Doctoral Dissertation

Feasibility Study of Mobility as a Service Considering the Built Environment

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Feasibility Study of Mobility as a Service Considering the Built Environment
（都市環境を考慮した Mobility as a Service の実装可能性に関する研究）

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Dedication

This thesis is dedicated to my late father (Jeremiah Perogers Terhemba Agbe) and my mother (Mwuese Anas Agbe).

Acknowledgments

First, I express my profound gratitude and appreciation to my supervisor, Shiomi Yasuhiro, who believed in me, supported me and encouraged me to attain this milestone achievement. Second, I would like to thank the Graduate School of Science and Engineering (GSSE), faculty members and administrative staff who supported me through this journey in providing a conducive environment for conducting my research. Finally, my appreciation goes to my friends and family members who have made sacrifices to support my dream.

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Abstract (English)

Mobility as a Service (MaaS) promises a competitive transportation alternative to the use of private cars such that mobility services are combined and offered as flexible subscription transport services to users on demand via a single platform. Recently, MaaS is attracting attention globally, whether it is a one-stop solution for a sustainable society remains to be understood. MaaS has the potential to reduce congestion and other transport related problems significantly by reducing the reliance on car usage and car ownership. However, the service level of public transportation and transportation behavior differ greatly between urban and suburban areas, and the feasibility of MaaS is highly dependent on the built environment. Nevertheless, there are concerns about the acceptability of MaaS, limited knowledge about the potential demand for MaaS and the willingness to pay for MaaS. This thesis is a feasibility study that uses data extracted from an online stated preference survey in Shiga, considered as a suburb and Kyoto, considered as an urban area, to understand the users preference, potential demand for MaaS and willingness-to-pay for MaaS, also drawing comparisons regarding the behavioral intentions to use MaaS between the suburbs and urban areas. Using a censored regression model (Tobit type II) the findings indicate that the inclusion of train in a MaaS package as well as the people's travel behavior, especially the frequent use of public transport positively impacts the adoption of MaaS, which suggests that there is a potential market for MaaS in rural/suburbs. Furthermore, using Structural Equation Modelling along with multigroup analysis, we analyze the relationships of latent constructs and the intention to use MaaS. The results revealed that car ownership and attitudes towards car usage have a significant impact on the intentions to use MaaS. Also, the structure of the intention to use MaaS is almost same between Shiga and Kyoto, however, the stated intention to use MaaS, for what purpose and the willingness to pay differs in the questionnaire, which implies that built environment plays an important role. This study provides insights like MaaS package preference, age groups likely to use MaaS and the level of awareness of the MaaS concept, which supports the implementation of MaaS and spurs further research.

Abstract (Japanese)

Mobility as a Service は、複数のモビリティサービスを組み合わせ、単一のプラットフォームを介して利用者に提供するものである。 近年、MaaS は世界的に注目され、各都市で実装されつつあるが、これが自家用車利用から公共交通利用への転換を促し、持続可能な社会を実現するための解決策となるか否かは、まだ明らかではない。とりわけ、都市部と郊外部では土地利用、人口密度、公共交通機関のサービスレベルや交通行動が大きく異なるため、MaaS の実現可能性については、これらの都市環境に大きく依存すると考えられる。そのため、これらの都市環境を考慮した上で、MaaS の受容性、MaaS の潜在的な需要に関する限られた知識、MaaS に対する支払い意志を定量的に把握し、その実装可能性を検討することが必要である。

そこで本論文では、郊外部として滋賀県の大津市と草津市、都市部として京都市を対象として実施したオンラインアンケート調査に基づき、MaaS に関する利用者の意向やそれに基づく MaaS の潜在需要、MaaS に対する支払い意思額を把握するとともに、MaaS 利用に対する行動意図について郊外と都市部での比較を行った。 まず、利用意向と支払い意思額について、離散連続モデルの一つであるトービットモデルを用いて分析を行った結果、滋賀を事例として、地方・郊外に MaaS の潜在的な市場があることを示した。 さらに、構造方程式モデルと多母集団同時分析を用いて、MaaS の利用に関する行動意図構造を把握した。その結果、自動車所有率と自動車利用に対する態度が、行動意図構造に大きな影響を与えることが明らかとなった。 また、滋賀と京都では、行動意図構造はほぼ同じであるものの、アンケートでの表明意向が異なることから、建築環境が重要な役割を担っていることが示唆された。本研究は、MaaS の導入に向けた示唆を与えると同時に、さらなる研究の推進につながるものである。

Chapter 1

Introduction

1.1 Background of the Study

The world's population is increasing rapidly at a rate of 1.1 percent per annum and urbanization is also on the rise (The World Bank, 2019). By 2050 it is projected that more than two-third of the world's population will live in urban areas (Ritchie & Roser, 2018). Also, with the advent of trends in global public health challenges like the aging population, Covid19 pandemic just to mention a few, the way we live, work, travel and do businesses is transforming. These trends have put immense pressure on our environment, systems and services. For example, human population growth is a major contributing factor to global warming, given that humans use fossil fuels to power their increasingly mechanized lifestyles. The United States accounts for 4.25% of the total world population yet is the second largest producer of greenhouse gases after China (Wikipedia, 2021). Similarly, urbanization though a key to economic development, has some negative impacts on the society, like increase in demand for urban spaces, air and water pollution, increase in population density and energy consumption, increased demand for health and transportation services, just to mention a few.

Transportation is shaping our cities and suburbs and it plays a pivotal role in economic and sustainable development. However, transportation challenges have impacts on the way we live and travel, as well as the environment. Over the years as transport systems evolve, so also are their associated problems. For example, traffic congestion adversely impacts quality of life and economic productivity, in that it increases fuel consumption, cost of the traveler, cost of freight movement, road crashes and other losses due to delays as well as contributes to CO_2 emission that is harmful to the environment.

Consequently, cities have tried to manage these problems by introducing traffic management schemes, yet at lot still needs to be done in providing a one stop solution to the transportation problem. These schemes include, separate cycle lanes, traffic calming, low emission zones (London), congestion charges, road pricing, prioritized road lanes, park and ride, vehicle exclusion zones, carpooling and more recently smart mobility, on-demand transport services, Mobility as a Service (MaaS) scheme etc. Therefore, it is imperative that, instead of building our communities around cars, it is important to build and develop our transport systems around the built environment and communities.

Constantly, there have been emerging innovative mobility solutions to create a new experience for urban mobility. Furthermore, one may argue that these smart mobility solutions have the potential to substantially curbed traffic congestion and global warming (Tran & Brand, 2021), however, there are still concerns about the unintended consequences of MaaS. In recent times, a new transportation scheme commonly called Mobility as a Service (hereafter, simply called 'MaaS') is gaining attention around the world because it presents a new paradigm to the transportation industry. Mobility as a Service (MaaS) is said to provide a better alternative for our transportation needs than the use of private cars such that mobility services are combined and offered as flexible packages to users on demand via a single digital platform. MaaS has the potential to significantly reduce congestion, cut down on CO2 emissions and promotes an environmentally friendly community that is inclusive and sustainable by reducing car ownership (Goodall, Fishman, Bornstein, & Bonthron, 2017). Nevertheless, implementing MaaS is a continuous process with several components which cannot be achieved in one swoop. These components of the implementation include policy, demand/supply, consumer behavior, market forces, MaaS package design, wholistic feasibility, built environment etc. MaaS implementation comes with its challenges because a new service or technology will have to gain public acceptance for it to thrive. This feeds into the debate whether MaaS can meet the environmental goals, or whether MaaS is economically viable and sustainable, and can cause a shift in habitual travel behavior. This is a significant undertaking of this thesis.

1.2 Motivation of the Study

Transportation plays a crucial role to the development of sustainable cities. In line with Sustainable Development Goals (SDG) 11, which is to make cities and human settlements inclusive, safe, resilient and sustainable, world leaders seek to strengthen the integration of all modes of transport to achieve the Sustainable Development Goals (United Nation, 2021). It is hoped that these steps will promote policy synergies, trade facilitation, infrastructure connectivity and sharing economy (UN General Assembly, 2017). Therefore, concerted efforts are required by governments, transport planners and transport service providers to implement sustainable mobility schemes like MaaS. In addition, the feasibility of introducing these schemes is key to gaining good market penetration.

On the other hand, consumers have increasingly adopted new mobility schemes over the past decade. For example, bike share and carsharing schemes are spreading rapidly across the globe. There are bikeshare schemes in more than 50 countries and Uber (ride hailing service) have expanded to more than 500 cities around the world (Goodall, Fishman, Bornstein, & Bonthron, 2017). This is a clear indication that consumers travel behavior is evolving with global trends. Hence, there is potential to encourage widespread shift in travel behavior towards sustainable travels. This step invariably meets the goals for the development of a sustainable city.

Since MaaS is a new mobility concept, more user experience, data and literature around it will provide useful insights to drive policies, provide higher quality of service, and enhance market penetration and public acceptance. All these points necessitate the need for this study.

1.3 Purpose and Research Questions

The main purpose of this study is to introduce MaaS as one of the key components for developing a sustainable city. More specifically, examine the feasibility of implementing MaaS in an urban setting as well as non-urban areas which indirectly provides information about the potential demand. Also, investigate the determinants of the intention to adopt MaaS by the potential users which will help in designing a suitable MaaS package that is user centric as well as develop a good pricing strategy for the scheme.

To achieve this, first, I collect data for two human settlements – urban and rural and analyze them to ascertain the potential demand for MaaS in both cases.

Second, I investigate the factors that influences the user's decision to take up MaaS.

The key research questions answered in this thesis are as follows.

1. Is there a market for MaaS in a non-urban setting?
2. What are the key elements to consider when implementing MaaS?
3. What are the important factors that influences users' decision to adopt MaaS?
4. Will consumers ultimately give up their cars and take up MaaS?

1.4 Findings of the Study

Using a censored regression model, the findings of the first paper of this thesis indicates that there is a market for MaaS in a suburban setting which is fueled by the people's curiosity. This also implies that more people are willing to try MaaS depending on the price. Nevertheless, the feasibility of implementing MaaS should be examined further, considering different aspects of feasibility for example, operational and economic feasibility.

The findings from the second paper of this thesis highlighted the strong affinity towards the private car in relation to the users' behavioral intentions to use MaaS. Using the theory of planned behavior, these findings indicate that car ownership and people's attitude towards the private car strongly impacts the behavioral intentions to use MaaS. To encourage a shift from private car to subscription transportation services like MaaS, users' habitual behaviors must be considered to formulate strategies for a better market penetration.

1.5 Contributions of the Study

The above findings contribute to literature in three broad ways.

1. The rural MaaS context present an interesting discussion to investigate the feasibility, and sustainability of the MaaS in different settings which has not been sufficiently explored. This can contribute to literature over the debate on sustainable mobility vis-à-vis traffic congestion solutions and environmental benefits.
2. These useful market insights will encourage transport planners and service providers to show commitment in adopting new business models for the implementation of MaaS.
3. These insights will assist municipalities, authorities and governments toward policy formulation and synergy.

1.6 Organization of the study

This study is divided into two main parts. The first part deals with the feasibility of mobility as a service in a rural/suburban setting while the second part deals with the determinants that influences the residents' intention to adopt mobility as a service. Precisely, this thesis is outlined as follows: Chapter 2 describes the concept of mobility as a service, its evolution and current scientific advancement in the field. Chapter 3 lays down the theoretical and conceptual framework of this study as well as the questionnaire design considerations and data collection process. Chapter 4 describes the data collected and presents the preliminary results and brief comparative analysis between rural and urban settlements. Chapter 5 examines the feasibility of implementing mobility as a service in suburban areas and discusses the empirical results. Chapter 6 investigates the determinants of the intention to adopt MaaS and discusses the findings in relation to policy implications. Chapter 7 summarizes the findings of this study, highlights the policy implications, recommendations and contributions to the development of rural MaaS. This chapter also outlines the limitations of this study and prepossess future research works.

Chapter 2

Literature review

2.1 Introduction

In this chapter we discuss the importance of mode choice analysis in the traditional four step transportation demand estimation for urban planning. Furthermore, we discuss the common factors that influences the trip maker's mode choice behavior as well as the common methods used for mode choice analysis. In addition, we review the psychological and economic theories which forms the basis for the development of mode choice models. Some of these theories and methods are the major consideration of this study.

Next, we discuss the evolution of Mobility as a Service (MaaS), its prospects, challenges and current trends. Furthermore, we review the consumer behavior towards subscription services other than transportation services and the lessons from these behaviors are examined.

2.2 Evolution of Mobility as a Service (MaaS)

During the industrial revolution, the invention of the railroad and steam locomotive opened up the transportation landscape. Transportation systems were no longer limited to rivers and canals. Subsequently, the invention of a vehicle powered by gas engine (by Carl Benz in 1886, the birthing of the motor car as we have it in present day) opened up the urban space. Urbanization was on the rise and sub urban areas also emerged, and this led to decentralizing activities outside cities or transit corridors. Then, in the 21^{st} century – the digital age, also the information era, access to information technology everywhere opened up again the transportation landscape such there was a growing need for existing transportation systems to be more effective, efficient, user-friendly and environmentally friendly. Now, transport systems are becoming more tailored to what the user/consumer wants, and how they want it – user centric. This have provided more convenience and consumption choices for the users (Goodall, Fishman, Bornstein, & Bonthron, 2017).

Consequently, efforts have been made by experts and governments to solve the transportation problem. These efforts birthed intelligent transportation systems (ITS), combined mobility, multimodal integration, mobility on demand, paratransit, micro mobility, shared mobility and most recently mobility as a service (MaaS) in a bid to manage the transportation systems network to deliver the needed value to users and society at large.

Recently, with the rise of sharing economy, services like Netflix and Spotify emerged. In the music industry this have also birthed a concept call Music as a Service (MaaS). This is a new form of consuming music via online subscription streaming services (for example Netflix, Amazon video, Hulu, Spotify etc.).

Netflix and Spotify have changed the way people search for and purchase and consume movies and records/music albums (Dörr et al., 2013). Hitherto, people have to go to stores and buy CDs and DVDs, and of course have the players that support them and by which these media are consumed. Most people end up having a huge physical library that compete for spaces in their living rooms. Now with the Netflix and Spotify platforms, most movies and music records are uploaded, and consumers can access it via a monthly subscription. Also, playing these media do not require a big device like a video player, but these can be consumed using smartphones, tablets, smart TVs, video game consoles and personal computers. We do not need a physical space to store the movies and records but just virtual storage. These technological innovations have changed consumer behavior across different sectors of our society. Since the information era, consumer's behavior has been changing and in transportation field also, there is a shift of focus from purchasing means of transportation (private car) to the purchase of transport services (Uber, Lyft, Whim-MaaS).

2.2.1 The concept of MaaS

Since mobility as a service (MaaS) is still evolving, there is still no universally accepted definition of MaaS. However, the core characteristics of MaaS are; the integration of travel mode services, travel information (fares, routes, schedules) and booking/payment systems (Sochor, Arby, Karlsson, & Sarasini, 2018). (MaaS Alliance, 2019) defined Mobility as a Service (MaaS) as the integration of various forms of transport services into a single mobility service accessible on demand while (Hietanen, 2014) describes MaaS as the convergence of transportation services which are tailored to users' needs as monthly packages like a mobile phone contract. These offerings are packaged as monthly subscription plans or pay-as-you-go. MaaS is being implemented around the world at different integration levels. Figure 1 and 2 shows the basic architecture and topology of MaaS respectively.

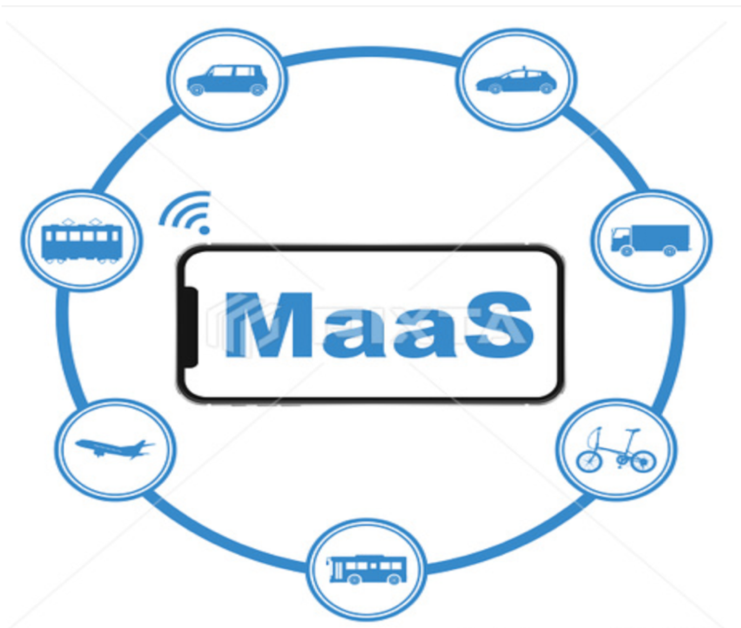


Figure 2. 1 Basic structure of MaaS *(source: pixta.jp)*

Figure 2. 2 Topology of MaaS showing the levels of integration

Source: adapted version from (Sochor, Arby, Karlsson, & Sarasini, 2018)

2.2.2 Benefits of MaaS

In principle, MaaS could be beneficial in the following ways:

1. For the customer, it could provide flexibility of choice of the modes to include or remove in a subscription package as the need arises. Also, it meets the mobility needs of users at the same cost or lower than their current travel modes (for example the Whim unlimited plans).
2. For the transport operators, MaaS could increase the market penetration and market share of the mobility services. It also boosts supporting services like payment systems, trip information/planner apps. For example, trip planner apps like whim provide data on trips, modes, routes, fares and subscription packages. This data is valuable to trip makers.
3. For government authorities, implementing MaaS can meet their long-term goals to reduce traffic congestion, cut down on CO_2 emissions and boost the economy (Rye, 2017). In addition, it creates the possibility of reducing public subsidy for public transport (Hensher, 2017).

However, there are some disadvantages that implementation of MaaS brings. It has the possibility of attracting more riders to auto based mobility services like ride hailing, car sharing and rental car services which invariably defies the overall objectives of MaaS. Moreover, there are fears of social exclusion for poor people or people without smartphones.

2.2.3 MaaS Acceptance

MaaS is not yet widely and consistently adopted globally, however significant progress has been made in some cities across Europe and their experiences provide great insights for future implementation of MaaS. Lessons from some of the operational MaaS schemes like Whim, UbiGo and *Reach Now,* all in Europe can be used for trying out MaaS in other regions. A brief history of the major providers of MaaS is shown in Table 2-1

Table 2. 1 The key service operators of MaaS

S/No.	MaaS scheme	Description
1	*Whim* – mobility app (MaaS Global Ltd-Finland)	i. Started operations October 2016 in Helsinki. ii. Offers monthly subscription packages and pay-as-you-go. iii. Modes included are public transport, taxi, rental car, e-scooter and citybike. iv. Whim cities: Helsinki, Turku, Vienna, Antwarp, West Midlands and greater Tokyo. v. Over 16 million trips since inception.
2	*UbiGo* – mobility app (Swedish Joint venture: Via-ID, SL (Regional PTA) and selected transport service providers)	i. Field operational trial in Gothenburg 2013 – 2014, 97% of the participants wanted to remain customers after the experiment. ii. Launched commercial operations in Stockholm in 2019 but operating only in some parts of Stockholm. iii. Offers mobility subscription packages with the following modes: public tansport, bike, taxi, car sharing, rental car. iv. Subscription packages can be shared among family members and friends.
3	*Reach Now* – mobility app (Corporate start-up within the Daimler and BMW ecosystem - Germany)	i. Formerly known as Moovel but renamed as "*Reach Now*" and establish in 2019. ii. One of the five joint ventures Daimler and BMW group namely, *Free Now, Share Now, Reach Now, Park Now* and *Charge Now*. iii. Featured modes are public transport, car sharing, taxis, bikes and e-scooters. iv. Services are offered in 22 cities and used by 7.5 million people.

Sources: https://whimapp.com/helsinki/en/history-of-maas-global/, https://www.ubigo.me/en/about-ubigo, https://www.daimler-mobility.com/en/innovations/mobility-services/history-of-the-dms/, https://www.reach-now.com/about/

2.2.4 A brief review of MaaS trends

Digitization and technological advancements have played a key role in the development of MaaS (Transport Systems Catapult, 2016). This trend has increased the demand for new and innovative transport solutions. An innovative solution like Mobility as a Service is a new concept that could provide seamless door-to-travel that meet the needs of the people. However, there is limited data on the user experience of MaaS on a large scale since most of the schemes are being piloted or operated at lower levels of integration. Some examples of MaaS schemes are Whim, Ubigo, Smile, Navigogo, HannoverMobil etc. Some of these schemes are implemented under a Public-Private Partnership arrangement, bringing all stakeholders on board to collaborate in delivering MaaS to the users. Many pilot projects are springing up around the world, like the Galileo for Mobility in Europe (UITP, 2019), MaaS America Advisory Committee-MAAC (ITS International, 2019) and in Japan, Softbank and Toyota's joint venture-Monet technologies. Consequently, Softbank and Toyota group are creating more alliance with other big players like Grab and Uber to provide ride-hailing services - Autono-MaaS and MaaS to cover Southeast Asia markets (Nikkei Asia, 2018).

Other mobility schemes like flat-rate system or subscription transport service positively influence the attitude towards the use of public transport, increases transit ridership and decreases the use of private cars (Satoshi & Ryuichi, 2003). Research groups around the world have also been working on the feasibility of implementing MaaS or subscription transport services to harness the benefits that come with these schemes. For example, (Kamargianni, Matyas, Li, & Schäfer, 2015) revealed that there seems to be a significant market for MaaS and even car owners are willing to make a shift to usage. Furthermore, the presence of mobility services like car sharing, bike sharing, taxi and public transport in a city or town makes it easier for MaaS to thrive (Kamargianni, Matyas, Li, & Muscat , 2018). Although, there is a growing attractiveness of the MaaS concept, in some places frequent public transport users find it less attractive (Ho, Hensher, Mulley, & Wong, 2018). Also, in Paleiskwartier Netherlands, most residents did not express interest to take up MaaS as revealed in the stated preference survey conducted by (Fioreze, Gruijter, & Gaurs, 2019). Different places have their peculiar issues, hence the feasibility, acceptability and market penetration of MaaS should be tested considering these peculiar factors. An optimal MaaS model in one place may not succeed in another place, for example in the case of developing versus developed countries. The following studies for the introduction of MaaS provided insights particular to the intended place of implementation. They are (Singh, 2019) in India, (Schikofsky, Dannewald, & Kowald, 2019) in Germany, (Fioreze, Gruijter, & Gaurs, 2019) in the Netherlands, (Esztergar-Kiss & Kerenyi, 2019) in European cities, (Mulley, et al., 2019) and (Vij, Ryan, Sampson, & Harris, 2018) in Australia.

MaaS still needs to be thoroughly researched if this will become a one stop solution to the transportation problem. Many people, including the automotive industry still believes in the comfort that private cars bring. Therefore, the idea of shifting completely from car ownership to usage as MaaS offers remains to be desired. In some climes the priority on environmentally friendly behavior has made automotive industries to invest in electric vehicles (EVs) and innovations in autonomous vehicles (AVs) to improve the consumer experiences. These innovation stretches the debate whether it supports the overall objective of MaaS. Since the inception of MaaS, there have been many trials and pilots in cities around the world. The awareness is increasing, and the behavior of city dwellers is changing significantly. However, most recently, with the covid19 global pandemic, there have been a sharp decline in the use of public transport and shared mobility. For example, mobility for commute to work in the US and Germany have decreased by 37% and 38% respectively. Also, Italy noticed a 60% decrease in the use of car sharing services due to the perceived risks by consumers (Garaus & Garaus, 2021). This presents a draw back to the efforts made for the widespread adoption of MaaS.

On the other hand, online subscription streaming services have benefited from the stay at home and work from work adopted during the pandemic. The consumers who spend time on streaming services have increase by 75% in 2020 (GlobalNewswire, 2022). Furthermore, telework and hybrid style of working which has become popular and it is redefining the way we live and work. Other global trends like climate change and urbanization are vital factors to be considered in implementation of MaaS. More efforts are needed to improve the social image of MaaS and mitigate the perceived public health risks. This study addresses the implementation and acceptance of MaaS considering these trends. Specifically, the built environment that provides an interesting component since consumers behavior differ in various human settlements or urban settings.

2.2.5 Implementing Mobility as a Service

The implementation of MaaS is a continuous process and requires a lot of investigation, feasibility studies and decision making. At the inception of the concept vis-à-vis the needs assessment, stakeholders especially government and private sectors collaborate to come up with a design. Many studies have explored the feasibility of implementing MaaS in different cities before going to the pilot stage. In most cases, these studies cover the big cities as a result, there is limited literature about the prospects of MaaS in rural areas. This study contributes to providing insights for MaaS implementation in the rural context. More so, this study explores a new area like Shiga which has not been explored before, at same time makes a comparison with a nearby city – Kyoto. This research uses the same survey design to compare two areas in proximity that are different in terms of built environment. Also, the respondents are not asked directly if they will use MaaS but use the flat-rate system, monthly subscription and the unlimited use features of a MaaS which serves as proxies to the intentions to use MaaS.

2.2.6 Attitudes towards MaaS adoption

Generally, there has been skepticism towards MaaS adoption, this may be due to fact that the idea of MaaS is yet to be fully understood (Fioreze, Gruijter, & Geurs, 2019), (Schikofsky, Dannewald, & Matthias, Exploring, 2019). Although some people find MaaS attractive because of the technology and the comfort it may bring however, they are reluctant to pay for it (Ho, Mulley, & Hensher, 2019). According to a stated preference survey conducted in Shiga-Japan, over 60% of the residents revealed that they will not use MaaS packages regardless of the price. This was largely due to habitual behaviors and strong reliance on the use of private cars (Agbe & Shiomi, 2021).

Notwithstanding, the curiosity about MaaS has been building over the years so it is crucial to dwell on it and develop a scheme that is widely accepted and sustainable.

Since Sweden and Finland are the pioneers of MaaS, it is important to examine the MaaS scheme operational in these countries to better understand MaaS acceptance and individual adoption. In Gothenburg, Sweden, MaaS trial was first implemented for a period of six months with 195 individuals from 83 households. The results of this trial showed that car owners reduced the usage of private cars and increased the use of public transport. Even non car owners who desired to purchase a car admitted that they did not see the need to purchase it anymore. In fact, 20 households set aside their cars completely during the trial period, 93% of the participants expressed satisfaction with the service, 79% said they will continue using the service while 18% want to continue using it depending on the cost. Overall, curiosity played a greater role in influencing decision to participate than the perceived benefits that MaaS could bring (Stromberg, Karlsson, & Sochor, 2018), (Sochor, Karlsson, & Stomberg, 2016).

