gather further insights. The first statement in Figure 6-9 is identical to that used in case study 1. 50% of respondents answered positively to this statement, which is 10% more than in case study 1. The responses to the two statements cannot be directly compared as the presentation and description of MaaS was different, however, both case studies show that there is a fraction of the sample who are willing to try new transport modes through MaaS. The second statement looks at respondents attitudes towards using MaaS as a pay-as-you-go service rather than a subscription plan based service. While 50% of respondents agreed with this statement 24% disagreed which means that they either prefer the MaaS plans or none of the service offerings. This statement needs further investigation, as no pay-as-you-go prices or service characteristics were presented so no trade-offs between MaaS plans pay-as-you-go options were captured. The third statement captures respondents attitudes towards the concept of having MaaS plans that include a combination of transport modes. 60% of respondents responded favourably to this statement, suggesting that overall there is a positive attitude towards multimodality via MaaS plans.

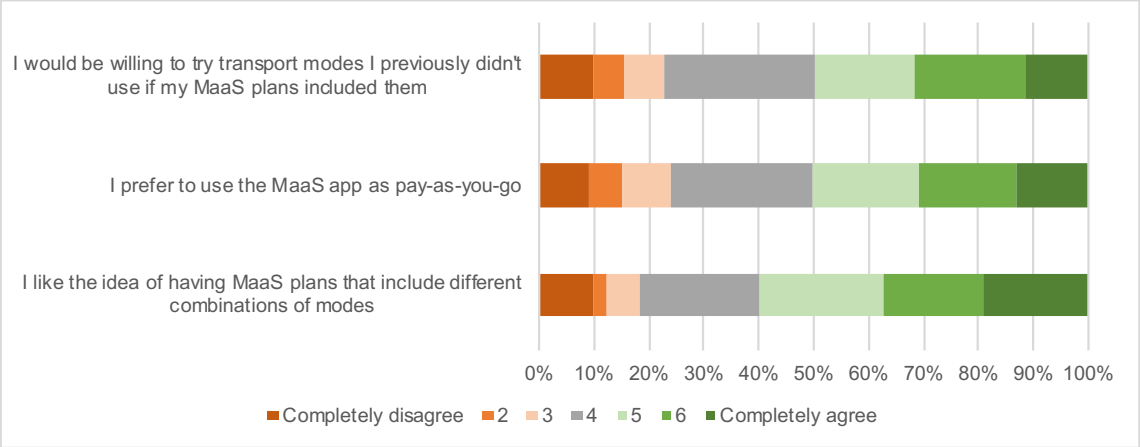

Figure 6-9: Case study 2: Attitudinal statements related to modes and pay-as-you-go

The statements presented in Figure 6-10 relate to reasons that could hinder respondents from purchasing a MaaS plan. The first statement relates to plans that include modes that respondents do not use. While many respondents stated that they would be willing to try new modes as part of their MaaS plans, 57% of respondents stated that they would be less likely to subscribe to MaaS plans that included modes that they do not use. This provides some initial insights into factors that deter people from choosing certain modes, and highlights the fact that not everyone evaluates transport modes in MaaS plans the same way. This will be further examined in Chapter 7 – although using the data from Case study 1.

The final two statements are identical to statements used in case study 1. The results support the findings of case study 1 in that over 50% of respondents would feel trapped and would worry about losing unused travel if they subscribed to MaaS plans.

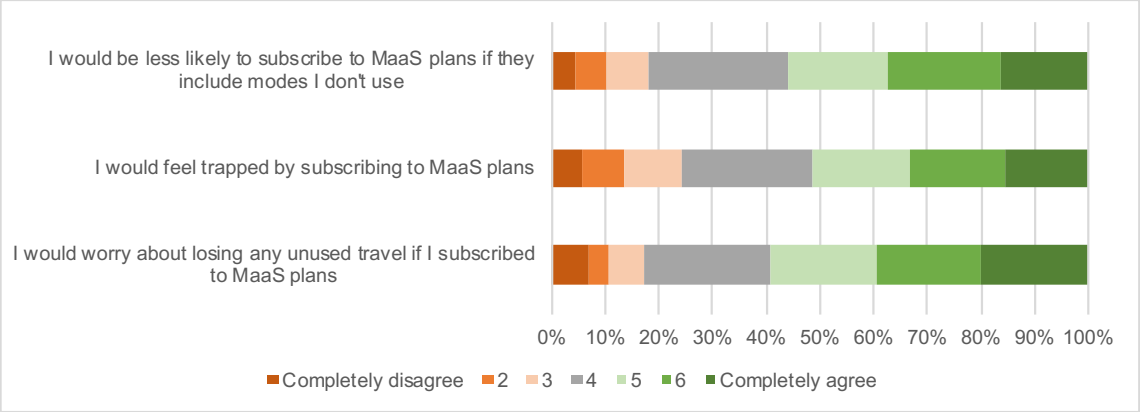

Figure 6-10: Case study 2: attitudinal statements related to subscribing

CHAPTER 7: EXAMINING INDIVIDUAL PREFERENCES FOR MAAS PLANS AND THEIR COMPONENTS: A MIXED METHODS APPROACH

The aim of this chapter is to analyse individuals' preferences for MaaS plans and their components. In doing so, an explanatory sequential mixed methods study is developed which consists of a quantitative element followed by qualitative element. Details on the study framework can be found in Chapter 3.

The chapter is structured as follows: Section 7.1 focuses on the quantitative analysis including data, methodology, model specification, model estimation results and discussion. Section 7.2 details the qualitative analysis including data collection and methodology, analysis and results. Finally, Section 7.4 brings together the findings from the quantitative and qualitative sections and discusses related industry and policy implications.

7.1 QUANTITATIVE ANALYSIS

7.1.1 Data and Methodology

The analysis in this chapter uses the data collected in Case study 1 for London. The sample consists of 1,068 respondents in 3,769 MaaS plan choice situations. The survey and sample characteristics can be found in section 6.1.

The empirical analysis of MaaS plan choice applies the random utility framework (Manski, 1977). In these models, the utility is decomposed into two additively separable parts, a deterministic component which is a function of measured attributes and a stochastic error component representing unobserved attributes affecting choice (Manski, 1977). The most commonly used family of models is the logit (MNL) model, which due to its IID properties assumes constant variances and zero covariances. However, the restrictive characteristics of this model do not take into account the repeated nature of SP data that result in each respondent being recorded in multiple-choice situations. This means, that there are unobserved effects which remain constant within an individual between replications leading to correlations among these observations (Hensher, 1994; Ortuzar

and Willumsen, 2001). To account for this panel/agent effect a Mixed MNL model with random coefficients specification is followed. This allows tastes to be constant across replications for the same respondent (intra-respondent taste homogeneity) but with variation in tastes across respondents (inter-respondent taste heterogeneity; Hess and Rose 2007, Kamargianni et al. 2014). The resulting utility, U_{int} , that decision-maker *n* receives from alternative *i* in choice situation *t* is assumed to be:

$$U_{int} = V_{int} + \alpha_{in} + \varepsilon_{int} \quad , i \in C_{nt} \tag{7.1}$$

Where V_{int} represents the observed proportion of the utility, and the term α_{in} corresponds to an additional additive common error term, which represents random taste variation across individuals. α_{in} is assumed to be normally distributed with a zero mean and σ_{panel} standard deviation. σ_{panel} becomes an additional parameter to be estimated. Following the MMNL framework, the systematic utility functions for modelling MaaS plan choice are now defined as:

$$V_{Plan1} = \beta' X_{1n} + \alpha_{panel} \tag{7.2}$$

$$V_{Plan2} = \beta' X_{2n} + \alpha_{panel} \tag{7.3}$$

$$V_{Plan3} = \beta' X_{3n} \tag{7.4}$$

where β' are vectors of unknown parameters and X_{in} are vectors of observed attributes of each plan, which in our model are the modes included in the plans. The individual-specific error terms were added to only two alternatives as one needs to be normalised.

7.1.2 Model Specification

The analysis is based on a MaaS plan preference model. The core variables in the model are the transport modes that are included in the plan. Bike sharing is entered into the model as a dummy variable (1 = included, 0 = not included), as this transport mode attribute takes only these two levels in our SP. The public transport mode attribute is split into two dummy variables: 1. bus pass (unlimited access to busses), and 2. travelcard (London's public transport pass that allows unlimited travel on all modes). Car sharing is split into two continuous variables: 1. car sharing hours, and 2. car sharing days. This is done because car sharing services in London charge by the hour and the day. Also, people perceive these two durations differently: car sharing hours is for short trips, while days is more like the traditional car rental for longer trips. The last transport mode, taxi, is entered into the model as a continuous variable (distance based). The coefficients for the modes are generic as there are no significant differences between respondent preferences if entered into each alternative separately. This was tested by running

models with alternative specific constants and examining the sign and significance of the coefficients. This was expected as the plan names themselves do not carry any meaning. The next category of variables are the additional features, such as 10-minute taxi guarantee, that were included as attributes in certain plans. These were all entered into the model as dummy variables. A summary of the variables and variable types is presented in Table 7-1.

Table 7-1: Variables and variable types

Variable	**Variable type**
Bike sharing	Dummy variable (1 = included, 0 = not included)
Public transport	Bus pass dummy (1 = unlimited access to busses; 0 = not included) Travelcard dummy (1 = unlimited access to all transport modes; 0 = not included)
Car sharing	Car sharing hour – continuous Car sharing days – continuous Car sharing dummy (1 = included, 0 = not included)
Taxi	Distance (miles) - continuous
Additional features (e.g. 10-minute taxi guarantee)	Dummy variable (1 = included, 0 = not included)

In addition, systematic taste variations are included via interactions between the attributes of the MaaS plans and socio-demographic variables. A number of individual characteristics were tested including age, gender, employment status (e.g. full time employed, student) education level, household composition (e.g. children in the household) and current mobility patterns (mobility tool ownership and use); however, only a few proved significant.

7.1.3 Model estimation results

The results of the MMNL choice model are presented in Table 7-2 and were estimated in Pythonbiogeme v2.6 (Bierlaire, PythonBiogeme: a short introduction, 2016).

Table 7-2: MaaS plan choice model results

Name	Coefficient	p value
Plan cost	-0.296	0.00
Bike sharing (dummy)	-0.395	0.00
Bus pass (dummy)	0.602	0.00
Travelcard (dummy)	0.551	0.00
Car sharing – days (continuous)	-0.572	0.00
Car sharing – hours (continuous)	-0.060	0.00
Taxi (continuous)	-0.685	0.00
Floating car sharing included (dummy)	-0.283	0.00
Any car sharing company can be used (dummy)	-0.313	0.00
Car sharing can be paid by the minute (dummy)	-0.444	0.00
Luxury taxis only (dummy)	-0.446	0.00
10-minute taxi guarantee (dummy)	-0.318	0.00
Taxi pool included (dummy)	-0.579	0.00
Household cycle ownership interacted with bike sharing in plan	0.254	0.02
Santander cycles use interacted with bike sharing plan	0.310	0.01
Travelcard ownership interacted with travelcard in plan	0.254	0.03
'Frequent taxi user' interacted with taxi (continuous) in plan	0.051	0.00
Household income under £25,000 interacted with bus pass in plan	0.380	0.01
Over 65 interacted with bike sharing in plan	-0.247	0.06
SIGMA	0.842	10.72
		Sample size: 3769
		Init. log likelihood: -4140.67
		Final log likelihood: -3347.02
		Likelihood ratio test for the init. model: 1587.29
		Rho-square: 0.192

Firstly, highly significant coefficient was obtained for the standard deviation of the random panel effect $\sigma_{panel,}$ which means that this model allows for capturing intrinsic correlations among observations of the same individual.

Turning to the plan characteristics, as presumed, the cost coefficient is negative and statistically significant at the 95% confidence level. This means that as plans become more expensive, people prefer them less. Regarding the transport modes in the plans, all of them are statistically significant. This shows that the type- and amount of transport modes in the plans are important to users and should be carefully considered in the design of plans. Only the public transport options (bus pass and travelcard) have positive coefficients, meaning that people prefer plans when one of these are included (in the SP design, these were mutually exclusive). This result shows two things. First, it demonstrates the importance of public transport as the backbone of MaaS. Second, it supports the fact that the public transport system in London has very good coverage and is very popular among the city's residents.

Looking at the other modes, all of the remaining coefficients are negative. For the dummy variable bike sharing, this means, that when these modes are included, people tend to prefer them less. For the continuous variables car sharing day, car sharing hour and taxi, this means that the more that is included of these modes, the fewer people will prefer them. The fact that only the public transport options are preferred may seem alarming at first to those questioning MaaS plans; however, this result is not unexpected, in a city where 54% of overall journeys are conducted with public transport (excluding walking; Transport for London, 2015). It is well known that travel is a habitual behaviour and it has been shown many times that much of travel behaviour is driven by pure repetition and habit rather than by conscious deliberation (Schlich and Axhausen, 2004; Klöckner and Matthies, 2004; Friedrichsmeier et al., 2013). This same idea can also be seen if the interaction terms between the respondent's current mobility patterns and the modes in the plans are examined. For example, the interaction term between travelcard ownership and travelcard in the plan is positive and significant. This means, that those respondents who currently own travelcards prefer to have these in their plans more than those respondents who currently do not own one. Along the same lines, a variable about the frequency of taxi use is interacted with taxi. A frequent taxi user was defined as someone who uses taxi at least once a week. The interaction term is positive and significant at the 95% confidence level; that is, people who use taxi frequently prefer to have more taxi in their plans compared to those who use taxi less. In addition, two variables were interacted with bike sharing. When household cycle ownership is interacted with bike sharing, the coefficient is positive and significant. This means that those people who have bikes in their households prefer to have bike sharing in their plans more than those people who do not own bicycles. The same positive and significant coefficient can be seen when the variable 'previous use of Santander Cycles' is interacted

with bike sharing in the plans. This indicates that those who have previously used Santander Cycles (London's bike sharing scheme) prefer to have bike sharing in their plans more than those who have not used this service before.

The next variables, are the additional features. Not all features made it into the final model as several of them (e.g. minivan access included in car sharing) had insignificant coefficients. For those that remained in the model, all the coefficient signs are negative, meaning that respondents are less likely to choose MaaS plans that include these features in them. There can be a number of reasons behind this. First, when one or more features are presented in the plan, it becomes more complex to comprehend, which can be a deterring factor for many people. Second, many of the features are most likely not attractive to the general population. An interesting insight is that the feature "transferability" (meaning that unused credit can be transferred over to next month) proved to be insignificant in the model (thus was excluded from the final model).

Finally, out of all of the tested socio-demographic characteristics, only two proved to create significant differences between preferences for modes included in the MaaS plans. The variable 'household income under £25,000' is interacted with bus pass, and its coefficient is positive and significant. This means, that people with lower household incomes prefer to have bus passes more than those with higher incomes. The explanation for this is that bus passes are much less expensive than the other public transport option, travelcards, but at the same time have similar coverage. Individuals with lower household incomes have a lower willingness to pay for transport and a higher willingness to accept increased travel time that comes with using busses. Next, the 'over 65' variable is interacted with bike sharing is significant and negative. This indicates, that people over 65 gain less utility from both bike sharing in their plans compared to younger people.

7.1.4 Discussion

Looking at the results from the model, the coefficient signs are unexpected. They indicate that on average, there is strong preference towards public transport, but strong disfavour towards the other modes. The negative coefficient estimates for bike sharing, car sharing and taxi initially, may even seem like they are incorrect as this would mean that on average there is a negative willingness to pay (WTP) for these modes. While this is unusual, this is not the only MaaS plan model that results in negative coefficient signs for certain modes. For example, a study looking at MaaS plans in the canton Zurich,

Switzerland[9] (Guidon et al., 2018) also get negative coefficients for bike sharing, electric bike sharing and taxi, and conclude that the average customer does not want these modes. The model results also indicate that there is either indifference or disfavour towards the additional features in the plans. These are shown by several features having insignificant coefficients, and those that were significant were negatives.

These results on their own do not provide much information about *why* these coefficient values emerged. There are clear overall trends, but it is important to understand the reasons behind these. Is it because people do not understand MaaS or the concept of MaaS plans? Is it because respondents really do not want these modes, and if yes, does this apply to all people? Are there certain reasons why they do not want some modes and features, and can this attitude be changed? These are just some of the many questions that arise as a consequence of the model results. In order to gain some insights into respondents' thought processes, the study is extended with a qualitative phase which is structured around these 'why' questions.

7.2 QUALITATIVE ANALYSIS

7.2.1 Data and Methodology

As the quantitative survey restricted the question and answer frame - meaning that potentially critical information may not be captured - the qualitative phase was purposefully conducted without a strict structure. As such, a semi-structured discussion guide was created covering the selected areas, which were used during the interview. The questions included in the interview focused around three priority areas where in-depth qualitative insights could complement the findings from the quantitative models. The three areas are:

(1) General understanding of MaaS,

(2) Evaluation criteria of MaaS plans,

(3) Overall opinion of the concept.

The discussion guide included one or two main questions and a number of follow-up prompts for each area to help navigate the interview. Participants were encouraged to provide their own reasons for their answers in their own words and if necessary were reminded that there is no right or wrong answer. Question prompts were used selectively

[9] Zurich is hilly in nature, which may be an important factor in respondents not preferring bike sharing in their MaaS plans. However, this aspect was not examined in the referenced study.

depending on the flow of the discussion. The main question about this priority area and the prompts/follow-up questions are presented in Table 7-3.

Table 7-3: Semi-structured questions and prompts used in interview

Section	Priority area	Main question	Follow-up prompts
Foundation questions	Understanding of the MaaS concept	Could you describe in your own words what Mobility as a Service (MaaS) is?	• What are the main features of MaaS? • How would it work in practice?
Primary questions	Evaluation criteria of MaaS plans	What was going through your mind when you were choosing between the presented MaaS plans?	• Most important factors you were looking for when considering the plans? • Anything you were specifically looking for and why? • Anything that specifically discouraged/deterred you from choosing certain plans and why? • Specific modes? • Additional features? • Price vs mode trade-off?
Secondary questions	Overall attitude towards MaaS	Overall, what was your impression of the MaaS concept in general?	• Would you be interested in signing up? • What would make you more interested? • Are there any barriers? • Anyone you know who would be interested?

The same respondents who completed the quantitative survey could not be used, therefore a new sample had to be recruited. To recruit participants a mix of convenience and purposive sampling was used. Individuals were eligible if they lived within Greater London and were over 18. Participants with various socio-demographic characteristics (age, gender, family status, vehicle ownership) were chosen to ensure that different views were heard (Table 7-4). It needs to be pointed out that the sample did not include anyone in the age group 65+, however, as this is not the primary target audience of MaaS, this is not a major drawback at this stage. It should also be emphasized that the purpose of the qualitative research is not to gain a representative sample, but to illustrate important themes that may arise and can be examined further in future research. 30 participants took part in the study and the interviews took place during June-July 2018. Each interview lasted between 45 and 75 minutes, depending on how long it took the participant to complete the survey and how interested they were during the interview. The interviews were audio-taped with written consent from the participants and transcribed.

Table 7-4: Characteristics of participants

Characteristic	Group	Number of participants
Gender	Male Female	13 17
Age	18-25 26-45 45-65 65+	9 11 10 0
Employment	Full time job Part time job Student Other	14 6 7 3
Household composition	No children Children	13 17
Household vehicle ownership	Yes No	19 11
Household vehicle driver	Yes No	17 13

Before moving on, it is important to take note of the sample size. Although the sample size is quite small (and the author notes that this is a limitation), similar samples have been used in many occasions in the literature for qualitative studies. 7-5 for a list of qualitative studies where the sample size is similar). As with the studies presented below, this sample is also able to add value to the research community and practitioners.

