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Explorative analysis of potential MaaS customers: an agent-based scenario

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Abstract

Mobility-as-a-Service (MaaS) is a user-centered service that combines different mobility services offered to the users by means of different packages. The users fulfil their daily mobility needs using a subscription-based smartphone application, which gives them access to the services within their mobility budget. Various surveys on MaaS have been run in the last years to capture which transport mode can be more suitable within a package and the user's willingness to pay. Moreover, pilot projects have been employed to figure out potential MaaS users' characteristics and inclination. Results among stated preference scenarios differ due to the different characteristic of the demand and supply. Hence, there is not a general consensus of the potential of MaaS membership choice. This study embraces three different approaches: agent-based, transport economy and discrete choice theory to further explore this direction. We simulate two scenarios by using the state-of-the-art agent-based software MATSim, which allows to maximize the user's utility of performing activities and account for travel costs. The first one is MaaS scenario which is implemented considering car-sharing systems and public transport as a basic MaaS package. We employ an economic approach which assumes MaaS services costs to be perceived as fixed costs by the customers. The second is a Pay-as-to-go (NoMaaS) scenario where users pay the service as much as they travel. Moreover, the study assumes all transport modes to be accessible to the generated population of the city of Berlin. By evaluating the differential of users' utility this study aims to explore potential MaaS customer. The results indicate a propensity to subscribe among public transport and two-way car-sharers, whereas MaaS seems to capture new free-floating customers. Both carsharing services are employed for more than 50 % of travel time keeping the car longer in their daily trip chain, because MaaS system allows users to do not consider marginal cost in their daily travel pattern. Click here and insert your abstract text.

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1. Introduction

Mobility-as-a-Service (MaaS) is a recent concept, formally introduced by Hietanen and Heikkila in 2014 [1]. MaaS is described as a mobility model, which integrates different transport services under a single interface of one

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provider to offer tailored and seamless mobility packages. MaaS is a user-centric-system which brings multiple mobility services together under one subscription and provides users' access to a plan through a digital interface [2]. Moreover, making users more aware of a wider available set of transport modes, MaaS is perceived as a possible alternative to car-ownership [3],[4]. Furthermore, this new concept can bring more sustainable forms of travel behavior and by bundling transport modes under one offer it has the potential to generate sustainable value that benefits more than just individual users [5]. Three aspects are critical to organize the new service structure: "bundles", "budgets" and "brokers". The first one represents the integration of different mobility services into a package gathered under one subscription, the second individualizes user's preference and service provision possibilities and the third is the new entrepreneurial model providing aggregating function, B2C interface and financial clearing system [6],[7]. Furthermore, developing an efficient and financially sustainable MaaS system needs cooperation among different actors; the demander who subscribes to the package, the broker who provides different mobility services in bundles, the transport service suppliers and the government which should give the accessibility to provide developing MaaS system and supervising the level of service and quality control [6]. By connecting all these actors the MaaS system can be described as a complex supply chain which tries to define and customize travel users' needs under one subscription building a more sustainable mobility network and letting customers capture added value of having a wider transport service portfolio.

A challenge to implement a MaaS system is to identify a specific package including different mobility services which provides specific travel options considering heterogeneous users' travel needs and values [8],[2]. Previous researches have mainly focused on which transport mode could be more suitable in a MaaS package and to capture users' perception of the service and willingness to pay a MaaS plan or specific mobility service [9],[10]. Moreover, some pilot projects have been implemented in order to understand the appeal of a MaaS system selecting specific target of participants [11],[12]. A generic MaaS membership choice model which captures potential customer's characteristics and travel needs has not been implemented yet. This work presents the first step towards developing such model by exploring the potential MaaS customer attributes. To do so we apply different approaches: agent-based simulation to capture daily users' travel pattern and needs at microscopic level, an economic approach which considers how public transit costs (disutility) are perceived and discrete choice theory by evaluating the differential of users' daily utility function between scenarios.

2. Literature review

MaaS is a user-center system which aims to overcome the transport market fragmentation offering a seamless mobility plan under one subscription. Being a MaaS member allows customers to access a wider set of mobility choices that satisfies their travel needs. Identifying which MaaS package suits best for a specific customer's profile is a challenge because it's necessary to figure out how MaaS can be integrated with the current users' mobility needs. Every user has different travel pattern and activities to achieve and bundling mobility services under one plan should allow users to fulfil their needs. Clustering different types of customer within a limited number of bundles is a difficult task due to the fact that the service is not available on the market.

