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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 characteristics of the demand and supply. Hence, there is not a general consensus around the potential of MaaS membership choice. This study embraces an agent-based modeling approach which allows to maximize the user's utility of performing activities and account for travel costs to simulate two scenarios. The first one considers carsharing systems and public transport as a basic MaaS package. We further employ an economic approach which assumes MaaS services costs to be perceived as fixed costs by the customers. We assume the same MaaS package to be accessible to the generated population of the city of Berlin. The second is a Pay-as-you-go (NoMaaS) scenario where users pay the service experiencing trip-based costs. Evaluating the differential of users' utility when comparing the two scenarios this study aims to explore the characteristics of the potential MaaS customers. The results indicate a higher propension to subscribe among public transport and two-way car-sharers, whereas MaaS seems to capture new free-floating customers. The potential users employ both carsharing services longer in their daily trip chain in the MaaS scenario, because the new mobility system allows users to do not consider marginal cost in their daily travel pattern. Outcomes also indicate that MaaS will not be a direct substitute to private car, and it's likely to extend rental time of car sharing systems.

Keywords: Agent-based modeling; MaaS potential customers ; travel costs

1. Introduction

Mobility-as-a- Service (MaaS) is a recent concept, formally introduced by Hietanen and Heikkila in 2014 [1].

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MaaS is described as a mobility model, which integrates different transport services under a single interface of one provider in order 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 potentially foster 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 modes [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]. 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 packages including different mobility services which provide specific travel options considering heterogenous 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 services to be included in the packages [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 behavioral theory by evaluating the differential of users' daily utility function between scenarios.

2. Literature review

MaaS is a user-centric system which aims to overcome the transport market fragmentation offering a seamless mobility plan under a single 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 since commercial deployment has been done only in few cities and mainly via pilots. 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]. In 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. 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 and assuming these measures 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 Caiati et al. estimated a MaaS membership choice model by requesting to the interviewee to pick from 0 to 7 transport modes in his/her own package from a list of 9 pre-selected mobility services; this has been called “pick-any” approach and with this technique each participant develops a different MaaS package and not a 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 [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]. Nowadays the most deployed MaaS platform is “WHIM” which has been adopted in many countries providing 3 monthly plans and also Pay-as-you-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, carsharing, 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 a 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-you-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 behavioral theory evaluating the differential of users’ daily utility function between scenarios [20].

3. Methodology

In this study free-floating, two-way carsharing and public transport have been considered as MaaS services gathered under single plan. 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 $\sum_{q=0}^{N-1} S_{trav,(mode)q}$ where q is a trip which follows the activity q with N as number of activities Eq.(1):

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

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

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

$$S_{trav,q,mode} = \alpha_{mode} + \beta_{t,mode} * t \tag{3}$$

Equation (2) is the cost function of travelling by carsharing services, where α_{cs} is the mode-specific constant. Whereas, $\beta_{c,cs} * (c_t * t_r + c_d * d)$ 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 $\beta_{t,cs} * t$ t is the additional unit of utility spent travelling by carsharing [21]. Equation (3) is the cost function of travelling by the other available modes in other words bike, walk and public transport, where α_{mode} is the mode-specific constant and $\beta_{t,mode} * t$ is the marginal utility of time spent travelling by that specific mode. 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, which assumes 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 decrease of agent's score between scenarios we identify the added value of subscribing to a MaaS service . Figure (1) shows the methodological framework. Two different scenarios have been run considering public transport, two-way and free-floating carsharing services as public transit (PT) and also bike and walk accessible to all agents, and private car according with user's availability have been simulated as transport modes The first scenario is a Pay-as-you-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 of 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 this assumption we evaluate the users' scoring value between scenarios to capture the differential of score among agents who have employed MaaS services in the MaaS scenario if compared to NoMaaS.

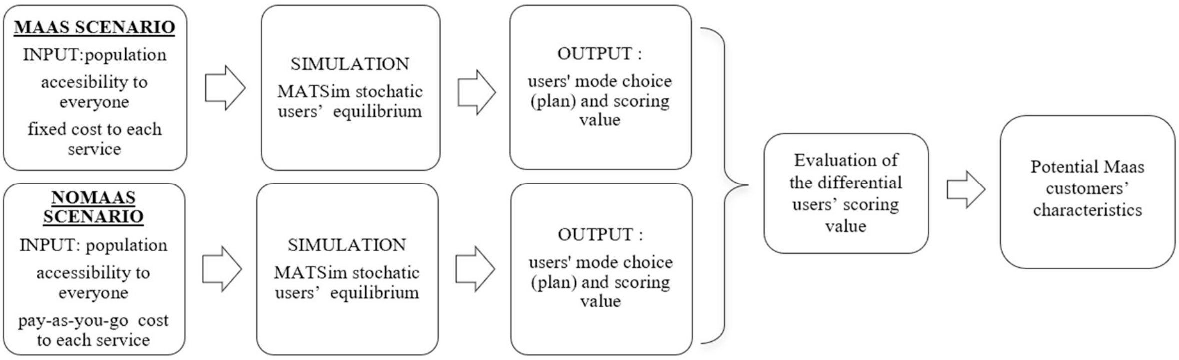

Fig.1. Methodology framework

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 (Eq 2 and 3) we simulate the MaaS scenario, without considering any booking and travelled distance costs of the public transit. Whereas, all reservation and trip-based costs have been considered in the Pay-as-you-go scenario by applying a previously calibrated carsharing scenario in the city of Berlin . Moreover, we consider the same fare 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 with 107 available cars and 62 stations each offering two cars for two-way system 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 stochastic and the evaluation of the best score takes into account the last 4 in order to have reasonable simulation time.

4. Results

This section shows the results of the comparative analysis between "No MaaS" and "MaaS" scenarios. Agents who have chosen at least one trip made by MaaS service in the MaaS scenario have also been analyzed in the NoMaaS scenarios in order to identify the differential (Δ) of users' daily utility function. Table 1 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 these increases are due to a shift from walk and bike choices to Maas , instead car choice seems to be constant, which suggests that the mobility services gathered in MaaS plan are not likely to substitute private cars.

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

Table 2 represents the percentage of the number of users that keep their mode choice between scenarios (second column) and the percentage of these who increase their utility function, in other words who has a positive differential of score between scenarios (third 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. Results show an increase of score among two-way users, when they have to travel more than 80% of their daily travel in MaaS scenario, instead in the NoMaaS scenario this is more than 30%. Whereas, free-floating customers travel as high as 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. Hence, results indicate that MaaS will be, given the specifications of the simulated scenarios, very attractive for public transport users, and in general for performing short and frequent trips, which on the other hand were mainly done with active modes.

Table 2.Mode choice between scenarios and $\Delta>0$ among them

Travel modes	mode choice (%)	$\Delta>0$ (%)
Public transport	>90%	>80%
Free-floating	40%	28%
Two-way	54%	>60%

Table3. Shared mode

Travel modes	NoMaaS	MaaS
Free-floating	As high as 40%	Greater than 70%
Two-way entry	Greater than 30%	Greater than 80%

5. Summary and conclusion

In this study we adopted agent-based modeling 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 more sustainable transport modes such walk and bike. This suggests how MaaS is not likely to be a competitive service to private cars. Potential MaaS members seem to be frequent public transport users since more than 80% of them experience an increase in score 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 carsharing 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-you-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 services by a fixed price and not as pay-as-you-go service which is the main goal of MaaS system. Potential customers are more willing to subscribe if they already used regularly 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 carsharing services should be limited, hence avoiding the customers to use carsharing 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 propension 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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