Table 7-5: Sample size comparisons with other qualitative studies

Reference	Data collection method (qualitative)	Sample size
Seedat et al. 2006	Interviews	19
Beirao and Sarsfield-Cabral, 2007	In-depth interviews	24
Mote and Whitstone, 2011	In-depth interviews	12
Schneider, 2013	Interviews	26
Wilton et al, 2011	Semi-structured interviews	32
Fishman et al., 2012	Focus groups	30
Graham-Rowe et al., 2012	Semi-structured interviews	40
Miralles-Guasch et al., 2014	In-depth interviews	34
Simons et al., 2014	Focus groups	36
Thomas et al., 2014	Focus groups	27

To start the examination, the transcripts were transferred into the NVivo qualitative data analysis software, through which a systematic approach could be taken to the analysis. Next, transcripts were closely scrutinized and pertinent excerpts were assigned a provisional conceptual code or codes (if the same text related to two or more separate codes). Codes are words, phrases or sentences that summarise interesting and relevant features of the data. They help organize your data into meaningful groups (Braun and Clark, 2006). The codes were arranged hierarchically, with wide, general groups at the top and narrower sub-groups at the bottom. By systematically reading and rereading the transcripts semantic themes emerged, which were refined and cultivated throughout the process.

7.2.2 Results

To start with a few contextual points are worth mentioning. Travel habits and lifestyle contexts varied greatly within the sample. Some were devoted public transport users, who also exhibited multimodal travel involving cycling or taxis. Others were captive car users, who either for personal or geographical reasons commute mainly with private vehicles. From the discussion, some clear themes emerged, and a wealth of insights were gained which are presented below. Quotations are provided in italics to illustrate themes and related concepts and an identifier is used to indicate the characteristics of the respondent. The code represents their gender (Male or Female), age group (18-25, 26-45, 46-65) and vehicle use (Driver or Non-driver) respectively. The results are structured in two main sections: (1) participants understanding and overall impression of the MaaS concept and its potential impacts; (2) participants evaluation of the MaaS plans and their attributes.

(1) Participants' understanding and overall impression of the MaaS concept and its potential impacts

When asking respondents to give an explanation of MaaS in their own words, it became clear, that in general, the concept was well understood. Almost all participants comprehended the main elements of MaaS, and were confident in describing this. For some individuals, a couple of follow-up questions were necessary, however, in most cases the participants were able to explain the concept without the interviewer having to prompt them. During the analysis of the transcripts, it was interesting to see which elements of the concept most stuck with people. When asked to recall a concept, people tend to remember those factors that are most relevant to them and what they can most relate to. During the analysis, three core themes with several factors emerged, which will

be discussed below. The themes are presented in bold below, with discussions and example quotes.

MaaS is a centralized and streamlined solution

A common theme that most participants described is the fact that MaaS is a centralised solution that simplifies travel in the city. Even though having increasing amounts of transport options available to city dwellers seems like it would encourage multimodality, it can also cause a general sense of unease. By integrating these into a single system, MaaS could give confidence to a number of people. The centralised single system was commented on by respondents as being both easier and safer than the current fragmented solutions. These characteristics of MaaS were viewed very favourably by participants, and there was a frequent positive undertone to the comments that were made regarding this:

> *"Mobility as a Service to me is the combined use of many different types of transport all in a centralised solution so that you can get from A to B or you can get goods from A to B without having to independently use different services or different things. So yeah, I guess a centralised solution." M25-34D*

> *"I like the idea of one place where you can do it, rather than putting your card into a machine and tapping wherever you go. I feel a bit like the world is starting to get a bit scary. So I guess it makes sense that you have one person to respond to rather than when things do go wrong when you feel like you have been overcharged and there is no voice on the line." F45-54N*

More specifically, a number of people highlighted the single MaaS application and the fact that this could replace the many travel apps they need to use nowadays. The convenience of the integrated app was also mentioned on several occasions:

> *"It's an app which kind of links all modes of transport in one app so you don't need to go on multiple apps, say for example Uber. So everything is there for you, which I guess is quite convenient depending on what you want." M18-24N*

> *"A mobile app that allows you one stop shop transport with your needs all supplied at a click of a mouse." M45-54N*

> *"I think the idea is good to use an app for transport or travelling in London and you don't have to check in different apps, so you can find everything in one app, I think that is quite useful." F25-34N*

The prevalence of similar statements in the interviews illustrate that there is a general frustration with the sheer number of various different apps that individuals need in order

to use different transport modes. This shows the importance of one of the key pain points that MaaS aims to tackle. Some participants even took it further and grasped the idea that MaaS would not only consist of an integrated app, but it would also provide ticketing and payment integration as well:

> *"This basically would be one app which gathers all the possible transportation methods, like tube, public transport, taxis, bicycles, and car sharing and everything, and it would have everything in one app you could even pay for it so you don't have to have separate oyster cards, tickets or anything." F35-45N*

MaaS increases awareness of new modes and the options available

The analysis of the transcripts revealed that respondents (7 interviewees) focused a lot on exposure to new modes when they were discussing the MaaS concept. A characteristic that was frequently mentioned with a positive connotation, is the fact that MaaS increases awareness of the various transport options that are available in London. Some participants even noted that they had not heard of certain modes (e.g. car clubs) before, but think that MaaS would be a great way for them to be introduced:

> *"Making users aware of all potential modes of transport that they may not have seen before. I did enjoy the fact that it seemed like it would give me an easy way of being introduced to certain things that I've always been intrigued by when I see them on the street." M25-34D*

> *"Using more public transport that's available and different methods that are available but you may not know about." F35-44D*

Another aspect that materialized from the analysis of the transcripts is that MaaS can expand respondents' perceived choice set. Through the discussions it became clear that many respondents (9 interviewees) were aware of the existence of the various modes but they never (or rarely) considered this as part of their choice set. With MaaS, the decision is still in the hand of the traveller, but their perception of the array of options that they can choose from is modified:

> *"To give members of the public a choice of not just those that are probably seen as the usual modes of transport (the train, tube) but also car sharing, bike sharing." M25-34D*

> *"Trying something that you perhaps haven't tried before - I think that for me it would be borrowing bikes." F45-54ND*

> *"It is the concept of involving many different forms of transport, or public transport, together for members of the public to be able to use or choose from." M25-34D*

MaaS could decrease private vehicle use

The final theme that was prominent in several respondents' (6 interviewees) descriptions of MaaS is the fact that MaaS could have an impact on private vehicle use. It is important to note, that there were questions in the survey that aimed at getting respondents thinking about what effect MaaS could have on private vehicle use, which may have caused respondents to think about this aspect more than they would have otherwise. Nevertheless, it is interesting that many respondents, regardless of whether they were car drivers or not, specifically pointed towards MaaS decreasing dependence on private vehicles:

> *"I think it would definitely promote people to use this over their cars which is good." M18-24N*
>
> *"For example, my sister, she has got a car sitting outside and she never uses it because she takes the tube to and from work, so it's pointless of her having a car. So this sort of thing would be ideal for her. The times when she does need a car or a weekend away, she could just use this." F55-64D*
>
> *"It's an innovative way to get people to stop using their own cars to help lower emissions and it's something that you need to share more and have less individual ownership." F35-44D*

(2) Participants' evaluation of MaaS plans and their attributes

This section provides insights into the themes that emerged with regards to participants' evaluation between the different plans and more specifically the components within them. Figure 7-1 maps out the areas in which themes emerged. First, the themes are split between those that are related to the transport modes within the plans (top half of the figure) and those that are related to the additional features within the plan (bottom half of the figure). Regarding the evaluation of modes within MaaS plans, the analysis of the transcripts revealed that respondents sorted them into three categories: (1) essential, (2) considered, and (3) excluded. When examining whether there are any common rationales or reasons for doing so, several key themes emerged, which are summarised in the figure below. Regarding the themes related to the additional features in MaaS plans, two themes emerged, both pointing against any sort of preference for these. In the following, each of the elements outlined in Figure 7-1 will be discussed in more detail.

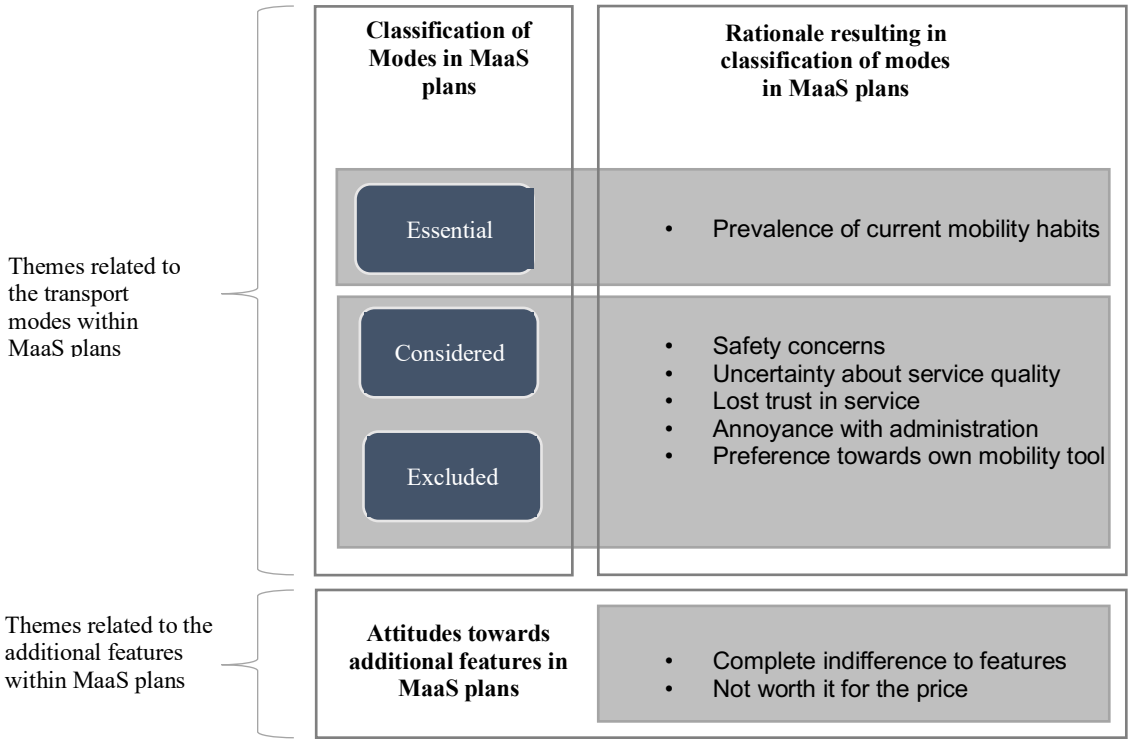

Figure 7-1: Overview of themes related to respondents' evaluation of MaaS plan attributes

Transport modes within MaaS plans are classified into essential, considered and excluded

The analysis revealed that participants classified transport modes into three groups: essential, considered, and excluded. Table 7-6 provides an overview of the three classifications, with example quotes and the number of participants who's statements pointed directly at each theme. Below the table, the three categories are discussed in more detail.

Table 7-6: Respondents' classification of transport modes within MaaS plans

Classification	Example quotes	Number of respondents
Essential	*"The first thing I looked at was whether they had public transport and the second thing was whether they had the bike sharing because they are the two things that I use every day at least twice a day so they had to be in the plan really." M18-24N* *"The main one for me is public transport, and then the other one for me is access to a car, whether it be my own car or a shared one, I would need it because on the weekends I like to have a car and drive out of the city. So those are the two really important things to me." F45-54D*	21

	"The specific modes I am looking for according to my current daily mobility pattern is unlimited public transport, that's the main one, then it's taxi trips." M25-34N	
Considered	*"The only bit of all of that, that I would consider doing is using the bikes when I am in London." M55-64D* *"Taxi was just an added bonus." M18-24N* *"Bike sharing would be the third mode I would actually involve in my plan because, although I currently don't use it, it would be nice to know that I have an option with just a minor change in the price to have this option as well." M25-34N* *"The car sharing, since I've never used one, yes that's something I could consider, but it would have to be that flexibility and speed of access and that it's not too far to walk to get one." F35-44D* *"It doesn't matter if there is bike sharing in it and maybe once or twice I would use the bike. I mean it would be fun once or twice if someone comes to visit and do bicycle site seeing. So probably I would still use it if there were other options in the package that is good for me." F25-34N*	12
Excluded	*"I don't feel comfortable actually being the driver, so that eliminated any car shares, and I also don't feel comfortable riding a bike in the city so that eliminated that, so it was pretty much anything that didn't involve me as a driver so public transport and taxi services is what I would be interested in more than using the others." F25-34D* *"I wouldn't use even if they were available. I mean things like car sharing or bike sharing - I've got my own bike, so if I wanted to cycle somewhere I would use that and I have my reasons why I don't tend to cycle around London and that wouldn't change even if there was a cycle share option. And similarly with the car sharing, I think if I didn't have a car, I would probably just do without - I can't really see a scenario in which I would chose to join a car club." F45-54D* *"But for the other options, like for car sharing, bike sharing, I was not really too interested in those offers that were presented." M18-24D*	12

21 respondent very clearly referred to the fact that there were modes that they immediately looked for in their plans. Those modes that respondents frequently used were deemed as critical/essential elements of MaaS plans and they would not choose

plans without these. As illustrated by the quotes above, habit plays an important role when choosing between MaaS plans. Through the discussions, it became clear that the first element people would think about is the transport modes they use for their daily commutes as well as those they may use on a regular basis. In all cases, these resulted between one to three essential modes, without which, respondents would not even contemplate choosing a plan. This does not come as a surprise, as it has been widely documented that travel is a habitual behaviour (Schlich and Axhausen, 2004; Polydoropoulou et al., 2013). Another important element can be seen through the quotes below, and that is the importance of public transport. Almost all respondents, regardless of whether they are car drivers or not, stated that public transport is an essential part of their travel patterns and would only consider buying MaaS plans that included this. The fact that so many respondents indicated that they would not consider plans without public transport in them solidifies the idea that public transport should provide the backbone of MaaS (at least in the case of London). This means, that even if other plans provided much more at a relatively cheaper price, most people would not consider those plans. All the other transport modes are frequently viewed more as supplements to public transport, rather than core elements of individuals' mobility portfolio.

The second category of modes were those that respondents would be willing to consider in their plans. 12 respondents used words such as "consider", "probably", "maybe", "don't use it but like the idea" etc. Some of these modes they may have used before, but are not an essential element of their modality portfolio. In other cases, respondents revealed that they would be willing to consider modes in their MaaS plans that they may have never tried before, or currently do not use. In these situations, MaaS plans could provide people with easy access to new modes such as bike or car sharing. As illustrated by the example quotes in Table 7-6, MaaS could be a platform to get individuals using several different types of transport modes. Some which they rarely use, or others that they may not use at all. This middle category of modes, the "considered modes" is where MaaS could truly make an impact with regards to behavioural change.

The third category of modes were those that participants completely eliminated from their evaluations. 12 participants expressed clear disfavour towards certain modes. These respondents used phrases like "eliminate", "don't want", "would never use", "get rid of", "no point of having" to describe these modes. They also stated that any plan that included those modes would be excluded from their choice set, no matter the other characteristics of the plan. The quotes below demonstrate that many respondents had very strong oppositions towards certain modes. Through the discussions, it became clear, that these were embedded into their thoughts and it would be difficult to change these.

Turning specifically to the reasons why individuals only consider or exclude certain modes, five themes can be highlighted. Understanding these reasons can give some important insights into characteristics of these services that need to be improved in order for more people to use them. Each of these themes makes people wither apprehensive towards a mode or in extreme cases makes them completely exclude a mode. The extent of these feelings places the relevant modes into one of the two categories. An overview of the different themes can be found in Table 7-7 alongside example quotes and the number of respondents who mentioned each theme.

Table 7-7: Reasons for disfavouring modes

Theme	Example quotes	Number of respondents
Safety concerns	*"I personally don't use bike for a transportation mode, it's very rare that I do that because of the danger of riding on London roads. I use it for my own physical exercise. So the biking for me wouldn't really make a difference unless London does something with safety." F35-44D* *"I think I would be quite frightened cycling in London. I don't trust drivers, buses." F45-54N* *"I would like the roads to be improved and be a bit more safe. You see so much in the TV people in the middle of the road getting knocked of their bikes because drivers aren't paying attention. Especially as a driver, you can see it, it's getting worse and worse - driving is atrocious. We were actually just having a conversation with my family the other day about how appalling London drivers are now. They could even take your life in a car, god knows with a bike or motorbike." F35-44D*	11
Uncertainties about service characteristics	*"Maybe if it was something that was available in the area and it was a definite that I could always access it, then I would definitely consider getting rid of my car and using a car share if it had the things that I need - if I knew that there was always going to be a baby seat in the trunk or something that I could use and then if it was close." F35-44D* *"But obviously, for a lot of families it would be nice to have a plan where if you ordered a big enough cab with a child seat or one which you can put your buggy in. Or especially, I have a few friends with dogs and they find it difficult to get a cab because not all of the cabs would take a dog on. So that would be a nice feature that you could just tick that you would want a dog friendly car." F35-44N*	8
Lost trust in service	*"I had a bad experience with it [car sharing]. The car wasn't there - the previous people had overrun and I was desperate to use the car.*	5

	And then I was told where it was and it was locked, so it was just very difficult. And then I lost confidence a bit." F45-54D *"I don't trust it (Uber), because too many horror stories. As a woman travelling on my own I wouldn't get into an Uber, I would get into a black cab. Even if it was easier and it was half the price or a third of the price. If it was free, I still wouldn't get into an Uber because of those experiences." F55-64D* *"Black cabs have created apps, but it depends on the quality of the app. And I've tried to use the black cab apps and there are never any available and they are not where they say they will be. So I like the technology and obviously Uber has nailed it and it is just so much." F45-54D*	
Annoyance with administration	*" I guess, like the bike share, that's quite easy in itself that you can do on an app quite quickly but the car you tend to think that that will be a really long process." M25-34D* *"I have used everything before, I have used the Zipcars and I found it useful at the time, because I didn't have a car, but I had to take my children to school or do a shop, but still something that worried me with all these things like Zipcar, you need an app and are a lot of hoops to jump through to be able to use it so it's a bit intimidating. So I thought maybe this new plan may take away some of the admin and that would be a good thing. And then I would definitely use things more if I didn't have to go through as many hoops and obstacles." F45-55D* *"Bike sharing isn't contactless on the Barclay's thing and I haven't tried the other one. So virtually the only reason why I don't use the Barclay's one is because it takes longer to rent the bike than do the journey - if you don't subscribe to it. For tourists it must make sense but if you are using it for a form of transport the biggest barrier is just getting the bike." M45-55D*	6
Preference towards own bike or car	*"It's a good idea, but I prefer my own bike because it's my own and if there is no base for those bikes I need to find somewhere else for them. For my own bike I can just lock it up anywhere so it's easier." M|18-24|ND|S|NC* *"It's comfort. I can get into my car straight outside of my house. I don't need to work towards anyone else's schedule, I am running to my own schedule. I have a lot to carry so something door to door is handy for me." F25-34D*	6

The first key theme that emerged through the analysis of the transcripts was the frequent mentions of safety concerns when it comes to driving and especially cycling around

London. These concerns were especially prominent when women were talking about their apprehension towards using these modes. Many people (11 interviewees) commented on the fact that their perception of cycling in London is quite negative and that they are too scared to ride them outside of parks. Some people (4 interviewees) mentioned that they would love to cycle more and they like the concept of bike sharing, however they are too nervous to do so. One participant also said that they are not keen to cycle in London because of the bad air quality. Some (4 interviewees) respondents also mentioned safety as a concern when discussing driving and car sharing, however this was not as prominent as in the case of cycling.

The second theme that emerged was the fact that people were reluctant towards using services because they were unsure about all the available features. This was especially prevalent when it came to individuals with special needs, such as families or pet owners. These respondents expressed that they would be much more open to using these if they would be ensured that all their needs would be met.

Third, although this was not prominent, a few respondents (5 interviewees) pointed out that due to a bad experience, they are no longer interested in using a service. The examples in the table show, that with all the available services nowadays, people do not have to stick with one service if they do not feel comfortable with it. People lose trust in a service quite easily, and expect constant high quality. This is especially true for new, innovative services, where people are quite unforgiving towards bad services. The discussions showed strong emotional experiences.