In Helsinki, Finland, MaaS app called Whim was introduced in late 2016 with a full launch coming after in November of 2017. Since then, downloads of the app and subscribers have been growing steadily over the years. A survey was conducted a month after the launch and the results revealed that 62% of Helsinki residents were aware of the app and 46% were interested in the concept (especially people within the ages of 18-34). Furthermore, users increased their use of public transport from 48% to 74% and the use of private cars reduced by half to one time in every five trips (ITS International online magazine, 2018). Generally, the initial results show a positive attitude towards MaaS but whether their decisions are driven by environmental concerns, technology, economy or curiosity remains unclear.

Acceptance has often been highlighted as a key factor for a successful introduction and intended use of a new technology/transport service. A similar study in Pakistan showed that gender, employment, income, travel cost and travel time have a significant effect on the users' acceptance and willingness-to-use a new car sharing service (Ullah, Liu, & Vanduy, 2019).

In this study, we investigate the determinant for the intention to adopt MaaS in urban and rural areas using stated preference survey data. We employ structural equation modelling approach to examine the effects of the relationships between latent variables, observed variables and the intention to use MaaS. Also, a comparison is drawn to understand the key elements that influences MaaS adoption in urban and rural areas.

2.3 Transport mode choice

2.3.1 Background to travel mode choice

Transport mode choice is basically the decision a trip maker makes about the mode of transport to use when embarking on a journey. This is one of the most important stages in the transportation planning process because it directly affects policy direction. Mode choice analysis helps us understand the complex nature of human behavior in terms of the decision-making process (Minal & Ravi Sekhar, 2014). Understanding the traveler's behavior in respect to mode choice is important because customer's satisfaction with transport services is a key performance indicator for transport service providers (Mintesnot & Shin-ei, 2008), (Madhuwanthi, Marasinghe, Rajapakse, Dharmawansa, & Nomura, 2016). Consequently, travel mode choice has received much research attention.

2.3.2 Factors influencing mode choice behavior

The factors that influences an individual's travel mode choice behavior can be categorized into four main groups namely, the characteristics of the trip maker, the characteristics of the journey, the characteristics of the travel mode and land use/built environment respectively (Ortúzar & Willumsen, 2011), (Madhuwanthi, Marasinghe, Rajapakse, Dharmawansa, & Nomura, 2016) , (Lee, Nam, & Lee , 2014).

1. Characteristics of the trip maker: this includes but not limited to,
    - Age
    - Gender
    - Income
    - Vehicle ownership
    - Household structure
    - Occupation
    - Possession of drivers' license etc.
2. Characteristics of the journey which includes
    - Purpose of the trip
    - Time of the day when trip is undertaken, for example peak and off-peak periods
    - With whom the trip is undertaken, for example, alone or with friends or family

- Accessibility of the destination area, for example, mountainous areas, islands, remote areas etc.

3. Characteristics of the travel mode which includes
    - In-vehicle time
    - Cost of the mode
    - Availability
    - Reliability
    - Travel time and value of time (VOT)
    - Comfort and convenience
    - Safety
    - Level of service (LOS) of travel mode
4. Land use/built environment
    - Population density
    - Land use types like commercial or residential
    - Intersection density for example, density of the road networks as well as connectivity

2.4 Considerations of the built environment

Built environment refers to the human-made structures, features and facilities that collectively provides the setting for human activities. This encompasses all the physical parts of where we live, recreate and work like homes, buildings, parks, green spaces, open spaces, public spaces, utilities, streets, sidewalks, road network, water/electricity distribution systems, bridges and transportation systems (Kaklauskas & Gudauskas, 2016). Particularly, accessibility to transport systems and the structure of transport infrastructure influences mode choice and invariably travel behavior. For example, the access and egress time can determine if a traveler will walk to the station/bus stop or use a bicycle as well as the availability of parking at a station can encourage travelers to drive, park and transfer.

The built environment does not only affect mode choice, but it also influences the travel distance and car ownership (de Vos et al., 2021). The components of the built environment are referred to as the '3Ds' of built environment which are density, diversity and design (Cervero & Kockelman, 1997). Later, these factors were expanded to include destination accessibility and distance to transit station now referred to as the 5 Ds, factors of the built environment(Ewing & Cervero, 2010). These factors have proven to significantly influence mode choice and travel behavior (Matthew McKibbin, 2011). Density is the most researched variable of the built environment; it provides the compactness of the living arrangement of people which may indicate that potential trip origins and destinations are withing a neighborhood. The extent to which density affects mode choice and travel behavior is unclear. Furthermore, it is unclear whether it is density or the associated variables like residential self-selection, accessibility, generalized travel cost and access to transit stations that influences mode choice and travel behavior. Diversity provides the access to activities on different land uses. This potentially reduces long distance travels. Design deals with the aesthetics and character of the neighborhood. It attracts people to explore the environment and it invariable promotes the use of non-motorized modes of travel.

This study considered the aspects of built environment which are aggregated into urban, suburban and rural area. It is widely believed that people who live in urban areas often use public transport due to the proximity of origins and destinations to public places. Therefore, based on this assumption, it is expected that more people who live in urban areas will adopt MaaS.

2.5 The theory of planned behavior (TPB)

Consumer's behavior has been studied to understand the choice decision making process. This knowledge helps to improve the quality of the product or service rendered. In many studies in transportation and economics, Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) are used to explain consumers choice of a product or service. Theory of Planned Behavior (TPB) states that the likelihood of an individual to engage in a logical behavior is strongly correlated to the strength of his or her intentions to engage in that behavior (Kagee & Freeman, 2017). This theory is used to predict behavioral intentions, which are determined by a combination of three factors namely, attitude towards the behavior, subjective norms and perceived behavioral control.

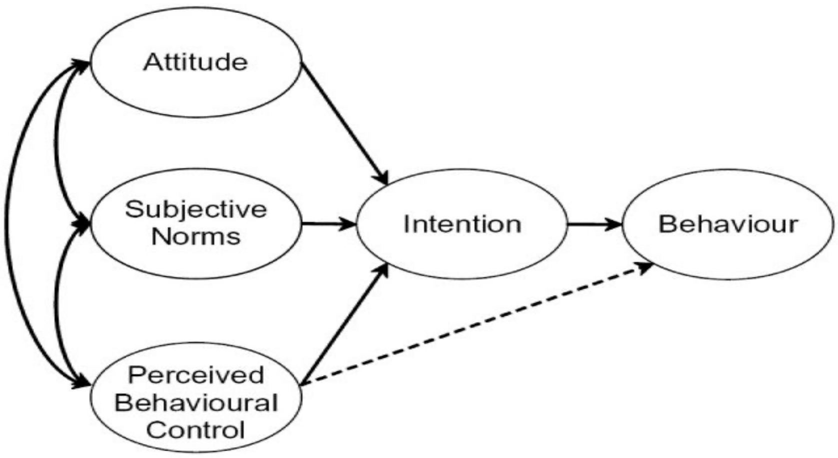


Figure 2. 3 The Theory of Planned Behavior (TPB) (Ajzen, 1991)

1. Attitude towards the behavior refers to the extent to which a person has an evaluation of the behavior to be performed. That is whether the person has a positive or negative feeling towards the behavior to be performed. This involves the consideration of the outcomes of performing the

behavior of interest. For example, when someone believes that if he or she smiles often he or she will make more friends.

2. Subjective norm refers to the social pressure to perform the behavior in question. For example, all my friends use iPhones, so it normal for me to buy one.
3. While perceived behavioral control refers to the ease or difficulty of performing the behavior in question which is based on past experiences or expected obstacles. For example, I am most likely to forget to turn off the lights when I leave my apartment for work. These factors have direct impact on intentions and indirect impact on behavior. On the other hand, perceived behavioral control has a direct effect on behavior (Figure 3).
4. Behavioral intention is predicted using a combination of the above-mentioned factors. The assumption is that when one intends to do something, they actually do it, however, intention to do something does not accurately predict the actual behavior. For example, someone with a phobia may intend to remain calm, but when faced with the situation ends up with a panic attack. Nevertheless, in accordance with TPB the stronger the intention the more likely to perform the behavior of interest.

2.6 Addressing the knowledge gap

Even though the interest on MaaS amongst policy makers, experts and academics is rising, to date there are still discussions and disagreements to the universal definition of what MaaS is and what the core components should include. In this thesis we attempt to define MaaS and contribute to the general debate on what MaaS truly represents. Also, more attention has been given to implementing MaaS in cities/urban areas but there is limited research for MaaS in suburbs and rural areas. This study also seeks to contribute to the existing knowledge about the role of MaaS in rural development and social inclusion from a Japanese context. Furthermore, research is lacking in the returning of driver's license by elderly drivers that is induced by the introduction of MaaS. It is not clear if the introduction of MaaS will influence the return of licenses however this is subject to further investigation. Evidently, there has been a rise in elderly Japanese voluntarily returning driver's license however more is still left to be desired since there are still significant amount of road accidents by elderly drivers. In this study we attempt to test the strength of the user's intention to adopt MaaS vis-à-vis the return of drivers license especially by elderly drivers in Japan.

Chapter 3

Study areas and conceptual framework

3.1 Introduction

This chapter gives a detailed description of the target areas under study and discuss the conceptual framework as well as the research model approaches used to arrive at the outcomes of this study. Also, discusses the survey considerations and finally present the questionnaire design used for data collection.

3.2 Description of the study areas

The study areas are in the south-central part of Japan, also known as the Kansai (or Kinki) region of Japan. The specific areas under research are categorized into two namely, rural/suburban and urban respectively. This categorization is done based on the population densities of the areas of interest. For the rural/suburban area Otsu and Kusatsu cities in Shiga prefecture were selected, which met the criteria. Similarly, Kyoto city which also met the criteria for an urban area was selected.

3.2.1 Otsu and Kusatsu - General

These cities are the most populated areas of Shiga prefecture and are located at the southern part of Biwako (lake Biwa is Japan's biggest freshwater lake). Otsu city (35°1´N, 135°51´E) is the headquarters of Shiga prefectural government with a population of 345,070 persons while Kusatsu has a population of 143,913 persons. These cities share boundary and although, the area of Kusatsu (67.82km^2) is smaller than Otsu (464.5km^2), Kusatsu has a population density of 2,122 persons per square kilometer which is higher than that of Otsu city with 743 persons per square kilometer (City population, 2020). Lake Biwa is a major tourism site which attract a lot of tourists who come for sightseeing and other water sports.

3.2.2 Transportation system

These towns (Otsu and Kusatsu) serve as bed towns to big cities in the Kansai region like Kyoto and Osaka. There are two major transit corridors in this area that connects Kyoto city to the central region of Japan and the Sea of Japan. Figure 3-1 shows the two major lines in Shiga which are *Biwako line* and *Kosei line* as called by the operator Japan Railway Company (JR West). The road networks provide access to the hinterland and serves are feeder into the main transit corridors.

Several transportation companies are providing mobility services in this area but the accessibility by public transport as expected in any metropolitan city is limited. Table 1 shows the transport service providers for the modes available in the area. However, some places are not accessible by these train lines, so bus companies like Keihan, Teisan and Ohmi Tetsudo operate in this area and serve as feeder modes to the main lines. Also, operating in this area are rental car services, rental bicycles as well as taxis.

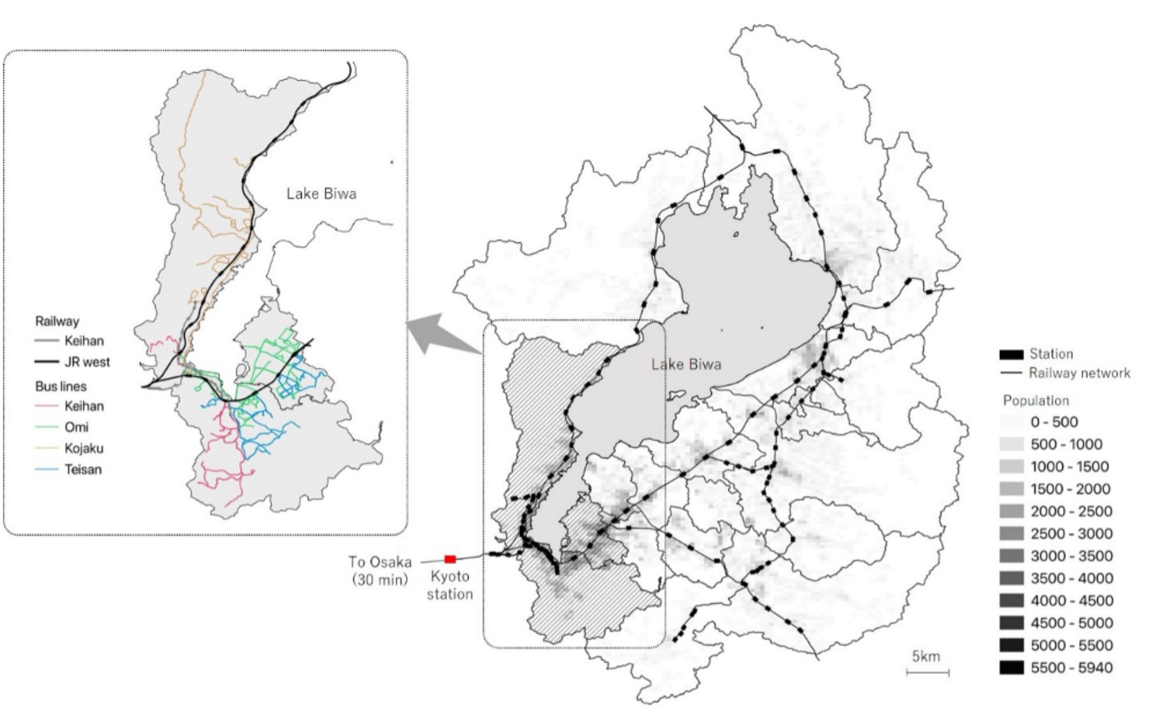


Figure 3. 1 Map of Shiga showing Otsu and Kusatsu and the two major transit lines

Although, there is no shared micro mobility services yet in operation around the Biwako valley, in recent times, taxi-hailing services-like DiDi, have also been introduced and this enhances the ease of using taxis in the target area. Digital Payment systems like IC card apps on smartphones or the physical IC cards (e.g., Suica, Pasmo, ICOCA) are used on trains in Shiga. In a few cases, the IC card is also used for payment on buses like Keihan bus plying Ishiyama routes in Shiga. The payment system is not fully integrated so the IC cards cannot be used on buses for some routes.

Also, commuter passes are available for trains and buses, with various subscription periods. Route and fare information are integrated and so it can be accessed via trip planner apps like Google maps, Jorudan, Navitime, Yahoo transit, etc. Public transport accessibility and connectivity is low in comparison to Kyoto, Osaka and Kobe. Ritsumeikan university, Ryukoku university, Shiga university teaching hospital, Panasonic company among others are located within the target area, and they generate trips around this transit corridor. Therefore, the introduction mobility schemes (like shared micro mobility, Mobility as a Service) to improve the door-to-door trip experience of the residents of this area is highly desired.

Table 3. 1 Transport service operators[1] in Otsu and Kusatsu

Rail (2)	Bus (3)	Rental Car (6)	Taxi (10)	Bicycle (10)
JR west Railway	Ohmi Railway Co., Ltd	Toyota Rent-a-car	Shiga MK Taxi	Katata Tourism Association
Keihan Railway	Teisan Hunan Transportation Co., Ltd	Nippon Rent-a-car	Shiga Yasaka Motor Co., Ltd	Ogoto Onsen Tourist Park
	Kojak Bus Co., Ltd	Station Rent-a-car (Ekirentaka)	Otsu Daiichi Kotsu Co. Ltd	Sakamoto Tourism Association
		ORIX Rent-a-car	Lake Biwa Taxi Co., Ltd	Optex Co., Ltd
		Times Car Rental	Kosei Transportation Co., Ltd	Nagisa Park Rental cycle
		Nissan Rent-a-car	Kyoritsu Taxi Co., Ltd	JR station rent-a-car (Station Rin-Kun)
			Miyako Taxi Co., Ltd	Biwaichi Support Salon
			Omi Taxi Co., Ltd	Biwako Hotel
			Sakura Taxi Co., Ltd	Otsu Prince Hotel
			Teisan Taxi Co., Ltd	Lake Biwa Otsukan

Sources: https://pluscycle.shiga.jp/, https://www.mapion.co.jp/phonebook/M12014/25206/, https://www.homemate-research-rent-a-car.com/25/

[1] The list of the transport operators in this area is not exhaustive.

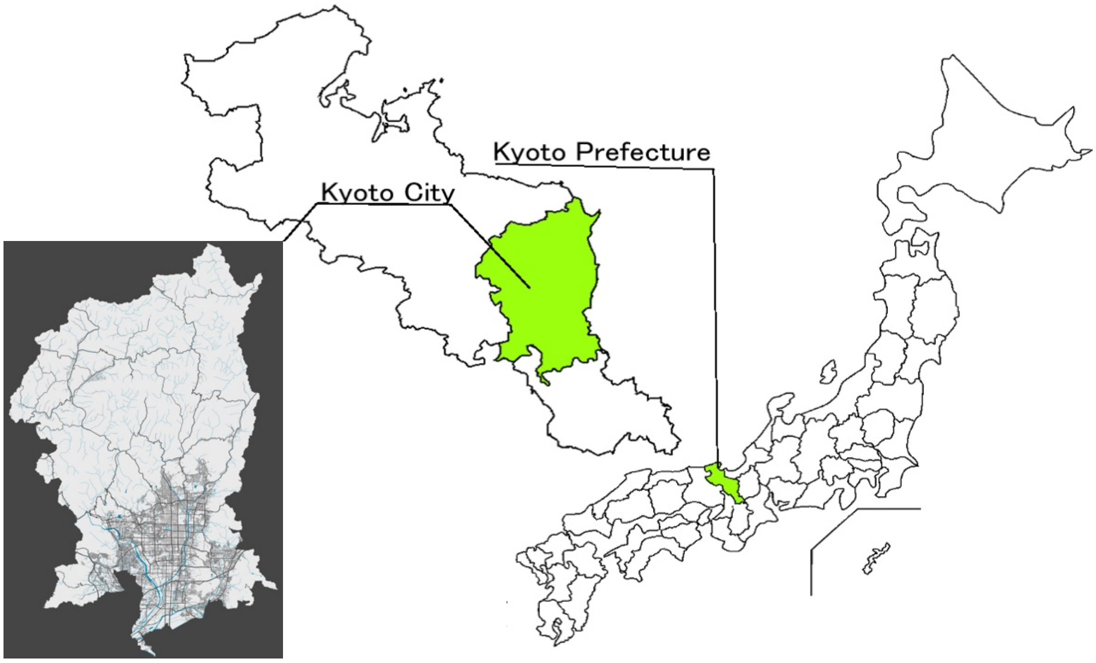


Figure 3. 2 Map of Kyoto showing the area under survey

(Sources: lifebeyondtourism.org, VectorStock.com)

3.2.3 Kyoto city – General

Kyoto prefecture consists of many cities, towns and villages, however the main city center and the seat of the Kyoto prefectural government is called "*Kyoto city*" (Figure 3-2). Kyoto city alone has a population of 1,463,723 persons. Kyoto city of Kyoto prefecture was selected because it possesses the features of an urban setting. Therefore, the coverage of the survey for this study was limited to Kyoto city only. Kyoto city (35°0'42"N, 135°46'6"E) is the center of tourist activities in Kansai region with numerous Japanese traditional sites. In 2019, about 88 million tourist who visited Kyoto for sightseeing activities (Statistica, 2022).

3.2.4 Transportation system

Kyoto city is the seat of government and commercial center of Kyoto prefecture and therefore attracts a lot of trips towards the central business district (Figure 3-2). The bus companies in Kyoto operate a flat rate system and the bus network is interconnected with the trains and subway stations. One day passes and other commuter pass packages are available for both bus and trains within Kyoto. Recently, micro-mobility shared services (for example, Luup e-scooters) have now been introduced in Kyoto city, which is easy to use by residents and tourist. Table 3.2 shows a list of transport operators in Kyoto; however, this list is not exclusive and exhaustive.

Table 3. 2 Transport service operators[2] in Kyoto city

Rail (5)	Bus (4)	Rental Car (8)	Taxi (10)	Rental Bicycle (10)	E-scooter (1)
JR west Railway	Kyoto City bus	Toyota Rent-a-car	Shiga MK Taxi.	Fuune.	Luup.
Keihan Railway	Kyoto Bus	Nippon Rent-a-car	Yasaka Taxis. Miyako Taxis.	Kyoto Cycling Tour Project (KCTP).	
Hankyu Railway	Keihan Bus	Budget car rental	Hijirikyoto-kanko Taxis.	Kyo no Raku Chari.	
	West JR Bus	ORIX Rent-a-car	Ecolo Taxi.	Tabi Chari.	
Kintetsu Railway		Times Car Rental	Gion Motor Co Ltd.	eMusica.	
Eizan Railway		Nissan Rent-a-car	Nagaoka Taxi.	Carillon Kitaoji.	
Keifuku Railway		MK heart rental car	Nagata Kyoto Taxi.	J-Cycle.	
Kyoto City subway		NicoNico rental car Kyoto	Ginrei Taxis.	Kyoto rental cycle	
		Hyakuen rental car	Kyoto Teisan Taxi.		

Sources: https://guidetokyoto.com/kyoto-public-transport/system/bus-train/ , Google map, http://www.cyclekyoto.com/bike-rental , https://luup.sc/#lp_area

[2] The list of the transport operators is not exhaustive.

3.3 Theoretical framework

Introducing a shared multi modal mobility scheme like MaaS comes in stages, each with its challenges and it is a continuous process hence this study is captioned *Implementing mobility as a service.* I identify key stages of the implementation of MaaS, they are, exploration, initial implementation and full implementation. At the exploration stage, the key stakeholders should define the terms of reference and the agreement about the overall objectives reached. Also, needs assessment and the feasibility of the project is done (putting the relevant considerations into account) to ascertain insights that inform policy and strategies for implementation. Next, is the initial implementation stage where pilots are conducted. Pilots presents an opportunity to implement at a small scale to evaluate the feasibility of the project, the costs and adverse events. This helps to improve the design of the MaaS package and business model prior to the full-scale implementation. Finally, the full implementation stage comes with the launch of the mobility service into the market and available for public use. In this study I focus on the exploration stage of MaaS implementation, where I conduct a feasibility study to ascertain the potential demand for MaaS (MaaS acceptance) considering the dynamic of a rural and urban setting. Hitherto, megacities and urban areas have been the focus for the implementation of MaaS. Furthermore, there is limited study in extending MaaS to suburbs or rural areas. Therefore, with these findings I contribute to literature and general discussion surrounding exploring MaaS prospects in the Asian context and in rural or suburban context. Furthermore, I investigate the determinants that influence the behavioral intention to use MaaS. Details of these peer reviewed journal papers are discussed in the subsequent chapters. These outcomes help for the development and conceptualization of sustainable MaaS models for both rural and urban areas. Implementing MaaS also depends on the availability and management of data. The benefits of carrying out feasibility studies on MaaS comparing rural and urban settings are, it reduces cost, saves time, encourages widespread adoption, improves livability in bed towns, provides strategies to improve rural accessibility.

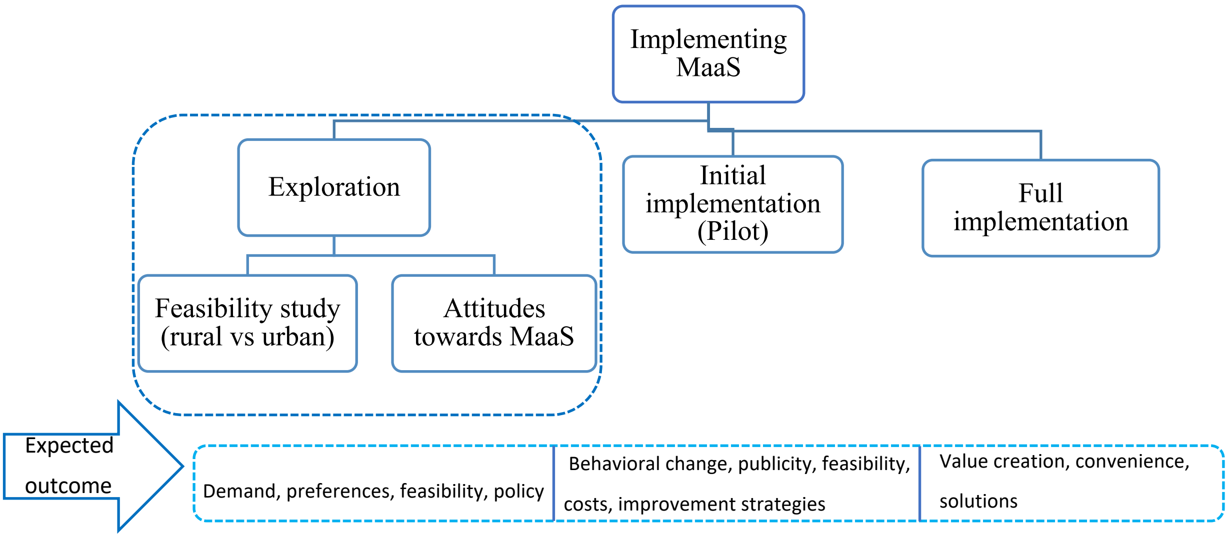


Figure 3. 3 Conceptual framework (source: Author)

3.4 Research models

I employ two research topics and by extension methods for this study. First, for the feasibility of implementing MaaS in rural/suburban areas and second, for investigating the determinant for the intention to use MaaS. I discuss the models used which are Tobit type 2 regression model also called a censored regression model and structural equation modeling (SEM) which is a multivariate statistical technique used to measure and analyze complex relationships of observed and latent variables. The details of the research models are discussed in Chapters 5 and 6.

3.5 Questionnaire design

3.5.1 Stated Preference survey

Stated Preference (SP) surveys have been used to examine consumer's preference or intentions to use a new service or willingness to pay for a product or service yet to be introduced into the market. Therefore, I adopted the online SP questionnaire style because of its benefits of time savings, cost savings and wider coverage. This online questionnaire is designed to primarily understand the current situation of the respondents' travel behavior, to examine their decision-making process when presented with new mobility solutions and to gather data on individual characteristics. The online questionnaire is structured as follows: Section 1 gathers information on travel characteristics of the respondents which includes, commuting trips, shopping trips, leisure trips as well as the frequencies and main modes used while making these trips. Section 2 presents the stated preference scenarios of the six hypothetical MaaS plans, and the amount users are willing to pay for each MaaS plan, and whether they will give up using car or return their licenses for these MaaS plans. The proposed plans are set to operate as a flat rate system with unlimited rides within the target areas while section 3 collects the personal information of the respondents.