MaaS has been mainly studied by using stated preference surveys. A study in Sydney, Australia, evaluated the willingness to pay for each item in a MaaS package. The participants answered about their socio-economic characteristics, current travel pattern and based on it, a four types of mobility plans were offered: two fixed-cost MaaS packages, a pay-as-to-go plan and further it was asked to the interviewee to create his/her own plan. Results have shown how MaaS seems not to be attractive to public transport users and there are no preferences among MaaS plans, but the probability of subscribing increases with age and number of the children in the household [13]. Another MaaS survey carried on in London; four different MaaS plans have been presented to the participants and the 4th was created by themselves. By estimating a mixed multinomial logit model authors have shown how including public transport mode, bus pass and travelcards increases the probability to subscribe [14]. Another stated preference survey in Australia consisted of four different scenarios; per each scenario there were two hypothetical MaaS schemes that differed by transport modes offer, level of ticketing, booking integration, degree of personalization, availability of real-time, subscription model and price, and a further hypothetical pay-as-to-go package was shown. A latent class choice model has been estimated, outcomes have shown how MaaS customers are young or middle age individuals and well-educated further the attitude to subscribe increases if the customer already uses shared transport modes [10]. In the Netherlands another approach has been employed by considering a series of attitudinal indicators to understand the MaaS users' attitudes. A latent class cluster analysis has been performed under the hypothesis that attitudes of these indicators are somehow correlated to each other in a MaaS subscription.

The analysis has shown that there is a positive attitude among individuals with an attitude toward public transport and low car drive and these attitudes are aligned with current mobility user's patterns [15]. Among stated preference surveys one in particular has also estimated a MaaS membership choice model requesting to the interviewee to pick from 0 to 7 transport modes in his/her own package in a list of 9 mobility services, it has been called "pick-any" approach and with this technique each participant develops a different MaaS package and not general one [16]. By estimating a binary logit model, results have shown the probability of subscribing to a MaaS service decreases monotonically with the increase of the packages price. Furthermore, social influence (if someone among friends already has the subscription), time commitment and public transport offered in the plan increase the probability of subscribing to a MaaS plan. Whereas, people who have in their daily trip chain walking, bicycle or car as driver are less apt to pay for the plan [16]. Furthermore, some pilot project has been employed, among others the "UBIGO" was a 6 months project in the city of Gothenburg, Sweden, involving 20 households as participants which have accessed a family MaaS plan made using the existing transport modes [17]. A pilot at the university of Ghent, Belgium has been run with 100 participants choosing three different packages [11]. Both the projects ended due to the lack of integration within suppliers and the government. Nowadays the most deployed MaaS platform is "WHIM" which has been adopted in many countries providing 3 monthly plans and also pay-as-to-go solution [12]. The MaaS system has been simulated in an agent-based model using the software MATSim, considering walk, bike, private car, public transport, car-sharing, electric bike sharing and ride sharing as transport modes in the city of Zurich. The researches aimed to analyze how MaaS contributes to welfare and resource efficiency of the transport system focusing on the supply side [18]. Utility function parameters of shared modes have been based on a previous stated-preference study on automatic vehicles. Furthermore, no fares subscription for any service has been considered in the scenarios and all the shared modes are accessible to all agents indiscriminately without any restricted membership.

The reviewed literature is not fully aligned especially in assessing if public transport users are willing to subscribe or not, and in general what will be the mode shift expected from pay-as-you-go services to MaaS packages. Furthermore, stated preference surveys mainly evaluated which travel service could be more suitable in a specific plan. This type of analysis does not always guarantee a realistic estimation of travel behavior model, due to the fact that participants have claimed their future intention based on hypothetical services or developing their own plans. Moreover, specific target of participants has been selected in the pilot project limiting the research results.

This research aims to analyze MaaS potential customer attributes by simulating and comparing two scenarios: MaaS and Pay-as-to-go using the agent-based software MATSim in order to reach a stochastic users' equilibrium reflecting the maximization of their daily utility [19]. Moreover, we capture users' added value to subscribe, applying an economic study about how customers perceive MaaS service costs in a multimodal system and evaluating the differential of users' daily utility function between scenarios [20].

3. Methodology

In this study free-floating, two-way and public transport have been considered as available mobility services. An agent-based approach has been used since it can explicitly model the spatial and temporal distribution of single users giving a microscopic approach to the research, which is essential to simulate MaaS services which have employed for different and interrelated purposes and activities [19]. Moreover, agent-based modeling allows to have a dynamic response of the demand to the variation of the supply side.