Fourth, during the interviews, when discussing shared modes, the hassle and administration side of using these services was brought up on a number of occasions (5 interviewees). Respondents mentioned that the complexity of using these services significantly discouraged them from using them. This was especially true for car sharing, where the perception of the registration process is that it is very long – even if the person does not actually have any prior experience with this mode.

Fifth, for private car and cycle owners, some respondents (6 interviewees) had strong preferences towards using their private vehicles and bicycles. These were mainly for practical reasons, such as being able to store personal effects in the car or being able to leave them wherever they want.

Additional features within MaaS plans are not preferred or disregarded

The analysis of the transcripts corroborated the negative coefficient signs in the model results for the additional features presented alongside the modes in the MaaS plans. As these additional features mainly showed up in more ‘complex’ plans which included more

modes at an increased price, a number of respondents expressed that the increase in price alongside the disinterest of the features would drive them away from choosing those plans.

> *"They tended to be more expensive than I probably could see any reason to go for and knowing that they would also be features that I probably wouldn't be using." F46-65D*

> *"I think I noticed a couple of them, but they were nothing to draw me in on that sort of price per month." M26-45D*

> *"I did look at them, but then I did look at the price as well, so they did influence my decision, but they didn't influence me enough to warrant me selecting that option." M18-25N*

These additional features, that were linked to certain transport modes such as '10-minute taxi guarantee' or 'includes minivan access', did not play an important role in the evaluation of plans. Most participants did not even notice them as their main focus was on the modes and the price in the plans.

> *"I did see them. They wouldn't swing the decision for me." M18-25N*

> *"I noticed them, but they wouldn't probably weigh in." F46-65D*

> *"I didn't really notice them, I did notice the minivan one, but I didn't even notice the luxury cab one, so it didn't make any difference. I just focused so much on the unlimited public transport and the bikes that I didn't really pay attention to what's in the car sharing option." F26-45D*

7.3 DISCUSSION

7.3.1 Integration of results

To bring together the results from the quantitative and qualitative phase, the qualitative element has both helped explain and extended the results of the quantitative phase. Regarding the preference for transport modes, the importance of public transport that was observed through the significant positive coefficients in the quantitative model, were supported during the qualitative analysis. Public transport was a key 'essential' mode, that individuals looked for regardless of whether they are car owners or not. This supports the fact that public transport should be the backbone of a MaaS service, especially in cities such as London where the mode share of public transport is very high.

Turning to the other three modes, the quantitative analysis revealed that overall there is significant disfavour towards them, meaning that people do not want them in their MaaS

plans. Looking into the reason for this through the qualitative analysis, it became clear that many people directly reject plans that include modes they would not want and not even examine these (excluded modes). This causes them to select plans that from a modelling perspective may not seem rational. Even though these negative views seem to indicate that plans overall may not make sense, both the quantitative and qualitative analysis provide some insights to the contrary. First, the model results also showed that people who currently use these are more likely to want them in their MaaS plans. This was echoed in the qualitative analysis, where current mode use resulted in modes mostly falling under the 'essential' category (although these were in much less cases than public transport). Second, the qualitative analysis highlighted a theme, that many people would indeed be interested in certain modes other than public transport (considered modes) if certain level of service was guaranteed, or certain characteristics were improved. Further, the qualitative analysis showed that MaaS plans can help people get exposed to new modes, thus grow their consideration set.

The final characteristics of the MaaS plans that are important to mention are the additional features. Both the quantitative and qualitative results indicated that individuals either do not want, or are indifferent to these. The reasons for this are that MaaS plans are conceptually already hard to comprehend and there are many attributes (modes and amounts) that are included, that any additional feature is 'lost' among all the other information.

7.3.2 Limitations

There are some limitations to the analysis and results presented in this chapter. Regarding the quantitative analysis, the collected data may be biased due to the subjective description of what MaaS is. As mentioned in Chapter 6, the description of MaaS lacks objectivity which may cause respondents to form a more positive view of MaaS than they otherwise would. Further, the decision was made to focus only on the three fixed plans and not use those who considered or chose the 'create your own' plan. A next step in this study is to model including this option as well and deal with the large choice set using methods such as aggregation of alternative or sampling of alternatives. Regarding the qualitative analysis, the main limitation is the sample. Even though small samples are frequent in literature (as shown above), the results could be made more robust with an increased sample size. That would also allow for further insights into the importance of socio-demographic characteristics in preferences for MaaS plans and their elements.

CHAPTER 8: INVESTIGATING HETEROGENEITY IN PREFERENCES FOR MAAS PLANS: LATENT CLASS MODEL

The aim of this chapter is to examine the effect of individuals' characteristics on their preferences for MaaS plans and identify whether there is heterogeneity among preferences of different user groups. Understanding the existence of heterogeneity is important so that specific MaaS target groups can be identified who are more likely to be interested in the service. The chapter is structured as follows: Section 8.1 outlines the methodology, including the data and the modelling framework used. Section 8.2 provides the model estimation results, including details of each user group that emerged through the analysis. Finally, section 8.3 provides some additional discussions and conclusions about the chapter.

8.1 METHODOLOGY

The data used for this analysis is the data collected through Case study 2 for Greater Manchester. The survey consisted of a revealed preference and a stated preference section. The choice situation that respondents were faced with included three labelled plans, and a no choice option. To ease the discussions below, the characteristics of the three plans are presented in Table 8-1. The sample consists of 475 respondents (for details please refer to Chapter 6).

Table 8-1: MaaS plan types

Play type	Basic	Urban	Extra
Core elements	This plan focuses on public transport and/or bike sharing. This is the simplest plan with only those two modes in them, and are also the cheapest option.	This plan always includes unlimited use of public transport. On top of this, some level of bike sharing and taxi is also included.	This plan always has unlimited use of public transport and bike sharing. On top of this taxi and/or car sharing is also included.
Price levels	Always the cheapest option	Always the middle option	Always the most expensive option

To capture individual heterogeneity, Latent Class Choice Models (LCCM) are used. LCCMs assume that the population can be segmented into a finite number of groups, according to some combination of characteristics. Each group is similar in their traits, while dissimilar from those in other groups. The early developments of LCCMs date back to the 1950s with the work of Lazarsfeld (1950), but have since been developed in terms of estimation methods, complexity of models and types of data (Goodman, 1974; Haberman, 1979; Hagenaars, 1990; Vermunt and Magidson, 2000).

Latent class models consist of two components: a class membership model and a class specific model (Green and Hensher, 2003; Vij et al., 2013; Kamargianni and Polydoropoulou, 2013). The class membership model formulates the probability that a decision-maker belongs to a particular class as a function of the characteristics of the individual. The people within a class share common characteristics, while those in different classes are dissimilar to each other regarding those characteristics (Coogan et al., 2011). The class specific choice model describes the choice behaviour of each class (Walker and Li, 2007).

Standard statistical tests are used to determine how many segments should be used to classify the population. These latent classes, or segments, capture the heterogeneity within the population. Class membership is assumed to be probabilistic so each individual can, possess characteristics of each class to varying degrees according to their class membership probabilities. The modelling framework used in this paper is presented in Figure 8-1.

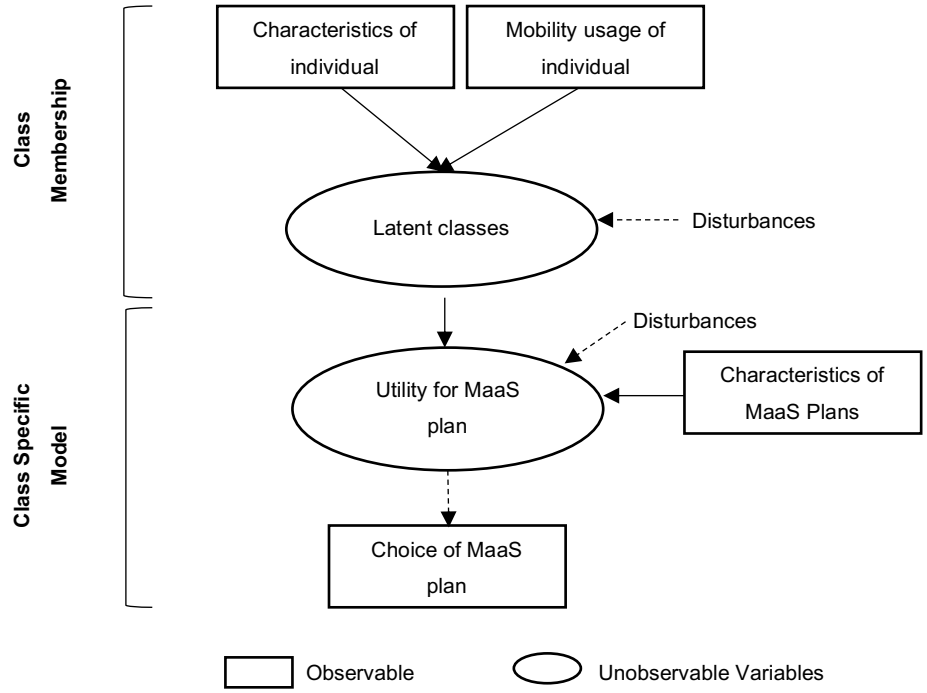

Figure 8-1: Latent class modelling framework

Based on the framework provided in Greene and Hensher (2003), first a class specific choice model is introduced that predicts the probability that individual *n* over choice situation *t* choosing MaaS plan *j*, conditional on the individual belonging to latent class *s*. In the current study, the class specific model is a logit model for discrete choice by individual *n* belonging to class *s* from the set of alternatives J_n comprising of *j* alternatives, in choice situation t_n, is expressed as:

$$P_{jn|s} = \frac{\exp\left(X_{ntj}\beta_s'\right)}{\sum_{j=1}^{J_i}\exp\left(X_{ntj}\beta_s'\right)} \tag{8.1}$$

where β_s' s the parameter vector associated with the vector of explanatory variables X_{nt}.

Turning to the class membership model, this segments individuals into s_n classes based on their socio-demographic and mobility characteristics (Hess and Daly, 2014). The probability that individual *n* falls under mobility style *s,* conditional on the characteristics of that individual X_n, is $P(s|X_n)$.

The class membership and class-specific functions are estimated simultaneously. Given the characteristics of the individual (X_n) and the attributes of the MaaS plans (X_i), the probability of individual *n* to choose MaaS plan *j* in choice situation *t* is expressed as:

$$P\left(j_t|X_n, X_{njt}\right) = \sum_{s=1}^{S} P\left(j_t|X_{njt}, s\right)P(s|X_n) \tag{8.2}$$

where $P(s|X_n)$ is the probability of individual *n* with characteristics X_n to have mobility style *s,* and $P(j_t|X_{njt}, s)$ is the probability of individual *n*, conditional on having a mobility style *s*, to choose MaaS plan *j* with attributes X_{njt} as perceived by individual in choice situation *t.* The associated likelihood function for individual *n* is given by:

$$L = \prod_{n=i}^{N} P\left(T_i \middle| X_{j,} s\right) \sum_{s=1}^{S} P(s|X_n) \tag{8.3}$$

In determining the final model specification for the sample population, numerous models were estimated, where the utility specification was varied, variables included, and number of classes. The estimation process was exploratory; the behaviour of each class was revealed during the process of testing different model specifications. A number of other variables were selected prior to analysis, that were identified as potential factors to be tested in the class membership model. These are summarised in Table 8-2 below. Although all the presented variables were tested, many did not prove to be significant, as can be seen in the results of the final models below.

Table 8-2: Tested variables in class membership model

Personal & Household – Related Variables		**Mobility-Related Variables**	
Gender	dummy	*License*	*Yes-no dummy*
Age	Continuous	*HH vehicles*	*Yes-no dummy*
	Over 50- dummy		*HH vehicle number - continuous*
	Under 30 - dummy	*HH vehicle driver*	*Yes-no dummy*
Education	*Bachelors or above - dummy*	*TT to work*	*Continuous*
	Masters or above dummy	Travel pass	*Free travel pass*
Employment	*Full time - dummy*		*Discounted travel pass*
	Part time - dummy		Owns travel pass -dummy
	Student - dummy	*Car sharing awareness*	*Yes-no dummy*
	Retired - dummy	*Car club member*	*Yes – no dummy*
Employment flexibility	*Complete flexibility - dummy*	*Bike sharing awareness*	*Yes-no dummy*
	No flexibility - dummy	*Bus usage*	*Continuous (# of times per week)*
HH income (imputed)	*Continuous*		*Yes -no dummy*
	Categorical	*Tram usage*	*Continuous (# of times per week)*
			Yes -no dummy
Children	Under 6 - dummy	Bike usage	*Continuous (# of times per week)*
	Under 12 - dummy		Yes -no dummy
			Continuous (# of times per week)

	Bike sharing usage	*Yes -no dummy*
	Car ownership	*Yes-no dummy*
	Car usage	*Continuous (# of times per week)*
		Yes -no dummy
	Car to work	*Yes-no dummy*
	Car sharing usage	*Continuous (# of times per week)*
		Yes -no dummy
	Taxi usage	*Continuous (# of times per week)*
		Yes -no dummy
	Taxi (app) usage	*Continuous (# of times per week)*
		Yes -no dummy
	Smartphone for travel information	*Dummies for each duration*
	Smartphone for journey planning	*Dummies for each duration*
	Smartphone for navigation	*Dummies for each duration*
	Multimodal 3– uses 3 or more modes/week	*Dummy*
	Multimodal 4– uses 4 or more modes/week	*Dummy*
	Multimodal 5– uses 5 or more modes/week	*Dummy*
Variables in italic were excluded from the final model as they were insignificant at the 90% level[10].		

8.2 RESULTS

8.2.1 Selection of number of classes

The number of classes, is not a parameter of the model, meaning that the optimal amount cannot be estimated endogenously (Swait and Adamowicz, 2001; Shen, 2009). As such, several model specifications with different numbers of classes and explanatory variables were tested and scrutinized during the process of choosing a final model. Table 8-3 presents the summary statistics and performance indicators of six estimated models, including a model without segmentation, and five latent class models with segments

[10] The author acknowledges that studies typically adopt 95% confidence intervals to determine the significance of variables. While increasing the confidence interval to 90% grows the chance of being wrong, it also makes it easier to conclude that the coefficient is different than zero (Hair et al., 2009; Hazelrigg, 2009). 90% can be used when there is lower power to detect an effect such as with a smaller sample sizes or new phenomena. In the current study, 90% is adopted as a threshold for variable inclusion to allow for more flexibility in identifying variable that could have an effect on MaaS plan choices.

varying from two to six. The class specific and membership models had the same specification in order to isolate the effect of the varying number of classes.

Table 8-3: Summary statistics of estimated models

	LL	BIC(LL)	AIC(LL)	No. par	$\bar{\rho}^2$
1-Class Choice	-2507.24	5063.24	5030.47	8	0.0449
2-Class Choice	-1818.59	3826.14	3699.17	31	0.3976
3-Class Choice	-1629.25	**3587.67**	3366.49	54	0.5302
4-Class Choice	-1564.33	3598.04	3282.66	77	0.5896
5-Class Choice	-1511.98	3633.55	3223.96	100	0.6033
6-Class Choice	-1466.07	3681.92	3178.13	123	0.6221

To determine how many classes to use, first the performance estimates are examined in more depth. Following the conventional approach used in the literature, three performance indicators are focused on during this discussion: rho-bar squared, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Kamakura and Russell, 1989; Swait, 1994; Vij et al., 2013). Higher rho-squared values, while lower BIC and AIC values imply better model fits.

Examining these values in Table 8-3, every statistic suggests that all models with segmentation outperform the no segment model. This supports the existence of heterogenous latent classes within the data. Regarding the models with segmentation, not all performance indicators point to the same model being desirable. On the one hand, increasing the number of parameters implies an increase in the goodness-of-fit when evaluating it based on the rho-bar squared and the AIC. However, the rate of improvement in performances significantly diminishes when estimating four, five and six class models. For example, the increase in rho-bar squared between models 1 and 2 is 0.35 and between 2 and 3 is 0.13, this drops to 0.06 between models 3 and 4 and 0.01 between 4 and 5. On the other hand, when the evaluation is based on the BIC, as this statistic imposes a harsher penalty on the lack of parsimony it points to the three-class model being superior (Prato et al., 2016). At this point, the easiness and logic of the behavioural interpretation of the parameter estimates are also introduced into the process of selecting the number of classes. As discussed by Swait (1994), the statistics of the models, especially AIC and BIC, should only be used as a guide to determine the optimal number of classes; the objective of the study and the judgement of the researcher should direct the decision on the final number of classes. Based on these evaluations, the three-

class model was selected. This model gives the best balance between goodness-of-fit, parsimony and the interpretability of the model estimation results

8.2.2 Model estimation results

The selected 3-class model has a rho-bar squared of 0.53. The class membership model includes various individual characteristics and mobility habits as explanatory variables, and the corresponding parameter estimates are presented in Table 8-4. The class-specific choice models include the MaaS plan attributes and alternative specific constants (ASC) and the results are presented in Table 8-5. The classes have been ordered in terms of increasing interest in MaaS plans.

Table 8-4: Class membership model

	Class 1		**Class 2**		**Class 3**			
	Est.	**z-value**	**Est.**	**z-value**	**Est.**	**z-value**	**Wald(=)**	**p-value**
Intercept	0.324	0.94	-0.548	-1.33	0.224	0.55	0.32	0.94
Male - dummy	-0.157	-0.92	***-0.443***	***-2.22***	***0.600***	***2.92***	8.68	0.01
Age - continuous	***0.022***	***3.06***	0.007	0.84	***-0.029***	***-3.19***	13.24	0.00
Masters or above - dummy	-0.058	-0.25	***-0.538***	***-1.99***	***0.597***	***2.50***	6.64	0.04
Student - dummy	-0.869	-1.40	***1.602***	***3.25***	-0.733	-1.19	10.58	0.01
Household income								
Under £15,000	0.002	0.01	-0.098	-0.30	0.096	0.30	33.05	0.00
£15,000 - £24,999	-0.155	-0.79	0.002	0.01	0.153	0.67		
£25,000-£34,999	0.127	0.66	***0.492***	***2.30***	***-0.620***	***-2.56***		
£35,000 - £49,999	***0.356***	***1.97***	0.025	0.11	*-0.382*	*-1.84*		
£50,000 - £74,999	*0.344*	*1.69*	0.339	1.34	***-0.683***	***-2.37***		
£75,000 or more	***-0.794***	***-3.40***	0.368	1.54	***0.426***	***2.07***		
Prefer not to answer/Don't Know	0.120	0.30	*-1.129*	*-1.90*	***1.009***	***2.69***		
Kids under 6 - dummy	***-0.606***	***-2.75***	0.248	1.06	0.358	1.52	7.63	0.02
Bike user - dummy	***-0.655***	***-3.62***	***0.475***	***2.29***	0.179	0.85	13.88	0.00
Public transport user	***-0.333***	***-2.33***	0.212	1.34	0.122	0.73	11.47	0.02
Does not use public transport, but not due to the fact that it is too expensive - ordinal	-0.108	-0.91	-0.189	-1.37	***0.297***	***1.97***		
Does not use public transport, due to the fact that it is too expensive - ordinal	***0.441***	***3.02***	-0.022	-0.12	***-0.419***	***-2.02***		
Public transport pass holder - dummy	***-0.347***	***-2.79***	0.045	0.29	*0.302*	*1.90*	8.35	0.02
Frequent taxi user - dummy	***-0.746***	***-2.50***	0.239	0.87	*0.508*	*1.92*	6.71	0.04
Estimates in bold and italic are significant at the 95% level; estimates in italic only are significant at the 90% level. The Wald test for all included variables was significant at the 90% level.								