By using a Likert scale respondent were asked their intentions to use MaaS, willingness to give up car or license. For example, I asked, if all trains, buses, taxis and rental bicycles providing unlimited service, operating in the target area are available for one month, would you like to purchase this MaaS plan? The respondents are expected to choose from the stated responses which are, *"I will buy it depending on the price"* or *"I will not buy it regardless of the price"*. For those who indicated that they would buy depending on the price, they are then expected to state how much they are willing to pay for that plan. Also, a 5-point Likert scale was used to test the strength to which they are willing to adopt MaaS. For example, to *"give up car"* or *"give up license"* the respondents answered by choosing from the following options. *1) I do not think so at all, 2) Not so much think, 3) Neither 4) I think so a little and 5) I think so.* These tailored MaaS packages are proposed based on the envisaged travel needs of the people and the transport services available and operational in the study areas.

3.5.2 Data collection

A structured online questionnaire containing six hypothetical MaaS subscription plans was administered to residents of Otsu and Kusatsu cities hereafter referred to as *Biwako valley* in Shiga prefecture (Figure 3-1) and Kyoto metropolitan City (Figure 3-2).

The respondents are persons who are registered as a web-monitor of Cross Marketing inc. (a survey company in Japan), and the condition of participation is, the individual must be living in the target areas. When these web-monitors are recruited, they are motivated to get rewards in the form of points upon completion of the survey. A stratified sampling technique is used for data collection, Cross Marketing Inc. ensured to reach same number of samples by gender and age groups.

In this study, the samples used consist of 560 individuals from the Biwako valley in Shiga prefecture (rural/suburban), collected over a period of seven days (from 1st to 7th of July 2019) and 1,012 individuals from Kyoto city (urban), collected over a period of eight days (from 29th October to 5th November 2019). The demographics of these samples are representative of the population of Shiga and Kyoto based on gender and age. In this study, Kyoto metropolitan city is referred to as urban while the Biwako valley area in Shiga prefecture is considered rural based on population density. The next chapter presents the preliminary results with discussions and comparisons between Kyoto city and Biwako valley. The sample of the online questionnaire is attached in the next section of this study (see Appendix 3A and 3B).

Appendix 3A

SURVEY

Questionnaire title: Questionnaire on a new fare system for public transportation*

Description: In this questionnaire, we will examine the acceptability of a new fare system for public transportation such as buses, trains, and cabs (also known as Mobility as a Service) among residents.

All survey responses will be statistically processed, and no personal information will be used for any purpose other than research. In addition, individual responses will not be leaked to outside parties or published in a form that identifies the individual in any way.

Appeal: Please cooperate with this questionnaire, as it will be an important document for the improvement of the transportation system in the Biwako valley area and Kyoto city.

Section one: Daily travel behavior						
1. What's your main trip purpose	Commute	Shopping	Hospital	Visiting family	Entertainment	Others
2. Do you have a driver's license?	Yes	No				
3. Do you own a Car?	Yes	No				
4. How often do you drive?	Everyday	5-6 times/week	3-4 times/week	1-2 times/week	Once a month	
5. How much is monthly expense on your car?	500 – 100,000 JPY					
6. Which navigation app do you use while driving?	Google map	Navitime	Yahoo map	Others		
7. What is your month expense on public transport?	500 – 100,000 JPY					
8. Do you have train commuter pass?	Yes	No				
9. What is the origin and destination stations?						
10. What is the validity of your commuter pass?						
11. How much is the commuter pass?						
12. Do you have a bus commuter pass?	Yes	No				
13. What is the origin and destination stations?						
14. What is the validity of your commuter pass?						
15. How much is the commuter pass?						
16. Do you use shared car services?	Yes	No				
17. Do you use shared bike services?	Yes	No				
18. What is the nearest station to your work or school?						
19. What is the nearest bus stop to you work or school?						
20. How often do you go to work or school?	Everyday	5-6 times/week	3-4 times/week	1-2 times/week		
21. What mode do you commute to school or work?	Bus	Car	Train	Bicycle	Walk	Other
22. How long does it take?						
23. Do you make shopping trips?	Yes	No				
24. What is the name of the store?						
25. How often do you go shopping?	Everyday	5-6 times/week	3-4 times/week	1-2 times/week		
26. What mode do use for shopping?	Bus	Car	Train	Bicycle	Walk	Other
27. How long does it take?						
28. Do you make hospital trips?	Yes	No				
29. What is the name of the nearest station?						
30. How often do you go to hospital?	Everyday	5-6 times/week	3-4 times/week	1-2 times/week		
31. What mode do use for hospital visits?	Bus	Car	Train	Bicycle	Walk	Other
32. How long does it take?						
33. What other purpose of travel do you make?						
Section Two: Proposed MaaS plans						
34. Please check the map and confirm if the station, bus stop, taxi stand rental and bike are in your vicinity.						
35. Would you buy monthly plan of unlimited train + bicycle?	Yes, depending on price	No, regardless of price				
36. If yes, how much will you pay for it?	500 – 100,000 JPY					
37. For which purpose will you use it?						
38. Would you buy monthly plan of unlimited bus + bicycle?	Yes, depending on price	No, regardless of price				
39. If yes, how much will you pay for it?	500 – 100,000 JPY					
40. For which purpose will you use it?						

41. Would you buy monthly plan of unlimited train + bus + bicycle?	Yes, depending on price	No, regardless of price
42. If yes, how much will you pay for it?	500 – 100,000 JPY	
43. For which purpose will you use it?		
44. Would you buy monthly plan of unlimited train + bus + bicycle + taxi (1,000 JPY at 5km radius?	Yes, depending on price	No, regardless of price
45. If yes, how much will you pay for it?	500 – 100,000 JPY	
46. For which purpose will you use it?		
47. Would you buy monthly plan of unlimited train + bus + bicycle + taxi?	Yes, depending on price	No, regardless of price
48. If yes, how much will you pay for it?	500 – 100,000 JPY	
49. For which purpose will you use it?		
50. Would you buy monthly plan of unlimited train + bus + bicycle + taxi + rental car?	Yes, depending on price	No, regardless of price
51. If yes, how much will you pay for it?	500 – 100,000 JPY	
52. For which purpose will you use it?		

Will you give up your car if these MaaS plans are introduced?					
53. Train + bicycle	I don't think so at all	I don't think so	Neither	I think so a little	I think so
54. Bus + bicycle	I don't think so at all	I don't think so	Neither	I think so a little	I think so
55. Train + bus + bicycle	I don't think so at all	I don't think so	Neither	I think so a little	I think so
56. Train + bus + bicycle + taxi (1,000 @ 5km)	I don't think so at all	I don't think so	Neither	I think so a little	I think so
57. Train + bus + bicycle + taxi	I don't think so at all	I don't think so	Neither	I think so a little	I think so
58. Train + bus + bicycle + taxi + rental car	I don't think so at all	I don't think so	Neither	I think so a little	I think so
Will you give up your driver's license if these MaaS plans are introduced?					
59. Train + bicycle	I don't think so at all	I don't think so	Neither	I think so a little	I think so
60. Bus + bicycle	I don't think so at all	I don't think so	Neither	I think so a little	I think so
61. Train + bus + bicycle	I don't think so at all	I don't think so	Neither	I think so a little	I think so
62. Train + bus + bicycle + taxi (1,000 @ 5km)	I don't think so at all	I don't think so	Neither	I think so a little	I think so
63. Train + bus + bicycle + taxi	I don't think so at all	I don't think so	Neither	I think so a little	I think so
64. Train + bus + bicycle + taxi + rental car	I don't think so at all	I don't think so	Neither	I think so a little	I think so

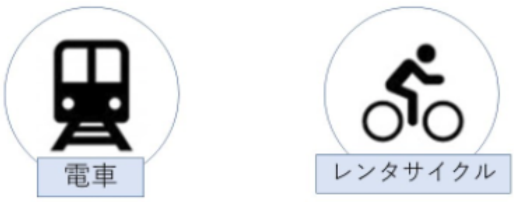
Section Three: Personal information							
65. Age	20s	30s	40s	50s	60s	70s	Above 80s
66. Sex	Female	Male					
67. Occupation	Student	Full time worker	Part time worker	Others			
68. Annual income	Low	Middle	High				
69. Household size							

**This questionnaire is originally in Japanese; it has been translated using the DeepL.com translator app.*

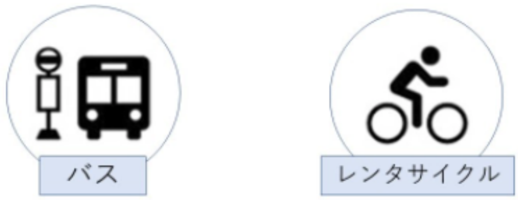
Appendix 3B

Screenshots of the MaaS plans as shown in the questionnaire

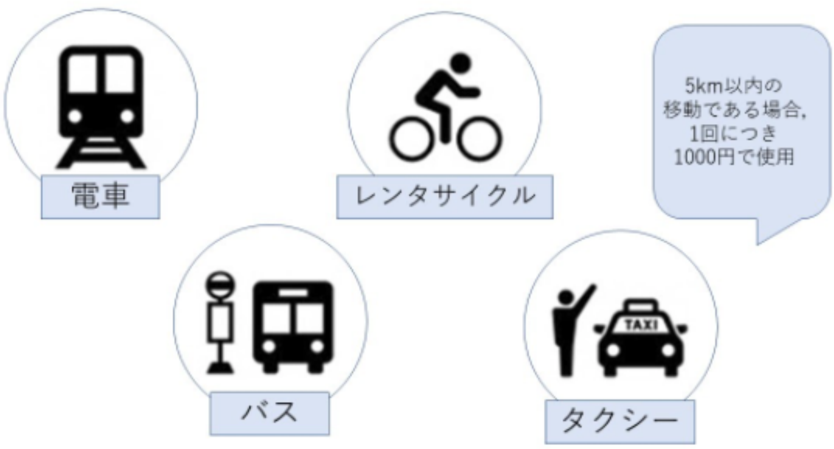
1. Train + bicycle



2. Bus + bicycle

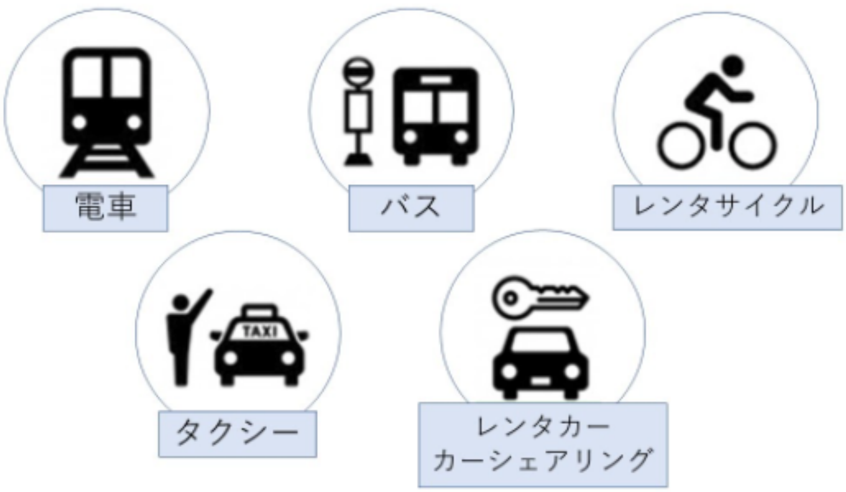


3. Train + bus + bicycle



4. Train + bus + bicycle + taxi – 1,000 @ 5km

5. Train + bus + bicycle + taxi



6. Train + bus + bicycle + taxi + rental car

Chapter 4

Basic results and comparative analysis

4.1 Introduction

This chapter focuses only on the description of the data collected and presents the results of descriptive statistical analysis. Also, a basic comparative analysis between the two datasets is done. This includes cross tabulations across the data of the Biwako valley and Kyoto city. The results from regression models and structural equation modelling are presented in the subsequent chapters.

4.2 Data description

The same questionnaire (see Appendix 3A in Chapter 3) was administered to the. Biwako valley and Kyoto city. The data in the Biwako valley area was collected via the online questionnaire for a period of one week, precisely from the 1st to 7th of July in 2019. Similarly, the data from Kyoto city was also collected for a week period, precisely from the 29th of October to the 5th of November in 2019. Even though these data were collected at different months in the year 2019, the period of the survey covered all the days of the week which may accounts for the daily travel patterns observed during weekdays and weekends. July and November are not holiday periods nor peak periods, so it is expected that the usual daily travel patterns would not be altered.

To draw a representative sample of the residents in these areas, a stratified sampling technique was deployed so that all segments of the population is included in the sample. For example, from the least driving age (18) to the elderly (over 80), and across all works of life, that is from students free-lance workers, to full time housewives to full time workers and then to the retired population.

Data was collected from 560 respondents in Shiga while in Kyoto city 1012 responses was collected. The questionnaire was originally in Japanese language; however, the responses were translated into

English language for the sake of this analysis. The next sections show the summary of the data for both Shiga and Kyoto.

The data collected comprises of personal information, travel characteristics and the attitudes towards MaaS. The personal information collected are the basic attributes of an individual like age, gender, occupation, income level, household composition, and car ownership. It is believed that the personal attribute of an individual greatly impacts their travel mode choices (Madhuwanthi, Marasinghe, Rajapakse, Dharmawansa, & Nomura, 2016). This categorical data was collected such that all the subcategories of the variables were included. For example, the age groups included the young, middle and elderly generations as shown in Table 4-1. The inputs of the elderly generation are needed because a part of the study area is an aging society. Next, the information about the travel behavior of the respondents were gathered. More specifically, I collected data about their habitual trip patterns. This includes the travel mode, trip purpose, trip frequency, driving frequency, travel costs and travel time. The data types here are a mixture of discrete variables (travel mode, trip purpose), ordinal variable (driving/trip frequency) and continuous variable (travel time and cost). Finally, the attitudes towards MaaS are measured via a stated choice and a 5-point Likert scale. Since MaaS is not operational in the study areas, it is expected that the respondents will make their decisions based on the prior knowledge of MaaS or from the information about MaaS provided in the questionnaire. Six MaaS plans were presented as shown in Appendix 3B, the respondents had to choose these three options: *I will buy depending on the price, I will not buy regardless of the price, or leave it blank* (no choice). To evaluate their attitudes towards MaaS, they had to choose whether to give up using private car or give up driver's license for any of the six MaaS plans via a 5-likert scale with these options; *1) I do not think so at all, 2) I do not think so, 3) Neither 4) I think so a little, 5) I think so.* After this they had the choice to state their willingness-to-pay for MaaS.

4.3 Shiga data

Table 4. 1 A summary of the descriptive statistics of the Biwako valley (Otsu and Kusatsu).

Demographic charateristics (Total: n = 560)		Sample frequency (n)	Percent sample (%)
Gender	Female	286	51.1
	Male	274	48.9
Age (years)	Young generation (18-29)	109	19.5
	Middle generation (30-59)	327	58.4
	Elderly generation (60-80 and above)	124	22.1
Occupational status	Full time worker	306	54.6
	Part time worker	59	10.5
	Student	36	6.4
	Unemployed	33	5.9
	Retired	8	1.4
	Housewife	118	21.1
Annual income (JPY)	Low income (0~3M)	284	50.7
	Middle income (3M~6M)	135	24.1
	High income (6M and above)	116	20.7
	No response	25	4.5
Household size	1 person	66	11.8
	2 persons	324	57.9
	3 or more persons	167	29.8
	No response	3	0.5
Car ownership	Car onwers	423	75.5
	Non-car owners	137	24.5
Driver's license	License holder	493	88.0
	Non license holder	67	12.0
Trip planner app used	Google map	149	26.6
	Navitime	64	11.4
	Jorudan	76	13.6
	Yahoo! Norikae annai	234	41.8
	Ekispert	23	4.1
	None	14	2.5
Commuter pass	Holders	155	27.7
	Non holders	405	72.3
Bus pass	Holders	13	2.3
	Non holders	547	97.7

The representativeness of Shiga data regarding age, gender and income was ensured (City population, 2020). As seen in Table 4-1 over 50% of the respondents are full time workers and from family households. Also, most of the respondents (41.8%) use Yahoo! Norikae annai app for trip information. It is not surprising that the Yahoo! Transit planner is more popular than google map in this part of the world. In Japan this app is well integrated and conveniently used by many trip makers.

4.4 Kyoto data

Kyoto prefecture has many areas that are not urban, however, as mentioned in Chapter 3, the focus of this study is the Kyoto main business district, that is Kyoto metropolitan city. Data was collected in a similar manner, and it comprises of the same type of data as that of Shiga. It can be observed from Table 4-2 that the composition of the characteristics of the respondents from Shiga and Kyoto city follow a similar pattern. Similarly, more of the samples were drawn from the middle generation group (that is between the ages of 30 to 59 years). About 40% of the respondents are full time workers while 44.3% are from family households. As expected, a greater percentage of the respondents (34.5%) use the Yahoo! Transit planner app to support their trip making decisions. It is interesting to note that with Kyoto data, there are more non-car owners (42.4%) in comparison to Shiga respondents (24.5%). Also, in Kyoto more people (8.4%) do not use any trip planner app at all which is surprising since we would expect the digital literacy in the urban areas to be higher. On the other hand, this could suggest that people in Shiga have limited options especially low frequency public transport services, so they are more likely use transit planner apps to assist for better decision making. The travel behavior of the residents of Shiga and Kyoto city are compared in the subsequent sections.

Table 4. 2 A summary of the descriptive statistics of Kyoto city.

Demographic charateristics (Total: 1012)		Sample frequency (n)	Sample percent (%)
Gender	Female	501	49.5
	Male	511	50.5
Age (years)	Young generation (18-29)	190	18.8
	Middle generation (30-59)	635	62.7
	Elderly generation (60-80 + above)	187	18.5
Occupational status	Full time worker	406	40.1
	Part time worker	117	11.6
	Student	99	9.8
	Unemployed	50	4.9
	Retired	15	1.5
	Housewife	151	14.9
Annual income (JPY)	Low income (0~3M)	557	55.0
	Middle income (3M~6M)	268	26.5
	High income (6M over)	183	18.1
	No response	4	0.4
Household size	1 person	226	22.3
	2 persons	333	32.9
	3 or more persons	448	44.3
	No response	5	0.5
Car ownership	Car onwers	583	57.6
	Non-car owners	429	42.4
Driver's license	Holders	800	79.1
	Non-holder	212	20.9
Trip planner app used	Google map	268	26.5
	Navitime	122	12.1
	Jorudan	132	13.0
	Yahoo! Norikae annai	349	34.5
	Ekispert	57	5.6
	None	84	8.3
Commuter pass	Holders	206	20.4
	Non-holders	806	79.6
Bus pass	Holders	68	6.7
	Non-holders	944	93.3

4.5 Comparative analysis of descriptive statistics

In this section I draw some comparisons between Shiga and Kyoto respondents in terms of their travel behavior and their attitudes towards MaaS. This is to understand the determinant characteristics of the individuals and have a sense of the likely factors that influences the decision to use MaaS in the future before going into an in depth analysis.

4.5.1 Travel behavior analysis

I make some assumptions that people who use public transport frequently will be more likely to try a new mobility scheme being introduced for public use. Also, IT enthusiast will be curious and more likely to try ICT enabled mobility solutions. It is based on these assumptions that we examine the respondent's daily travel behavior like what kind of trips do they make? Which travel mode do they use? Whether they have prior experience of using car sharing or bike sharing services. When focusing on commuting trips it is observed that more people use public transport for commuting in Kyoto than Shiga (Table 4.3). Furthermore, cycling to work is more convenient in Kyoto than in Shiga. This suggests that the built environment greatly influences the travel mode choice of the people. This is also buttressed in travel time for commuting and the monthly expenditure on travels as seen in Tables 4.4 and 4.5 respectively.

Table 4. 3 Summary of travel mode for commuting

Area	Bicycle	Bus	Bus/Train	Private car	Train
Shiga	15.2%	4.1%	6.1%	39.5%	35.1%
Kyoto	28.8%	13.1%	8.3%	19.7%	30.1%

Table 4. 4 Summary of commuting time by mode

Area	Mode	Avg, commute time (min)	S.D	max	min
Shiga	Car	32	20.44	150	5
	Public transport	49	30.12	150	5
Kyoto	Car	31	22.78	150	5
	Public transport	44	24.90	150	5

Table 4. 5 Summary of monthly travel cost by mode

Area	Mode	avg. cost (JPY)	SD	Max	Min
Shiga	Car	10095.18	11537.10	100,000	500
	Public transport	5548.81	8384.82	70,000	500
Kyoto	Car	11486.79	13501.20	100,000	500
	Public transport	5241.04	7319.23	70,000	500

4.5.2 Attitudes towards MaaS

The prior experience or behavior of the respondents towards shared mobility was examined to ascertain if such experience may influence their decision or perception of MaaS. Even though, the behavior towards Shared mobility is similar between Shiga and Kyoto, the nuances need in-depth study. However, it can be noticed that in Shiga there is a greater use of car sharing services (Figures 4.1 and 4.2). Similar trends are noticed about MaaS in both Shiga and Kyoto city in that, the more travel modes in the packages, the more the attractiveness, the more the acceptance and perceived benefits (Figures 4.3 to 4.9). This suggests that the composition of the MaaS plan plays a key role.