In the simulation each agent is generated together with a daily plan with all the destinations to reach in order to perform daily duties and a score or a daily utility function represents the sum of all activity utilities $\sum_{q=0}^{N-1} S_{act,q}$ and all travel (dis)utilities $\sum_{q=0}^{N-1} S_{travel,(mode)q}$ where q is a trip which follows the activity q Eq.(1):

$$S_{plan} = \sum_{q=0}^{N-1} S_{act,q} + \sum_{q=0}^{N-1} S_{travel,(mode)q} \quad (1)$$

The travel disutility function represents generalized costs of travelling by specific mode in a daily trip q :

$$S_{trav,q,cs} = \alpha_{cs} + \beta_{c,cs} * (c_t * t_r + c_d * d) + \beta_{t,walk} * (t_a + t_e) + \beta_{t,cs} * t \quad (2)$$

$$S_{trav,q,cs} = \alpha_{pt} + \beta_{t,pt} * t \quad (3)$$

Equation (2) is the cost function of travelling by carsharing, where α_{cs} is the mode-specific constant,

$\beta_{c,cs} * (c_t * t_r + c_d * d)$ represents the cost of reservation and travelled distance, $\beta_{t,walk} * (t_a + t_e)$ is the walking path to and from the station and it is evaluated as walking trip and $\beta_{t,cs} * t$ is the additional unit of utility spent travelling by car sharing [21]. Equation (3) is the cost function of travelling by public transport where α_{pt} is the mode specific constant and $\beta_{t,pt} * t$ is the marginal utility of time spent travelling by public transport.

We adopt a transport economic approach to represent how public transit daily costs are perceived by users. This approach is based on a fundamental concept following, which assumed that users perceive the daily costs of public transit as fixed price [20]. We apply these daily fixed costs in the travel disutility function to all MaaS services considering the same price cost to each service. After simulating, the output provided are the users' plan which represents the daily mobility choice of each agent and his/her respective score. Studying a possible increase or detriment of agent's score between scenarios we identify the added value of subscribing a MaaS service .

Figure (1) shows the methodology framework taking into account all the approaches. Two different scenarios have been run considering public transport, two-way and free-floating carsharing services as public transit (PT) and also bike, walk and private have been simulated as transport mode. The first scenario is a pay-as-to-go or NoMaaS scenario where users pay the mobility services as much as they employ them during the day, instead a MaaS scenario is simulated applying a fixed daily cost of all public transit represented as a constant in their travel disutility function. Once we simulate the two scenarios this study explores the willingness to purchase a MaaS package taking into account that the purchase a membership-based service is worthy if an increase of daily satisfaction (score) to achieve user's daily goals is perceived by the potential customer. Considering that assumption we evaluate the differential score between scenarios to capture an increase of score among agents who have employed MaaS services in the MaaS scenario if compared to NoMaaS.

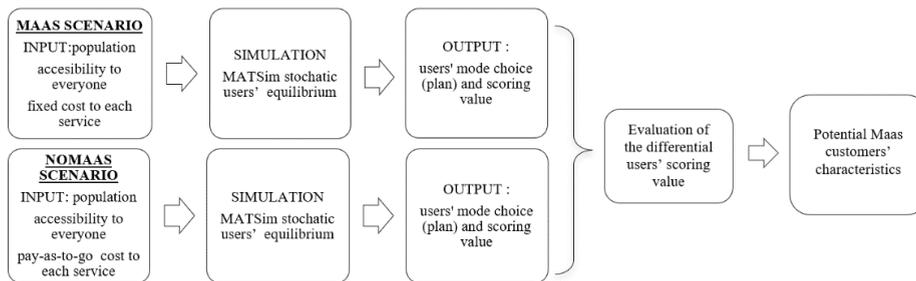


Fig.1. Methodology framework

3.1 Case study

This paper uses a previously developed scenario consisting of a synthetic population of 25560 users with socio-demographic characteristics in the city of Berlin [22].

The fixed cost of public transit has been employed considering 150 euro/month as subscription fee, which is the one considered in Caiati's study [16]. We split this monthly price to 20 working days and for 3 different mobility services: public transport, free-floating and two-way to have a fixed cost of 2.5 euro per day. By implementing this constant in the travel disutility functions (Eq2 and 3) we simulate MaaS scenario, without considering any marginal cost of the public transit. Whereas, all the marginal costs have been considering in pay-as-to-go scenario applying a previously calibrated carsharing scenario in the city of Berlin . Moreover, we consider same costs for both carsharing service types following Berlin's average price [23],[24]. Furthermore, per each scenario 500 iterations have been run and a restricted free-floating service area and also two cars per station for two-way system have been employed giving accessibility to the services to all agents. A limitation of this study are the usage of MATSim software which uses co-evolutionary algorithm to achieve users equilibrium, but it will never really reach the equilibrium of the system, therefore the distribution of transport mode during trip mode choice is random and the evaluation of the best score takes in to account the last 4 in order to have reasonable simulation time.