Table 8-5: Class specific model

	Class 1		Class 2		Class 3			
Attributes	**Est.**	**z-value**	**Est.**	**z-value**	**Est.**	**z-value**	**Wald(=)**	**p-value**
Constants								
Basic	0.329	0.85	***1.726***	***7.14***	***-0.582***	***-3.77***	142.16	0.00
Urban	-0.320	-0.73	***0.439***	***2.13***	***0.601***	***2.96***		
Extra	***-1.701***	***-1.99***	-0.483	-0.91	***0.925***	***3.29***		
None	***1.692***	***2.27***	***1.726***	***-3.68***	***-0.944***	***-2.05***		
Plan characteristics								
Public transport (dummy, where 0 is unlimited bus and 1 is unlimited all public transport)	-0.692	-1.37	0.175	0.67	***0.813***	***2.67***	6.99	0.03
Bike sharing usage* *(dummy)	0.089	0.86	0.089	0.86	0.089	0.86	0.00	.
Taxi (continuous)	***0.371***	***2.81***	***0.260***	***2.84***	0.043	1.35	10.53	0.01
Car sharing hours * (continuous)	***0.045***	***2.07***	***0.045***	***2.07***	***0.045***	***2.07***	0.00	.
Plan price	***-0.016***	***-4.08***	***-0.030***	***-6.10***	***-0.011***	***-4.13***	12.94	0.00

Estimates in bold and italic are significant at the 95% level, estimates in italic only are significant at the 90% level.

*Car sharing and bike sharing was constrained to be equal across classes as the Wald test did not show significant differences across classes for this attribute. The Wald test for all other attributes was significant indicating that there are differences based on Classes.

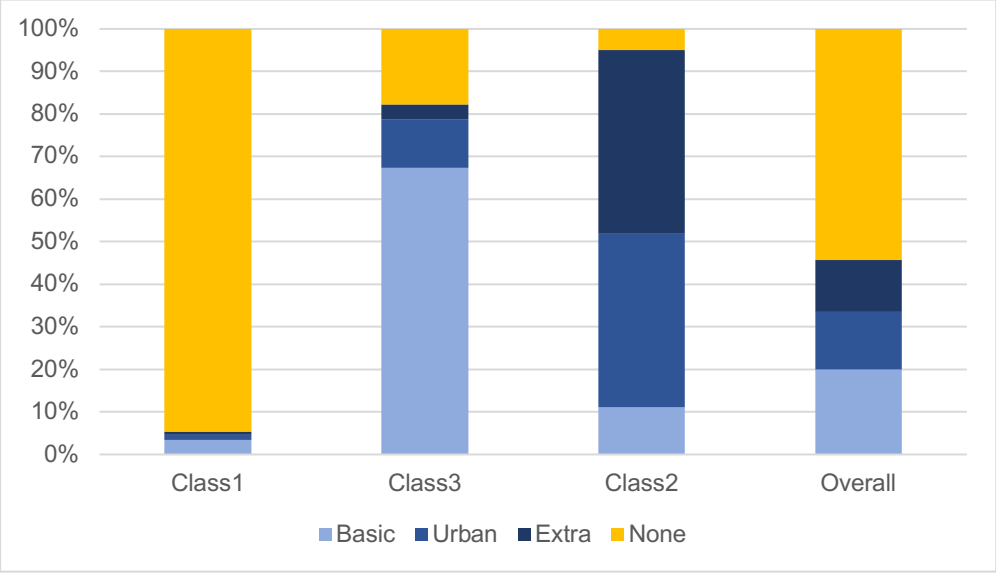

Figure 8-2: MaaS plan choices by class

Before turning to the description of each class, a note on the results of the Class Specific model results should be done. Most of the constants are highly significant and provide a clear indication of the each Class' MaaS plan preferences. For example, for Class 1, the

Extra plan alternative specific constant is significant and negative, while the constant for the None alternative is significant and positive. This aligns with the fact that almost all individuals in this Class chose the None option, while very few the Extra option. The same trend can be seen for the other classes as well, where the signs of the constants mirror their MaaS plan choices. There can be a few explanations behind this trend. First, the plans were labelled and ordered in the SP experiment, meaning that the Basic (smallest) was always first, the Urban (middle) was always second and the Extra (largest) was always third. Second, each plan type had a distinct presence, in that the Basic plan always had the least number of modes, the Urban the middle and the Extra the highest number – showcasing the difference in both size and price. These visual ques can significantly influence choice behaviour and their effects are captured by the ASCs. Further, individuals' propensity to choose certain types of products are also encompassed by the constant. For example, some individuals may, out of habit, never choose the largest/most expensive/most complex product. Not necessarily because they do not like it, or cannot afford it, but rather out of routine. Similarly, for other people the opposite may be true, meaning that they do not buy the smallest product, as they may perceive that they are missing out. All such unobserved affects are absorbed by the ASC.

Turning to the description of each Class, a high-level summary of the characteristics of each of them are provided in Table 8-6.

Table 8-6: High-level summary of classes

	Class 1 **MaaS plans avoiders**	**Class 2** **MaaS plan explorers**	**Class 3** **MaaS plan enthusiasts**
Class size	52%	23%	25%
Dominant MaaS plan purchasing behaviour	95% chose "None"	67% chose Basic plan	43% chose Extra plan and 41% chose Urban plan
Individual characteristics	More likely to be middle aged or older, have middle income, not have young children	More likely to be female, have no master's degree, be a student, have middle income	More likely to be male, be highly educated, have high income and be younger
Current travel behaviour	Less use of bicycle, taxi and public transport, less likely to own a public transport pass, likely to not use public transport due to it being too expensive (price sensitive)	More likely to be a bike user	More likely to be a public transport pass holder and a frequent taxi user. If not a public transport user, this is less likely to be due to financial reasons (less price sensitive)

Class 1 - MaaS plan avoiders: Comprising of 52% of the sample, this is the largest class. With 95% choosing the “none” option it is dominated by those who are the least likely to purchase MaaS plans. Even though this group prefers some of the plan attributes, they are unwilling to purchase these. Based on the results of the class membership model, individuals belonging to this Class are more likely to be middle aged or older, are less likely to be in the high income category (over £75,000) and tend to not have young children. 83% of our sample’s retired individuals fall into this class, supporting the older age of this group. Turning to their current travel behaviour, they tend to not cycle and are also less likely to be public transport and be frequent taxi users. Looking more closely at their relation to public transport, they are also less inclined to be public transport pass owners. In addition, the model results indicate, that those individuals who do not use public transport stated that they do so because it is too expensive. This gives an indication, that people in this class may be price sensitive, which could be one of the reasons for them not preferring any of the MaaS plans.

Class 2 – MaaS plan explorers: This class includes 23% of the sample. The majority of individuals favoured the Basic plan (67%), while a smaller 17% chose the Urban and 11% the none option. This suggests that this Class is interested in exploring the smaller MaaS plans, while completely avoiding the largest Extra plan. Compared to the other classes, they are more likely to be female, have no masters’ degree and have middle income. They are also significantly more likely to be bike users. An important characteristic of this class is that they are more likely to be students, with 71% of students in the sample fall into it.

Class 3 – MaaS plan enthusiasts: This class consists of 25% of the sample and are the most likely to purchase MaaS plans. With 41% opting for the Urban and 43% for the Extra plan, they show significant interest in the larger plans that have more modes included and are more expensive. Regarding the MaaS plan characteristics, they have a preference towards having unlimited public transport in their plans. In terms of distinguishing characteristics, individuals in this class are likely to be younger, male, have a masters’ degree and have higher income. Looking at the descriptive statistics of the class, 81% are full time paid employment, as opposed to 58% and 62% of the other two classes. Turning to their mobility habits, several variables proved statistically significant. Individuals in this class are more likely to be a public transport pass holder and a frequent taxi user. In those cases, where they were not a public transport user, this was less likely to be for a financial reason indicating that this class is less price sensitive. A further insight from descriptive statistics is that 12% of the class are car sharing users, compared to the 1% and 5% of the other classes.

8.2.3 Willingness to pay

It is valuable to examine further respondent's willingness to pay (WTP) for certain MaaS plans. Solely Classes 2 and 3 are focused on, which have a significant proportion of respondents who chose one of the three plans. Additionally, those plans that were chosen by a significant fraction (>30%) of respondents in each Class will be narrowed down on. The Basic plan was chosen in 67% of cases among those in Class 2; the Urban plan was chosen in 41% while the Extra plan was chosen in 43% of the cases among those in Class 3. The average willingness to pay (WTP) values for these Classes and plans are presented in Table 8-7. It is important to note that caution must be exercised when using these estimated WTPs in bundling and pricing MaaS plans for real-life applications. These results are specific to this case study and will likely suffer from survey biases.

Table 8-7: Willingness to pay

Class 2: 67% chose Basic Plan	
WTP for Basic plan, including unlimited public transport	£62.84
WTP for bike sharing	£2.93
Class 3: 41% chose Urban plan	
WTP for Urban plan, including unlimited public transport	£132.97
WTP for bike sharing	£8.33
WTP for 1 taxi trip	£4.05
Class 3: 43% chose Extra plan	
WTP for Extra plan, including unlimited public transport and bike sharing	£171.72
WTP for 1 taxi trip	£4.05
WTP for 1 hour of car sharing	£4.25

Looking first at the Class 2 results, the WTP for the plan itself, including unlimited public transport, is £62.84. This is under the cost of a monthly travel pass for the area, which at the time of the data collection was £118 /month. The WTP for bike sharing is £2.28, which brings the total cost of a typical plan to £65.77. An important element to point out is that this class includes most students in the sample. As students have discounts on public transport passes, this could be a reason behind the lower WTP values.

Moving to Class 3, the WTP for the Urban plan including unlimited public transport is £132.97. This number is over the cost of a monthly travel pass, indicating that this group is willing to pay for the extra convenience of having a MaaS plan. Their WTP for bike sharing is £8.33, which is higher than the price of a monthly pass at £9.90. The WTP for 1 taxi trip is £4.05, which is quite low. This indicates, that while they are willing to pay for taxi, this is not as high as the market value.

In addition, for Class 3, the WTP values for the Extra plan can be examined. For the plan itself, including in this case bike sharing and public transport, on average the WTP was £171.72, which is quite high. However, the WTP values for taxi and car sharing are low. This seems to indicate that some of the benefits of the inclusion of these modes are absorbed by the plan itself. This could potentially be the visual of having a 'large' plan with many different modes in it. Looking at these values together, an interesting observation can be made about possible MaaS-plans pricing strategies. Based on these numbers, it seems that people are willing to pay more than market price for certain modes in MaaS plans, and less for others. However, they are willing to pay those amounts for the modes within a plan. Various revenue redistribution models and optimal strategies can be explored to take advantage of these (although this is out of the scope of this thesis).

8.3 DISCUSSION

8.3.1 Reasons behind choosing 'none' option

Since a high fraction of respondents chose the 'none' option (54%), it is interesting to examine the reason behind this. This section is based on descriptive statistics, not model estimation results. The survey included a follow-up question for those who did choose any of the plans, allowing us to shed some light on the reasons that may hinder the uptake of MaaS plans. Respondents who chose the 'none' option were asked to indicate their reason(s) for why they did not choose any of the plans. The responses are presented in Table 8-8. The most common reason for not wanting any of the proposed plans is the price of the plan. 59.4% of those respondents who chose 'none' selected this as one of their reasons for not choosing a plan. The second most common response was 'It's not the right fit for me' (39.5%), while the third was 'It's less convenient than driving my car' (30.8%).

Table 8-8: Reasons for choosing 'None' option

It is too expensive	59.4%
It's not the right fit for me	39.5%
It is less convenient than driving my car	30.8%
I don't want to pre-pay for my monthly travel	18.4%
I would be worried about overpaying	11.7%
I would need more included in my subscription	8.5%
I would be worried about running out of subscribed travel	4.0%

Respondents were also asked what would make them consider buying a plan. This was an open-ended question, where respondents could enter any response. The answers suggest the price aspect of the plans was the most common theme but other concerns also emerged. First, several respondents pointed out that they do not travel frequently, especially not into the city centre of Manchester where several of these modes operate, so such a service would be of no use to them. These individuals are the architype of latent Class 1 discussed above. Second, some respondents pointed out that public transport is just not a viable option for them and that all plans included some level of public transport. Reasons for it not being viable included: living in the suburbs and not having proper access; it would take too long to commute with public transport compared to car; severe dislike of public transport and would only use it as a "last resort"; bus stop being too far away from home; unreliability and low comfort level of public transport; lack of appropriate bus routes between home and work and not being easily accessible. Third, some respondents pointed out that they would be happier trying the service if it had a pay as you go option. Finally, respondents with a car suggested that they would only consider such a service if they either: did not have their car anymore; could no longer drive; or driving became too expensive. This indicates that car drivers are split regarding their opinion on MaaS. There are those that are open (shown by the results of the model) and there are those who are not and are addicted/attached to their cars. This differentiation between types of attitudes among car drivers seems to indicate that there are underlying latent attitudes and perceptions that can be causing some of these results. Hybrid choice models that are able to capture these can be an important area of future development.

8.3.2 Conclusions

This chapter used a Latent Class Choice Model to examine heterogeneity with regards to MaaS plan preferences. The data was collected in the case study city of Greater Manchester, UK. The results imply significant heterogeneity with regards to preferences towards MaaS plans. Three latent classes emerged through the analysis, all with different MaaS plan preferences and individual characteristics. Understanding these groups can provide valuable insights into the types of people that should and should not be initially targeted with MaaS plans to maximise uptake. The word 'initially' is used because the MaaS concept, and the concept of MaaS plans, are very new and attitudes towards them may change as it diffuses and awareness increases.

Some main take away points regarding user segmentation. Age inversely related with likeliness to purchase MaaS plans, meaning that younger people are more likely to be interested in purchasing MaaS plans. Students seem interested in purchasing MaaS

plans, but tend towards the smaller ones including mainly public transport and bike sharing. Those individuals who are most likely to purchase the larger plans have higher income levels and are highly educated. Current travel behaviour seems to play a role in determining an individual's propensity to purchase MaaS plans, especially the larger plans with several transport modes included. Frequent public transport and taxi users seem to be ideal candidates to target with MaaS plans

No private vehicle related variables proved to be significant in the model. Several variables, including private vehicle ownership, number of household vehicles, using private vehicle as the main mode to work etc., were tested, however none showed significant differences among classes (insignificant Wald). This is a very interesting observation, as it indicates that, contrary to expectations, car users should not necessarily be ruled out as MaaS users. This finding is, of course, specific to the case study city and may differ elsewhere.

One final element to note is the question of social equality. The groups discussed above who should be targeted with MaaS plans already have good access to transport. As such, will providing MaaS plans to these specific groups increase further transport inequality? The answer to this, is that it will depend on how the wider MaaS ecosystem functions. If MaaS is offered by a company that is only interested in profit and not about social welfare, its products will likely be tailored towards those that are able to pay the most for them. However, if other actors, such as governmental bodies and councils play a role and promote MaaS products that are tailored to those groups who may have less access to transport, MaaS can also become a solution.

8.3.3 Limitations

There are a few limitations of this chapter should be highlighted. First, the results are specific to this sample and area, thus they may be very different elsewhere with dissimilar societal and transport characteristics. Second, the sample size is limited (475 individuals in a total of 2,375 choice situations) and only 5% was over 60 years old. This is not representative of the population of Greater Manchester, as such, the results should not be generalized. Third, since the survey, the modes available in Manchester have changed (e.g. no bike sharing anymore). Since the mobility environment is very volatile with companies emerging, entering/exiting the market every month, these results may change. However, the results could be used by any company that offer these modes in the region. Finally, from the model results it was not possible to evaluate the interest of MaaS plans without public transport. This is the way the survey was designed, due to prior insights into the importance of public transport in MaaS.

CHAPTER 9: CONCLUSIONS AND IMPLICATIONS FOR STAKEHOLDERS

This chapter, which provides this thesis' conclusions and implications for stakeholders, is structured as follows. Section 9.1 provides the most important insights into the research questions that were presented at the start of this thesis. Section 9.2 discusses the wider implication of the results for the transport industry and policy makers. Section 9.3 summarises the challenges and limitations of the research, whereas Section 9.4 discusses next steps and future research directions.

9.1 REVIEW OF RESEARCH QUESTIONS

The overarching aim of this thesis was to provide empirical evidence on individual preferences for MaaS plans and their components. In doing so, three research questions were focused on, which are summarised below. The fourth research question is tackled in Section 9.2.

RQ1: What are the specific challenges of designing surveys that capture individual preferences for MaaS plans compared to choice situations regarding other products or services in the transportation sector?

To answer this research question, chapter 5 presented a detailed outline of survey design examining preferences for MaaS plans. It also evaluated additional challenges that this concept introduces, which are summarised below.

The main challenge of creating MaaS surveys in general and MaaS plan-stated preference experiments in particular is that many aspects of MaaS are still unknown. This lack of understanding requires the survey designer to introduce multiple assumptions. These are related to product designs and business models, the composition of modes in a MaaS system, the interaction of competing MaaS providers and the detailed service attributes. It is not yet clear which MaaS product design and business model will become dominant, which leads to an overarching assumption about the composition of the MaaS product to study. The choice of what modes to include in MaaS plans and how to deal with a situation with multiple competing operators in an area are also a challenges. It is not yet confirmed under what circumstances and business models operators would be

willing to join a MaaS scheme, which requires researchers to make assumptions. A further difficulty is related to the transport service providers' characteristics and how these are presented in consumer surveys. While surveys focusing on an individual mode have the capacity to clearly detail all service attributes, this is more difficult with MaaS surveys when several transport modes and service attributes need to be explained. Finally, determining how to denominate each transport mode within the MaaS plans (e.g. presenting car sharing amounts by mile or by minute) is also a challenge as each mode has their own conventions but these may create inconsistencies in the survey.

RQ2: What are the identified user preferences for transport modes within MaaS plans and how do individuals choose between them?

To answer this research question a mixed methods study was conducted in London that relied on both quantitative and qualitative data. Both the quantitative and qualitative analysis showed a strong consumer preference towards having public transport included in MaaS plans. This mode is considered 'essential', meaning that individuals immediately look for it when presented with a MaaS plan and most would not consider a plan without it. This result remains consistent regardless of whether the respondent is a car owner or not. In contrast, the quantitative results showed that the other three examined modes – taxi, car sharing and bike sharing – are generally disfavoured in MaaS plans. However, the qualitative analysis revealed that these modes were evaluated differently by the respondents. Whereas some people immediately 'excluded' plans that contained these modes, no matter how attractive the plan was, others expressed that they would 'consider' MaaS plans containing these modes, depending on the characteristics of the service. The qualitative analysis also revealed reasons behind people disfavouring certain modes both in and out of their MaaS plan. These include safety concerns with cycling and driving, uncertainties characteristics and annoyance with the administration of shared services, and preference towards using their own bikes or cars.

RQ3: To what extent can the preferences for MaaS plans be explained by the characteristics of the decision maker and is there heterogeneity in preferences of different user groups?

This research question was tackled using data from Greater Manchester to estimate a Latent Class Choice Model (LCCM). The results imply the existence of heterogeneity in preferences towards MaaS plans. Three types of user groups with different MaaS plan preferences and individual characteristics emerged from the analysis. The 'MaaS plan avoiders' form the group that is least inclined to purchase MaaS plans. They tend to be middle-aged or older, have middle income and no young children. They are also less

likely to be current users of bicycles, taxis or public transport. The second user group, the 'MaaS plan explorers', is most inclined to choose smaller MaaS plans that are centred around public transport. This group is characterised by being more likely to be a female, have no master's degree and be a current bicycle user. Students also tend to fall under the 'MaaS plan explorer' group. The final user group, the 'MaaS plan enthusiasts', is the most inclined to choose larger MaaS plans that include a number of different transport modes. Individuals in this group are likely to be younger, male, have a masters' degree and higher income. Also, they tend to be public transport pass holders and frequent taxi users.

The results of the LCCM indicate that an individual's socio-demographic characteristics and mobility habits do, in fact, have an impact on their preferences towards MaaS plans. This is also supported by the results of the analysis using the London data (Chapter 7). The London results found that current mobility habits are especially important factors in determining people's MaaS plan preferences. For example, people who use taxi frequently prefer to have more taxi trips in their plans compared to those who do not rely on taxi services to the same extent. Similarly, those who have previously used London's bike sharing scheme prefer to have bike sharing in their plans to a larger extent than those who have not used this service before.