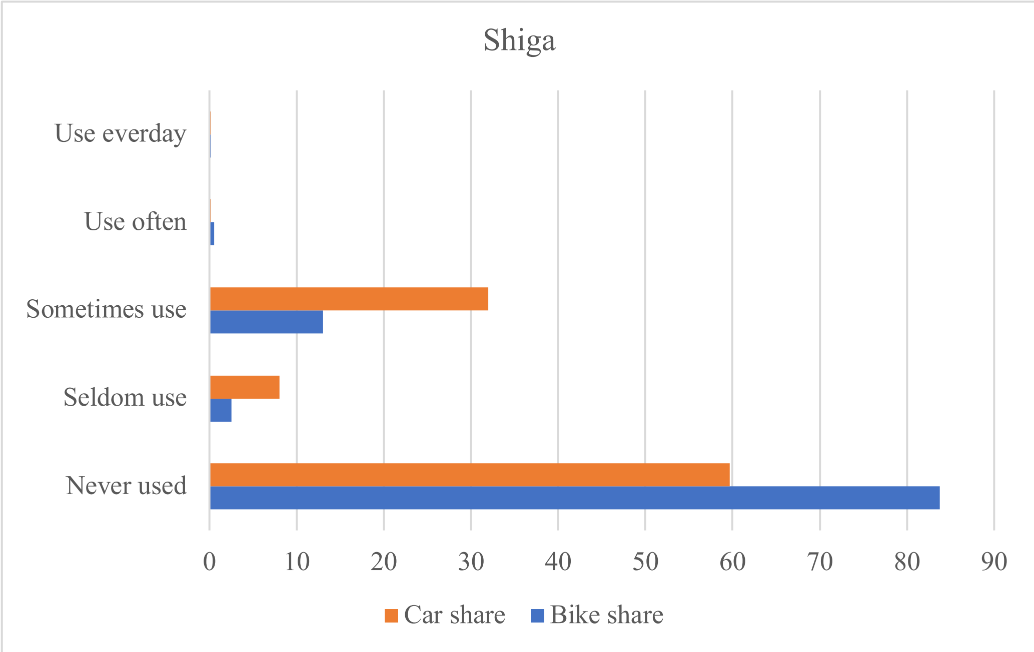


Figure 4. 1 Prior shared mobility experience in Shiga

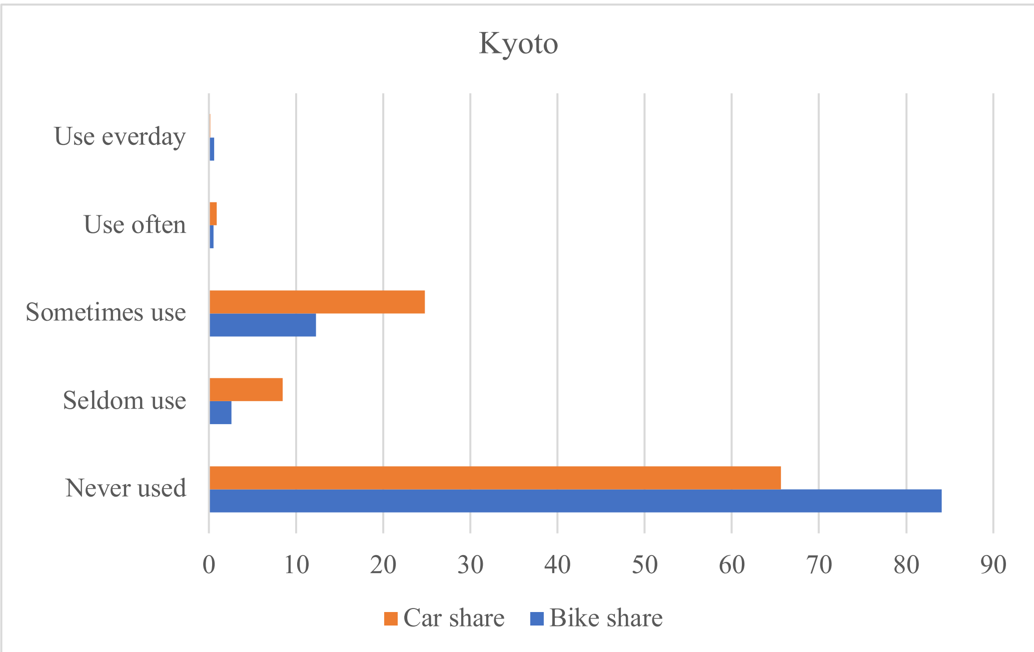


Figure 4. 2 Prior shared mobility experience in Kyoto city

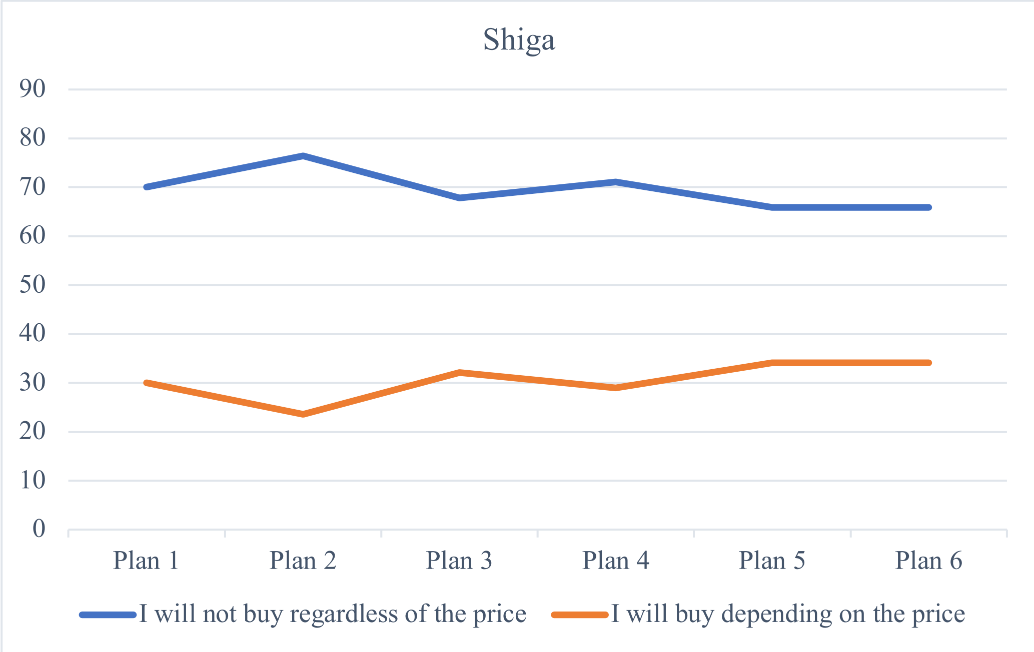


Figure 4. 3 MaaS acceptance in Shiga

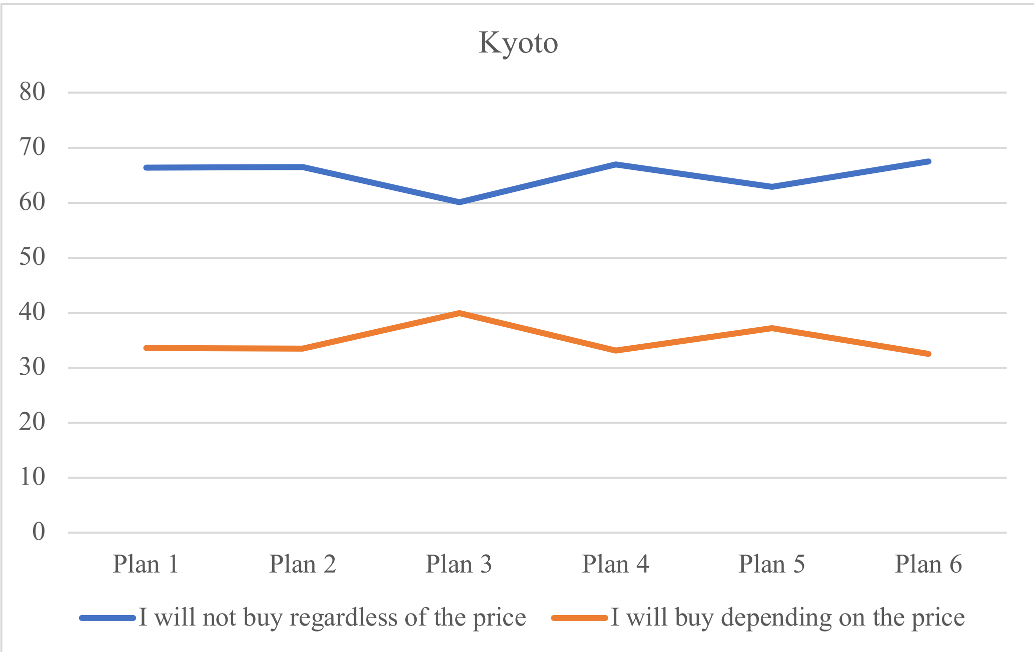


Figure 4. 4 MaaS acceptance in Kyoto city

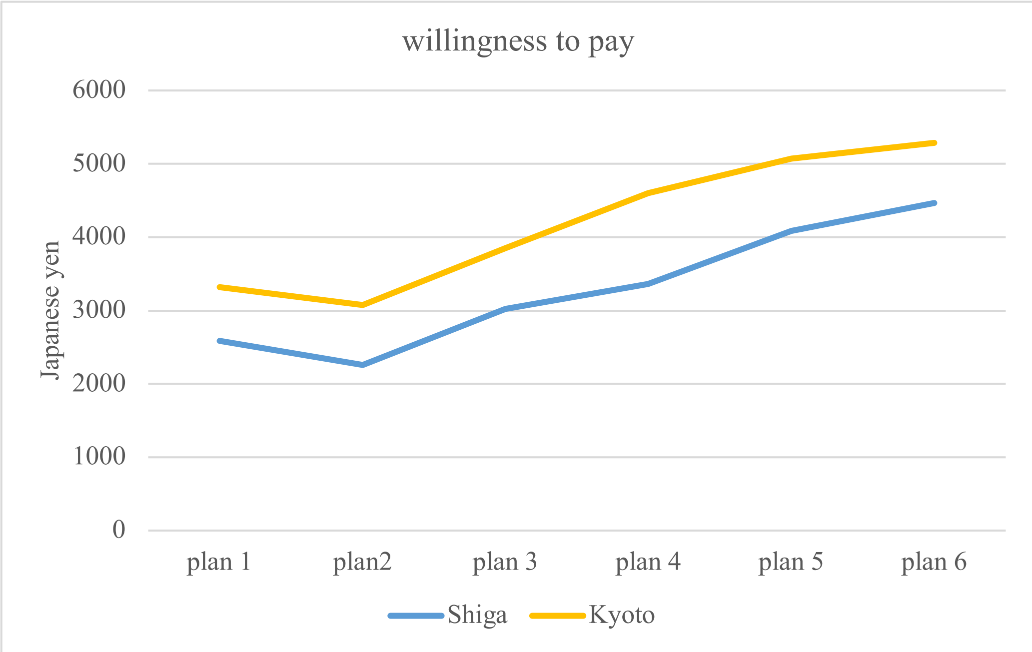


Figure 4. 5 Stated willingness to pay for the MaaS plans

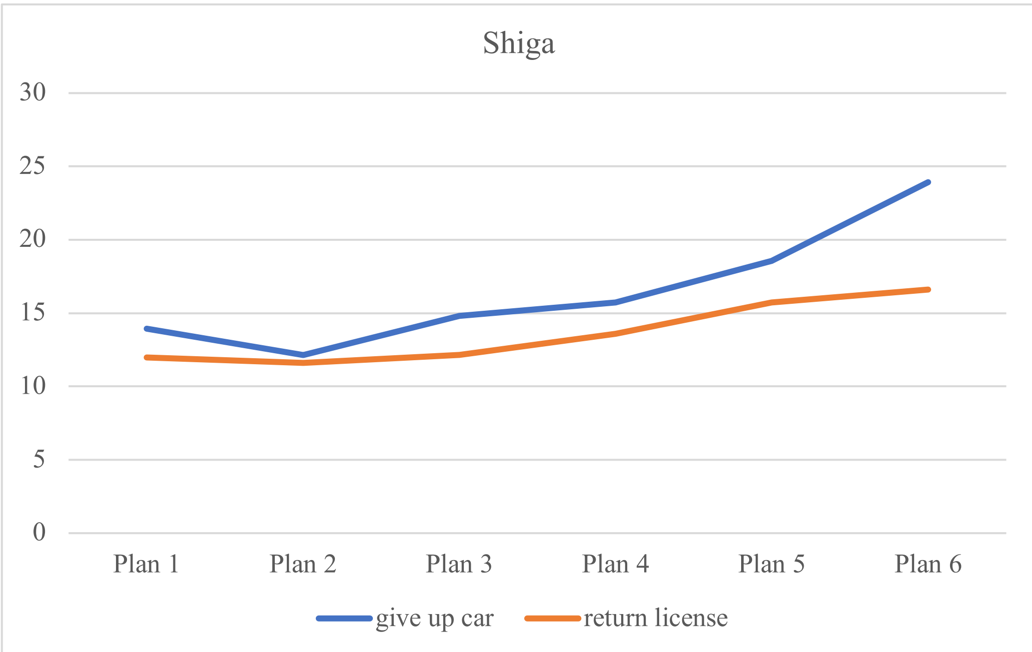


Figure 4. 6 Consumer attitude toward MaaS adoption in Shiga

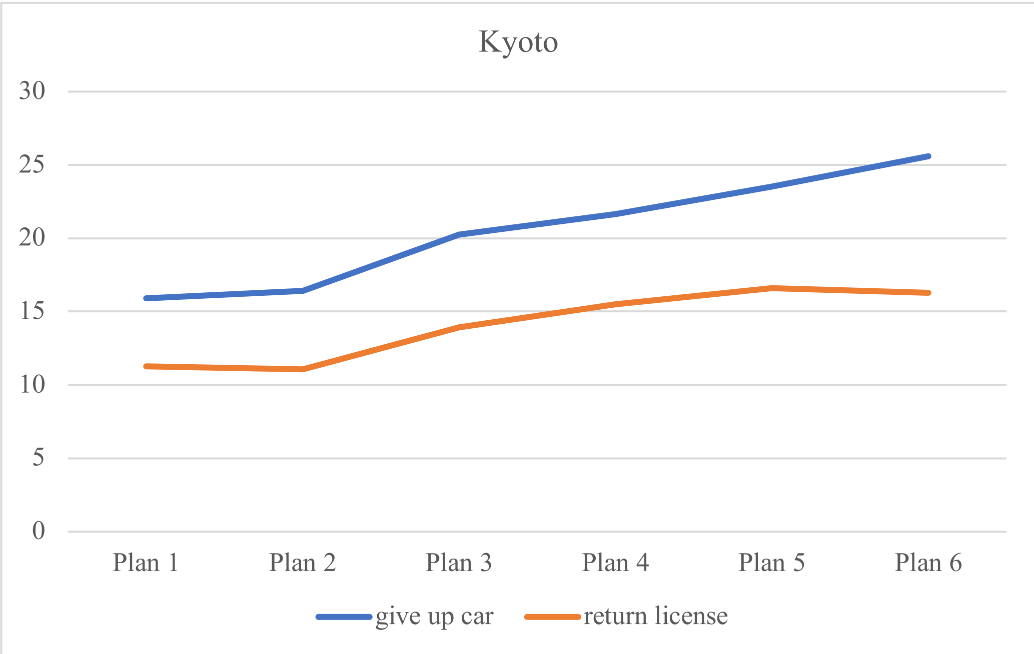


Figure 4. 7 Consumer attitude toward MaaS adoption in Kyoto city

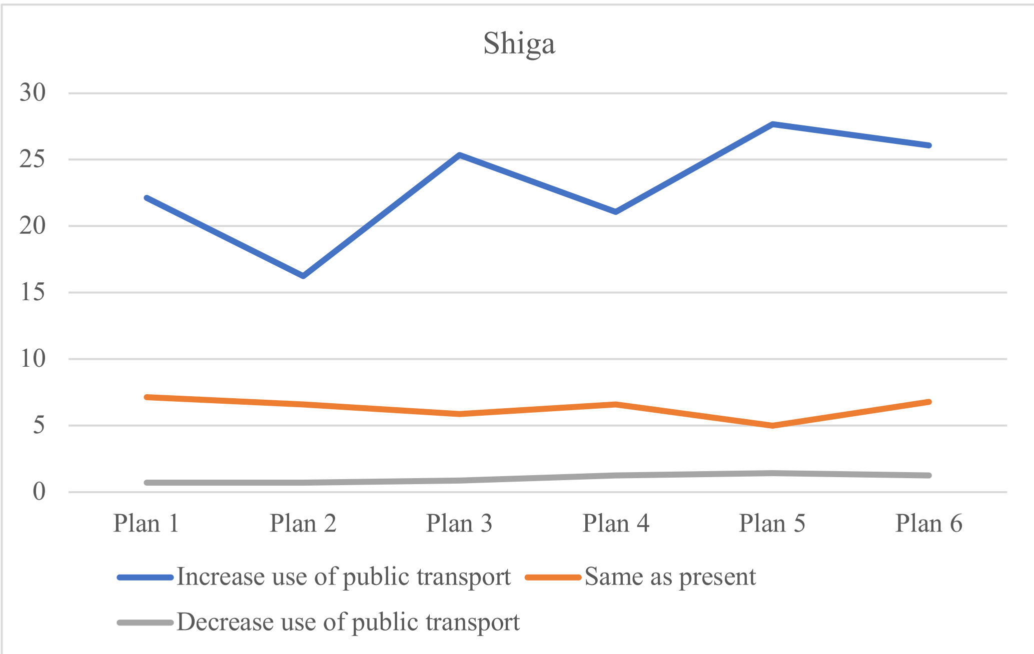


Figure 4. 8 Consumer perception about the impact of MaaS on public transport in Shiga

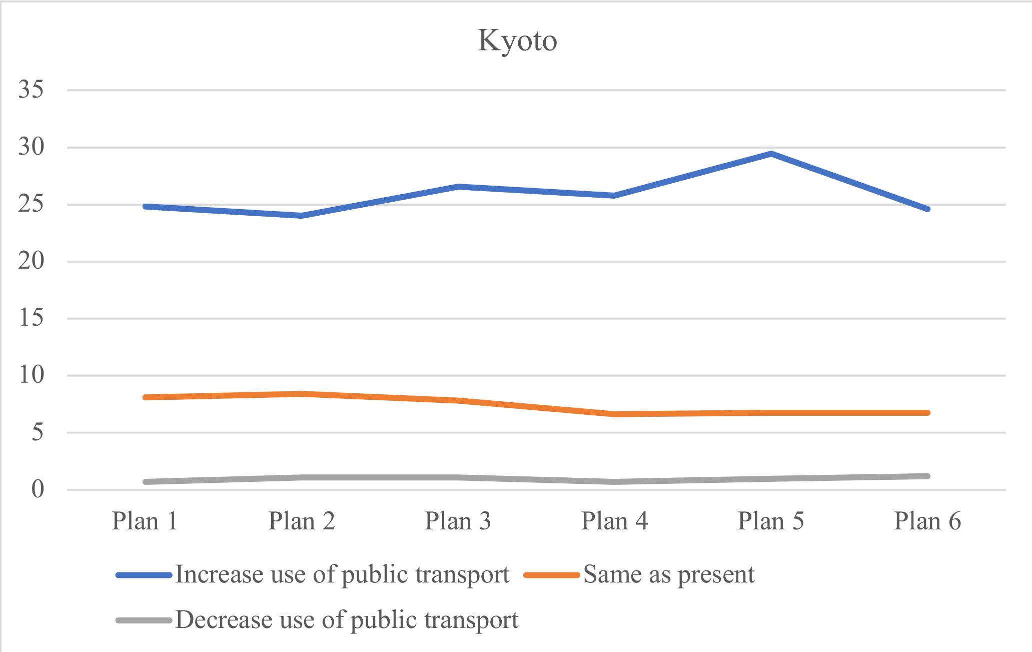


Figure 4. 9 Consumer perception about the impact of MaaS on public transport in Kyoto city

4.6 Brief discussion

It is evident that there is a growing awareness for the need for sustainable means of travel. As the dynamics of our living environment and work lifestyle is constantly changing people are becoming more willing to evolve with the current trends. Even though people who mostly have never used similar services and have strong attachments to the use of private cars, are curious enough to try MaaS. A significant percentage in both Shiga and Kyoto are willing to try out MaaS if the pricing is competitive. The MaaS plans with single modes (plan 1 and plan 2) were introduced as proxies to the MaaS concept, since MaaS is new, and we could not guarantee absolute comprehension of the concept from the respondents. These plans like the others still had the unique features like flat rate system and unlimited use in a month. As expected, we noticed the consumer's sensitivity to the price, and this spurs the need for further investigation. It is interesting to note that a significant amount of the residents believes that these schemes when introduced, it will have a positive impact on the use of public transport.

Chapter 5

Mobility as a Service in Suburban Areas: A focus on MaaS adoption and willingness to pay

5.1 Introduction

This chapter is based on the feasibility study to explore and understand the preferences of the intended users, potential demand and willingness-to-pay (which also represents the value the consumer places on) for MaaS in suburban areas. A feasibility study is simply the analysis of the viability of a proposed project. In this case, we hope to determine whether to go ahead with the idea of MaaS under consideration in the suburbs. This study focuses on answering that question from a demand point of view using Shiga as a case study. An online stated preference choice survey was conducted, and data was collected from 560 residents in the *Biwako valley*[3] for this analysis.

5.2 Background

Transportation systems continue to evolve as time progresses. Most recently, global trends like climate change, urbanization, digitization, sharing economy and technological innovations have birthed a new mobility concept called Mobility as a Service also known as MaaS (Goodall, Fishman, Bornstein, & Bonthron, 2017). Hitherto, mobility services were purchased separately but the advent of MaaS brought in new players-mobility aggregators or integrators who combined transport services into packages for users. Mobility aggregators like MaaS global in Finland have integrated shared mobility and public transit into a single platform, allowing users to buy mobility packages for a month according to their specific needs.

There is still ambiguity about the generally accepted definition of MaaS, however, some experts have defined MaaS based on their objectives and priorities. For example, according to (IRU, 2019) and

[3] *For this study, this is a name referring to Otsu city and Kusatsu city in Shiga prefecture.*

(MaaS Alliance, 2019) Mobility as a Service (MaaS) is the integration of various forms of transport services into a single mobility service accessible on demand. In the same vein, (Hietanen, 2014) describes MaaS as the convergence of transportation services which are tailored to users' needs as monthly packages like a mobile phone contract. These offerings are packaged as monthly subscription plans or pay-as-you-go. Furthermore, (Sochor, Arby, Karlsson, & Sarasini, 2018) proposed a MaaS topology for better understanding of the MaaS concept. It has different levels of integration which are as follows, integration of information (multimodal travel planner, price, info), integration of payment systems, integration of offered services and integration of societal goals. This is in tandem with the core characteristics of MaaS which are the integration of modes, travel information and booking/payment systems (Sochor, Arby, Karlsson, & Sarasini, 2018).

In this study, we shall attempt to define MaaS as the integration of available transportation services in any given place which is packaged into monthly plans so that customers can purchase according to their travel needs.

Mobility as a service (MaaS) started in Helsinki, Finland in 2014 and has received great attention around the globe. Consequently, MaaS has been piloted in Gothenburg, Vienna, Hanover among others, while other cities are making plans to try it. Lessons learned from the field operational test of MaaS pilots in Finland and Sweden showed increased usage of public transport and increased trips to new destinations (Sochor, Karlsson, & Strömberg, 2016). Still, there is limited research in MaaS schemes to adequately ascertain its successes. Transport planners, transport operators, authorities and policymakers are interested and concerned about the sustainability of the MaaS business model, demand for MaaS and users' willingness to adopt MaaS. These concerns beg the following questions: who will use MaaS and for what trip purpose? Where is it suitable to implement MaaS? What combination is suitable in a MaaS package?

MaaS has the potential of reducing traffic congestion and CO_2 emission by significantly cutting down on the use of private cars, which in turn makes a city more environmentally friendly. MaaS promises to be a competitive alternative to owning a private car, for example, the Whim Unlimited Plan of MaaS scheme operating in Helsinki offers unlimited rides on public transport and shared mobility for a month. This plan provides convenience, flexibility and comfort that arguably meets every need for private car and at a lower cost. In the development of sustainable societies/better livable environments, shifting the people's mindset from ownership to usage will have beneficial consequences in the long term.

Traffic congestion has evolved in auto-reliant suburban areas because many people use their cars to move around. Suburban areas with large car owners seek to explore MaaS as a possible solution to reduce this trend.

The purpose of this study is to examine the possibility of introducing Mobility-as-a-Service (MaaS) in suburban areas. This feasibility study aims to understand the residents' attitude towards adopting MaaS, the potential demand for MaaS, users' perception/preferences for MaaS and the willingness-to-pay for MaaS subscriptions plans. We take a case study of two cities Kusatsu and Otsu in Shiga prefecture of Japan. It is hoped that useful insights will be utilized from this study for the development and implementation of MaaS in suburban areas.

5.2.1 Implementing MaaS: prospects and challenges

Implementing MaaS requires governments, stakeholders and the private sector collaborating to achieve a common goal. The authorities must enact laws or enabling policies that support MaaS, transport operators and other key players must collaborate, share needed information to enable aggregating these transport services (Hensher, 2017). For example, the open data policy helped in the implementation of MaaS in Helsinki (Li & Voege, 2017).

Even though the MaaS concept is still evolving, many MaaS pilots are springing up in a bid to understanding the best model. MaaS aims to significantly cut down car ownership and encourage the use of public transport and or shared mobility by providing flexibility and convenience with user tailored mobility packages. On the other hand, MaaS has also been proposed as a catalyst for promoting an environmentally friendly society. This concept could change the paradigm from owning to usage. For the authorities, MaaS could reduce congestion, pollution and utilize urban space for parking. For the operators increased usage would sustain the business model and create room for innovative business solutions and the users it creates expanded destination choices, flexible options, convenience, and seamless travel experience. Results from MaaS pilots in Sweden indicates a positive shift towards public transport or shared mobility (Smith, Sochor, & Karlsson, 2018).

Since MaaS is new in most places, acceptability and market penetration is a real concern. Some of the challenges of implementing MaaS are given below as follows:

1. Even though in most cases, already existing transport services are used for the integration, new technologies must be procured like a smartphone app, webpage platform, payment systems, devices, and equipment as well as investments in infrastructure. This comes with huge cost implications which private companies or government are skeptical to bear.
2. Incentivizing the scheme is crucial to attracting users nevertheless, in a place where there is no subsidy, profitability of the scheme is questioned.
3. More so, getting the operators to work together or share information to a third party is challenging.
4. Also getting the users who already use other transit apps to abandon them and adopt a new app is difficult (Li & Voege, 2017).
5. Most of the pilots were implemented in cities, urban areas with multimodal transport networks, it is unclear if MaaS can be implemented in the rural or suburban areas.

On the other hand, the highlighted prospects of MaaS includes but not limited to the following:

1. reduction in traffic congestion,
2. reduction in CO_2 emissions and mitigating the impact of global warming,
3. improve the livability of a settlement and its environment,
4. increased ridership on public transport,
5. serves as a good catalyst for springing up new businesses within the ecosystem,
6. provide flexibility, convenience and seamless door-to-door travel and a better experience for the users (Kamargianni , Li, Matyas, & Schäfer, 2016).

5.2.2 Willingness-to-pay for MaaS

The willingness-to-pay for goods or services to a greater extent reflects the value the consumer attaches to it. In other words, the (potential) buyer makes a choice influenced by the attractive attributes of that product, among other alternatives. WTP can be defined as *the highest price an individual is willing to accept to pay for some goods or services* (Breidert, Estimation of willingness-to-pay. Theory, measurement, and application, 2005). The knowledge of WTP from likely customers plays a crucial role in pricing decision or strategy of the new product or service to be introduced. Nevertheless, it is important to note that, WTP values from consumers under experimental conditions may not be realistic to use in a real market situation.

Good WTP estimates test the customers' perception of added value or unique attributes of the goods or services against competing alternatives. Actual purchase data are good to derive WTP estimates, however, for new or hypothetical products like introducing a new mobility scheme, observing previous purchase behavior of similar service can be used to make predictions (Breidert, Hahsler, & Reutterer, 2006). Studies have shown that 8 to 15% of all companies derive a pricing strategy based on potential customers' response behavior (Monroe & Cox, 2001). In transportation studies, discrete choice analysis is used in WTP estimations where the respondents choose between alternatives in a choice set. The price variations are included as attributes contributing to the utility function at each price level. The probability of choosing a particular alternative is expressed by the multinomial logit model (Ben-Akiva & Lerman, 1985)

(Vij, Ryan, Sampson, & Harris, 2018) argued that in Australia, consumers prefer the pay-as-you-go schemes more than the unlimited plans, whereas, in London, the reverse is the case. Creating MaaS packages that is suitable for all proves to be challenging nevertheless, trying out MaaS in various cities may be the only way to ascertain the sustainability of this scheme. Therefore, it is important to understand the specific aspects that play out in any given city in terms of feasibility, acceptability, behavioral aspects, package design, profitability and willingness-to-pay to successfully introduce MaaS. In this study, we attempt to do this taking a case study of Otsu and Kusatsu.

5.3 Methodology

5.3.1 Data collection

Data was collected over seven days from 560 individuals living in the Biwako valley using an online questionnaire. We adopted an online survey because of the wide reach, time and cost-efficiency. A stratified sampling technique was used for data collection and ensured a representative sample for gender and age groups.

The respondents were expected to choose from any of the six (6) MaaS plans proposed, comparing them with their current travel mode (private cars for the case of car owners). The monthly costs on cars as represented in the questionnaire, are estimates which considers purchase of the car, gasoline, taxes, maintenance and parking fees. These MaaS packages are proposed based on the envisaged travel needs and transport services operating within the study area. The proposed plans are set to operate as a flat rate system with unlimited rides within the target area (Table 5.1).

Table 5. 1 Proposed MaaS subscription plans

MaaS Plans (flat rate within the target area)	Intention	WTP (JPY)*
1. Train + Rental Bike	○buy ○will not buy	0-100,000
2. Bus + Rental Bike	○buy ○will not buy	0-100,000
3. Train + Bus + Rental Bike	○buy ○will not buy	0-100,000
4. Train + Bus + Rental Bike + Taxi (5km @ ¥1000)	○buy ○will not buy	0-100,000
5. Train + Bus + Taxi + Rental Bike	○buy ○will not buy	0-100,000
6. Train + Bus + Taxi + Rental Car + Rental Bike	○buy ○will not buy	0-100,000

**Exchange rate: 1USD =108 JPY*

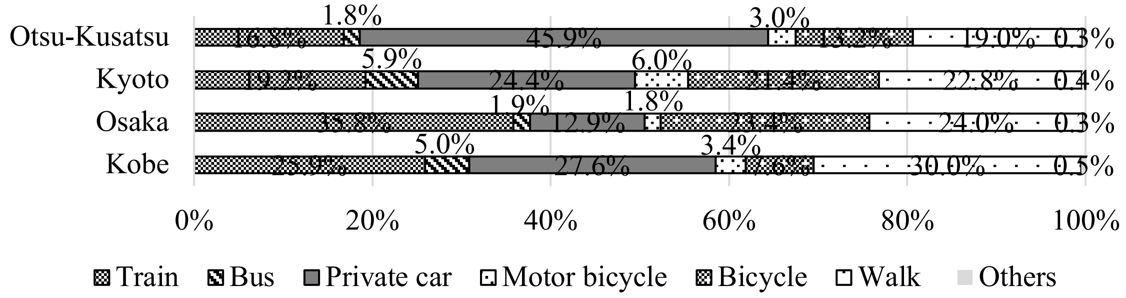


Figure 5. 1 Mode share in the Kansai region

The motivation for the combinations in the proposed packages is based on the modal share data in this region. Train and bus are mostly used for commuting whereas bicycle and walking are mostly used as an access and egress modes (Figure 5.1).