4. Results

This section shows the results of the explorative analysis between "No MaaS" and "MaaS" scenarios.

Agent who has chosen at least one trip made by MaaS service in Maas scenario has also been analyzed in "No MaaS" scenarios in order to identify the differential (Δ) of users' daily utility function.

Table 1. Overlapping of mode choice between scenarios

Travel modes	NoMaaS	MaaS
Car	410	407
Walk	358	13
Public transport	549	1197
Free-floating	34	111
Two-way	13	46
Bike	393	13

Table1 shows the mode choice per single trip between scenarios among customers who have increased their daily utility function. It seems that public transport choice is more than two times greater than in a NoMaaS scenario, whereas carsharing choice is more than three times greater. All those increases are due to a shift from walk and bike choices, instead car choice seems to be constant, which suggests that MaaS is not likely to substitute private cars.

Table 2. Mode choice between scenarios and Δ among them

Travel modes	mode choice(%)	Δ (%)
Public transport	>90%	>80%
Free-floating	40%	28%
Two-way	54%	>60%

Table3. Shared mode

Travel modes	NoMaaS	MaaS
Free-floating	Up to 40%	From 70%
Two-way entry	From 30%	From 80%

Table 2 represents the percentage of the number of users that keep their mode choice between scenarios (first column) and the percentage of these who increase their utility function (second column). The public transport users are more than 90%, and almost all of them have an increase of their daily utility function. The increase is achieved when the daily trip chain has more than 3 intermediate destinations while daily total travel time is no longer than 3h. Free-floating users are less than 40% between scenarios, instead more than 50% of the free-floating users seem to use the service for the first time in the MaaS scenario. Whereas, more than half of two-way customers in the NoMaaS scenario still use the service and more than 60% increased their utility function. Furthermore, in Table 3 we consider the percentage of daily travel time made with carsharing and compare the differential of daily utility function to capture some collinearity between these variables. The results show an increase of score among two-way users, when they have to travel more than 80% of the daily travel in MaaS scenario, instead in the NoMaaS scenario this is more than 30%. Whereas, free-floating customers travel up to 40% of their daily travel time to have an increase of the score, instead in MaaS scenario there is a shift of the percentage, it seems that more than 70% of daily travel time done by free-floating increases the user's score.

5. Summary and conclusion

In this study we adopted agent-based modelling to assess the potential take up of MaaS and the potential modal shift from single services. We observed that for people which have had an increase of daily scoring function MaaS services mainly substitute eco-friendly transport modes such walk and bike. This suggests how MaaS is not likely to be a competitive service to private cars. MaaS members seem to be frequent public transport users since more than 80% of them have an increase of utility function in a MaaS scenario and this result is aligned with some of the survey results in the literature [14],[16]. Additionally, potential users are those having a complex trip chain with different activities to achieve but with a relatively short trip time. The potential subscriber who already takes public transport keeps using it because once he paid for one trip in a MaaS scenario he/she has free accessibility to the service and keeps using it to perform activities. Moreover, due to the high percentage of public transport users who increase their score, this service should be regarded as a basic transport mode in a potential MaaS package.

Customers of two-way car-sharing services tend to adopt MaaS (54%) and more than 60% of them have increased their utility function. Moreover, they seem to use the service longer in a MaaS scenario, to increase their utility which is expected considering how MaaS system shifts mobility costs from marginal (pay-as-to-go) to fixed. The two-way customers use longer the service once they purchase a package, therefore they keep the car longer since they do not perceive any marginal cost of the service. Instead free-floating mode seems to attract new users in a MaaS scenario, because less than 40% are still keeping the service. Whereas, the new free-floating customers seem to keep the car for more than 70% of their total travel time. They use the service as a rental car system because once they purchase the plan, they do not perceive any marginal cost of the service since they are considered in a MaaS business [18]. The MaaS customer who has an increase of utility function perceived the transport service by a fixed price and not a pay-as-to-go service which is the main goal of MaaS system. Potential customers are more willing to subscribe if they

already experienced public transport and two-way in their travel pattern, whereas they are willing to use free-floating as a new additional service in their daily transport choices. It should be however pointed out that the study does not consider time limits for the use of each service. In a MaaS plan, it is foreseen that booking hours of car-sharing services should be limited, hence avoiding the customers to use car-sharing as daily rental cars.

Future research will study which activities are achieved by potential MaaS members. Furthermore, the users' willingness to pay and further users' attributes that increase the propensity to subscribe. Once we obtain more potential customer's attributes, which will allow to estimate a generic MaaS membership choice model to be able to identify the percentage of potential MaaS members in different contexts.

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