9.2 IMPLICATIONS FOR TRANSPORT INDUSTRY AND POLICY MAKERS

There are several important take away points for transport industry and policy makers that stem from this thesis. These will be discussed below, however, all are presented with the caveat that the findings are based on these specific case studies, which may be biased or inapplicable to areas with different characteristics.

MaaS users

The research in this thesis showed that potential users are generally interested in the concept of MaaS. Most people like the idea of having a service that it accessible through a single smartphone app and integrates a combination of different transport modes. More than half of the survey participants stated that they would be willing to download a MaaS application, which is the first step in being able to use the service. Those who would not download such an app emphasised that they do not see how to benefit from MaaS or that they already have too many apps on their phones. To attract those individuals who currently may not be willing to download the app, product designs and marketing campaigns should focus on highlighting the unique selling points of a MaaS application and its elements that differentiate it from any other journey planning applications.

Functions such as integrated booking and ticketing within the MaaS app and the MaaS products that can be accessed via the app can be among those highlighted.

The results of this thesis also provided insights about the characteristics of likely early adopters of MaaS plans. As with all innovative products and services in new markets, MaaS initially only needs to be adopted by a small fraction of people who can then help spread it over the rest of the population (Rogers, 2010). Key overarching characteristics of those that are more likely to adopt MaaS include their comparatively young age (20s and 30) and their tendency to already use different transport modes. Older population groups, those with lower income and those who travel less or only use a single transport mode should not be targeted during the initial stages of MaaS introduction. Depending on the characteristics of the individual, different MaaS plans will most likely appeal to different types of innovators and early adopters. Smaller, less expensive plans including modes such as public transport and bike sharing can be used to target students or middle-income people with high overall mode usage. These groups want to be mobile and get around, but do not have the disposable income for plans that include a variety of different modes. Larger, more expensive plans that include modes such as taxi and car sharing in addition to public transport, will be attritive to individuals who are likely younger, male, well-educated with higher income and already use a variety of transport modes. For example, young city workers, who have high incomes, could be a possible user group.

Based upon the above, those consumer groups that should be initially targeted as early MaaS adopters already enjoy a certain level of overall mobility, are young, and in most cases, also earn a mid to high disposable income. This raises the important question of whether MaaS will contribute more to inequality in transport, rather than helping solve transport poverty. Those population groups that are currently less mobile, for example the elderly or those with very low income, are not part of the potential early adopters for MaaS plans. An explanation may be that in the current study, the presented plans were not tailored to their needs – however this is also the case in most actual MaaS services. As such policy measures, such as government subsidies can play an important role in creating an environment where MaaS operators are incentivised to also customise their products for those in need. This is an important question, which is only touched upon at this point, but should be a key area of future research.

MaaS products

While the research in this thesis showed that certain population groups are interested in purchasing pre-paid MaaS plans, most people are hesitant in committing to these MaaS products. This is in part due to the fact that they feel trapped by subscribing and worry about running out of their subscribed amount. This reservation may also be driven by the

lack of familiarity with MaaS and lack of trust in a potential services provider. In contrast, people tend to feel more comfortable when offered the choice to use MaaS as a pay-as-you-go service, rather than plans that come with a larger upfront and sunk cost. Because consumers are interested in MaaS per se, but not yet confident enough to subscribe to plans, it may be more beneficial to introduce a MaaS scheme in an area with pay-as-you-go products first and then, if these prove successful, introduce MaaS plans. This stepwise approach would also allow a potential service provider to initially be more flexible and alter the characteristics of offered service if needed as the provider will not be tied-in with monthly contracts. Further, starting with only pay-as-you-go options would give the provider the opportunity to get a better understanding about local market conditions and user preferences and then create tailored packages based on the collected knowledge.

MaaS as a Demand Management tool

Another area where policy intervention could be important is setting the objectives of what MaaS systems aim to achieve. If left to the market forces, especially in the case of a private sector driven MaaS system, profit maximisation will drive the decisions. This, for example, could create systems where taxi is proposed over public transport or cycling even when the latter modes could be feasible and convenient, resulting in an overall increase in congestion. However, if policy makers set appropriate boundaries, such as through road pricing, MaaS could be used as a demand management tool to promote environmentally sustainable and active modes. A MaaS service could also be a platform for increasing awareness of transportation modes that may not be fully utilised by the transportation system. The results of this thesis showed that many people would consider using modes they had previously not used if these were included in their MaaS products. This means, that MaaS could not only raise awareness but also potentially change travel choices.

A further area that was researched in this thesis is individuals' preferences for transport modes within MaaS plans and how people evaluate between each transport mode. The analysis showed that respondents classify modes within MaaS plans into three categories based on how much they want them in their MaaS plans: 'essential', 'considered' and 'excluded' (see section 9.1 above). If MaaS is used to induce travel behaviour change, individuals 'considered' modes should be targeted first as the respective MaaS plan offers the largest potential for a mode shift. As the 'considered' modes for each individual are unique, there is a need for segmentation based on attitudes and behaviours to help guide decision making. The concept of segmentation is in line with previous research, see Anable (2005) and Steg (2005). Strategies promoting each mode should be targeted at those individuals who are 'considering' these as this is where it will have the highest

impact. There is potential for MaaS plans to provide the platform for targeted marketing campaigns promoting those modes specifically that each user is willing to consider. This is also an area of future research, as the exact 'consideration' set for each socio-demographic user group is still unknown. Further, the characteristics, attitudes and perceptions of individuals that influence 'consideration', for example prior experiences, need to be examined in more depth, to be able to clearly identify which modes to target for each person.

Individual modes within a MaaS system

The research in this thesis also provided some evidence for the reasons behind individuals disfavouring certain transport modes in their MaaS plans. The five identified factors can inform policies aimed at both individual services and services within MaaS systems. The first key point is safety, especially in terms of cycling. Women particularly expressed concerns with car drivers and how they do not feel confident enough to try to cycle on London's roads. A number of respondents spontaneously pointed out that they do not have a problem with cycling per se and would actually like to cycle more, but this desire is outweighed by their anxiety of being involved in an accident. These respondents are especially afraid of car drivers, buses and other transport modes. The perception of cycling safety as a significant barrier to increasing the mode share of both personal cycle and cycle sharing use has also been identified by other researchers (Chataway et al., 2014; Parkin et al., 2007). Regarding policy implications, mixed traffic infrastructure layouts are perceived less safe but a sustained level of cycling infrastructure investment can help create the perception of a safer environment (Kaplan and Prato, 2013). Cycle tracks and buffered cycle lanes can improve safety perceptions, especially for women (Monsere et al., 2012; Garrard et al., 2008). Looking at this insight through the MaaS plan setting, the MaaS app and journey planner could be used to guide users through safer cycle routes and away from high traffic intersections.

The second aspect that emerged was that individuals seem to be uncertain about the characteristics of the services themselves. This is especially prevalent for participants with special needs (e.g. parents of small children, pet owners). In order for MaaS users to be comfortable and confident using these services, they need to be assured that the services have all the necessary features. This aligns with findings from other studies where information issues and lack of awareness and understanding have been mentioned as barriers to adoption (Yau and Mahn, 2015; Hazée et al., 2017). This insight is also important for individual service providers, who may be losing out on a significant number of users because they cannot guarantee elements, such as child seats, in their vehicles.

The third finding is that people tend to lose trust in services easily and even one bad experience can discourage them from using the service ever again. New services should thus be encouraged to do ‘soft’ launches or alpha and beta test runs before large scale introductions. Also, policies that support customer protection could be made more prominent, in order to encourage minimal service disruptions.

The fourth deterring factor from certain modes is the annoyance with administration that comes hand in hand with these modes. This is also in line with previous findings from literature looking at barriers to adopting individual modes (Nawangpalupi and Demirbilek, 2008, Bielefeldt et al., 2016). Strategies that support safe, but streamlined administrative processes of trying out and using new services could aid in their uptake. This is where MaaS could also play an important role by centralising all administrative processes and allowing users to use a single app and verification process for all services (even multiple services for the same transport mode e.g. multiple car sharing service providers). This would require services to accept and adhere to a centralised solution and the central verification agency would need to ensure unbiased and prompt responses.

The fifth and final theme about disfavour towards certain shared modes is that some individuals have strong preferences towards using their own bike or car. For example, some car users are self-proclaimed car addicts and have a psychological dependence on private vehicles (Anable, 2005). Policies that aim at shifting individuals to car sharing should target market segments that are willing to change. Those individuals who are emotionally attached to their cars will have no intention to change their behaviour and any sort of policy approach or marketing campaigns promoting car sharing targeted towards this group would probably not be successful (Beirao and Sarsfield-Cabral, 2007). With regards to MaaS plans, as these modes are most likely “excluding” modes (that is, any plan that includes them would be eliminated) it is important to create methods to detect these individuals, and propose MaaS plans to them that do not include car sharing.

Based on the factors mentioned above, a MaaS system will potentially have to overcome the barriers of several individual modes for people to start using it. The fact that MaaS includes a combination of modes adds an extra layer of complexity in that the concerns of each individual service should be tackled. This may be quite a difficult task, especially in the case where the MaaS business model includes a variety of different service providers and where the contractual obligations within the MaaS scheme are limited.

9.3 CHALLENGES AND LIMITATIONS

Topic

The topic of MaaS came with a number of unforeseen difficulties. As alluded to throughout the thesis, the MaaS concept is still developing and there are uncertainties related to several aspects such as business models, commercial agreements and revenue allocation. This is especially true for the case study cities, where no full MaaS service exists. This meant that a large amount of time was spent discussing the concept with industry actors, attending industry events and carrying out thought experiments on how the concept could materialise in these cities. A number of assumptions had to be made regarding the modes that could be included and how MaaS would look like. This is a limitation of the thesis as it does not capture all possible modes that can be included in MaaS. As the concept becomes more widespread, certain product designs and business models will prevail and these will guide consumer analysis.

Data

The survey design and data collection had several limitations which impact the quality of the collected data and should be taken into account when interpreting the results.

- Not using Bayesian efficient design: Case study 1 used a random- and case study 2 an efficient survey design. However, neither of the applications used the most advanced Bayesian efficient design. The Bayesian design allows random variation when assigning prior values to the parameters being estimated but also requires much greater computational efforts (ChoiceMetrics, 2018). Although there are arguments questioning how much those efficient designs benefit a choice analysis even comparing to the traditional orthogonal and random designs; flexibility could be allowed in choosing the different design techniques as the effects on model estimation could vary case by case (Walker et al., 2018).
- Subjective presentation of MaaS: Both surveys suffer from subjective presentation of the MaaS concept. This is especially prevalent in case study 1, where several positive words are used to describe what MaaS is. These may have introduced a bias to the results as respondents could have had more favourable view of the concept than if it was presented in a more impartial and neutral way.
- Not including weighting: Neither case studies used weighting adjustment to the data, which would have allowed for better representation of the population. As such, all the results should be looked at with the caveat that these are *only* for the sample and cannot be generalised to the wider population.

- Use of panels: The survey panels used to collect data in both London and Manchester case introduce a bias because these are ‘professional’ panels. This means that respondents likely fill in surveys regularly and are more inclined to click through without evaluating each question in detail.
- Small qualitative sample: The qualitative data collections – the interviews – were conducted with only 30 people. While this is an acceptable size based on literature (see chapter 7), the results would be more robust with a larger sample.

Analysis

The analysis presented in the thesis also comes with limitations. As much of the work focused on designing the surveys and on collecting data, there was less room for advanced model development. As such, the models presented can be further improved (see section 9.4 for examples).

9.4 NEXT STEPS AND FUTURE RESEARCH DIRECTIONS

There are many future research directions based on the work presented in this thesis. First, there are potential extensions to the current research based on the data collected during this thesis. Second, this thesis only covered a narrow topic within MaaS-related research and there are several suggested research directions that could be explored.

9.4.1 Next steps

A wealth of data was collected during the course of this thesis, however, there was only limited scope to analyse this information. As such, the work presented in this thesis offers several extensions using the data collected during the two case studies:

The surveys in both case study 1 and case study 2 included several questions related to the respondents’ attitudes and perceptions about mobility, car ownership and use, and MaaS products characteristics. These unobservable latent mindsets could have a significant impact of people’s choices between MaaS plans, thus should be included in the MaaS plan choice models. To improve the realism of DCMs by implementing a model system that encapsulates the endogeneity of ‘soft’ variables such as attitudes and perceptions alongside ‘hard’ variables such as socio-demographic characteristics, hybrid choice models will be developed (Ben-Akiva et al., 2002; Daly et al., 2013). The reasoning behind these models is that decision makers differ from one another in the way that they make choices. This can be directly linked to the individuals’ socio-demographic characteristics, but the underlying attitudes and perceptions may be equally as important

(Walker and Ben-Akiva, 2002; Kamargianni and Polydoropoulou, 2013). While socio-demographic characteristics can be observed, attitudes and perceptions can only be inferred from proxies for the underlying latent attitudes. As the surveys were built pre-empting the usage of these models, all the variables necessary to apply these are available.

The second continuation of the work done in this thesis is with regards to doing further analysis of individuals' willingness to download the MaaS application. Using data from Case Study 2, the collected information includes participants' responses to a question with an ordered response framework (definitely yes, probably yes, not sure, probably no, definitely no). To properly assess the factors that determine individuals' willingness to download the app, models that are able to capture the ordered nature of the discrete choices are used. Regarding methodology, the basic models that are used in this case are ordered logit and ordered probit models (the latter preferred due to fat tails) (e.g. Lee and Abdel-Aty, 2005; Xu et al., 2016; Bansal and Kockleman, 2018). However, more recently, generalised ordered logit models are used which relax some assumptions that the 'basic' models have, and these are taken further with mixed generalised ordered response models that allow random heterogeneity in the thresholds (Yasmin and Eluru, 2013; Balusu et al., 2018). It is also possible to extend ordered models by either including latent variables (attitudinal variables, commonly used in hybrid choice modelling; e.g. Efthymiou and Antoniou, 2016) or with latent classes (e.g. Yasmin et al., 2014). Both these approaches could be used in the case of modelling willingness to download the MaaS application.

In addition, planned work includes tackling the model with data collected from the 'create your own plan'. Due to the size of the possible choice set, aggregation of alternatives or sampling of alternatives methods will be used (see Appendix E for details of possible methods to deal with large choice sets). There is also the issue of possible endogeneity which needs to be further explored.

Finally, it is planned that the presented MaaS survey design will be applied and customised to other areas around the world. There are already discussions about adapting it for the United States market as well as potential other areas. These would provide very interesting comparisons and further insights into how to examine this topic.

9.4.2 Proposed future research directions

In addition to extra analysis conducted on the data collected during this thesis, due to the novelty of the concept, there are ample opportunities for future research on MaaS. The paragraphs below present some potential future research directions:

First, further research can be conducted on the factors that affect individuals' preferences for MaaS packages. As the findings from current studies are not consistent regarding the preferred transport modes in MaaS packages and the individual characteristics that influence individual preferences (see chapter 2), there is need for more research to better understand the reasons behind such contradicting results. It is possible that the inconsistencies stem from the fact that MaaS is not yet well understood by survey participants and as MaaS becomes more widespread the insights will converge. However, it is also possible that underlying factors that influence MaaS preferences have not been fully captured by existing analyses. Studies that emphasise the affect that an area's transportation system, urban landscape, local culture and transport habits have on preferences for MaaS plans could help create more robust results.

Second, research including additional transport modes in MaaS packages could provide a more comprehensive view into the attractive packages for potential users. Public transport and taxi are present in most current studies, while modes such as on-demand minibuses, electric-bike sharing, car-sharing, car rental, e-hailing and shared electric scooters are not. Although the inclusion of each mode is highly dependent on the case study area, including a wider range of transport modes could increase the ability of a MaaS system to serve users' needs. However, it is also possible that the inclusion of more modes discourages users from participating, as it increases the complexity of the system. Studies examining more transport modes could help better understand these uncertainties.

Third, as mentioned above, further analysis on individuals' consideration set is needed to better understand MaaS's potential to encourage modal shift to more environmentally sustainable transport modes. Analyses that evaluate individuals' consideration set and identify the factors that influence these could provide valuable insights to stakeholders. Individual socio-demographic characteristics, travel habits and past experiences are just some factors that can be important in determining an individual's consideration set thus should be included in the analysis.

Fourth, further research can be conducted focusing on individual preferences for other MaaS product designs. While most research looks at preferences for product bundles that combine a pre-determined amount of each transport mode, there are also other possible MaaS products that have not received as much attention. One product that is emerging in market developments is the pay-as-you-go option, where users do not need to pre-purchase their monthly or weekly travel. Although some studies (e.g. Ho et al., 2017) include pay-as-you-go option in their survey, this is not the main focus of the study.

Research could be conducted that only examines MaaS under pay-as-you-go scenarios, allowing for the characteristics of such a product to be examined in more detail.

Fifth, there is need for more studies that are part of pilots or real market MaaS schemes. MaaS is still not well known among the general population in most areas. Therefore, conducting surveys will always be challenging as respondents will need to be explained what MaaS is inevitably introducing biases. However, if studies are part of an actual MaaS scheme, whether pilot or market, participants will be able to form their own, unbiased views on MaaS. Such studies would be able to use revealed preference (RP) data on MaaS product choices rather than having to rely on stated preference experiments. Additionally, pilot- or market-linked MaaS research has the advantage of allowing researchers to examine the impact that MaaS could have on mode choices, travel habits and car use.

Sixth, there is ample room for additional in-depth qualitative research to be conducted on individual preferences for MaaS. As demonstrated in the literature review, there are not many studies that use these methods and the research in this thesis only made a modest step in this direction. Topics that could be further explored include: the opportunities and barriers MaaS can bring to individuals, the impact of social interactions on intention to use MaaS, the types of MaaS products potential users would prefer, the characteristics of the MaaS app that users would prefer and the impact that MaaS could have.

Seventh, future studies could examine preferences for MaaS in different geographic areas. Current research mainly focuses on Europe and Australia, with other areas lagging behind. Conducting studies in Asia and the Americas could provide insights into whether MaaS has potential in other cultures with different transportation systems. It would be especially valuable to conduct research on all MaaS pillars – users, policy, technology and business – together in areas where MaaS remains unexplored. A holistic analysis can provide insights into the feasibility of introducing MaaS, including the barriers it may face and opportunities that it can bring.

Although the focus of this thesis was on examining user preferences for MaaS, it is important to acknowledge that users are just one part of the whole MaaS ecosystem. Creating products that individuals prefer will not be enough for MaaS's realization. For this reason, research should also be expanded on the other pillars - business, policy and technology – to assemble the necessary knowledge for successful MaaS implementation.

APPENDIX

APPENDIX A: LIST OF PUBLICATIONS AND CONFERENCE PRESENTATIONS

Peer-reviewed journal articles:

Matyas, M. and Kamargianni, M. 2019. Survey Design for Exploring Demand for Mobility as a Service Plans. *Transportation,* 46 (5), pp.1525-1558

Matyas, M. and Kamargianni, M. 2019. The Potential of Mobility as a Service Bundles as a Mobility Management Tool. *Transportation. 4*6 (5), pp1951-1968

Kamargianni, M., Li, W., Matyas, M., and Schäfer, A. 2016. A Critical Review of New Mobility Services for Urban Transport. *Transportation Research Procedia*, 14, pp.3294-3303.

Matyas, M. (in press). Opportunities and barriers to multimodal cities: Lessons learned from in-depth interviews about attitudes towards Mobility as a Service. *European Transport Research Review*.

Working papers:

Matyas, M. and Kamargianni, M. 2018. Exploring Individual Preferences for Mobility as a Service Plans: A Mixed Methods Approach. MaaSLab Working Paper Series, Paper No. 18-01.

Academic conference presentations:

Matyas, M. and Kamargianni, M. (2020). Investigating Heterogeneity in Preferences for Mobility-as-a-Service Plans through a Latent Class Choice Model. Paper accepted for poster presentation at the 99th Transportation Research Board Annual Meeting, Washington DC.