5.3.2 Background on mode choice methods

The concept of choice in the transportation and economics sectors is studied largely using discrete choice models which includes multinomial logit model (MNL), nested logit models and probit models (Ben-Akiva & Lerman, 1985) , (Bierlaire, 1998). These models are based on random utility maximization which is derived from econometric theories. Furthermore, these models examine consumer behavior which is applied in economics and transportation planning. However, they have received some criticism because of its major limitations which are; model structure is predefined in advance which does not account for partial relationships between explanatory variables, inability to model complex non-linear relationships and patterns cannot be extracted from subgroup of observations except for conditions that hold across the whole population (Xie, Lu, & Parkany, 2003). Consequently, soft computing techniques emerged and have been employed for travel mode choice analysis. These machine learning techniques like artificial neural networks (ANN) and decision trees (DT) have achieved better results and alleviates the aforementioned limitations (Xie, Lu, & Parkany, 2003), (Chalumuri, Errampalli, Bujangan, & Subamay, 2009). For example, a comparative study conducted by (Xie, Lu, & Parkany, 2003) using work related travel data revealed that artificial neural networks (ANN) yielded a better result compared to multinomial logit (MNL) model.

5.3.3 Discrete Choice Models

Disaggregated models also known as Discrete Choice Models refers to the choice behavior of the decision-maker, in this case the individual. Discrete Choice Models (DCM) captures how individuals make choices (i.e. the outcome of a successive decision-making process) and this is guided by a set of assumptions. Referring to (Ben-Akiva & Bierlaire, 2017), (Bierlaire, 1998), (Ben-Akiva & Lerman, 1985) the assumptions are presented as shown below:

i. the decision-maker – defining who the decision-maker is and his/her characteristics,

ii. alternatives – determining the available option to the decision-maker,

iii. attributes – measuring the costs and benefits of any of the alternatives to the decision-maker,

iv. the decision rule – describing the process the decision-maker uses in choosing an alternative.

1. Decision-maker: The decision-making entity can either be an individual or a group such as family, household or an organization. In considering the decision-making entity as a group, the internal interactions of group members or the differences in preferences of the members of

the group are ignored. The outcome of their decision is usually influenced by the dominant member, for example the breadwinner of the family. In the case where the individual is the decision maker, usually referred to as disaggregate model, the individual's characteristics such as age, gender, education and income are considered to influence the outcome.

2. Alternatives: This refers to a set of alternatives available to the decision-maker during the decision process. It is assumed that the decision-maker chooses an alternative from a universal set of alternatives called the choice set. The choice set is termed as discontinuous because there exist a discrete number of alternatives within the choice set. This is determined by the environment of the decision-maker, feasibility of the alternative and knowledge of the existence of an alternative.
3. Alternative Attributes: The attributes of an alternative are the characteristics or features of the alternative that influences the utility function related to that alternative. This influences the overall attractiveness of the alternative. Some of these attributes may be generic to all alternatives or specific to a particular alternative. Examples of these attributes in relation to travel demand modelling are travel time, travel cost, waiting time, number of transfers and comfort levels.
4. Decision Rule: This is the process the decision-maker uses to evaluate the attributes of the alternatives in the choice set and determines the outcome. There are many decision rules proposed by researchers like (Ben-Akiva & Bierlaire, 2017), (Ben-Akiva & Lerman, 1985), (Slovic, Fischhoff, & Lichtenstein, 1977) and (Svenson, 1979) some of which includes dominance theory, satisfaction theory, utility theory and lexicographic rules. However, the utility theory is more popular, and most models use it for travel behavior applications. It works

on the assumption that the individual chooses the alternative with the highest utility (Ding & Zhang, 2016).

5.3.4 Random Utility

The random utility approach as expressed by (Manski, 1977) corresponds with economic consumer theory, in that the decision-maker has a perfect discrimination capability, in other words the decision maker can choose the alternative that offers the highest utility. However, it is assumed that the decision maker do not have complete information, hence, uncertainty must be taken into account. The four sources of uncertainty or randomness as suggested by (Manski, 1977) are; unobserved alternative attributes, unobserved individual characteristics (unobserved taste variations), measurement errors and imperfect information and instrumental (proxy) variables.

The utility is modeled as random variable to show this uncertainty. Therefore, the utility *U* that the individual *n* associated with alternative *i* in the choice set C_n is given as

$$U_{in} = V_{in} + \varepsilon_{in} \tag{5.1}$$

Where V_{in} is the deterministic or systematic part of the utility and ε_{in} is the random term which captures the uncertainty. The utility with the highest utility is chosen, therefore, the probability that alternative *i* is chosen by the individual *n* from the choice set C_n is given as

$$P(i|C_n) = P\left[U_{in} \geq U_{jn} \forall\, j \in C_n\right] = P[U_{in} = \max_{j \in C_n} U_{jn}] \tag{5.2}$$

For logit models the means of the random terms are assumed to be equal to a convenient value *c*, usually zero or the Euler constant γ. Suppose we denote the mean of the error term of alternative *i* by $m_i = E[\varepsilon_{in}]$, then we can define a new random variable $e_{in} = \varepsilon_{in} - m_i + c$ such that $E[\varepsilon_{in}]$ = c. So, we have

$$P\left[U_{in} \geq U_{jn} \forall\, j \in C_n\right] = P[V_{in} + m_i + e_{in} \geq V_{jn} + m_j + e_{jn} \,\forall\, j \in C_n] \tag{5.3}$$

The deterministic part of the utility function is given as $V_{in} + m_i$ and the random term are e_{in}(with means c). the term m_i are included as the Alternative Specific Constant (ASC) which captures the mean of the random terms. Therefore, it is assumed without any loss of generality that the error terms of random utility models have a constant mean c by adding ASCs in the deterministic part of the utility functions.

Generally, in terms of transportation analysis, the utility function is derived as the weighted sum of attributes corresponding to the alternatives which can be expressed as;

$$U = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \tag{5.4}$$

Where;

U is the utility corresponding to an alternative,

α is the Associated Specific Constant (ASC) which represent all the unobserved sources of the utility. Including ASCs to the model allows for the control of the unobserved attributes that may corelate with the observed covariates (Klaiber & Haefen, 2016),

$\beta_1, \beta_2, \beta_n$ are the parameters which defines the direction and importance of the effects of the attribute on the utility of an alternative, and

x_1, x_2, x_n are the values of the attributes of an alternative.

5.3.5 Multinomial Logit Model

(Keane & Wasi, 2012) Pointed out that the random parts of the utility functions derives many potential models like models within the logit family for examples Binary Logit Model, Multinomial Logit Model, Nested Logit Model, Cross Nested Model and Generalized Extreme value Model, which are based on the probability distribution of the maximum of a set of random variables, introduced by Gumbel and while the Probit-like models used for binary outcomes which is based on normality assumptions motivated by the Central Limit Theorem (Ben-Akiva & Bierlaire, 2017).

Logit model was first introduced in the context of binary choice where the logistic distribution was used. The generalization into more than two alternatives is referred to as Multinomial Logit Model (MNL). The derivation of MNL assumes that the error terms of the utility functions are independent and identically Gumbel distributed (Bekhor & Shiftan, 2009).

i.e. ε_{in} for all *i,n* is distributed as:

$$F(\varepsilon) = \exp\left[-e^{-\mu(\varepsilon-\eta)}\right], \mu > 0 \tag{5.5}$$

$$f(\varepsilon) = \mu e^{-\mu(\varepsilon-\eta)} \exp\left[-e^{-\mu(\varepsilon-\eta)}\right] \tag{5.6}$$

Where η is a location parameter and μ is a strictly positive scale parameter. The mean of this distribution is

$$\eta + \gamma/\mu$$

Where

$$\gamma = \lim_{k\to\infty} \sum_{i=1}^{k} \frac{1}{i} - \ln(k) \cong 0.5772$$

Is the Euler constant. The variance of the distribution is

$$\pi^2/6\mu^2.$$

The probability of a an individual *n* who chooses an alternative *i* within the choice set C_n can be expressed as

$$P(i|C_n) = \frac{e^{\mu V_{in}}}{\sum_{j\in C_n} e^{\mu V_{jn}}}. \tag{5.7}$$

5.3.6 Estimation Methods

There exist many approaches to finding estimators however, most often, maximum likelihood estimation and least squares estimation methods are used.

5.3.6.1 Maximum likelihood

This is a general and straight forward method for finding estimators, simply put, *a maximum likelihood estimator is the value of the parameters for which the observed sample is most likely to have occurred.* The likelihood of the sample as a function of the parameters θ can be expressed as, if the observations are drawn independently and at random from the population and that the observed values ($\mathbf{x}_n's$) are nonstochastic, thus;

$$\mathcal{L}^* = \prod_{n=1}^{N} f(y_n|\mathbf{x_n}, \boldsymbol{\theta}) \tag{5.8}$$

The maximum likelihood estimators have some properties under the following general assumptions;

1. they are consistent,
2. they are asymptotically normal,
3. they are asymptotically efficient, and hence their asymptotic variance is given by the Cramer-Rao bound.

5.3.6.2 Least square

The least square estimation is mostly studied in cases of linear regression. Generally, the least square estimators are referred to as those values $\boldsymbol{\Theta_N}$ that minimizes the sum of squared differences between the observed and the expected values of the observation. This is expressed as $\boldsymbol{\Theta_N}$ is a least square estimator for $\boldsymbol{\theta}$ on the condition that it is solution to

$$\min_{\theta_N} Q = \min_{\theta_N} Q \sum_{n=1}^{N} (y_n - \mathcal{E}[y_n|\theta_N, x_n])^2 \tag{5.9}$$

Where $\mathcal{E}[y_n|\boldsymbol{\theta}_N, \mathbf{x}_n]$ is the expected value of y_n conditional on $\boldsymbol{\Theta_N}$ and $\mathbf{x_n}$.

Details of these estimation methods are found in (Ben-Akiva & Lerman, Discrete Choice Analysis: Theory and Application to Travel Demand, 1985).

5.3.7 Estimation model

Discrete choice models like Logit, Probit and Tobit are used to estimate the relationships that contain variables that are non-metric or consists of a lower or upper limit. Logit and Probit are used for binary or two or more outcomes while Tobit is a form of linear regression that the dependent variable is constrained or censored such that it takes a positive value for some observations and zero for other observations. These models usually employ maximum likelihood estimation method to estimate the parameters as discussed in the previous section.

This study uses the Tobit type II model (also known as Heckman's standard sample selection model), which is a censored regression model. Tobit type II model is commonly used in economics and transportation fields, especially in cases of sample-selection bias. Refer to (Heckman, 1976), (Heckman, 1979) and (Amemiya, 1984) for details on this model.

In this method, we utilize the Maximum Likelihood Estimation (MLE) technique to estimate the parameters in the model.

5.3.8 Tobit type II model

This regression model is suitable when the dependent variable is bounded at one of the extremes, that is when the dependent variable is binary (bounded at between 0 and 1). It assumes normality however has a limitation which is assumes that the processes in both regimes of the outcome are equal to a constant of proportionality.

To account for the selection biases, we use the Tobit type II model (also known as Heckman's standard sample selection model), which is a discrete-continuous model. Tobit type II model is widely used in the field of economics and especially in cases of sample-selection bias. Refer to (Heckman, 1976), (Heckman, 1979) and (Amemiya, 1984) for details on this model.

In this study, we use the Maximum Likelihood Estimation (MLE) method to estimate the parameters in the model. This is a two-part model where, a latent variable y_1^* that determines whether or not the outcome of interest is observed and y_2^* also a latent variable of interest. For example, the outcome of the intention to purchase a MaaS plan is given by y_1^* while the amount consumers are willing to pay is given by y_2^*. The two latent variables are observed as shown in equations 1 and 2.

$$y_1^* = \beta_1 x_1 + \varepsilon_1 \tag{5.10}$$

$$y_2^* = \beta_2 x_2 + \varepsilon_2 \tag{5.11}$$

Where; x_1 and x_2 are explanatory for the selection and outcome equation respectively, β_1 and β_2 estimated coefficients, while ε_1 and ε_2 are error terms. y_1^* and y_2^* are not completely observed, instead we observe only their positive values as stated in the conditions in equations 3 and 4 below.

$$y_1 = \begin{cases} 1 \; if \; y_1^* > 0 \\ 0 \; if \; y_1^* \leq 0 \end{cases} \tag{5.12}$$

$$y_2 = \begin{cases} y_2^* \; if \; y_1^* > 0 \\ 0 \; if \; y_1^* \leq 0 \end{cases} \tag{5.13}$$

The error terms are usually specified to be a joint normal.

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix} , \begin{pmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{pmatrix} \right) \tag{5.14}$$

The maximum likelihood estimation maximizes the log-likelihood function and it is based on the joint density $f(y_1, y_2) = f(y_2|y_1)f(y_1)$. By definition the density $f(y_2|y_1 = 1) = f^*(y_2|y_1^* > 0)$. Hence, $f(1, y_2) = f^*(y_2|y_1^* > 0) \times Pr[y_1^* > 0]$. Consequently, the density $f(y_2|y_1 = 0)$ has a probability 1 on the value $y_2 = 0$ and the probability 0 on any other value since $y_2 = 0$ when $y_1 = 1$. Thus, $f(0, y_{21}) = f(y_2|y_1 = 0)f(y_1 = 0) = Pr[y_1^* \leq 0]$.

The likelihood function is given as,

$$\mathrm{L} = \prod_{i=1}^{n} \{Pr[y_{1i}^* \leq 0]\}^{1-y_{1\,i}} \times f(y_{2i}|y_{1i}^* > 0) \times Pr[y_{1i}^* > 0]^{y_{1\,i}} \tag{5.15}$$

5.4 Results

In this study, we collected data from 560 respondents and analyzed their characteristics and travel behavior. First, descriptive analysis was used to examine the travel characteristic segment of the sampled population that is willing to adopt MaaS, what trip purposes will be suitable for MaaS, and the factors influencing their decisions. This is based on a premise that; frequent trip makers will likely adopt MaaS if they perceive it to be more attractive. This is also indicative of the potential demand for MaaS in Shiga should it be introduced. Second, Heckman's standard sample selection model is used to estimate the regression model, taking into account the sample selection bias that exists.

5.4.1 Descriptive analysis

The summary of the respondent's demographics is shown in Table 5-2. Respondents were presented with six hypothetical MaaS plans and responses from 560 respondents were collected and analyzed with respect to their current travel behavior and personal characteristics. From the results shown, 75% of the respondents fall within the ages of 20 to 59 years, which is the working class and 88% of them are family households.

Table 5. 2 Summary of results (demographics)

Demographic characteristics	sample n = 560	percent	% Residents to adopt MaaS n=191
Gender			
Female	286	51.1	55.5
Male	274	48.9	44.5
Age			
Young generation (<20 ~ 29)	109	19.5	23.6
Middle generation (30 ~ 59)	327	58.4	52.4
Older generation (60 ~ >80)	124	22.1	24.1
Occupation			
Full time workers	306	54.6	57.6
Part-time jobs	59	10.5	9.4
Students	36	6.4	7.9
Unemployed	33	5.9	2.1
Retired	8	1.4	2.1
Housewife	118	21.1	20.9

Annual Income (JPY)			
Low income (<1m ~ 3m)	284	50.7	44.5
Middle income (3m ~ 6m)	135	24.1	19.9
High income (6m ~ >12m)	116	20.7	30.9
No response	25	4.5	4.7
Household size			
1 person	66	11.8	11.0
2 persons	324	57.9	30.4
3 or more persons	167	29.8	58.6
No response	3	0.5	-

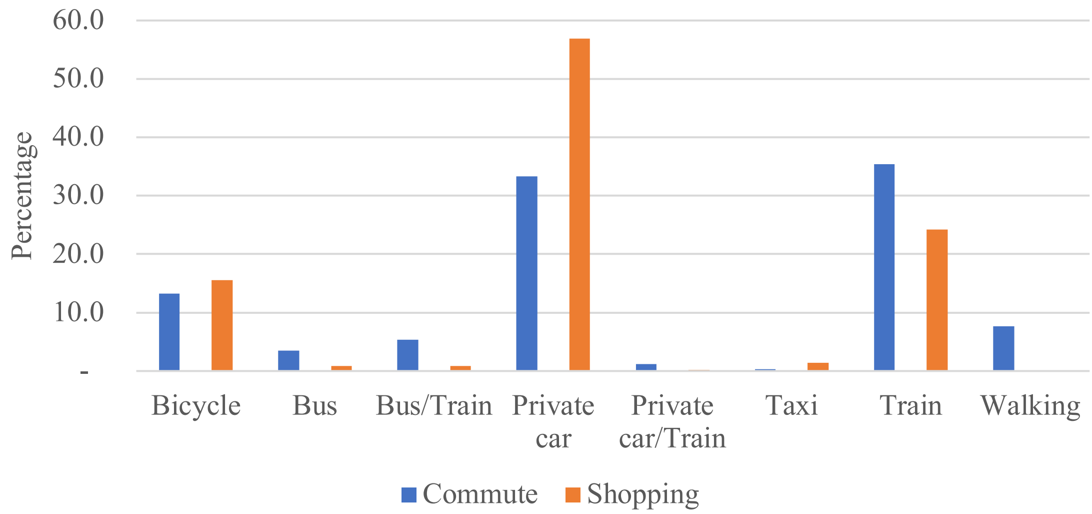


Figure 5. 2 Mode share for commuting and shopping trips

Figures 5.2 and 5.3 show the travel characteristic of the respondents. It can be observed that there is a strong reliance on the private car for commuting and other trips like shopping. The strong affinity toward the use of the private car is buttressed by the information from Figures 5.4 and Figure 5.5 showing that over 35% and 80% of respondents drive every day and possess a driving license, respectively. The commuter pass in Figure 5.5 refers to users of public transport. It is observed from Figure 5.6 that, for the respondents who belong to the category of frequent trip makers, over 50% of them commute and over 30% do shopping trips, respectively. In the same vein, Figure 5-7 shows the average monthly cost of a private car, which is 10,095.18 yen ($93.50)[4] while the average monthly cost on public transport is 5,548.81 yen ($51.40).

5.4.2 Insightful responses from the SP survey

A greater percentage (over 60%) of respondents did not wish to purchase MaaS packages regardless of the price. However, between 24% and 34% were willing to buy depending on the price.

The willingness-to-pay for the MaaS plans increases as the level of service and the attributes of the packages increases. Details are shown in Table 5-3 and Figure 5-8.

The WTP values placed on MaaS plans are lower than their current average monthly spending on travel, hence this is indicative of the fact that the price of the packages or its affordability will play a key role for the residents to take up MaaS (Ho, Hensher, Mulley, & Wong, 2018) . Figure 5-9 shows that the respondents were more eager to give up using their private cars for MaaS but skeptical to return their driver's license.

In the survey, a question was asked of the respondents if they were willing to give up the use of the private car and their driver's license for the proposed MaaS plans. Surprisingly, the results reveal that the elderly generation was more willing to give up their cars for MaaS. It is also observed that the respondents in their 20s who have recently obtained their driver's license and are at their early stage in career may want to continue driving or keep their license for future use, which is consistent with the concept of peak car. This trend is shown in Figure 5-10; the histogram shows the percentage of respondents who agree about giving up their cars for MaaS across the age groups.

Table 5. 3 WTP for MaaS subscription plans

[4] *The exchange rate at the time of this study is 1 USD = 108 JPY*

MaaS Plans (flat rate within the target area)	WTP Mean values (JPY)[5]	Std. dev.	% WTP	n = size
1. Train + Rental Bike	2583.33	2278.04	30	168
2. Bus + Rental Bike	2257.58	1962.22	24	132
3. Train + Bus + Rental Bike	3022.22	2576.51	32	180
4. Train + Bus + Rental Bike + Taxi @ ¥1000 (5km)	3406.25	3311.53	29	160
5. Train + Bus + Taxi + Rental Bike	4086.39	3874.22	34	191
6. Train + Bus + Taxi + Rental Car + Rental Bike	4465.97	4475.66	34	191

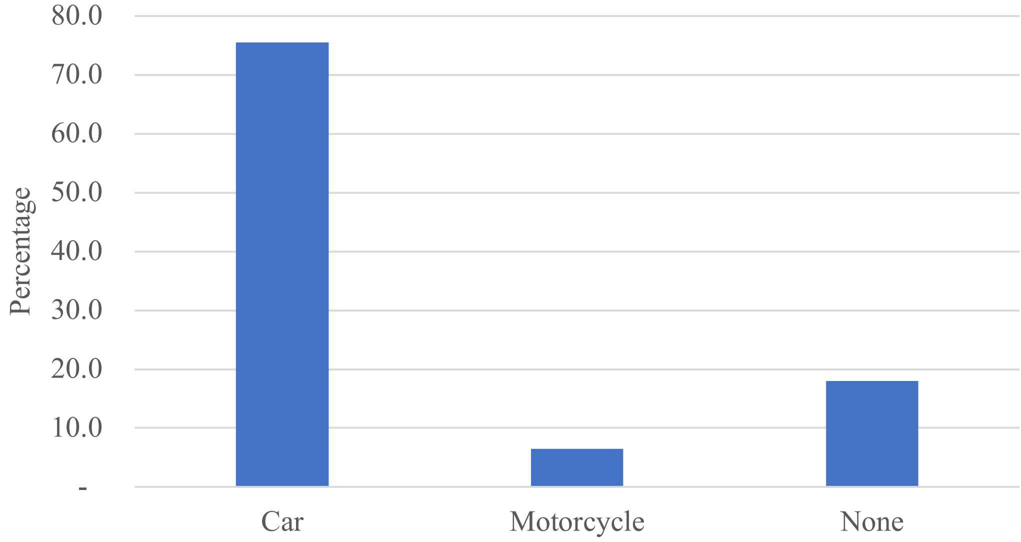


Figure 5. 3 Car ownership of the respondents

[5] *Exchange rate: 1USD =108 JPY*

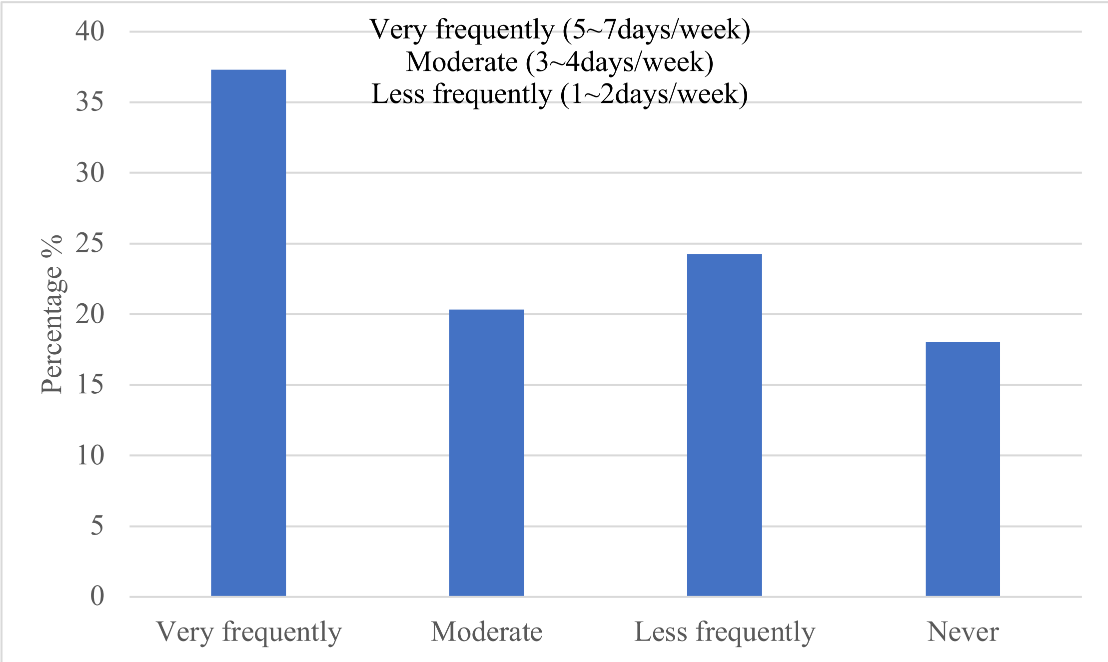


Figure 5. 4 Driving frequency

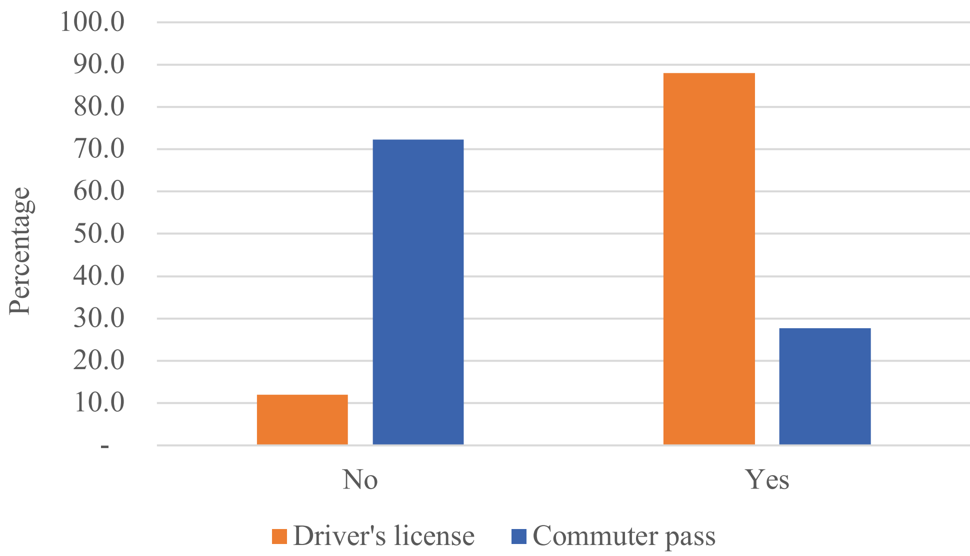


Figure 5. 5 Driver's license versus the commuter pass

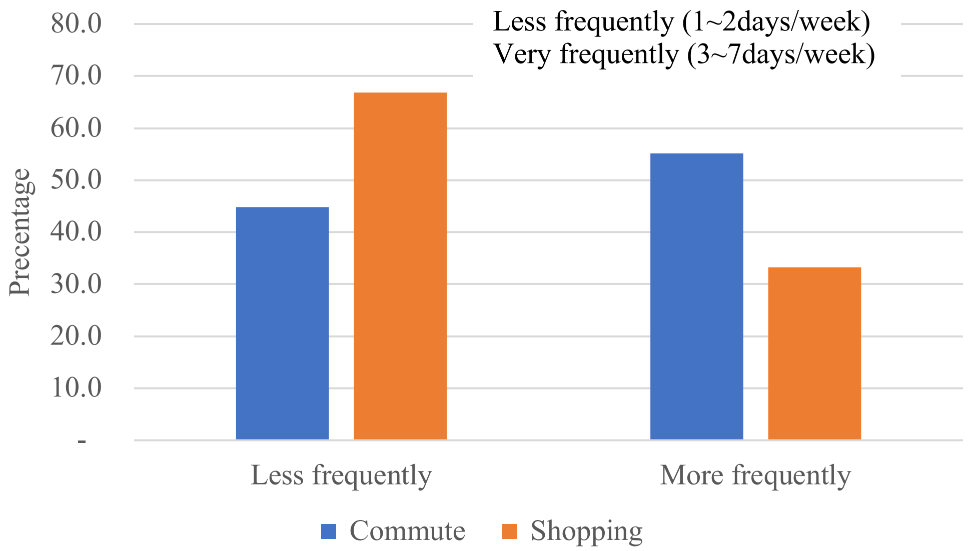


Figure 5. 6 Trip frequency by purpose

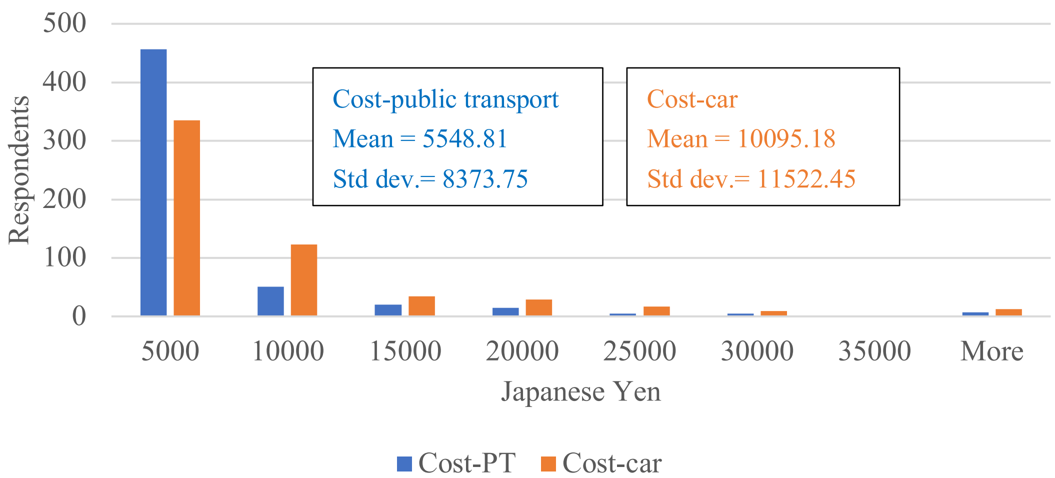


Figure 5. 7 Average monthly cost on travels.