Matyas, M. and Kamargianni, M. (2020). Examining preference heterogeneity for Mobility-as-a-Service Plans. Paper accepted for presentation at the Transportation Research Arena, Helsinki, Finland.

Matyas, M. and Kamargianni, M. (2019).Using Mixed Methods to Examine User Preferences for Mobility as a Service Subscription Plans. Paper presented at the 98th Transportation Research Board Annual Meeting, Washington DC.

Matyas, M. and Kamargianni, M. (2018) Including the Effect of Latent Modal Styles in Mobility as a Service Plan Choice Models. Poster presented at the 7th Symposium of European Association for Research in Transportation (hEART), Athens, Greece.

Matyas, M. and Kamargianni, M. (2018) The Potential of Mobility as a Service Bundles as a Mobility Management Tool. Presented at the 97th Transportation Research Board Annual Meeting, Washington DC.

Matyas, M. and Kamargianni, M. (2018) Factors Influencing Willingness to Purchase Mobility as a Service Products. Presented at the 2018 Transportation Research Arena, Vienna, Austria.

Matyas, M. and Kamargianni, M. (2017). Mobility as a Service Plans: How Much do we Prefer Flexibility? Presented at the 20th EURO Working Group on Transportation Meeting. Budapest, Hungary.

Matyas, M., and Kamargianni, M. (2017) Stated Preference Design for Exploring Demand for “Mobility as a Service” Plans. Presented at the 5th International Choice Modelling Conference, Cape Town, South Africa.

Matyas, M., and Kamargianni, M. (2017) A Holistic Overview of the Mobility as a Service Ecosystem. Presented at the Transportation Research Conference, Hungary.

Kamargianni, M., and Matyas, M. (2017). The Business Ecosystem of Mobility as a Service. Presented at the 96th Transportation Research Board Annual Meeting, Washington DC.

Kamargianni, M., Li, W., Matyas, M., Papanikolaou A. (2016). Investigating the Mobility-as-a-Service Concept for London. Presented at the Smart Urban Transport Policy Futures Workshop, Greenwich, UK.

Reports:

ERTICO – ITS Europe (editor). (2019). Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning. Available at: https://www.eltis.org/sites/default/files/mobility_as_a_service_maas_and_sustainable_urban_mobility_planning.pdf

Kamargianni, M., Matyas, M., Li, W., Muscat, J., Yfantis, L. (2018). The MaaS Dictionary. MaaSLab, Energy Institute, University College London.

Kamargianni, M., Matyas, M., Li, W., and Muscat, J. (2018). Londoners’ attitudes towards car-ownership and Mobility-as-a-Service: Impact assessment and opportunities

that lie ahead. MaaSLab - UCL Energy Institute Report, Prepared for Transport for London.

Kamargianni, M., Matyas, M., Li, W., Schäfer, A. (2015). Feasibility Study for Mobility as a Service Concept for London. UCL Energy Institute report, Prepared for the UK Department for Transport.

APPENDIX B: LITERATURE ON PRODUCT BUNDLING

Packaging or bundling is defined as the sale of two or more products together for a single price (Guiltinan, 1987; Stremersch and Tellis, 2002). It is a frequently used marketing method in many industries. There is ample research about bundling in sectors such as telecommunications (Ben-Akiva and Gershenfeld, 1998; Yang and NG, 2010; Klein and Jakopin, 2014), multimedia services (Nam et al., 2006), travel (Carroll et al., 2007; Gillen and Morrison, 2003), food and beverage (Prasad and Hyma, 2014) and consumer goods (Arora, 2011; Soman and Gourville, 2001; Sheng et al., 2007). Based on how the products are marketed, they can be sold as pure units, pure bundles or mixed bundles (Adams and Yellen J. L, 1976). Pure unit sale is the traditional approach when the products are sold independently and no packaged option is available. On the other extreme, pure bundling implies that the supplier only sells the bundle of goods together, but not the bundle elements separately. As a combination of the two, when mixed bundling is used the firm sells both the bundle as well as the individual elements on their own. An example for the latter is a restaurant that has 3 course menu options but also allows customers to select individual elements.

Researchers have also classified packaging strategies based on whether they focus on price or product bundling (Stremersch and Tellis, 2002). The price bundling approach creates packages where the package price is lower than the sum of the individual item prices. In this case, the products are not integrated in a way that provides value to the consumers, thus the reservation price for the bundle is the sum of all elements in it. The motivation provided to users to purchase the package rather than the individual elements is solely the discounted price, although researchers also point out that the opportunity cost of time related to purchasing individual elements is also a factor (Carroll et al., 2007). While price bundling does not offer any other advantages to customers besides the price discount, product bundling aims to integrate products in a way that adds value to the customers. In these cases, the packager is able to capture additional consumer surplus that is created by bundling certain products together in a seamless experience.

Another interesting dimension of bundling is whether users are provided with static, predetermined bundles or with flexible, customizable options. Enabled by the availability of widespread internet, consumers are able to influence the supply chain directly and create bundle of products that best fit their need. These bundles are consumer-driven and able to keep up with consumers changing demands (Romano, 2005; Ayazlar, 2014). Also called dynamic packaging in the tourism industry, these bundles must be supported by real-time highly adaptable inventory from the supplier (Carroll et al., 2007). Customizable bundles provide suppliers the opportunity to learn about their customers, and can be a stepping stone towards fixed bundles. As pointed out in the literature, a major challenge of allowing customization is the flexibility complexity trade-off (Sonsino and Mandelbaum, 2001; Fogliatto and da Silveira, 2012).The amount of choice options needs to be carefully considered, as adding too many may cause confusion and defer consumers from choosing the product at all.

The benefits of bundling for both suppliers and consumers has been widely studied. From a supply side view, historically the main advantages of bundling were the reduction in production, distribution and transportation costs (Guiltinan, 1987; Eppen et al., 1991). However, as nowadays many bundles are not physical products, for example telecommunication subscription bundles, these benefits are less important. More relevant is the fact that packages can create greater economic rent to suppliers. Bundling products together increases consumers acceptance and willingness to pay (Eppen et al., 1991; Stremersch and Tellis, 2002). If the ‘product bundling’ method is used and the integration of products provides additional benefits to users, value is generated and suppliers gain additional profits. If there is great complementarity between the products, it is likely that the consumer surplus will be transferred among elements (Guiltinan, 1987). This also means, that the package will have a higher reservation price and in return a greater economic rent to the packager. If transparency is limited and the prices of the individual components and the underlying mark-ups are conserved, even greater gains are possible (Carroll et al., 2007; Tanford et al., 2011). Another way additional rent is achieved is by encouraging consumers to purchase goods that they might have not otherwise purchased (Guiltinan, 1987). A further benefit of bundling is that supply and demand imbalances can also be smoothed out (Carroll et al., 2007). For example, tickets to a sporting event can be bundled with off-season hotel stays in the same region.

Bundling can help attract attention to products that are less visible to potential buyers. For example, in the telecommunication industry service providers frequently bundle attractive phones together with subscription plans to motivate people to user to their plans (Tallberg et al., 2007). Similarly, bundling has also been proven to offer strategic benefits

when introducing new products or services. If a new product is bundled together with existing ones, it increases consumers' quality perception, purchase intention and willingness to pay for the new product (Sheng and Pan, 2009; Simonin and Ruth, 1995). As such, bundling can be used as a market launch strategy. It can also be used as a tool to support the diffusion of innovations. In a recent paper, Fojcik and Proff (2014) propose bundling battery electric vehicles (BEV) together with other mobility concepts to create a value-added offer. They find that the bundles increase consumer acceptance and leads to higher willingness to pay for BEVs. Another study by Reinders et al. (2010) examines bundling as a strategy to facilitate the adoption of radial innovations. Their results show that bundling radical innovations with existing products can increase the new product's evaluation and adoption intention but it does not increase comprehension of the radical innovation. However, they also find that the level of these significantly decreases when the consumers only perceive a moderate fit between the products in the bundle (Reinders et al., 2010). Bundling can also aid the introduction of new brands to the market if they are packaged together with existing ones which consumers already trust (Sheng and Pan, 2009). Although Sheng and Pan (2009) point out the caveat that consumers quality perception of the new brand is significantly affected by the brand image of the bundle partner and the complementarity of the goods in the bundle.

The supply side benefits can be developed through strategic alliances between firms who offer complementary products, allowing them to both charge higher prices (Mialton, 2014). However, in all cases, there are many elements that can impact the success of bundling. For example, Mittelman and Alrade (2017) found that the product order can determine the way customers perceive the bundle. Their results show that people from Western countries prefer bundles when their most valued product is presented on the left – which is the first thing they will see. Also, the way that the products are advertised and the level of complementarity between the goods greatly influences the performance of the bundled products (Yan et al., 2014).

Looking at the demand side, bundling can also provide a number of advantages to consumers. From an economic point of view, products that are conveniently packaged together reduce search and acquisition costs to users (Yadav and Monroe, 1993; Harris and Blair, 2006). Due to the simplicity of purchasing these products, they can also reduce the opportunity cost of time by freeing up the time spent on seeking out each individual item. Further, in a number of cases packages are also sold at a discounted cost providing direct savings to customers (e.g. Kim et al., 2009). As discussed above, rather than providing discounts, firms can also create integrated bundles that create value to users that would not exist if the products were only sold individually.

Looking at it from a psychological angle, researchers have argued that bundles simplify the decision-making process for users. According to the cognitive miser principle (Fiske and Taylor, 1991) people seek to limit the amount of cognitive effort they have to put in to reach a decision. This means that decisions are not always rational, and psychological shortcuts are frequently used to simplify decision making (Kahneman et al., 1982). Also, when consumers would like to purchase a number of products at the same time, information overload can lead to confusion and dissatisfaction (Lee and Lee, 2004). These cases may increase tendency to rely on mental shortcuts, such as purchasing bundles of pre-chosen products. Additionally, bundles decrease the perceived risk to consumers and can help reduce uncertainty (Sarin et al., 2003; Harris and Blair, 2006).

There are ample studies about all aspects of bundling in a wide array of industries. Looking more specifically to the transportation industry, the most similar existing concept is that of public transport passes (or season tickets). These, in many cases, allow access to several public transport modes (e.g. bus, metro, tram) for a fixed pre-paid fee. Studies have found that travel passes have a significant positive impact on patronage of the included modes (Axhausen et al., 2000; Bandoe and Yendeti, 2007; Lathia and Capra; 2011). This finding remains consistent over several geographical areas as Axhausen et al. (2000) examined this in Switzerland, Bandoe and Yendeti (2007) in Toronto and Lathia and Capra (2011) in London. A study by Shad et al. (2005) even examined mobility packages that included car sharing and car rental in addition to public transport season passes. They found that these mobility packages not only increased the usage of these modes but also decreased private vehicle ownership and use.

APPENDIX C: LONDON SURVEY

Table C-0-1: Case Study 1: survey questionnaire

Question wording	Shown if	Mandatory	Response format	Response options
1/6 Demographic				
How old are you?		*	Field	[*NF 16-99*]
What is your gender?		*	Single choice	Male
				Female
				Prefer not to answer
Marital status		*	Single choice	Single, never married
				Married/living with partner
				Divorced
				Widowed
Employment status		*	Single choice	Full time paid employment (30+ hours a week)
				Part-time paid employment (less than 30 hours a week)

				Full time self-employment (30+ hours a week)
				Part time self-employment (less than 30 hours a week)
				Student
				Waiting to take up job
				Unemployed or looking for work
				Unable to work because of long-term illness or disability
				Retired
				Regular unpaid or voluntary work
				Looking after home or family
				Other non-working
Education		*	Single choice	No formal qualifications
				GCSE or equivalent
				A-levels (high school diploma)
				Bachelor's degree
				Master's degree
				Doctoral or Professional degree
				Other
Ethnic group		*	Single choice	White British
				Irish
				Other White
				Mixed or multiple ethnic groups
				Black or Black British
				Asian or Asian British
				Other ethnic group
Thinking about all sources of income such as salary/wages, benefits, pensions and so on, which numbers best represent the total income of your household before taxes and other deductions?			Single choice	Less than £ 5,000
				£5,000 - £9,999
				£10,000 - £14,999
				£15,000 - £19,999
				£20,000 - £24,999
				£25,000 - £34,999
				£35,000 - £49,999
				£50,000 - £74,999
				£75,000 - £99,000
				£100,000 or more
				Prefer not to answer/Don't Know
Including yourself, how many people live in your household?			Single choice	*[DM 1-10]*
Who else lives in your household?	If household member number greater than 0		Multiple choice	Spouse/Partner
				Parent(s) or parent(s)-in-law
				Child(ren)
				Grandchild(ren)
				Other relative
				Live-in domestic helper
				Other non-relative/roommate/housemate
				Prefer not to answer
Please tell us the ages of children or grandchildren who love in your household	If children in household		Multiple choice	Under 5
				.5-11
				.12-15
				.16-18

				Over 18
What are the first 3 digits of your home post code?			Field	[Open Field]
What are the first 3 digits of your work (or education) post code?			Field	[Open Field]
2/6 Mobility - private modes				
How many bicycles does your household own?			Single choice	[DM 1-10]
Do you hold any of these types of driving licences? Please check all that apply if licence is currently valid in the UK.		*	Multiple choice	Full licence - car
				Full licence – motorcycle or moped
				Provisional licence - car
				PSV licence
				HGV licence
				None
Does your household own or have access to any vehicles (cars, lorries, motorcycles, excluding car club vehicles) on a regular basis? Please include vehicles that you may only use as a passenger		*	Single choice	yes
				no
Do you regularly drive any vehicles that you own or have access to?	If household vehicle	*	Single choice	yes
				no
How many of each of these types of vehicles does your household own or normally have access to?	If household vehicle		Multiple choice in dropdown menu	Car (incl. people carriers, 4x4s etc)
				Motorcycle or moped
				Small van
				Other van or lorry
				Other motor vehicle
Give a name for the vehicle (this label will be used during the later parts of the survey)	If household vehicle		Field	[Open field]
How much do you spend an average month on parking? Please include the cost any permits, occasional parking etc.		*	Field in table	NF
On an average month, how much are the fuel costs of this vehicle? If you don't know, please give your best guess.		*	Field in table	NF
How much do you spend average month on other vehicle related costs? Think of taxes, congestion charging, insurance etc		*	Field in table	NF
3/6 Mobility - shared modes				
Are you aware of car club schemes? By Car Club we mean a club where you can rent a vehicle to drive for a short period of time, usually hourly.			Single choice	yes
				no
Are you a member of a car club?	If license owner and aware of car club	*	Single choice	yes
				no
				Enterprise Car Club (former City Car Club)

Which car club are you a member of?	If member of a car club		Multiple choice	Zipcar
				DriveNow
				CoWheels
				E-Car Club
				Hertz on Demand
				Community car club (for example Easy Car Club)
				Other (please specify _____)
Which of the following best describes your membership status?	If Enterprise car club member		Single choice	1o I pay £60/year for Standard plan
				2o I pay £20/month for Enhance plan
				3o I pay £6/ month for the Under 22 plan
				4o I pay £20/year for the Van only plan
	If Zipcar car club member		Single choice	1o I pay £6/month for membership
				2o I pay £59.50/year for membership
	If Drivenow car club member		Single choice	I only pay usage fees
				I pay £21/month for a Savings package
				3o I pay £34/month for a Savings package
				4o I pay £66/month for a Savings package
				5o I pay £128/month for a Savings package
	If E-car club member		Single choice	I am a Casual Member so I don't pay any monthly fees
				I am a Community Member and pay £15/month
Please specify other	If other car club member		Field	
Which of the following best describes your membership status?		*		I pay monthly membership fees
				I pay yearly membership fees
				I don't pay membership fees just usage fees
Monthly fees	If other car club member		Field	
Yearly fees	If other car club member		Field	
How much do you use this service on an average month?				2 dropdown menus with one being "daily rental": 0-10+ other being: "hourly rental": 0-20+
How much do you pay for using this service during an average month? Please exclude membership fees. (If you don't know please give your best estimate)	If car club member	*	Field	
Have you ever used Santander Cycles previously Barclays Cycle Hire)?		*	Single choice	yes
				no
Do you have yearly bike access to Santander Cycles or do you use it through Pay as you Pedal (24 hour access at a time)?	If Santander cycles user	*	Single choice	yes (Yearly access)
				no (Pay as you Pedal)
How often do you use the following taxi services?		*	Single choice in table	
Black cab hailed off the street				Never
				Once a month or less
				2-3 times a month
				Once a week
				2-3 times a week
				More than 3 times a week

Black cab using an app on your phone (e.g. Hailo)				Never
				Once a month or less
				2-3 times a month
				Once a week
				2-3 times a week
				More than 3 times a week
Uber ordered on your phone				Never
				Once a month or less
				2-3 times a month
				Once a week
				2-3 times a week
				More than 3 times a week
Other minicab				Never
				Once a month or less
				2-3 times a month
				Once a week
				2-3 times a week
				More than 3 times a week
Shared taxi ordered on your phone (e.g. Uberpool)				Never
				Once a month or less
				2-3 times a month
				Once a week
				2-3 times a week
				More than 3 times a week
During an average month how much do you pay for these trips in total? If you don't know, please give your best guess.				
Black cab hailed off street	If use black cab	*	Field	
Black cab using an app on your phone	If use black cab ordered via phone		Field	
Uber	If use Uber		Field	
Other minicab	If use minicab		Field	
Shared taxi	If use shared taxi		Field	
				I have a taxicard
				My employer pays for my taxi travel
In an average month, how much time do you spend in a taxi? (this includes all kinds of taxi, Black Cab, minicab, Uber)		*		2 dropdown menus with one being "daily rental": 0-10+ other being: "hourly rental": 0-20+
4/6 Mobility -Public Transport				
Do you currently hold any kind of public transport pass, Railcard or photocard entitling you to free travel or reduced fares? Please include freedom passes, students photocards etc. (Please check all that apply)		*	Multiple choice	Free bus travel
				Free tube/rail travel
				Reduced rate bus travel
				Reduced rate Tube/rail travel
				Do not hold any pass
		*		Bus pass (for travel on busses and trams only)

Which of the following tickets do you hold for travel in the London area? Only include those that are valid for a week or longer and if you or someone else paid for it (i.e. it is not a free pass). The ticket may be on an Oyster card or a paper/magnetic ticket. (Please check all that apply)			Multiple choice	Travelcard (for travel on underground, DLR, rail, trams and busses)
				Other *[OE____]*
				None of these
What period is it valid for?	If has bus pass	*	Single choice in dropdown	7 day
				Monthly
				Annual
Cost [NOTE: This question was removed later]		*	*Field*	*NF*
What zones and for what period is your travelcard valid for and how much did it cost? Please also provide us with its Oyster card number (you can find this on the back of your card) as it would really help us gather some additional information from TfL.	If has travelcard	*	Multiple choice	1
				2
				3
				4
				5
				6
				7
Period		*	DM	7 day
				Monthly
				Annual
Cost		*	Field	NF
Number			Field	NF
What zones do you regularly travel through? Don't just think about public transport, also include any zones you drive through, take the taxi in etc. Unsure? Click here to see a map.	If has travelcard		Multiple choice	1
				2
				3
				4
				5
				6
				7
What is the name of the other pass?	If has other pass		Field	OE
What modes is your "other" pass valid for? What period is it valid for and how much did it cost?				
Modes		*	Single choice in dropdown	Bus&Tram
				National Rail
				All Public Transport Modes
Period		*	Dropdown menu	7 day
				Monthly
				Annual
Cost				
Zones (check all that apply)		*	Multiple choice	1
				2
				3
				4
				5
				6
				7

Have you ever used any of the following methods of contactless payment on TfL services?			Multiple choice	Contactless payment card
				Apple Pay
				Barclays Contactless Mobile
				bPay (wristband, key fob or sticker)
				EE Cash on Tap
				Vodafone SmartPass application
				None
Do you have any long-term physical or health issue that limits your ability to travel and get around?		*	Single choice	Yes
				No
				Prefer not to answer
How easy or difficult is to use the below transport modes?	If has disability			
Buses			Single choice in table	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Underground/overground				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
DLR				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Tram				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
National Rail				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
London black cab				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Uber				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Cycling				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Walking				Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
5/6 Mobility - Information				
		*		Multiple times a day