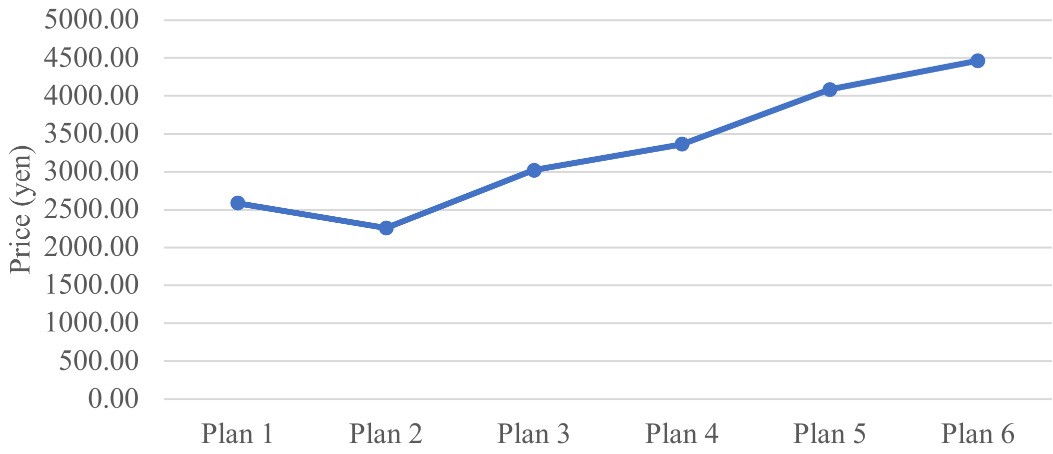


Figure 5. 8 Willingness-to-pay averages across the MaaS subscription plans

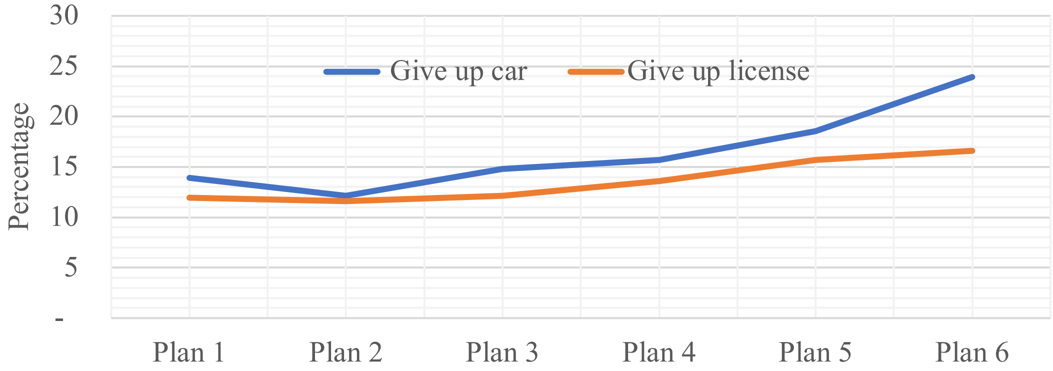


Figure 5. 9 Choice of giving up car or driver's license for MaaS subscription plans

While Figure 5-11 shows a closer look at the respondent who agreed to give up using their private car for MaaS shows that at least over 30% of them use their cars very frequently (almost every day).

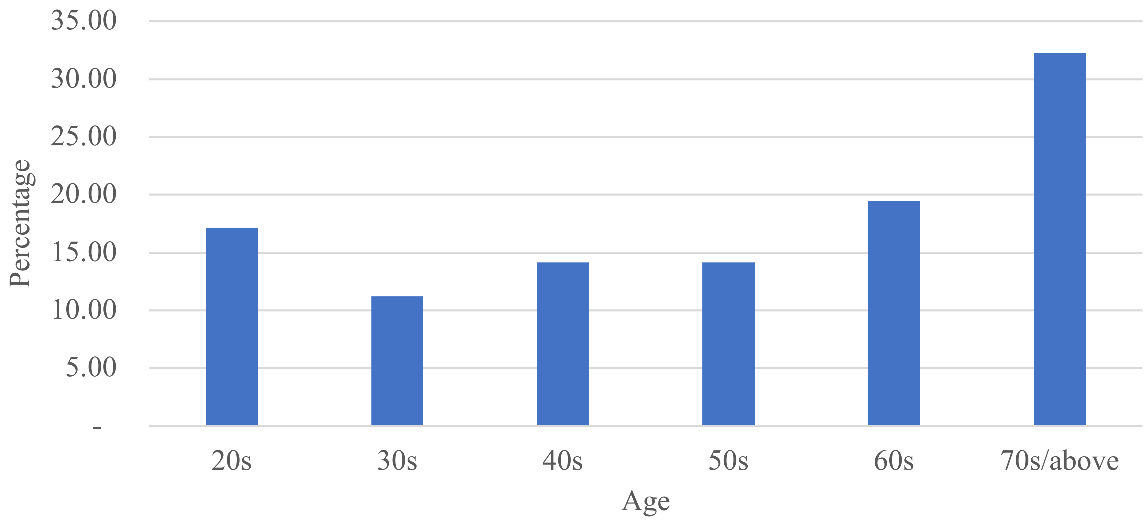


Figure 5. 10 Willingness to give up the car for MaaS by age

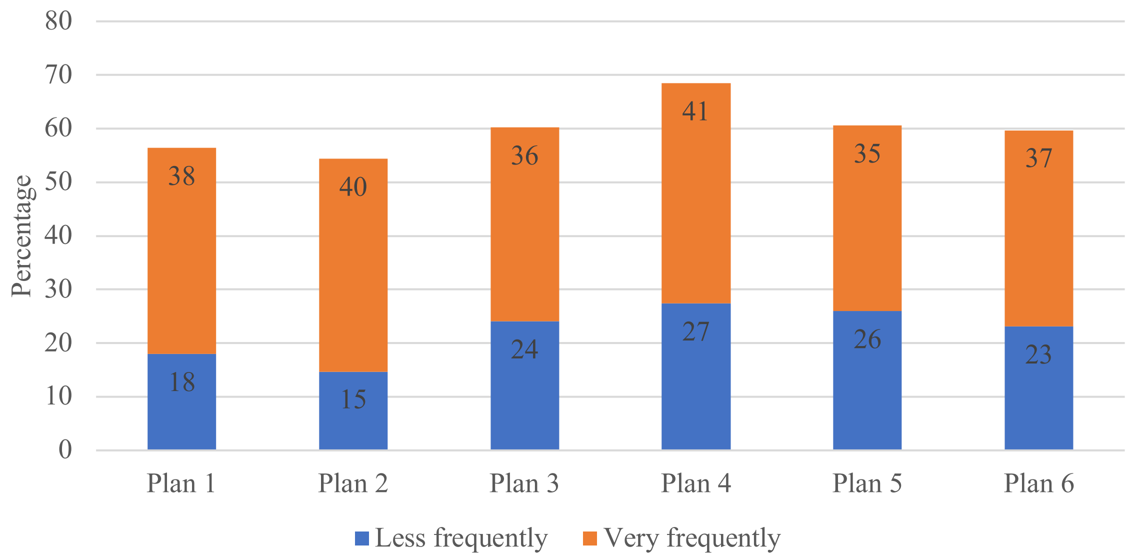


Figure 5. 11 Driving frequency for respondents who agreed to give up their car for MaaS

5.4.3 Model estimation results

The sample selection model was estimated for the cases of Kyoto and Shiga respectively, and the results are shown in Table 5-4.

Table 5. 4 Model estimation results

Probit selection equation:										
	Kyoto	Shiga	Kyoto	Shiga	Kyoto	Shiga	Kyoto	Shiga		
Variable	Estimate		Std. Error		t. value		Pr(>| t |)		*K*	*S*
(Intercept)	-8.741	-1.183	5.962	1.104	-14.66	-10.71	< 2e-16	< 2e-16	***	***
Train	1.755	2.574	2.748	6.856	6.385	3.754	1.84e-10	0.0001	***	***
Bus	1.582	6.882	2.737	6.556	5.782	1.05	7.77e-09	0.2939	***	
Taxi @ 5km	-5.648	-1.121	2.629	6.566	-2.149	-1.708	0.0317	0.0878	**	.
Rental car	9.941	1.628	2.656	6.451	0.374	0.252	0.7081	0.8007	*	
Gender	-2.004	2.403	1.695	4.885	-1.182	4.919	0.2370	9.12e -7		***
Age-*middle*	-4.16	-2.468	2.157	5.291	-1.928	-4.665	0.0538	3.21e -6	.	***
Age-*elderly*	-1.095	1.047	2.767	6.614	-3.956	1.583	7.71e-05	0.1134	***	
Commute freq.	7.24	2.863	3.502	5.424	2.067	5.279	0.0387	1.38e -7	*	***
Shopping freq.	4.332	1.932	2.135	5.244	0.203	3.684	0.8392	0.0002		***
Commuter pass	3.719	3.227	4.128	5.75	0.901	5.612	0.3675	2.17e -8		***
Cost-public trans.	2.237	8.819	1.857	3.206	12.04	2.75	< 2e-16	0.0059	***	**
Outcome equation:										
(Intercept)	10.387	8.213	0.102	0.187	101.30	43.861	<2e-16	< 2e-16	***	***
Rental car use	-0.099	-0.061	0.116	0.058	-0.86	-1.05	0.3896	0.2939		
Commuter pass	-0.043	-0.349	0.048	0.071	-0.898	-4.905	0.3695	9.78e-7		***
Commute freq.	0.038	-0.063	0.098	0.066	0.387	-0.965	0.6987	0.3347		
Household size	0.050	0.116	0.022	0.037	2.256	3.127	0.0241	0.0017	*	**
Income (high)	-0.155	0.159	0.063	0.066	-2.436	2.421	0.0149	0.0155	*	*
Error terms:										
Sigma	2.858	0.993	0.052	0.056	54.53	17.767	<2e-16	< 2e-16	***	***
Rho	-0.990	-0.564	0.001	0.098	-913.3	-5.741	<2e-16	1.02e-8	***	***
Significant codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1										

Model summary:	
Tobit 2 model (sample selection model - Kyoto)	Tobit 2 model (sample selection model - Shiga)
Maximum Likelihood estimation	Maximum Likelihood estimation
Newton-Raphson maximisation, 7 iterations	Newton-Raphson maximization, 4 iterations
Log-Likelihood: -7485.828	Log-Likelihood: -3281.865
6072 observations (3949 censored and 2123 observed)	3360 observations (2343 censored and 1017 observed)
21 free parameters (df = 6051)	20 free parameters (df = 3340)

It can be observed that using Tobit type 2 model, the estimation results for Kyoto and Shiga are fairly the same with a few variations. The bus mode in Kyoto has a positive estimate as expected and is significant. In Kyoto city bus seems to be attractive because of its connectivity, same fare system and well multimodal integration. Also, the estimate for gender is significant in Shiga but not significant in Kyoto. Furthermore, the dummy variable for elderly generation has a negative sign for Kyoto and is statistically significant whereas in Shiga it has a positive sign and not significant. These little differences and variations give the need for further investigation.

The estimation results from Table 5-4 are consistent with logic as the train and taxi have positive and negative signs for Kyoto and Shiga respectively. Because using the train is convenient especially commute around the city, so it affects the choice positively whereas taxi negatively affects the choice, and they are both significant. This provides initial insights about the modes that should be included in a MaaS package for Shiga. It is worthy of note that bus, rental car and age are not statistically significant parameters for this model for Shiga. This is not surprising more so that the use of the rental car is seasonal or occasional. The trip frequency, commuter pass and cost on public transport have a positive relationship with choosing MaaS plans and are statistically significant. As expected, the respondents who use public transport often are more likely to try out MaaS. In respect to the willingness-to-pay, income, household size and possessing a commuter pass plays a significant role. The later has a negative relationship whereas income and household has a positive relationship. The use of the rental car and commuting frequency were not statistically significant in predicting the willingness-to-pay.

5.5 Discussion

From the descriptive analysis, we can see that over 50% of the respondents are full-time workers, have at least a family of two and fall within the low-income bracket. Their affinity to the private car is logical in the sense that there is poor connectivity of public transport in Shiga. Consequently, it is more convenient to use a private car to meet travel needs. This strong reliance on the private car can be seen in the travel characteristics of the respondents and the expenditure on travel. The average amount for the willingness to pay for MaaS is below their current spending on travel which shows the value they place on MaaS vis-à-vis the current mode. Therefore, pricing will play a key role in those who will adopt MaaS. The trend in Figure 5-8 shows that the more attractive the MaaS plan is, the more likely the people will accept it and will be willing to pay for it.

Even though most of the respondents do not wish to take up MaaS, it is imperative to carefully examine the subset of about 30% who agreed they have the intention to use MaaS. It is interesting to note that the respondents who agreed to use MaaS, over 50% of them are full-time workers who make trips frequently and belong to a household of at least 3 members. Besides, about 75% of respondents are car owners, however, 45% of this group accepted to buy MaaS unlimited plan but only about 20% went further and agreed to give up their car completely for MaaS.

From the model estimation, which is in two parts; selection equation (discrete) and outcome equation (continuous), the results in Table 5-4 shows that train mode has a significantly positive parameter (2.574), indicating that the inclusion of train mode in the MaaS packages makes it attractive to the users. Moreover, since the Shiga cities are bed towns, some residents commute with the train out of Shiga to the city for work. Whereas the bus mode has similar estimate but is not statistically significant hence less attractive and is perceived as inconvenient since the bus services have a comparatively lower frequency and do not operate a flat rate system as it is done in Kyoto city. The estimate for taxi mode has a negative sign (-1.121) and is statistically significant at the 10% level. This implies that the taxi mode is less attractive and expensive. This perception of taxi been expensive is consistent with logic since cost plays a key role in the selection process. In tandem with the premise that the frequency of trips will positively affect the likelihood of selecting MaaS, the estimates for commuting and shopping frequencies conforms to the above premise and are both significant. On the other hand, rental car mode and the age of the elderly people is not a significant predictor of the model.

The second part of the model (outcome equation) shows the predictors for the willingness to pay should a MaaS plan be selected. The results show that the higher-income people (0.159) and bigger households (0.116) are more willing to pay for MaaS. This is positively significant and conforms with the logic that people with higher income level and households may have the luxury to try out a new mobility scheme than others in the lower income levels. In the same vein, commuter pass (-0.349) has a negative relationship with the WTP and is statistically significant. This is indicating that those with commuter passes are skeptical to try out MaaS because of their current subscription to a mobility service. Note most of these subscriptions sometimes have an effective period of three months and above and customers will want to have value for money before trying something new. Finally, commuting frequency and rental car usage are not significant predictors for the WTP and are not statistically significant as shown in Table 5-4. Even though a greater percentage of the residents stated they will not use MaaS, this model reveals the factors that influenced the decision to take up MaaS or not. Having in mind that these MaaS packages were hypothetical, a lot is still desired to ascertain the feasibility, profitability and sustainability of MaaS, especially in an auto reliant suburban settlement like in the Biwako valley.

5.6 Limitation of the research

In this research, the sample size is constrained to the budget provided by the Shiga local authority. Also, the sample may not have been a representative subset of the residents as such the results may be biased. Similarly, explaining the concept of MaaS via this only survey to the residents may not have provided enough understanding for them to make informed choices as such some irrational responses were noticed. This may have influenced the outcome since the MaaS packages were merely hypothetical. As a result of the following limitations, it should be considered that these findings may have some bias.

5.7 Future research directions

This research has drawn attention to some key areas which need more investigation. First, it is one thing to claim to have demand for MaaS and another thing to operate a MaaS scheme successfully. Therefore, there is need to research on the operational feasibility of MaaS in Shiga and Japan at large. Second, it is clear that the residents in the Biwako valley heavily rely on the car mode for most of their trips, so it will be important to research on the possibility of incorporating the private car in the MaaS package to attract car owners to use MaaS. For example, considering free parking for car owners who subscribe for MaaS so that they can only use the car for the first/last miles part of the trip. Third, since most people who accepted MaaS in this research are family households, the viability of family MaaS packages should be examined. Finally, a field operational test should be carried out for some time and results compared with an SP survey. There is reason to believe that the concept of MaaS may not be fully understood by the residents and this may have affected their choice. Also, the extent of the impact of the built-in environment on implementation of MaaS is desirable.

5.8 Conclusion

In this paper, we seek to provide insights/understanding of the implementation of MaaS in Shiga, Japan. This includes the acceptability of MaaS (which is judged by their choices vis-a-vis their current travel behavior), the potential demand for MaaS, the composition of the MaaS package suitable for Shiga residents and the willingness to pay which also reflects the value individuals place on MaaS.

A stated choice survey administered online was conducted of 560 individuals who indicated their choices for MaaS and the willingness-to-pay for it. MaaS packages were designed based on the envisaged travel needs of the residents of Shiga. A unique feature of the survey is, we adopted a flat rate system within the study area, which is not currently operational, rather than stating prices for each MaaS plan.

In this study, our results show that over 60% of the respondents are more likely not to use MaaS. About 30% of respondents accepted the proposed MaaS plans and also expressed the willingness to pay for it depending on the price, therefore we came to a conclusion that there is latent demand for MaaS in both Shiga and Kyoto should it be introduced. Frequent trip makers, higher-income earners and households of at least two members and above are more likely to take up MaaS. Also, interestingly, the willingness to give up a private car and adopt MaaS has a linear relationship with age.

Hence, from the demand standpoint, there are indications that MaaS seems to be feasible in Shiga. The operational feasibility is yet to be thoroughly investigated, however, there are indications that it is also feasible. Currently, trip/route information and payment system have a reasonable level of integration which is a good enabler for MaaS. In terms of the policy, governments in Japan have made serious steps towards the implementation of MaaS, like this project was sponsored by the Shiga prefectural government to provide insights for policy direction.

Chapter 6

Investigating the Determinants of Intention to Adopt Mobility as a Service using Structural Equation Modelling

6.1 Introduction

This chapter investigates the determinant factors that influence the intention to use MaaS. Since this is a hypothetical scenario, users indicated their intentions under experimental conditions however, we seek to understand factors that influences their decision by examining their daily travel behavior as well as their personal attributes. A structural equation modeling technique is employed for this analysis.

6.2 Background

Since the inception of Mobility as a Service (MaaS) scheme in 2014 named UbiGo-launched in Gothenburg Sweden, this concept has gained interest around the world. In 2016 MaaS Global launched their MaaS scheme called Whim in Helsinki Finland and over the following years extended its services to the United Kingdom, Belgium and Austria (Whim, 2019). Also, researchers around Europe, America, Asia and Australia have been discussing the possibility of implementing MaaS.

The basic idea of the MaaS concept is to integrate public transport, taxi and shared mobility (car rentals, ride-hailing, bike and e-scooter share services) into subscription packages that users can configure based on their travel needs, usually via a mobile application (MaaS Alliance, 2021). So far MaaS promises to significantly reduce car dependency and create business opportunities within the mobility ecosystem. Furthermore, MaaS promises to boost public transport ridership and meet sustainability goals of cities in the long term (Rye, 2017). However, the extent of the impact of MaaS on the environment and transportation industry in general is still unclear. Due to environmental concerns, traffic congestion and urbanization, there has been an increasing need for innovative and sustainable mobility solutions.

Implementing MaaS can be considered in three aspects namely, regulator, supplier (operator) and demand (user). The regulator is usually the government agencies or authorities/municipalities which are responsible for policies and regulations that will support the implementation of MaaS. The supply side deals with mobility operators that provides the services. It is important to ascertain the operational feasibility, profitability and technological prerequisites required to deliver a MaaS scheme to the public. On the other hand, the demand side tells whether there is a potential market for MaaS to thrive. Public acceptance, adoption of MaaS and the willingness to pay for it are key factors to tell if MaaS is viable in a particular environment. In general, the users' acceptance of MaaS largely depends on their attitude, quality of service and the built environment.

In this paper we explore the users' behavior towards MaaS to examine the attributes that significantly influence their intention to adopt MaaS. Through a stated preference survey, structural equation modelling which uses the theory of planned behavior as an initial framework is used to analyze these causal relationships. The comparison of the attitudes and daily travel habits of individuals living in urban areas versus those living in rural/suburban areas is done to better understand MaaS adoption. In many parts of the world, where MaaS is not operational, this concept is neither known nor well understood. One of the core characteristics of MaaS is that it is user centric, therefore it is imperative to examine the potential users across specific target groups to strategically position it in a competitive market.

6.3 Theoretical framework

In many studies on technology adoption in transportation field, theories such as Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) are used to explain users' intention to adopt/use a technology or new service. In this study, we rely on the Theory of Planned Behavior (TPB) which states that the likelihood of an individual to engage in a logical/reasoned behavior is strongly correlated to the strength of his or her intentions to engage in that behavior (Kagee & Freeman, 2017) to explain the determinants of the intention to adopt MaaS. The concept of the TPB is illustrated in the diagram (Figure 1). This theory is used to predict and understand behavioral intentions, which are determined by a combination of three factors namely, attitude towards the behavior, subjective norms and perceived behavioral control. Attitude towards the behavior refers to the extent to which a person has an evaluation of the behavior to be performed. Subjective norm refers to the social pressure to perform the behavior in question while perceived behavioral control refers to the ease or difficulty of performing the behavior in question which is based on past experiences or expected obstacles. These factors have direct impact on intentions and indirect impact on behavior. On the other hand, perceived behavioral control has a direct effect on behavior as shown with the dotted line, as well as an indirect effect on behavior, which is the dependent variable and outcome.

6.4 Research hypothesis

In the framework of this study, we assume that the car ownership (CO) status of residents affects their current travel behavior (TB) and their attitudes toward private car (ATC). Also, we assume that the current travel behavior (TB) of the residents has a direct effect on their intentions to use MaaS (IUM). In the context of the theory of planned behavior, "Attitude" is represented by the attitudes of the respondents to stop using car (ATC). For example, whether they will give up the use of car for MaaS or whether they will give up their driver's license too. "Subjective norms" is represented by the latent variable-travel behavior (TB) which is measured by the driving frequency of the respondents. Since the built environment influences the daily trip patterns, we assume this to be a social norm, for example Shiga residents mostly use car for commute. For the "perceived behavioral control", we assume that car ownership (CO) has great control over our own behavior in terms of choosing similar or alternative modes.

These relationships between the latent variables can be tested using observable endogenous or exogenous variables generated by the respondents. Furthermore, we introduce a moderating effect (location of the residents) to test the strength or direction of the relationships and whether there are differences in outcome within the subgroups. The hypothesis we test on these relationships are as follows.

1) **H1**: There is a significant relationship car ownership (CO) and intention to use MaaS.

2) **H2**: There is a significant relationship between TB and intention to use MaaS.

3) **H3**: There is a significant relationship between ATC and intentions to use MaaS.

4) **H4**: There is a significant difference between the relationships of the latent variables and the

The first hypothesis implies that the individual characteristics like age, gender, income etc. significantly influences the decision to use MaaS. The second hypothesis suggest that the daily travel behavior of an individual significantly affects the intentions to use MaaS. Likewise, the third hypothesis implies that the attitudes towards the use of private car, significantly affects the intentions to use MaaS. The fourth hypothesis implies that individuals living in urban areas are more likely to use MaaS.

6.5 Methodology

6.5.1 Structural Equation Modelling (SEM)

Structural equation modelling (SEM) is a common statistical analysis technique that measures and analyses complex relationships between observed variables and latent constructs. SEM incorporates several statistical methods such as regression analysis, discriminant analysis, factor analysis, confirmatory analysis, path analysis among others (Westland, 2015). Related research on the application of SEM includes (Si, Guan, & Cui, 2019) who analyzed the relationship between the latent variables and the behavioral intentions of using taxis and online car-hailing services in China, (Schikofsky, Dannewald, & Kowald, 2020) who identified the key motivational mechanisms behind the intention to adopt MaaS in Germany, and (Acheampong & Siiba, 2020) who investigated the car-sharing adoption intention among young people in Ghana, west Africa.

Similarly, a multigroup analysis (MGA) is applied to test whether there exist significant differences within subgroups in a single population. Many studies report their findings from a single population without exploring whether they are significant differences across two or more categorical groups (like age, gender, occupation, status, location etc.) within the dataset and this can be misleading. Group-specific path analysis are done using these categorical moderating variables mentioned earlier to account for the observed heterogeneity and this reduces the risk of misinterpreting the outcome (Matthews, 2017). Many feasibility studies about the implementation of MaaS are done in urban areas, therefore, it will be interesting to know the situation in rural or suburban areas.