How often do you use your smartphone to find travel-related info?			Single choice in dropdown	Once a day
				Few times a week
				Once a week
				Once a fortnight
				Once a month
				Never
For which transport modes do you usually use a journey planner for? (Choose all that apply)	If uses smartphones to find travel related info		Multiple choice	Walk
				Bicycle
				Bike share
				Tube, DLR, Rail
				Bus
				Car share
				Black cab
				Peer-to-Peer Taxi (i.e. Uber)
How well do the following statements describe your attitude towards journey planners?	If uses smartphones to find travel related info		Single choice in each row of table	Where 1 is strongly disagree and 7 is strongly agree
Journey planners make my life easier				
I feel lost when my phone runs out of battery and I can't use my journey planner				
Not having access to my journey planner stresses me out				
Authorities should make more data available so that journey planners can provide all the information I need				
Authorities should make more data available so that more travel-related apps can be developed				
6/6 Mobility - Attitudes				
How well do the following statements describe your attitude towards innovative products and services?			Single choice in each row of table	Where 1 is strongly disagree and 7 is strongly agree
Using innovative mobility apps and services gives me a sense of personal enjoyment				
Innovative mobility services make my life exciting and stimulating				
I love to use innovative mobility products and services that impress others				
People I know often consult me for help when choosing the best innovative mobility product or service available on the market				
How well do the following statements			Single choice in	

describe your attitude about cars?	If have license but no vehicles		each row of table	Where 1 is strongly disagree and 7 is strongly agree
I will definitely buy a car in the future				
I believe there is no need to own a car in London				
There is no need to own a car in the “as a service” era we live				
I think people should buy less cars				
The number of cars is a big problem in London				
I just want to go from A to B; there is no need to own a car				
Owning a car is a big hassle				
How well do the following statements describe your attitude towards car sharing schemes?				
Car sharing schemes is a great way to have access to cars without owning one				
Overall, vehicle sharing schemes make sense				
car sharing is a better way of using cars than everyone buying their own				
I will likely participate in car sharing in the future				
I would happily rent someone’s car if I needed a car				
I think renting someone’s car is exciting				
If I had a car I would happily rent it to other people				
It is exciting to drive a different car every time				
Sharing a car instead of owning my own is a good option for me				
How well do the following statements describe your attitude about cars?	If have license and vehicle:		Single choice in each row of table	Where 1 is strongly disagree and 7 is strongly agree
Owning a car is a big expenditure for my household				
Driving in London is a nightmare				
It takes me a lot of time to find a parking space when I use my car				
Congestion is a problem when I drive				
I am attached to my car				

I would love to have access to a car without the hassle of owning one				
How well do the following statements describe your attitude towards vehicle sharing schemes?				
Car sharing schemes is a great way to have access to cars without owning one				
Overall, sharing cars makes sense				
Car sharing is a better way of using cars than everyone buying their own				
I wouldn't mind renting my car to other people				
Renting my car to other people could benefit me financially				
Renting my car to other people would improve my image within the community				
I can see myself renting my car to others more frequently in the future				
More people should rent their cars to other people when they are not using it				

Table C-0-2: Case Study 1: Questions related to potential impact of MaaS

Do you think this package will increase or decrease your usage of the different modes of transport? [shown after each choice situation]			
	Increase	**No change**	**Decrease**
Car			
Public Transport			
Bike			
Bike Share			
Taxi			
Car club			

Table C-0-3: Case Study 1: Attitudinal statements related to car ownership and MaaS

Attitude towards cars (car owners)	
I would be willing to sell my car if I had unlimited access to car sharing for the next couple of years	Responses on a 1-7 Likert scale
I would be willing to rent my car to other MaaS users for a fee	
MaaS would help me depend on my car less	
MaaS would remove all the hassle related to owning a private vehicle from my daily life	
Attitude towards cars (non-car owners)	
If MaaS were available I would delay buying my own car	Responses on a 1-7 Likert scale
If MaaS were available I would nlot need to buy a car at all	
Attitudes towards MaaS	
I would be more willing to subscribe to MaaS if it gave me discounts	Responses on a 1-7 Likert scale
I would feel trapped by subscribing to MaaS	
I would worry about losing any unused travel if I subscribe to MaaS	
I would worry about running out of my subscribed amounts of travel	
MaaS special offers would motivate me to subscribe to MaaS	
I would be willing to try transport modes I previously didn't use if my MaaS plan included them	
I would cycle more if I was given discounts on MaaS products for every mile	

APPENDIX D: LONDON MOBILITY SURVEY EXTENSION USING A SMARTPHONE BASED TRAVEL SURVEY

An addition extension of the London Mobility Survey (LMS), is its integration into a smartphone based travel survey tool. The survey as a whole and the SP experiment and was included as an extension to a smartphone based prompted recall travel survey that was adapted for the purposes of our study (FMS; Cottrill et al., 2013). Having access to a state of the art smartphone based travel survey provided a great opportunity to use this tool to enhance the quality and quantity of data collected and available for analysis. An overview of the steps of this version of the London Mobility Survey is as follows:

Step 1: Create your account;

Step 2: Answer the questionnaire;

Step 3: Download the app, log in, and start tracking and validating your activities;

Step 4: After a week of tracking go to the post survey to check your statistics and complete the MaaS SP.

In the following, the most important alterations to the original survey are demonstrated. After filling out the questionnaire about basic socio-demographic information and details about their current mobility tool choices, respondents are tracked via a smartphone app for a seven-day period. During the span of the tracking, they are reminded to verify their travel and non-travel activities and are asked to answer additional questions about their experiences (completed either on the web interface or their smartphones). These questions, just like the questionnaire ones, focus heavily on usage and attitudes towards the various characteristics of shared modes and innovative services. As the case study area is Greater London, all the elements of the survey are adapted to fit the local environment. After the seven days of tracking is complete the stated preference (dubbed post-survey) becomes available. First, the questionnaire data is aggregated and users are presented with a summary record of their mobility behaviour (aggregated to a month), broken down by transport mode and including information about travel-cost, time, and distance and number of trips. Travel cost was estimated using a combination of sources. Responses from the RP survey and the validation provided most of the information. In addition, Transport for London open APIs (Application Programming Interfaces) were connected in the back end of the survey to collect precise information about public transport fares (Kamargianni et al., 2016). This mobility record (MR) will become an important element to build the SP survey and an example can be seen in B-1. Please note, the legend was not shown in the actual survey. Instead, hover over explanations of the modes were used.

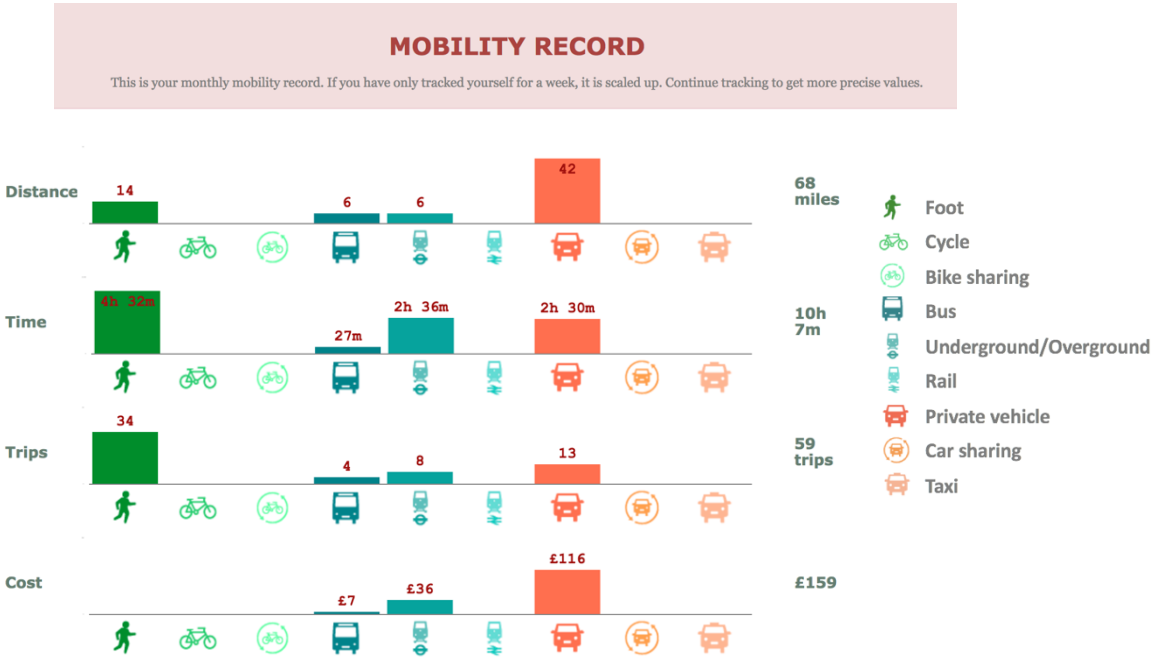

Figure D-1: MaaS Survey smartphone extension: mobility record (MR)

The MR shows the distance, time, number of trips and costs for each transport mode the individual uses. The data used to create this is a combination of pre-survey responses, tracking and verification information as well as data gained from integrating external APIs into the system. The example seen in Figure D-1 is for a respondent who only walks, takes the bus, the tube and drives his personal vehicle; which is why the other transport modes have no values. The MR encourages the respondent to start thinking about their overall travel on a monthly basis as well as the concept of multimodality. Through our focus groups, it was discovered that subjects found it very exciting to see their travel broken down as such and were very surprised by their statistics. The MR can be a great incentive for respondents to continue with the survey, especially if it is made interactive (not a current feature). For example, respondents could select on dials what breakdown they would like to see, such as weekday-weekend or hours of the day.

The order that the modes were presented remained consistent throughout the mobility records as well as all the plans in each scenario. This way they were familiar with the mode icons and could easily comprehend the main plan concept without having to spend too much time on each page. This approach is preferred as MaaS is a new concept and decrease the effort for the participants is important.

Even though in this version of the London Mobility Survey the SP is an extension of a smartphone based travel survey, the SP element is only available on the computer based

online interface so that all the plans could be seen next to each other. Alongside the plans a short version of the respondent's personal MR was presented to give context (see Figure D-2). This is similar to a status quo alternative, even though the respondent can't actually choose it. However, after asking the respondents' preference among the four plans, they are asked if they would buy their chosen plan if it were available today (the option to use MaaS as pay-as-you-go is also available). Here, they could use their MR as a reference, knowing, that if they would not buy the MaaS plan, they would be picking their status quo. The remainder of the survey is the same as the other version of the survey. This will allow for later analysis between the different collection methods.

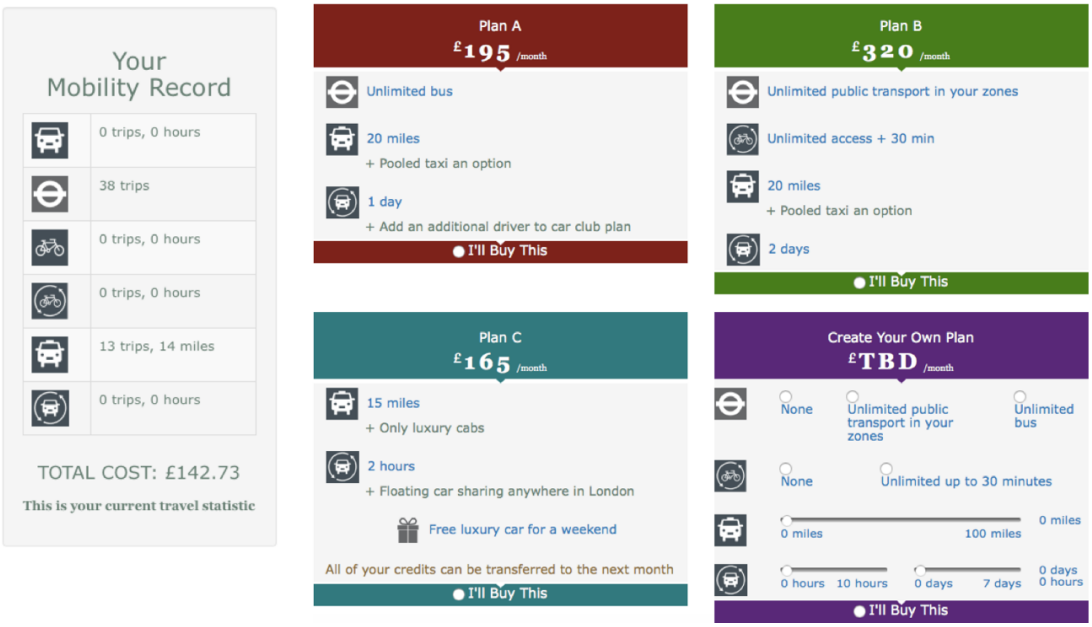

Figure D-2: SP presentation with Mobility Record

The above-described survey design was used to collect data during three survey waves. The first two waves of data were collected during November – early December 2016, while the third during February 2017. The data was collected using Exterion Media's[11] community panel. The panel is made up of individuals living within London's urban environment who signed up join this community panel so that they can answer various questionnaires. As the panel frequently participates in questionnaires, this may introduce biases, which should be acknowledged.

During the three waves 111 surveys were fully completed, meaning that the questionnaire, seven full days of validation and the SP were all finished. The waves were kept small intentionally to be able to adequately monitor all the elements and adjust if necessary. It should be noted that the sample size is more limited than the basic survey, but the purpose of these waves was to test an extension of the basic LMS using advanced, contemporary survey methods. The survey completion rate at 33% is quite high considering the length and involvement required from respondents (completion rates of each of the steps can be seen in Table D-1). The main dropout point was the user validation of trips, which gives an indication for areas of future development. The respondents were entered into small scale lotteries (approx. £20/prize) during three stages of the survey as a reward for participation. The respondents were told the number of prizes drawn, but not their odds of winning. To aid completion, respondents also

[11] (www.exterionmedia.com/uk)

received personalised push notification reminders once a day that were tailored to their progress in the survey (obviously this only worked if they got to the app download phase).

Table D-1: Smartphone-based LMS completion rates

	Wave 1	**Wave 2**	**Wave 3**	**Total**
Registration	128 / 100%	108 / 100%	98 / 100%	334 / 100%
Completed pre-survey	128 / 100%	98 / 91%	85 / 86%	311 / 93%
Tracking app download	104 / 81%	77 / 71%	70 / 71%	252 / 75%
7+ days validate in diary	64 / 50%	29 / 27%	37 / 38%	130 / 38%
Post-survey completed (including SP)	54 / 42%	26 / 24 %	31 / 31%	111 / 33%

The difficulties in actually carrying out such a survey should be mentioned. First, as there was no established contact with a specific market research company, several were contacted to help carry out the survey. However, most companies either flat out rejected the idea of implementing the survey or even if they would, this would have been at an extremely high cost. Finally, the company who conducted the survey saw additional value in the data that would be collected and were willing to help. At the time of the of preparing for the extended survey data collection (Summer-Autumn 2016), using a smartphone as a data collection tool was not yet well established. Since then, various discussions have led us to believe, that nowadays (Spring 2019) these methods are more accepted and it would most likely be easier to find market research company to assist with the sample.

Second, while the above shown completion rates are very good, this will not likely hold in most cases. The reason for the high rates in this specific application is the particular community panel that was used. This excellent panel showed great enthusiasm and commitment, which Is very rare with traditional market research panels. There are several aspects of smartphone based travel diary surveys that discourage people from doing them, including the time it takes and privacy concerns.

Another difficulty worth pointing out is that due to the technical complexity of this survey, a helpline and online chat function was implemented using Zendesk[12]. This had to be attended to on a daily basis and all technical issues had to be dealt with immediately to not risk higher dropout rates. While having this function is very beneficial for the survey, it also has high time and opportunity costs.

[12] https://www.zendesk.co.uk

Even though the richness of the data collected through a smartphone based travel survey extension to the base MaaS survey, the above discussed difficulties should be carefully weighed before opting for this method. As such surveys become more advance and increasingly widely available, the mentioned burdens should significantly decrease and should be simpler to implement.

APPENDIX E: MODELLING IMPICATIONS OF 'CREATE YOUR OWN' MAAS PLAN OPTION

It is important to make a note regarding the modelling implication of the 'create your own' option. One of the complexities of model development using menu data, stems from the choice set. Taking into account all the possible combinations available to the respondent, the set of alternatives is over 26,000. Large choice sets arise from many decision contexts. Frequent examples include: residential location choice, trip destination choice, route choice, vehicle acquisition choice and departure time choice.

There are three main strategies to navigate around such large choice sets: (1) aggregation of alternatives, (2) full sample enumeration and (3) sampling of alternatives. The first approach to deal with large choice sets is to build aggregate categories of alternatives to greatly reduce dimensionality (Ben-Akiva and Lerman, 1985). This is especially useful when looking at choice sets where there are common characteristics in alternatives (Kim et al., 2003; Carod and Antolin, 2004; Pinjari et al., 2008; Song and Knapp, 2004; Roudriguez et al., 2006). For the current study, this method is followed, due to the relative ease of application. Also, as a result of the characteristics of our data, it is fairly straightforward to identify categories of alternatives. The alternatives from the menu can be aggregated based on the types of modes included in them.

The second approach is full enumeration. In some cases, it is computationally feasible to estimate models with full enumeration of the choice set (e.g. Habib and Kockelman, 2008). However, due to the sheer number of alternatives and comparatively limited observations, this could not be applied to the MaaS SP data in this application. The third approach is the sampling of alternatives method (Ben-Akiva and Lerman, 1985). Some studies do sampling of alternatives by choosing a simple random sample which includes the chosen alternative (e.g. Pozsgay and Bhat, 2001; Nerella and Bhat, 2004). However, this method comes with a number of caveats. Most notable to this research is that one of the requirements of the positive conditioning property set out by McFadden (1978) under which consistent estimates can be obtained is that each choice observation be treated independent (Daly et al., 2014). As a result, this method can be used in the case of MNL models, but not in mixed logit, nested logit or other specifications (Lemp and Kockelman,

2012). In addition, Nerella and Bhat (2004) suggest that even in the case of the MNL, at least one-eighth of the full choice set should be used in estimations, as model performance and estimator efficiency decrease by smaller sample sizes. This can be computationally impossible in many modelling situations, including the MaaS SP. Other studies turn to importance sampling to generate choice sets for model estimation (e.g. Ben-Akiva and Watanatada, 1981; Train et al., 1987; Fejinger et al., 2009). The argument for importance sampling is that samples should include attractive alternatives, as comparing an attractive alternative to a set of highly unattractive alternatives will not give much information about the decision-making process (Fejinger et al., 2009). When using importance sample, the probability of selecting attractive alternatives is higher than unattractive alternatives. When using this approach, if alternative specific constants (ASC) are estimated, all parameter estimates are unbiased even without using correction terms for sampling bias (Manski and Lerman, 1977; Fejinger et al., 2009). However, in many cases, including ours, ASCs are not included in the model specifications, therefore correction for sampling is essential. Lemp and Kockelman (2012) argue that there is no one clear approach for generating such choice set probabilities a priori and most researchers exercise intuition to guide their procedures. To add, importance sampling can yield consistent estimates for MNL models, but the same is not necessarily true for other model structures (Brownstone et al., 2000, Lemp and Kockelman, 2012). With both these methods, the limiting MNL specification would not be suitable to the MaaS SP data. However, recently there has been practical approaches to estimating consistent, asymptotically normal and relatively efficient estimators for other model specifications, such as logit mixtures, using sampling of alternatives (e.g. Naïve approach presented in Guerava and Ben-Akiva, 2013), although, this is not yet widely applied. Due to fact that any information regarding MaaS plan preferences is largely unknown alongside our limited sample and the nature of our data (rendering MNL model structures inappropriate), applying the sampling of alternatives approach to the London Case study data would be difficult. However, following the work of Guerava and Ben-Akiva (2013) could be a route for further study.