The greatest advantages of SEM are that it examines linear causal relationship among variables while simultaneously accounting for measurement error. SEM test complex patterns of relationships simultaneously including mean structures and group comparisons and test for compatibility of the model with the data. Conversely, SEM comes with some challenges which includes, sometimes SEMs give unreliable results due to small sample sizes and nonnormal data. Also, sometimes two model with different assumptions gives same model fit, so it becomes difficult to interpret the results and base a decision by it.

The procedure to evaluate model fit for SEM is not straightforward because there is no single index or test that can check the consistency of the model with the empirical data. Usually, the goodness-of-fit indices used depends on the estimation procedure used in the model. These fit criteria show how the model fits the empirical data. Generally, a χ^2 (chi-squared) test statistic is used for statistical hypothesis testing to evaluate the appropriateness of SEM. Given that the assumptions of SEM (large sample size and normally distributed) still hold, χ^2 test is used to evaluate whether the population covariance matrix $\boldsymbol{\Sigma}$ is equal to the model-implied covariance matrix $\boldsymbol{\Sigma}(\theta)$. χ^2 invariably tests the null hypothesis, given that the differences between the elements of $\boldsymbol{\Sigma}$ and $\boldsymbol{\Sigma}(\theta)$ are all zero: $\boldsymbol{\Sigma} - \boldsymbol{\Sigma}(\theta) = \mathbf{0}$. The matrices are unknown because these are population parameters, as a result, the sample counterparts are examined. The empirical covariance matrix $\boldsymbol{S}$ and the model-implied covariance matrix $\boldsymbol{\Sigma}(\hat{\theta})$, where $\hat{\theta}$ is the $(t \times 1)$ vector of estimated parameters. Assuming that the null hypothesis is correct, then the minimum fit function value times $(N - 1)$ converges to a χ^2 variate (Schermelleh-Engel, Moosbrugger, & Müller, 2003). This is expressed in equation (3.7) given as

$$\chi^2(df) = (N-1)\, F\, [\boldsymbol{S}, \boldsymbol{\Sigma}(\hat{\theta})] \tag{6.1}$$

Where, $df = s - t$ degrees of freedom,

s represents the number of nonredundant elements in $\boldsymbol{S}$,

t represents the total number of parameters to be estimated, while

N is the sample size,

$\boldsymbol{S}$ represents the empirical covariance matrix and

$\boldsymbol{\Sigma}(\hat{\theta})$ represents the model-implied covariance matrix.

6.5.2 Data collection

Inhabitants of the Biwako valley in Shiga prefecture and Kyoto metropolitan City (see map; Figure 6-1) were surveyed using online questionnaires. We adopted an online survey because of the wide reach, time and cost efficiency.

In this study, the samples collected consist of 560 individuals from the Biwako valley in Shiga prefecture (rural/suburban), collected over a period of seven days (from 1st to 7th of July 2019) and 1,012 individuals from Kyoto city (urban), collected over a period of eight days (from 29th October to 5th November 2019). The demographics of these samples are representative of the population of Shiga and Kyoto based on gender and age.

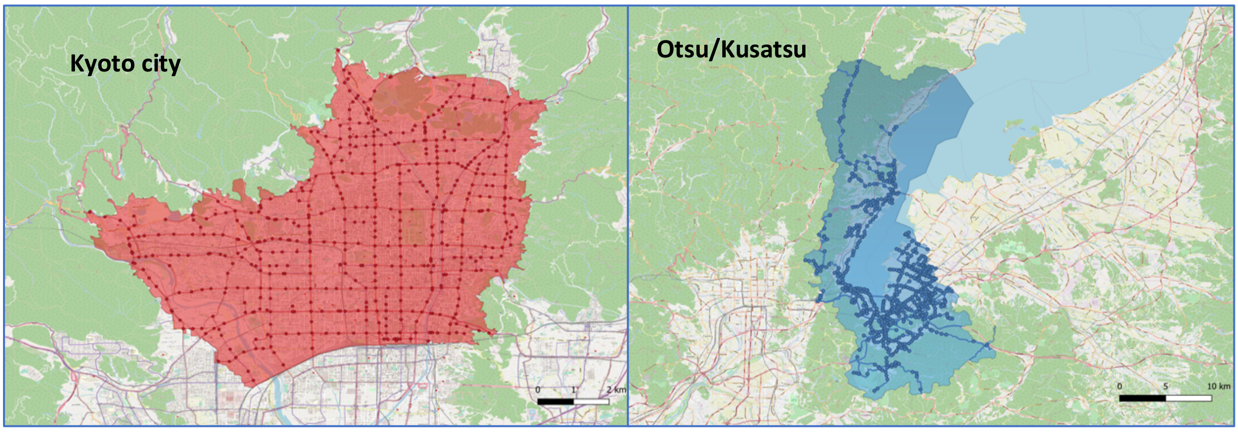


Figure 6. 1 Map of Kyoto and Shiga showing the bus lines within the coverage area of the survey

For example, in Shiga we have 51.1% and 48.9% for females and males respectively, while in Kyoto we have 49.5% and 50.5% for females and males respectively. The coverage area for this survey is seen in Figure 6-1 showing the map of Kyoto and Shiga with their bus networks. In this study, Kyoto metropolitan city is referred to as urban while the Kusatsu and Otsu area in Shiga prefecture is considered rural based on population density.

6.5.3 Stated Preference survey

SP surveys have been used to examine consumer's perception/preference or intentions to use a new service or willingness to pay for a product or service yet to be introduced into the market. By using a Likert scale respondent were asked their intentions to use MaaS, willingness to give up car or license. For example, we asked, if all trains, buses, taxis and rental bicycles operating in the target area are available for one month, would you like to purchase the ticket? The respondents are expected to choose from the stated responses which are, "I will buy it depending on the price" or "I will not buy it regardless of the price". For those who indicated they will buy depending on the price, they are expected to state how much they are willing to pay for that plan. These MaaS packages are proposed based on the envisaged travel needs and transport services available in the study areas. Also, for 'give up car or license' the respondents answered using a 5-point Likert scale as follows. 1) I do not think so at all, 2) Not so much think, 3) Neither 4) I think so a little and 5) I think so.

The online questionnaire is structured as follows: Section 1 gathers information on travel characteristics of the respondents which includes, commuting trips, shopping trips, leisure trips as well as the frequencies and main modes used while making these trips. Section 2 presents the stated preference scenarios of the six MaaS plans, and the amount users are willing to pay for MaaS, give up car or license. The proposed plans are set to operate as a flat rate system with unlimited rides within the target areas (Table 6-1) while section 3 collects personal information.

Table 6. 1 Proposed MaaS subscription plans as presented in the SP survey.

MaaS Plans (flat rate within the target area)	Intention	WTP (JPY)
1. Train + Rental Bike	○ yes ○ no	0-100,000
2. Bus + Rental Bike	○ yes ○ no	0-100,000
3. Train + Bus + Rental Bike	○ yes ○ no	0-100,000
4. Train + Bus + Rental Bike + Taxi (5km @ ¥1000)	○ yes ○ no	0-100,000
5. Train + Bus + Taxi + Rental Bike	○ yes ○ no	0-100,000
6. Train + Bus + Taxi + Rental Car + Rental Bike	○ yes ○ no	0-100,000

Exchange rate: 1USD =108 JPY (2019)

6.6 Results and Discussion

6.6.1 Descriptive analysis

After cleaning the data of outliers, irrational responses and errors, and then sorting and organizing it, we had a total of 1,308 respondents. Their individual characteristics and travel behavior was analyzed in relation to their choices of the proposed MaaS packages. In this study, we selected the packages which has all the modes included (for example, plan 5 or 6 in Table 6-1) for analysis. This package is believed to be more attractive and comparable to owning a car.

Table 6. 2 Summary of demographic information

Demographic characteristics	Kusatsu and Otsu n=560	percent (%)	Kyoto n=1012	percent (%)
Gender				
Female	286	51.1	501	49.5
Male	274	48.9	511	50.5
Age (years)				
Young gen. (18~29)	109	19.5	190	18.8
middle gen. (30~59)	327	58.4	635	62.7
Elderly gen. (60~above 80)	124	22.1	187	18.5
Occupation				
Full time worker	306	54.6	406	40.1
Part time worker	59	10.5	117	11.6
Student	36	6.4	99	9.8
Unemployed	33	5.9	50	4.9
Retired	8	1.4	15	1.5
Housewife	118	21.1	151	14.9
Annual income (JPY)				
Low income (0~3M)	284	50.7	557	55.0
Middle income (3M~6M)	135	24.1	268	26.5
High income (6M ~ above)	116	20.7	183	18.1
No response	25	4.5	4	0.4
Household size				
1 person	66	11.8	226	22.3
2 persons	324	57.9	333	32.9
3 or more persons	167	29.8	448	44.3
No response	3	0.5	5	0.5
Car ownership				
car owners	423	75.5	583	57.6
non-car owners	137	24.5	429	42.4

From the results shown in Table 2, the actively working class which belong to the young and middle generation, falls within the ages bracket of under 20 to 59 years. This amount to over 75 percent (Table 6-2. 19.5% + 58.4%) of the respondents and 88 percent of them are from family households.

The stated WTP by Kyoto residents was higher (plan 6 = ¥5,286) than Shiga residents (plan 6 = ¥4,466) which may be an indication that they place a higher value on shared mobility schemes. Furthermore, people in Kyoto were more willing to *adopt MaaS*[6] than people in Shiga (Figure 6-2).

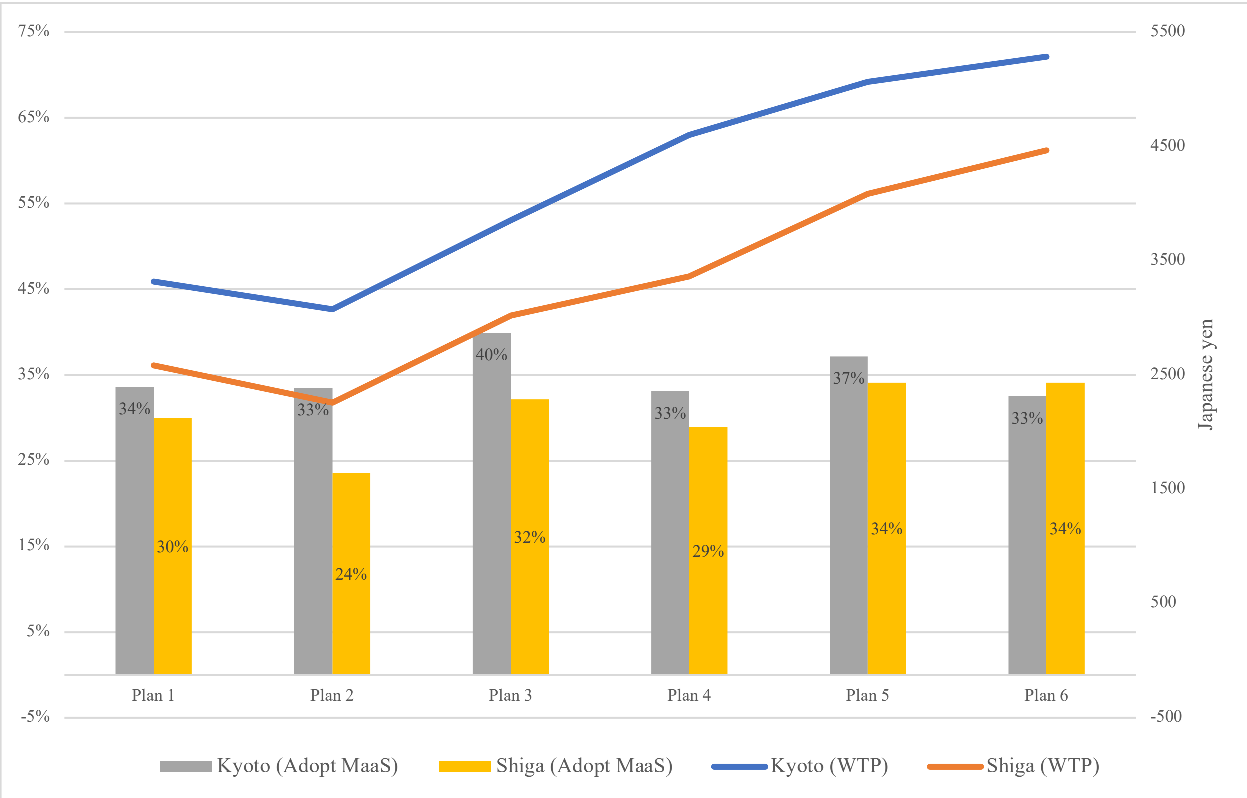


Figure 6. 2 MaaS acceptance and willingness to pay

[6] Adopt MaaS in this case refers to those accepted to purchase the MaaS packages depending on the price.

Table 6. 3 Percentage of willing to adopt MaaS by Kyoto and Shiga residents (combined data)

Demographic characteristics	number (Kyoto and Shiga) n=1308	% Residents to adopt MaaS n = 514
Age (years)		
Young generation (18-29)	239	20.4
middle generation (30-59)	982	73.3
Elderly generation (60-80 above)	87	6.2
Occupational status		
worker	910	72.2
non-worker	398	27.8
Annual income (JPY)		
Low income (0~3M)	595	42.0
Middle income (3M~6M)	441	33.1
High income (6M ~ above)	272	24.9
Car ownership		
Car owners	966	73.5
non-car owners	342	26.5
Living environment		
rural/suburbs (Biwako valley)	466	31.9
urban (Kyoto city)	842	68.1

In Table 6-3, the data from Kyoto and Shiga was merged (n=1308) after deleting irrational responses. From the initial analysis, it could be seen that 73% of the middle-aged people within the ages of 30 to 59 as well 72% of the respondents who are actively working are willing to use MaaS. Interestingly, about 74% of car owners are willing to try out MaaS with a greater percent of this group coming from Shiga (rural/suburban). Meanwhile residents from Kyoto (urban) are more willing to try MaaS than residents of Shiga (rural/suburb) with percentages of 68% and 32% respectively (Table 6-3).

6.6.2 Comparison between Shiga and Kyoto using cross tabulation

The classification of urban (Kyoto) versus rural/suburban (Kusatsu/Otsu) was done based on population density and person trips in these areas. We compared the daily trip behavior of the residents in Shiga and Kyoto using cross tabulation. Detail of the results are found in Figures 6-3, 6-4, 6-5 and 6-6. The cross-tabulation results show that 66.5% and 62.4% of respondents residing in Kyoto and Shiga respectively commute daily (Figure 6-3). In Kyoto, 30% of the residents commute using train followed by about 29% who use bicycle (Figure 6-4). On the other hand, Shiga residents commute mainly using private car followed by train. Specifically, 39.5% use car for commuting while 35.1% use the train. This is not surprising since Shiga is an auto reliant community, also Shiga serves as a bed town to the big cities like Kyoto and Osaka. In Kyoto it is evident that the residents prefer to shop at stores closer to their homes hence about 37% walk to do shopping activities (Figure 6-5). Also, noticeably, in Shiga private cars are used for shopping. This is consistent with the common knowledge that Shiga is more auto reliant when compared to Kyoto city. In Figure 6-6 most of commute time values fall within the lower end of the range. Shiga has a higher median value than Kyoto for commuting with public transport (same with the means; Shiga = 49mins, Kyoto = 44mins), implying better access in Kyoto. Even though both have same value at third quartile (Q3/75th percentile) and outliers within same range, it still supports the perceived attractiveness of public transport services in Kyoto city vis-à-vis Shiga.

Pearson chi-square = 11.8; df = 3; P value = 0.0081

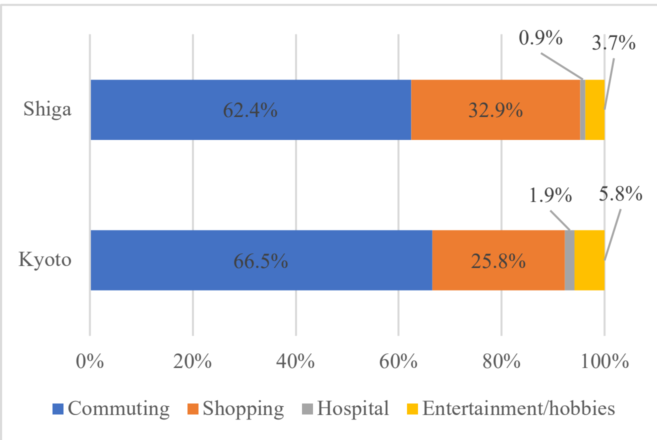


Figure 6. 3 Trip purpose

Pearson chi-square = 60.59; df = 4; P value = 0.0001

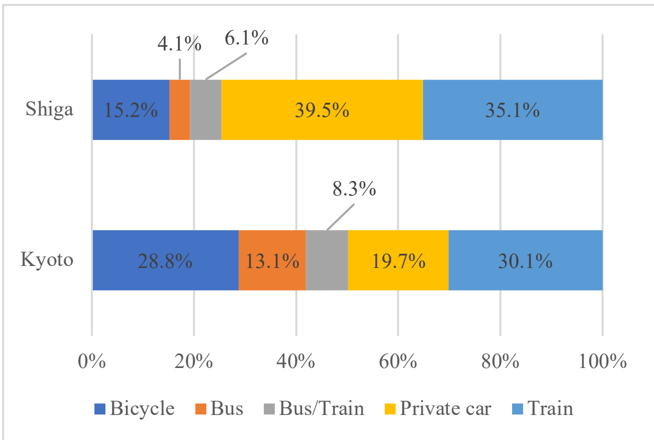


Figure 6. 4 Commute mode share

Pearson chi-square = 94.43; df = 4; P value = 0.0001

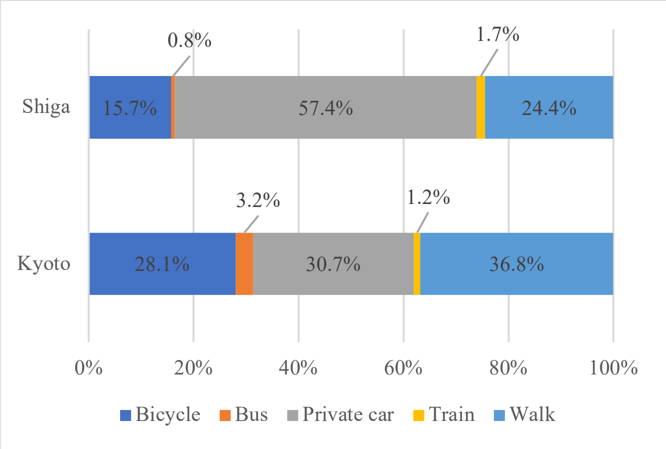


Figure 6. 5 Shopping mode share

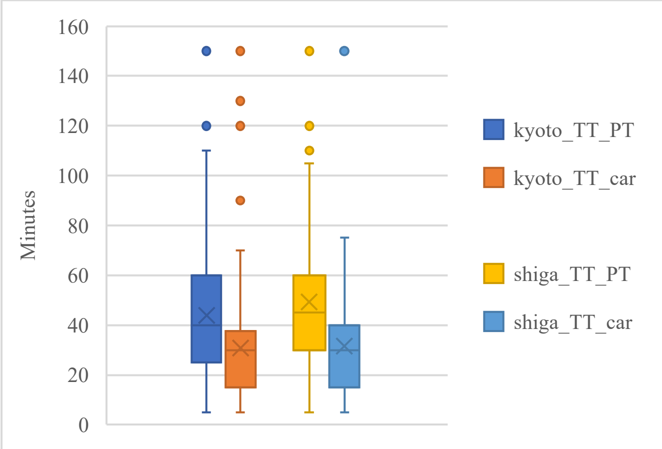


Figure 6. 6 Commuting travel time by mode

6.6.3 Base model of SEM

We utilized a partial least-square (PLS) structural equation model estimation to test the relationships between the postulated latent constructs as well as the behavioral intention to use MaaS. We used the software package SmartPLS 3.0 for the data analysis and benefited from its advantage that it does not require any specific distribution assumptions like normal distribution of the variables.

The latent variables consist of attitudes to stop using car (ATC), travel behavior (TB), car ownership (CO) and intention to use MaaS (IUM). ATC is measured by the observed variables "give up car" and "give up license", TB is measured by the driving frequency of the respondents while the measure variable "car ownership dummy" represents the latent variable "car ownership". The intention to use MaaS (IUM) is measured by the dummy variable "adopt" as shown in Figure 6-7. The cross-sectional data was then analyzed in SmartPLS.

6.6.4 Model fit

According to (Henseler, et al., 2014) and (Lohmöller, 1989) the Standardized Root Mean Square Residual (SRMR) and Normed Fit Index (NFI) are indices used to evaluate the approximate model fit. The values of these criteria are usually within a certain threshold (SRMR < 0.08) and (NFI > 0.9) whereas, in this study the SRMR is 0.021 and NFI is 0.991 (Table 4), which indicates a good model fit. The saturated model assesses correlation between all constructs while the estimated model which is based on a total effect scheme and takes the model structure into account is a more restricted version of the fit measure (SmartPLS, 2021). Squared Euclidean distance (d_ULS) and geodesic distance (d_G) are other criteria for model fit. These criteria define a perfect model fit when they are both equals to zero (Dijkstra & Henseler, 2015).

Table 6. 4 Fit summary

	Saturated Model	Estimated Model
SRMR	0.014	0.021
d_ULS	0.003	0.006
d_G	0.001	0.001
Chi-Square	6.996	9.534
NFI	0.994	0.991

6.6.5 Construct Reliability and Validity

In SmartPLS, a reflective model's construct reliability is tested through composite reliability with a preferred minimum threshold value of 0.5 while the convergent validity is checked using Cronbach's alpha with a threshold value (>0.60). This proves that the model is internally consistent. In this study, the value of Cronbach's alpha for the latent variable ATC is 0.736. the other latent variables have a value of 1 since they were measure by a single variable.

6.6.6 Structural Equation Modeling (SEM) results

Figure 8 shows SEM results, with path coefficients after running a consistent PLS algorithm on SmartPLS ver. 3.0. The SEM results show that the model is compatible with the data. The intention to use MaaS is positively affected by car ownership (0.096) and attitudes to stop using car (0.400). Also, travel behavior is positively affected by car ownership (0.424) while IUM is positively affected by TB (0.023). Afterwards, we ran a bootstrapping which computes the statistical significance of the PLS-SEM results. The result demonstrates that indeed car ownership significantly affects the intention to use MaaS (Table 6-5). In addition, other paths like ATC to IUM, CO to TB and CO to ATC are all statistically significant. Consequently, the results support the hypothesis H1 and H3 while H2 is insignificant and not supported. Furthermore, there is an indirect effect of CO on IUM, and the path CO – ATC – IUM is statistically significant.

6.6.7 Multi-Group Analysis (MGA) results

We also seek to investigate if there is a significant difference in the paths if we consider subgroups like built environment within the sample. Therefore, we considered the subgroup of those living in the city (Kyoto) and rural areas (Shiga). In our analysis the results in Table 6-5 show that there was no significant difference in the path estimates except for the path CO – ATC which conforms with logic. It is obvious that the attitudes of residents in urban and rural areas towards using and or owning a car will differ largely due the built-in environment. Consequently, the hypothesis **H4** is not supported.

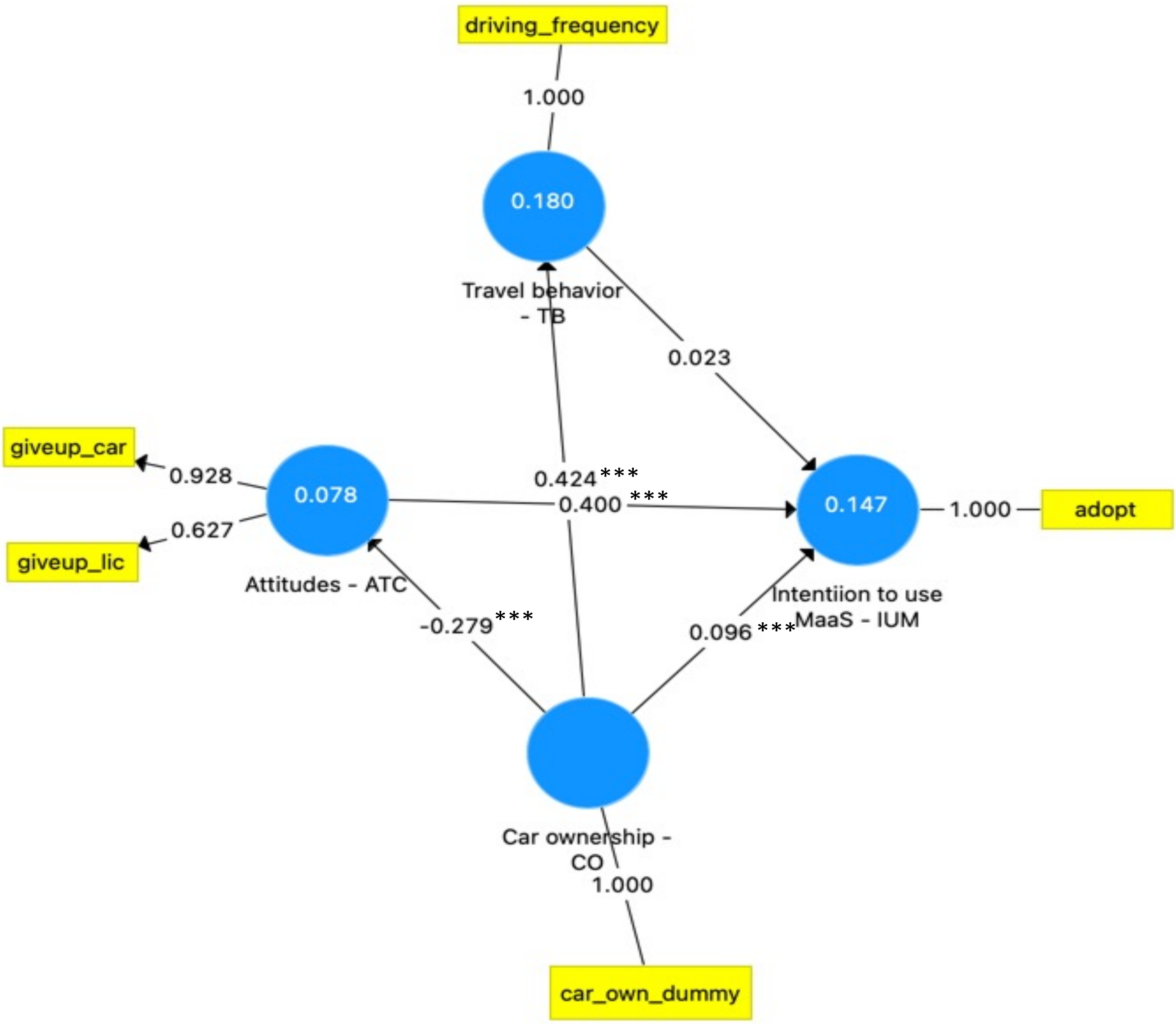
Table 6. 5 PLS-SEM results

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values[7]	Remark
ATC - IUM	0.400	0.399	0.031	13.055	0.000***	supported
CO - ATC	-0.279	-0.279	0.031	8.960	0.000***	supported
CO - IUM	0.096	0.096	0.030	3.183	0.001***	supported
CO - TB	0.424	0.424	0.018	23.462	0.000***	supported
TB - IUM	0.023	0.022	0.028	0.790	0.429	not supported

Table 6. 6 Specific indirect effect

Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
CO - ATC - IUM	-0.111	-0.112	0.016	6.987	0.000***
CO - TB - IUM	0.010	0.009	0.012	0.787	0.431

[7] *Significant codes: *** 0.001; ** 0.01; * 0.05*



Significant codes: *** 0.001; ** 0.01; * 0.05

Figure 6. 7 SEM with path loadings

Table 6. 7 PLS-MGA – (urban vs rural)

Path	Path Coefficients-diff (urban - rural)	p-Value original 1-tailed (urban vs rural)	p-Value new (urban vs rural)	Remark
ATC - IUM	-0.062	0.872	**0.255**	not supported
CO - ATC	-0.170	0.998	**0.004****	support
CO - IUM	0.028	0.330	**0.660**	not supported
CO - TB	0.263			
TB - IUM	-0.032	0.689	**0.622**	not supported

*Significant codes: *** 0.001; ** 0.01; * 0.05*

6.7 Discussion

In this study, we set out to investigate the determinants that influences the intention to adopt a proposed MaaS scheme. From the results, we observed that the car ownership status of respondents is a strong determinant for the intention to use MaaS. The latent variable CO has both direct and indirect effects on the variable IUM as shown in Table 6-5. The path estimates of CO – IUM has a positive coefficient (0.096) which implies that car owners are becoming more curious to try out MaaS. From the descriptive analysis (Table 6-3) it could be seen that over 70% of car owners are willing to try MaaS. However, it is important to note that, this result from Table 6-3 is the outcome of a combined data sample of Kyoto and Shiga. More specifically, even though percentage of car owners in Kyoto is less, the sample sizes are not the same and Kyoto car owners are more likely to give up their cars and adopt MaaS. It is logical because, they live in the city and are already accustomed with shared mobility services.

Travel behavior (TB) which comprises of driving frequency is not a significant determinant for users' intention to adopt MaaS. In this case, how often the respondents drive has no effect on adopting MaaS. This is possible scenario since there seems to be many "paper drivers" in Japan, that is people who have driver's license yet do not own or drive a car.

The latent construct, attitudes towards car (ATC) was considered to investigate the effects that habitual behavior/strong reliance on the use of private car has on the intention to use MaaS. The residents were asked if they will give up their private car and or driver's license to gauge the strength of their intentions. This is justified by the theory of planned behavior (Kagee & Freeman, 2017). The SEM results revealed that ATC has a positive effect on IUM, and this relationship is statistically significant. The measured variable *"giveup_car"* is a strong contributor to the construct as shown in Figure 6-7 with an outer loading of 0.928.

Next, multigroup analysis MGA was done to explore further the data for salient relationships that may exist among certain groups in the sample population. The built environment, that is urban, rural/suburban areas were considered. Subsequently, the data from residents in Kyoto (urban) and Shiga (rural) were compared and analyzed. The result revealed that there is no significant difference between urban and rural dwellers in the path estimates. It implies that regardless of residential area, the effects of CO, TB and ATC on IUM remain the same. However, there appears to be a significant difference on the path CO – ATC as expected but this relationship was not hypothesized.

The main elements which can be drawn from these results that could drive policy are, car ownership strongly influences travel behavior. Therefore, attractive incentives should be provided to influence a behavioral change.

More specifically, the policies that may be inferred from the results of this study are,

1. Governments should incentivize the return of licenses by elderly drivers. This is crucial to improving both traffic safety and the implementation of Mobility as a Service schemes.

2. Since we compared the acceptance of MaaS adoption and users' intention in both Kyoto and Shiga, mobility management policies should be tinkered and domesticated for each case to encourage a widespread use of MaaS.

Also, since there exist some differences in travel behavior between urban and rural inhabitants, different approach or strategies should be adopted. More persons in Kyoto use train or bus regardless of the trip purpose, so the built environment plays a vital role in policy direction. In Shiga, which is more auto reliant, emphasis should be made on the first and last mile trips to encourage a shift towards public transport, especially encouraging the use of micro mobility and paratransit services which could be a mode to collect people to the main stations or transit hubs.

6.8 Conclusion

After investigating the factors that influences the adoption of MaaS we can conclude that car ownership and users' attitude toward private car significantly influences the decision to adopt MaaS. Car ownership and attitudes toward car have a positive relationship with the intention to use MaaS while travel behavior effect on the intention to use MaaS is insignificant. From the SEM results in Figure 8, it is revealed that car ownership and attitudes toward car are strong determinants of MaaS adoption. In addition, from the descriptive analysis we discovered that the built environment is a strong determinant for MaaS adoption. In contrast to Shiga residents, Kyoto residents showed a positive attitude toward MaaS and are more likely to adopt MaaS.

Subsequently, from the MGA there is no significant differences in the paths estimates across the subgroups like the built environment (urban vs rural).

In conclusion, two hypotheses were supported which include **H1** and **H3** while **H2** and **H4** were not supported.

This study has some limitations which are vital to how the outcome of this research is applied. The sample size was restricted due to budgetary constraints. The findings of this research apply only to Kyoto and Shiga prefectures in Japan. Other cities or rural areas in other countries may have different dynamics and these results may not apply due to cultural and societal differences. It is also worthy to note that under experimental conditions, respondents may state intention to engage in an action but will differ when presented with the real experience. Since the proposed MaaS scheme was presented in a stated choice format, a field trial will provide better insights for the implementation of MaaS in Japan. Nevertheless, the findings of this study give us useful insights towards the development of a sustainable MaaS scheme for Japan.

Chapter 7

Conclusion and implications

7.1 Introduction

This chapter concludes the study by summarizing the key research findings that addresses the research aims and objectives as well as the scientific contribution thereof. It also proposes the policy implication and recommendations of the study. Finally, it reviews the limitations of the study and proposes areas for future research.

7.2 Summary: Research objectives and main findings

In line with the current global trend that everything is moving towards a subscription economy and SDG number 11, this research investigated the possibility of introducing a innovative mobility service often referred to as Mobility as a Service (MaaS). More specifically, this study addressed these questions, whether there is a market for this new mobility scheme in urban as well as suburban areas. Also, who are the people that are more likely to use MaaS and what factors influences their decision to use MaaS. Addressing these questions requires conducting a survey to examine the people's willingness to accept MaaS or not, and their habitual behavior or attitudes that may hinder or influence MaaS adoption.

This study addressed these research questions by using a stated preference survey conducted in Biwako valley and Kyoto city. Data was collected from the residents in these areas which included their daily travel behavior, stated choices and personal attributes. A censored regression as well as structural equation modelling was employed to analyze the data. The main findings of this research are summarized below.

First, from the descriptive analysis, the results show that about 30% of the respondents in the Biwako valley and 68% of respondents in Kyoto city accepted to use MaaS depending on the price of the package. This suggest that there may be a significant potential demand and a growing market for MaaS to thrive in the study areas and that the curiosity of the people poses as potential demand for MaaS should it be introduced.

Second, in case of the Biwako valley, the estimation results from the Tobit type II model show that the travel mode train, has a positive effect on users choosing the MaaS packages whereas taxi had a negative effect. Rightly so because of the perception that taxis are expensive for daily trips. Furthermore, the monthly cost on using public transport and trip frequency also has a positive impact on choosing MaaS. The second part of the equation deals with the willingness-to-pay, in this case, the income, household size and possession of a commuter pass had positive effects on the willingness-to-pay for MaaS.

Third, to ascertain the determinants of the intention to use MaaS and the relationships between the latent variables and intention to use MaaS, structural equation modelling was used for this analysis. The SEM results show that car ownership and attitudes toward the use of private car are strong determinants for the intentions to use MaaS.

Furthermore, the research hypothesis and findings from Chapter 6 are as follows.

Table 7. 1 Summary of research hypothesis and findings

	Hypothesis	Expectation	Findings	Decision
1	**H1**: There is a significant relationship car ownership and intention to use MaaS.	Positive	Positive	Do not reject
2	**H2**: There is a significant relationship between TB and intention to use MaaS.	Positive	Negative	Reject
3	**H3**: There is a significant relationship between ATC and intentions to use MaaS.	Positive	Positive	Do not reject
4	**H4**: There is a significant difference between the relationships of the latent variables and the intention to use MaaS when considering urban residents and rural/suburban residents.	Positive	Negative	Reject

7.3 Contribution of the study

The main findings of this thesis contribute to literature in three broad ways.

1. These findings especially about the dynamics of the Biwako valley's built environment will help to develop strategies to integrate transport services in this area in a suitable and sustainable way. Should a pilot project be executed, these findings will form the basis for the inception and design of the MaaS packages that are well targeted towards the potential users. For example, creating a MaaS package around family households, care[8], and the first and last mile trips. This could improve accessibility, promote social inclusion,

[8] This refers to care and support for the elderly and disabled persons. For example, including ambulances, demand responsive transport to hospitals and supportive facilities for disabled persons to access public transport or share mobility.

improve quality of life and ultimately create a more environmentally friendly community (Barreto, Amaral, & Baltazar, 2018). The rural MaaS context present an interesting discussion to investigate the feasibility, and sustainability of the MaaS in suburbs or rural areas which has not been sufficiently explored. This can contribute to literature over the debate on sustainable mobility vis-à-vis traffic congestion solutions and environmental benefits.

2. These useful market insights will encourage transport planners and service providers to show commitment in adopting new business models for the development and implementation of MaaS.
3. These insights will assist municipalities, authorities and governments toward policy formulation that supports multi-modal integration.

7.4 Implications and recommendations

The findings of this research have the following implications which dwells on policy, MaaS development and the need for further research.

First, the results show that there is a market for MaaS in the study areas therefore, there is enough justification to go to the next stage of the implementation which is the pilot stage. With the percentage of respondents that stated intention to use MaaS, it is obvious that a pilot project will create more awareness about MaaS and its benefits, and it will create a better perception for value of MaaS after experiencing it for a certain period. Even though, there may be a demand for MaaS, nevertheless the operational feasibility still needs to be investigated. This is to ensure that the technology and systems support the implementation of MaaS.

Second, the results also reveals that the built environment plays an important role for the intention to adopt MaaS. Biwako valley has limited options in terms mobility services, accessibility, availability, and frequency of public transport, whereas the reverse is the case with Kyoto city. Therefore, it is not surprising that Kyoto city result shows a higher MaaS adoption in comparison with the Biwako valley. The people in Kyoto city are exposed to more mobility options especially the availability of shared micro mobility services improves accessibility. This implies that micro mobility could provide some level of convenience that is not found in the Biwako valley, as such shared micro mobility services should be introduced in the Biwako valley to cater for the first and last mile trips.

Lastly, the SEM results show that, car ownership and the peoples' attitude towards car usage are strong determinants of the intention to use MaaS. It is evident that in the city car ownership comes with associated cost which could be overbearing hence, single person household in Kyoto city are most likely not to own a car. This is due to the dynamics of the built environment; city residents naturally adopt public transport for obvious reasons. This also explains their willingness to use MaaS however the case is different especially within the Biwako valley since it is an auto reliant community. Since the residents already developed a habitual behavior of commuting or going for shopping with their private cars, it becomes difficult to change such behavior. In order to reduce car ownership in the Biwako valley and promote MaaS and make it attractive, government should adopt strategies like investing in non-motorized transport, educating the population to become part of the solution and formulate policies that should incentivize the return of license by elderly drivers, the use of cleaner vehicles and or public transport, and that improves digital accessibility of public transport services.

7.5 Limitations and future research

In this research, the sample size was constrained by the budget provided by the Shiga local authority. Also, the sample may not have been a representative subset of the residents. As such the results may be biased. Similarly, explaining the concept of MaaS to the residents only via this survey may not have provided sufficient understanding for them to make informed choices as such some irrational responses were noted. This may have influenced the outcome since the MaaS packages were merely hypothetical. As a result of these limitations, it should be considered that these findings may have some inherent bias.

On the other hand, the particular built environment attributes that strongly impacts the adoption of MaaS is still unclear and subject to further studies. Also, using tour or trip based origin and destination (for example work trips, non-work trips) as an analysis unit for MaaS adoption in the context of the built environment will provide more desired insights in the future.

Reference:

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211.

Amemiya, T. (1984). Tobit Models: A Survey. *Econometrics*, 24, pp. 3-61.

Bekesiene, S., Smaliukiene, R., & Vaicaitiene, R. (2021). Using Artificial Neural Networks in Predicting the Level of Stress among Military Conscripts. *Mathematics*, 9(6), 626; https://doi.org/10.3390/math9060626.

Bekhor, S., & Shiftan, Y. (2009). Specification and Estimation of Mode Choice Model Capturing Similarity Betwwen Mixed Auto and Transit Alternatives. *Journal of Choice Modelling*, 3(2), pp. 29-49.

Ben-Akiva, M., & Bierlaire, M. (2017). Discrete Choice Methods and Their Applications to Short Term Travel Deisions. In R. W. Hall, *Handbook of Transportation Science* (pp. pp. 5-33). Springer.

Ben-Akiva, M., & Lerman, S. R. (1985). *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge: The MIT press.

Ben-Akiva, M., & Lerman, S. R. (1985). *Discrete Choice Analysis: Theory and Application to Travel Demand.* Massachusetts: The MIT Press.

Bierlaire, M. (1998). Discrete Choice Model. In M. Labbe, G. Laporte, K. Tanczos, P. Toint, & (Eds), *Operations Research and Decision Aid Methodologies in Traffic and Transportation Management* (pp. 203-227). Springer-Verlag Berlin Heidelberg.

Breidert, C. (2005). Estimation of willingness-to-pay. Theory, measurement, and application. Vienna: ePubWU Institutional Repository.

Breidert, C., Hahsler, M., & Reutterer, T. (2006). A Review of Methods for Measuring Willingness-to-Pay. *Innovative Marketing, 2*(4), 1-3, 20-21.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. Transportation Research Part D: Transport and Environment, 2(3), 199–219. https://doi.org/https://doi.org/10.1016/S1361-9209(97)00009-6

Chalumuri, R. S., Errampalli, M., Bujangan, K. D., & Subamay, G. (2009). Applications of Neural Networks in Mode Choice Modelling for Second Order Metropolitan Cities of India. *Proceedings of the Eastern Asia Society for Transportation Studies vol. 7 (The 8th International Conference of Eastern Asia Society for Transportation Studies, 2009)*, p. 134, DOI https://doi.org/10.11175/eastpro.2009.0.134.0.

City population. (2020, June 8). Retrieved from City population website: https://www.citypopulation.de/php/japan-shiga.php

de Vos, J., Cheng, L., Kamruzzaman, Md., & Witlox, F. (2021). The indirect effect of the built environment on travel mode choice: A focus on recent movers. Journal of Transport Geography, 91, 102983. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2021.102983

Ding, L., & Zhang, N. (2016). A Travel Mode Choice Model Using Individual Grouping Based on Cluster Analysis. *Elsevier : Procedia Engineering*, 137; pp. 786-795.

Dörr, J., Wagner, T., Benlian, A., & Hess, T. (2013). Music as a Service as an Alternative to Music Piracy? Business & Information Systems Engineering, 5(6), 383–396. https://doi.org/10.1007/s12599-013-0294-0

Esztergar-Kiss, D., & Kerenyi, T. (2019). Creation of mobility packages based on the MaaS concept. *Travel Behaviour and Society*.

Ewing, R., & Cervero, R. (2010). Travel and the Built Environment. Journal of the American Planning Association, 76(3), 265–294. https://doi.org/10.1080/01944361003766766

Fioreze, T., Gruijter, M., & Gaurs, K. (2019). On the likelihood of using Mobility-as-a-Service: A case study on innovative mobility services among residents in the Netherlands. *Case Studies on Transport Policy* , 790-801.

Garaus, M., & Garaus, C. (2021). The Impact of the Covid-19 Pandemic on Consumers' Intention to Use Shared-Mobility Services in German Cities. Frontiers in Psychology, 12. https://www.frontiersin.org/article/10.3389/fpsyg.2021.646593

GlobalNewswire. (2022, February 5). *fotune business insight/video streaming market share.* Retrieved from www.globalnewswire.com: https://www.globenewswire.com/newsrelease/2021/12/15/2352238/0/en/Video-Streaming-Market-Share-to-Touch-USD-932-29-Billion-by-2028-Video-Streaming-Market-Size-2021-to-2028.html

Goodall, W., Fishman, T. D., Bornstein, J., & Bonthron, B. (2017). Deloitte Review: The Rise of Mobility as a Service (Reshaping how urbanites get around). *Deloitte University Press*(20), 112-129.

Heckman, J. J. (1976). The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models. In NBER, *Annals of Economic and Social Measurement, Volume 5, number 4* (pp. 475 - 492). NBER.

Heckman, J. J. (1979). Sample Selection Bias as a Specification Error. *Econometrica*, Vol. 47, No. 1, pp. 153-161.

Hensher, D. A. (2017). Future bus transport contracts under a mobility as a service(MaaS) regime in the digital age: Are they likely to change? *Transportation Research Part A*, 86-96.

Hietanen, S. (2014). Mobility as a Service - The new transport model? *Eurotransport; ITS and Transport Management Supplement, 12*(2), 2-4.

Ho, C. Q., Hensher, D. A., Mulley, C., & Wong, Y. Z. (2018). Potential uptake and willingness-to-pay for Mobility as a Service. *Transportation Research Part A*, 320-318.

IRU. (2019). *IRU website*. Retrieved August 9, 2019, from https://www.iru.org/innovation/maas

Kagee, A., & Freeman, M. (2017). Mental Health and Physical Health (Including HIV/AIDS). In *International Encyclopedia of Public Health (Second Edition)* (pp. 35-44). Elsevier.

Kaklauskas, A., & Gudauskas, R. (2016). 17 - Intelligent decision-support systems and the Internet of Things for the smart built environment. In F. Pacheco-Torgal, E. Rasmussen, C.-G. Granqvist, V. Ivanov, A. Kaklauskas, & S. Makonin (Eds.), Start-Up Creation (pp. 413–449). Woodhead Publishing. https://doi.org/https://doi.org/10.1016/B978-0-08-100546-0.00017-0

Kamargianni , M., Li, W., Matyas, M., & Schäfer, A. (2016). A critical review of new mobility services for urban transport. *Transportation Research Procedia* , vol 14, 3294 – 3303.

Kamargianni, M., Matyas, M., Li, W., & Muscat , J. (2018). *Londoners' attitudes towards car-ownership and Mobility-as-a-Service: Impact assessment and opportunities that lie ahead.* London: MaaSLab - UCL Energy.

Kamargianni, M., Matyas, M., Li, W., & Schäfer, A. (2015). Feasibility Study for "Mobility as a Service" concept in London. *UCL Energy Institute*, 1-84.

Keane, M. P., & Wasi, N. (2012, October 3). *Papers; Estimation of Discrete Choice Models with Many Alternatives Using Random Subsets: With an Applicarion to Demand on Frozen Pizza.* Retrieved from Economices.ox.ac web site: https://www.economics.ox.ac.uk/materials/papers/12755/2012-W13.pdf

Klaiber, A. H., & Haefen, R. v. (2016). Do Random Coeffiecients and Alternative Specific Constants Improve Policy Analysis? An Empircal Investigation of Model Fit and Prediction. *Wordpress North Carolina State University*, pp. 1-26.

Lee, D., Derrible, S., & Pereira, F. C. (2018). Comparison of Four Types of Artificial Neural Network and a Multinomial Logit Model for Travel Mode Choice Modeling. *Transportation Research Record*, 1-12; https://doi.org/10.1177/0361198118796971.

Lee, J.-S., Nam, J., & Lee , S.-S. (2014). Built Environment Impacts on Individual Mode Choice: An Empirical Study of the Houston-Galveston Metropolitan Area. *International Journal of Sustainable Transportation* , Volume 8, Issue 6 Pages 447-470; DOI: https://doi.org/10.1080/15568318.2012.716142.

Li, X., Wang, Y., Wu, Y., Chen, J., & Zhou, J. (2021). Modeling Intercity Travel Mode Choice with Data Balance Changes: A Comparative Analysis of Bayesian Logit Model and Artificial Neural Networks. *Journal of Advanced Transportation*, Article ID 9219176, 22 pages https://doi.org/10.1155/2021/9219176.

Li, Y., & Voege, T. (2017). Mobility as a Service (MaaS): Challenges of Implementation and Policy Required. *Journal of Transportation Technologies, 7*, 95-106.

MaaS Alliance. (2019, August 28). *MaaS Alliance homepage*. Retrieved August 9, 2019, from MaaS Alliance: https://maas-alliance.eu/homepage/what-is-maas/

Madhuwanthi, R., Marasinghe, A., Rajapakse, R. J., Dharmawansa, A. D., & Nomura, S. (2016). Factors Influencing to Travel Behavior on Transport Mode Choice - A Case of Colombo Metropolitan Area in Sri Lanka. *International Journal of Affective Engineering*, Volume 15 Issue 2 Pages 63-72; DOI https://doi.org/10.5057/ijae.IJAE-D-15-00044.

Manski, C. F. (1977). The Structure of Random Utility Models. *Theory and Decision*, Vol. 8 (3) pp. 229-254.

Matthew McKibbin. (2011, September 30). The influence of the built environment on mode choice – evidence from the journey to work in Sydney. https://www.worldtransitresearch.info/cgi/viewcontent.cgi?article=5590&context=research

Minal, S., & Ravi Sekhar, C. (2014). MODE CHOICE ANALYSIS: THE DATA, THE MODELS AND FUTURE AHEAD. *International Journal for Traffic and Transport Engineering (IJTTE)*, 4(3):269-285 DOI: 10.7708/ijtte.2014.4(3).03.

Mintesnot, G., & Shin-ei, T. (2008). Modeling the Relationship Between Travelers' Level of Satisfaction and Their Mode Choice Behavior Using Ordinal Models. *Transportation Research Forum*, Vol. 47, No. 2, pp. 103-118.

Monroe, K. B., & Cox, J. L. (2001). Pricing Practices that Endenger Profits. *Marketing Management, 10*(3), 42-46.

Mulley, C., Ho, C., Balbontin, C., Hensher, D., Stevens, L., Nelson, J. D., & Wright, S. (2019). Mobility as a service community transport in Australia: Can it provide a sustainable future? *Transportation Research Part A*, 131 (2020) 107-122.

Nikkei Asia. (2018, October 4). Nikkei Asian Review. *Business Deals*.

Ortúzar, J. d., & Willumsen, L. G. (2011). *: Modelling Transport, 4th Edition.* New York: Wiley Press.

Ritchie, H., & Roser, M. (2018). Urbanization. *Our World in Data, https://ourworldindata.org/urbanization (online resource)*.

Rye, T. (2017, August 22). *Tools & Resources - Civitas Prosperity.* Retrieved April 27, 2021, from Civitas Prosperity: http://sump-network.eu/fileadmin/user_upload/Innovation_Brief_Mobility_as_a_Service_22_08_2017_web.pdf

Satoshi, F., & Ryuichi, K. (2003). What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation*, Vol. 30(1) 81-95.

Sayed, T., & Razavi, A. (2000). Comparison of Neural and Conventional Approaches to Mode Choice Analysis. *Journal of Computing in Civil Engineering* , Volume 14 Issue 1 - January 2000, https://doi.org/10.1061/(ASCE)0887-3801(2000)14:1(23).

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the Fit of Structural Equation Models: Tests of Significance and Descriptive Goodness-of-Fit Measures. *Methods of Psychological Research Online*, Vol.8, No.2, pp. 23-74.

Schikofsky, J., Dannewald, T., & Kowald, M. (2019). Exploring motivational mechanisms behind the intention to adopt mobility as a service (MaaS): Insights from Germany. *Transportation Research Part A*, 131 (2020) 296-312.

Singh, M. (2019). India's shift from mass transit to MaaS transit: Insights from Kochi. *Transportation Research Part A*, 113, 219-227.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1977). Behavioral Decision Theory. *Annual Reviews*, 28: pp. 1-39.

Smith, G., Sochor, J., & Karlsson, M. I. (2018). Mobility as a Service: Development scenarios and implications for public transport. *Research in Transport Economics, 67*, 592-599.

Sochor, J., Arby, H., Karlsson, M. I., & Sarasini, S. (2018). A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. *Elsevier; Research in Transportation Business & Management, 27*, 3-14.

Sochor, J., Karlsson, M., & Strömberg, H. (2016). Trying Out Mobility as a Service: Experiences from a Field Trial and Implications for Understanding Demand. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2542(1) p.57-74.

Statistica. (2022, February 8). *Statistics*. Retrieved from Statistica.com: https://www.statista.com/statistics/1180945/japan-tourist-numbers-in-kyoto-prefecture/

Svenson, O. (1979). Process Description of Decision Making. *Organizational Behavior and Human Performance*, 23, pp. 86-112.

The World Bank. (2019). *Population growth (annual %).* Retrieved June 16, 2021, from https://data.worldbank.org/indicator/SP.POP.GROW?end=2019&start=1961&view=chart

Tran, M., & Brand, C. (2021). Smart urban mobility for mitigating carbon emissions, reducing health impacts and avoiding environmental damage costs. *Environmental Research Letters*, 16. 114023.

Transport Systems Catapult. (2016). *Mobility as a service: Exploring the opportunity for Mobility as a Service in the UK.* Transport Systems Catapult.

UN General Assembly. (2017, December 20). *Resolutions adopted by the General Assembly.* Retrieved from un.org: https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/72/212&Lang=E

United Nation. (2021, November 30). *Sustainable transport*. Retrieved from sdgs.un.org: https://sdgs.un.org/topics/sustainable-transport

Vij, A., Ryan, S., Sampson, S., & Harris, S. (2018). Consumer preferences for Mobility-as-a-Service (MaaS) in Australia. *ATRF 2018 Proceedings*, 1-8.

Wikipedia. (2021, November 27). Retrieved from wikipedia.org: https://en.wikipedia.org/wiki/Greenhouse_gas_emissions_by_the_United_States

Xie, C., Lu, J., & Parkany, E. (2003). Work Travel Mode Choice Modeling with Data Mining Decision Trees and Neural Networks. *Transportation Research Record 1854*, Paper No. 03-4338.