APPENDIX F: MANCHESTER SURVEY

Table F-0-4: Case Study 2: survey questionnaire

Question wording	Shown if	Mandatory	Response format	Response options
Demographic				
How old are you?		*	Numeric Field	[NF 14-99]
What is your gender?		*	Single choice	Male
				Female
What is the highest degree or level of education you completed?		*	Single choice in dropdown	Less than high school
				High school diploma or equivalent
				Bachelor's degree
				Masters degree
				Doctoral degree
				Other
What is your employment status?		*	Single choice in dropdown	Full time paid employment (30+ hours a week)
				Part-time paid employment (less than 30 hours a week)
				Full time self employment (30+ hours a week)
				Part time self employment (less than 30 hours a week)
				Student
				Unemployed or looking for work
				Unable to work because of long-term illness or disability
				Retired
				Looking after home or family
				Other
Which of the following best describes your working schedule?		*	Single choice in dropdown	I have very strict working hours
				I have some flexibility in when I leave the office but not when I arrive
				I have some flexibility in when I arrive to the office but not when I leave
				I have complete flexibility in when I arrive and leave
				I don't have working hours
Including yourself, how many people live in your household?		*	Numeric Field	[NF 1-12]
Who else lives in your household? Please select all that apply.	If household more than one person	*	Single choice	Spouse/Partner
				Parent(s) or parent(s)-in-law
				Child(ren)
				Grandchild(ren)
				Other relative
				Live-in domestic helper
				Other non-relative/roommate/housemate
				Prefer not to answer
How many children do you have?	If have child in household		Numeric Field	
Thinking about all sources of income such as salary/wages, benefits, pensions and so on, which numbers best represent		*	Single choice	Under £15,000
				£15,000 - £24,999
				£25,000-£34,999
				£35,000 - £49,999

the total annual income of your household before taxes and other deductions?				£50,000 - £74,999
				£75,000 or more
				Prefer not to answer/Don't Know
Do you have any long-term physical or health issue that limits your ability to travel and get around?		*	Single choice	Yes
				No
				Prefer not to answer
How easy or difficult is to use the below transport modes?	If have a disability			
Buses		*	Single choice	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Metro		*	Single choice	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Tram		*	Single choice	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Rail		*	Single choice	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Taxi		*	Single choice	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Cycling		*	Single choice	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Walking		*	Single choice	Impossible without help
				Difficult (but not impossible)
				Easy to use
				I do not have the experience
Private mobility				
Do you hold any of these types of driving licences? Please check all that apply if licence is currently valid.		*	Multiple choice	Full licence - car
				Full licence – motorcycle or moped
				None
Does you household own or have access to any vehicles (cars, lorries, motorcycles, excluding car club vehicles and bicycles) on a regular basis? Please include vehicles that you may use either as a driver or passenger.		*	Single choice	yes
				no
How many vehicles does your household own?	If have a household vehicle	*	Numeric Field	[NF 1-12]
		*		yes

Are you the main driver of one of those vehicles?	If have household vehicle and own a license		Single choice	no
How often do you use this vehicle?	If have a household vehicle	*	Single choice	Never
				Once per two/three months
				Once per month
				Once in a fortnight
				A Couple of times per week
				3-4 times a week
				Once per day
				Several times per day
What kind of vehicle is it?	If have a household vehicle	*	Single choice	Small city car
				Sedan
				SUV
How much do you think that you pay for using this vehicle per month? Please, take into account fuel, parking, insurance, tax, service costs.	If have a household vehicle	*	Numeric Field	
Where do you usually park the vehicle while at home? Please select all that apply.	If have a household vehicle	*	Single choice in dropdown	On street - resident scheme
				On street - metered
				On street - other
				Off street - public other
				Off street - private residential
				Off street - private non- residential
To what extent do you agree with the following statements related to private car usage?	If have a household vehicle			
I own a car because there is no other transport mode alternative in my area		*	Single choice	1=Extremely disagree to 7=Extremely agree
Having my own car is the most convenient way to move around				
I enjoy driving				
Owning a private car is a way of freedom for me				
Owning a car is a status symbol for my lifestyle				
Owning and using a car is a big expense for my household				
I lose a lot of time being stuck in traffic jam				
I am annoyed with the time it takes to find a parking space				
Switching from my private vehicle to shared modes would remove several pain-points related to my daily mobility				
I use a car because I have to transfer my kids to school and to their activities	If have a child in household			

How many bicycles does your household own?		*	Numeric Field	[NF 1-12]
How often do you use your household's bicycle for your trips (excluding cycling for sport/exercise)?	If have a bike	*	Single choice	Never
				Once per two/three months
				Once per month
				Once in a fortnight
				Couple of times per week
				3-4 times a week
				Once per day
				Several times per day
Public and shared modes				
How often do you use public transport?		*	Single choice	Never
				A few times per year
				Once per month
				Once per fortnight
				A few times per week
				Once per day
				Several times per day
Why do you not use public transport? Please select all that apply.	If use PT less than once a fortnight	*	Multiple choice	There is no public transport available near my home
				The public transport close to my home is too infrequent
				There are no public transport options available to my destinations
				It would take me too long to take public transport to my destinations
				I do not find public transport modes comfortable
				I find public transport too expensive
				I do not like travelling with other people
				I do not trust the timetables
				Other
What transport mode do you use to get from your home to the nearest public transport stop/station?		*	Single choice	Private car
				Walking
				Bicycle
				Taxi
				Other
How long does it take you (in minutes) to get from your home to the nearest public transport stop/station with this mode?		*	Numeric Field	
Are you eligible for any of the following public transport travel fare reductions?		*	Single choice	Yes, free travel
				Yes, discounted travel
				No, full fare
Do you hold a public transport travel pass that is valid for a week or longer?	If use PT	*	Single choice	Yes
				No
How much did this pass cost?	If have PT pass	*	Numeric Field	
Are you aware of car sharing schemes? By car sharing schemes, we mean both commercial and peer to peer car clubs where you can rent a vehicle to drive for a short		*	Single choice	Yes
				No

period of time, usually hourly.				
Are you a member of a car sharing scheme?	If aware of CS	*	Single choice	Yes
				No
How often do you use the car sharing scheme?	If member of CS scheme	*	Single choice	Never
				A few times per year
				Once per month
				Once per fortnight
				A few times per week
				Once per day
				Several times per day
How much do you usually pay per month for using a shared vehicle? Please, take into account the subscription and the cost per use.	If member of CS scheme	*	Numeric Field	
Are you aware of bike sharing schemes? Bike sharing is a service in which bicycles are made available for shared use to individuals on a very short term basis for a price.		*	Single choice	Yes
				No
Are you a member of a bike sharing scheme?	If aware of bike sharing	*	Single choice	Yes
				No
How often do you use the bike sharing scheme?	If aware of bike sharing	*	Single choice	Never
				A few times per year
				Once per month
				Once per fortnight
				A few times per week
				Once per day
				Several times per day
How often do you use the following taxi services?				
Taxi hailed off the street or called via phone		*	Single choice	Never
				A few times per year
				Once per month
				Once per fortnight
				A few times per week
				Once per day
				Several times per day
Taxi ordered through smartphone application		*	Single choice	Never
				A few times per year
				Once per month
				Once per fortnight
				A few times per week
				Once per day
				Several times per day
How often do you use your smartphone to find travel-related info?		*	Single choice	Never
				Once a month
				Once a fortnight
				Once a week
				Few times a week

				Once a day
				Multiple times a day
Mobility apps				
Which of the below apps that are related to daily mobility do you have on your smartphone?	If use smartphone mobility apps			
Journey planning app		*	Multiple choice	1=Yes, 0=No
Navigation app				
Taxi app				
Rail app				
Bike-sharing app	If aware of BS			
Car-sharing app	If aware of CS			
Car-rental app				
How often do you conduct the below travel-related activities via an app on your smartphone? Please, answer the below only for your daily trips; not for vacation trips.	If use smartphone mobility apps			
Searching information on how to go from A to B		*	Single choice	1 = Never to 7=Several times per day
Checking the timetables of the modes I would like to use				
Receiving real time information about delays				
Booking or ordering the transport mode				
Buying tickets				
Paying for my tickets				
Rating the transport modes I use				
To what extend do you agree or disagree with the below statements?	If use smartphone mobility apps			
It is time consuming to use different mobility apps to arrange my trips		*	Single choice	1=Extremely disagree to 7=Extremely agree
It is annoying to create an account for every mobility app				
It is confusing for me to use different apps to find the most appropriate modes for my trips				
It is annoying that each transport mode I want to use has different payment methods				
It is annoying that I have to get different types of tickets to access each transport mode				
Daily mobility				
		*	Single choice	Car/motorcycle - driver
				Car/motorcycle - passenger

What is the main transport mode that you usually use to go to work or education?				Car-sharing
				Bus
				Tram
				Metro
				Suburban rail
				Rail
				Walk
				Bicycle
				Bike-sharing
				Taxi
				Taxi ordered via smartphone app
				I mostly work from home
How long (in minutes) does it usually take you to go from home to work (or education)?		*	Numeric Field	[NF 1-1000]
Which are the three most important factors that affect your choice of mode for travelling to work?		*		Comfort
				Travel Time
				Ease of use
				Price
				Reliability
			ranking	Safety
What is the main transport mode that you usually use to go grocery shopping?		*		Car/motorcycle - driver
				Car/motorcycle - passenger
				Car-sharing
				Bus
				Tram
				Metro
				Suburban rail
				Rail
				Walk
				Bicycle
				Bike-sharing
				Taxi
				Taxi ordered via smartphone app
			Single choice	Online grocery shopping
How long (in minutes) does it usually take you to go from home to the area you do the grocery shopping?		*	Numeric Field	[NF 1-1000]
Which are the three most important factors that affect your choice of mode for grocery shopping?		*		Comfort
				Travel Time
				Ease of use
				Price
				Reliability
			ranking	Safety
What is the main transport mode that you usually use to go to leisure activities?		*		Car/motorcycle - driver
				Car/motorcycle - passenger
				Car-sharing
				Bus
				Tram
			Single choice	Metro

				Suburban rail
				Rail
				Walk
				Bicycle
				Bike-sharing
				Taxi
				Taxi ordered via smartphone app
How long (in minutes) does it usually take you to go from home to the area you do your leisure activities?		*	Numeric Field	[NF 1-1000]
Which are the three most important factors that affect your choice of mode for leisure activities?		*	ranking	Comfort
				Travel Time
				Ease of use
				Price
				Reliability
				Safety
What do you usually do while travelling? You can choose more than one.		*	Multiple choice	
Talking on phone				1=yes 0=no
Listening to music				
Working				
Playing games				
Reading books/magazines				
Eating				
Sleeping				
Nothing				
Other				
In an average week, how many trips do you conduct with the following modes?		*	Numeric Field	[NF 0-1000]
Car/motorcycle - driver				
Car/motorcycle - passenger				
Car-sharing				
Bus				
Tram				
Metro				
Suburban rail				
Rail				
Walk				
Bicycle				
Bike-sharing				
Taxi				
Taxi ordered via smartphone app				
Attitudes and perceptions				
Below are a few statements describing satisfaction for daily mobility. To what extent do you agree or disagree with the below?				

Overall, I am happy with my daily mobility				
I am happy with the transport modes I currently use for my daily mobility				
I do not feel a need to change the way I travel				
I wish I could spend less time on daily travelling				
I am happy with the amount of money I spend for my daily mobility				
Being able to do other activities while travelling makes my travel time productive				
My daily life is too busy and I want my trips to be convenient and relaxing				
Below are a few statements describing satisfaction about combining transport modes to reach your destination. To what extent do you agree or disagree with the below?		*	Single choice	1=Extremely disagree to 7=Extremely agree
I do not mind using more than one transport mode to go to my destination				
Changing transport modes to go to my destination is not convenient for me				
If it is faster, I don't mind transferring between transport modes				
I'd rather travel longer than have to change transport modes				
Convenience while travelling is the most important factor for choosing a mode				

Table F-0-5: Case Study 2: SP attributes and levels

MANCHESTER			
	Basic plan	**Urban plan**	**Extra plan**
Public transport	1 month unlimited bus within Greater Manchester	N/A	N/A
	1 month unlimited public transport within Greater Manchester	1 month unlimited public transport within Greater Manchester	1 month unlimited public transport within Greater Manchester
Bike sharing	No (not shown)	No (not shown)	N/A
	Free access to Mobike bike sharing	Free access to Mobike bike sharing	Free access to Mobike bike sharing
Taxi	N/A	N/A	No (not shown)
		1 taxi trips within Greater Manchester	N/A
		2 taxi trips within Greater Manchester	N/A

		3 taxi trips within Greater Manchester	3 taxi trips within Greater Manchester
			4 taxi trips within Greater Manchester
			8 taxi trips within Greater Manchester
			10 taxi trips within Greater Manchester
Car sharing	N/A	N/A	No (not shown)
			1 hour car sharing with Enterprise car club
			3 hours car sharing with Enterprise car club
			5 hours car sharing with Enterprise car club
			8 hours car sharing with Enterprise car club
			12 hours car sharing with Enterprise car club
Price	(sum of base prices) * 0.8	(sum of base prices) * 0.8	(sum of base prices) * 0.8
	(sum of base prices) * 0.85	(sum of base prices) * 0.85	(sum of base prices) * 0.85
	(sum of base prices) * 0.88	(sum of base prices) * 0.88	(sum of base prices) * 0.88
	(sum of base prices) * 0.95	(sum of base prices) * 0.95	(sum of base prices) * 0.95
	(sum of base prices) * 1	(sum of base prices) * 1	(sum of base prices) * 1
	(sum of base prices) * 1.05	(sum of base prices) * 1.05	(sum of base prices) * 1.05
	(sum of base prices) * 1.12	(sum of base prices) * 1.12	(sum of base prices) * 1.08
	(sum of base prices) * 1.15	(sum of base prices) * 1.15	(sum of base prices) * 1.15
	(sum of base prices) * 1.2	(sum of base prices) * 1.2	(sum of base prices) * 1.2

APPENDIX G: SP DESIGNS FOR ALTERNATIVE MAAS PRODUCT TYPES

SP design for MaaS plans with fixed unit prices

An alternative MaaS product type that is included in the Manchester survey is the concept of having MaaS subscription plans where users would be fixed unit prices for each service (but then would have to pay that amount whenever they actually use it). The longer they subscribe for, the less they pay per unit, that is, there is a trade-off between commitment and cost.

Different subscription durations and commitment levels are tested in this design. Also, the pay as you option is included which was similar to the other plans, just did not have any levels of commitment. As such, the choice set comprises of (1) pay-as-you-go; (2) weekly plan; (3) monthly plan; (4) none. A visual of an SP page is presented in Figure E-1.

Figure G-1: MaaS plans with fixed unit prices

As shown in Figure G-1 the attributes and levels for this product type are quite different than for the MaaS product bundles. For the pay-as-you-go alternative, this is a one-time subscription fee, which can be included or its level can be set to zero. For the weekly and monthly alternative, this is a fixed payment that users would need to pay when renewing their plans, either every week or every month. For these two plans, this also incorporates the cost associated with the public transport option, while for the pay-as-you-go option this is not the case. The next attribute is the public transport mode, which is chosen to include as a certain amount of unlimited travel for the weekly and monthly plans (this is why the cost for these is absorbed by the plan fee for these two alternatives). Regarding bike sharing and taxi, these have a cost/ride associated with them. Car sharing (although not demonstrated in the visual above as the visual is for a person who does not have a license), is denominate in cost/hour. The final attribute is the level of commitment. This is fixed at 'none' for the pay-as-you-go alternative, but it varies for the other two options. The final attribute-level table is presented in Table G-1.

Table G-1: Alternative SP attributes and levels

	Pay as you go	Weekly plan	Monthly plan
Public transport	PAYG at current rates	3 days unlimited travel	10 days unlimited travel
		1 week unlimited travel	1 month unlimited travel
Bike sharing	30 p/ ride	25 p / ride	20 p / ride
	50 p / ride	30 p / ride	25 p / ride
	60 p / ride	50 p / ride	30 p / ride
	70 p / ride	60 p / ride	50 p / ride
Taxi within GM	8 £ / ride	5.5 £ / ride	5 £ / ride
	10 £ / ride	6 £ / ride	5.5 £ / ride
	12 £ / ride	8 £ / ride	6 £ / ride
		10 £ / ride	8 £ / ride
Car sharing	£12/ hour	£10/hour	£8/ hour
	£13/ hour	£12/ hour	£10/hour
	£14/hour	£13/hour	£12/ hour
	£15/ hour	£14/hour	£ 13/hour
Plan fee	None	(sum of base prices) * 0.8	(sum of base prices) * 0.8
	Single £5 signup fee	(sum of base prices) * 0.85	(sum of base prices) * 0.85
	Single £10 signup fee	(sum of base prices) * 0.88	(sum of base prices) * 0.88
	Single £18 signup fee	(sum of base prices) * 0.95	(sum of base prices) * 0.95
	Single £20 signup fee	(sum of base prices) * 1	(sum of base prices) * 1
		(sum of base prices) * 1.05	(sum of base prices) * 1.05
		(sum of base prices) * 1.12	(sum of base prices) * 1.12
		(sum of base prices) * 1.15	(sum of base prices) * 1.15
		(sum of base prices) * 1.2	(sum of base prices) * 1.2

Contract level	None	Automatically stops after a week	Automatically stops after a month
		Rolling contract	Rolling contract
		3 week commitment	3 month commitment
			12 month commitment

Regarding the other design considerations, the chosen characteristics are:

- to have a choice set with four labelled alternatives as indicated above;
- to have a single discrete choice response format;
- to not include context;
- to have three repetitions (pages) of the choice task;
- to have a D-efficient design.

Questionnaire design for create your own plan

The final MaaS product type is the 'create your own' plan option. The survey is designed as a two-step process. Initially respondents' preferences are examined irrespective of price. This method was used to capture their pure modal preferences within MaaS plans, without being influenced by price. Knowing what individuals' 'dream' plans would be can give valuable insights into what different types of people would ideally have in their plan. This, first step, is presented in Figure G-2.

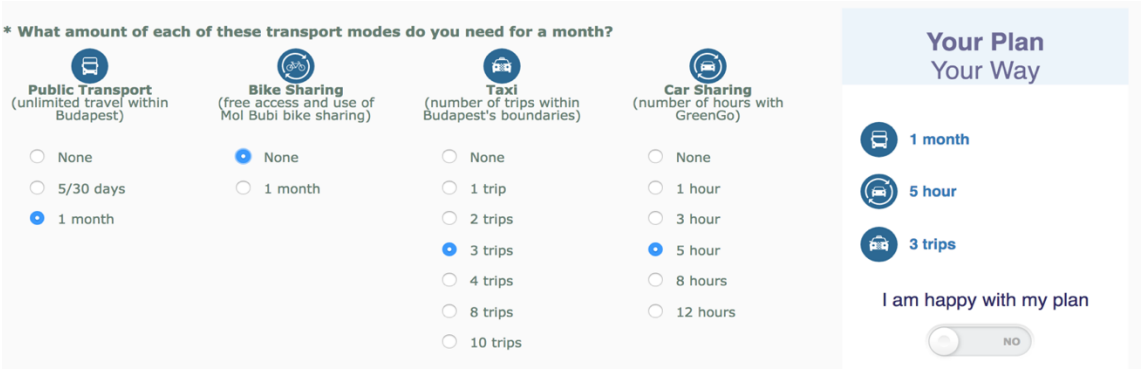

Figure G-2: Create your own plan visual

Once participants have indicated that they are happy with the plan they created, they are shown information about how much that specific plan would cost and are asked whether they would be willing to buy it or not. If they state that they would not, they are asked how much they would be willing to pay for it.

Although this method is someone unorthodox, it allows the collection valuable information about individual preferences. Even though this is not how a create your own menu would be presented in the market, it does provide interesting and important insights into individual preferences for MaaS products. The usual design considerations do not apply

in this case, as this page is only presented to respondents once, it is not the usual repeated choice situation. It could, hypothetically become a repeated choice where in each case different prices and options are presented, however, for this case it is keep to a simple single page.

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