Innovations in urban mobility and travel demand analysis: Mobility as a Service context

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Abstract: *As Mobility-as-a-Service (MaaS) is a new emerging mobility concept and its implementation is still limited, there is currently no sufficient knowledge about how to model individual and/or household decision-making process in adopting MaaS and consequently using the available services to travel. These two phases of the decision-making process can be considered as a long-term and a short-term mobility decision respectively. This is a discussion paper delineating some directions for researching the long-term mobility decision. It explores theoretically the key issues related to the investigation and modelling of long-term adoption of MaaS. These issues are related to the multi-faceted nature of MaaS, which is currently recognized as a technology enabled innovation that is revolutionizing the transportation system. This brings the need for new methodological approaches in travel behavior research. After having defined the MaaS concept, we propose a multi-theoretical framework, which can act as an initial conceptual foundation for further studies aimed at quantitatively estimating MaaS long-term adoption and consequently its diffusion into society.*

Keywords: *"Mobility-as-a-service", "travel demand analysis", "innovation", "technology acceptance".*

1. Introduction

Sustainability is linked with national, international and intra-national policy objectives in countless agendas around the world. However, continuing population growth, urban sprawl and growing demand pose constantly new challenges to urban planners and policy makers. In the context of transportation planning, a larger number of city inhabitants implies an increase in travel demand, which can produce growing environmental, social and economic problems. In order to mitigate these problems, new approaches to urban mobility planning are emerging that can stimulate a shift towards more sustainable transport modes, shifting away from the use of private cars, while increasing the infrastructure's network efficiency (European Commission 2007; European Commission 2013; OECD 2002; OECD 2015; United Nations 2012). Many innovative directions have been explored within the transportation field, taking into account the technological advances, the social context and the emerging challenges in order to achieve more sustainable transport systems. New mobility services developed under the labels of shared mobility, smart mobility, flexible and demand responsive mobility, or door-to-door mobility attempt to change the way in which people plan and execute their trips. Within this framework, Mobility as a Service (MaaS) is a new concept that has received increasing interest in the last few years. It focuses on the integration of a variety of transport modes (e.g. car-sharing, bike-sharing, taxis, bus, metro) and other transport-related services and available functionalities (e.g. travel recommendation system, booking and payment services) offered by different operators through a single integrated platform. Due to the novelty of this type of service, which is explicitly conceived in 2014 (Hietanen 2014), a

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scarce literature is currently available, despite it is increasingly growing as MaaS concept becomes more popular also in urban, national and international agendas.

One basic but comprehensive definition is the one describing MaaS as a mobility distribution model that delivers user's transport needs through a single interface of a service provider where users buy mobility services either as mobility packages or as pay-per-use (Hietanen 2014; Florence School of Regulation 2015; Kamargianni et al. 2015; Sochor, Strömberg & I.C. Marianne Karlsson 2015). It combines different transport modes to offer a tailored mobility package, similar to a monthly mobile phone contract. The role of Information and Communication Technology is important for the necessary information integration and convergence between users, transport providers, and services, a dynamic and interactive process that Internet of Things (IoT) can capture to describe the necessary information collection, processing and offering (Florence School of Regulation 2015; Nemtanu et al. 2016). MaaS concept envisions a 'seamless' combination of all transportation modes and a 'Mobility Aggregator' that gathers and sells all services through a single smartphone app, allowing easy fare payment and one-stop billing (CIVITAS 2016). For that reason it is important the role of subscription in MaaS both for daily usage of the service (i.e. booking, information access, payment) and as well as for tailoring the mobility services on the user's needs and preferences (Hietanen 2014; Atasoy et al. 2015; Kamargianni et al. 2015; Holmberg et al. 2016). The service is demand-oriented, while similar definitions consider the user-centered perspective from an operational point of view (Ghanbari et al. 2015; Kamargianni et al. 2016; Rantasila 2016). The main goal of MaaS systems is to provide seamless door-to-door mobility for users. This is made feasible by the technological advances, the cooperation of different operators and the bundling of several transport modes. Things have to be done in a smarter and more efficient way and by the full deployment of ICT and a stronger cooperation between public and private transport providers, this integrated service can result in a better allocation of resources and services, with the citizen as an end-user (Hietanen 2014).

There are a few operational Maas schemes around the world characterized by a varying degree of service provision in terms of the number of transportation modes that are offered, the tariff options (pay per use or mobility package subscription option) and the functionalities that are available including trip planning, real time information provision, smart ticketing, customization and personalization (Preston 2012; Schade et al. 2014; Kamargianni et al. 2014; Kamargianni et al. 2016). Some examples and applications around the world include 'Ubigo' (Gothenburg, Sweden), 'SHIFT' (Las Vegas), 'Whim' (Helsinki, Finland), 'SMILE' (Vienna, Austria), 'Mobility Shop' (Hannover, Germany), and 'MOOVEL' (Stuttgart, Germany). They attempt to deliver customer-centric tailored mobility services based on the needs of the transport user, fostering a more coordinated management of public and private transport networks with the use of ICT and real-time information (Kamargianni et al. 2014; Sochor, Strömberg & I.C. MariAnne Karlsson 2015; Sochor et al. 2016).

The rest of this paper is organized as follows: Section 2 presents the motivations for the research, the problem formulation and the research framework. Section 3 frames MaaS theoretical abstraction in order to identify and discuss the main theories that have to be considered in modelling MaaS adoption. In particular, we analyze these theories in order to better understand the variables needed to explain the long-term demand for MaaS and to build a conceptual framework, which is presented in Section 4. Finally, in Section 5 we provide a summary discussion and some concluding remarks about future research challenges.

2. <u>Motivation, problem formulation and research framework</u>

Introducing MaaS into the transportation system will bring many changes. It embraces a lot of contextual uncertainties to take into account which refer both to the diffusion of the service

into the market, approaching users as consumers able to shape the demand for the service, as well as to the daily usage of the services by the travelers that have adopted it. This means that for better exploring the demand side of MaaS we need to consider two different and interdependent perspectives of the user's decision making process: the long terms mobility decision and the short term mobility decision.

More specifically, the long-term mobility decision consists in choosing whether or not becoming a user of MaaS by subscribing to a mobility platform, which allows users to purchase mobility packages of services that can address their future travel demand. This choice can be compared to other possible choices made on a long-term basis, such as buying a new car or purchasing a public transportation seasonal ticket. Important research variables have to be taken into account considering: *(i)* the motivations that lead people to adopt such a service (e.g. their attitudes, satisfaction with current travel modes, social influence), *(ii)* the effect of various factors on the decision to adopt and renew the subscription (e.g. individual observable and unobservable characteristics, perceived service attributes, perceived uncertainty), *(iii)* the presence of dynamic loops generated by the network effects characterizing the multi-sided platform-based services, as MaaS (Meurs & Timmermans 2017). Thus, the long-term research aspect is inspired by literature not only from transportation, but also from other disciplines, such as psychology, sociology, information science, marketing and network economics. They offer many behavioral theories potentially relevant for understanding human adoption decisions and generating richer models of choice behavior than the conventional models used in travel behavior research.

The short-term mobility decision consists in making daily travel decisions (in terms of choice of a single travel mode or combination of multiple travel modes, departure time, etc.) to conduct a certain activity in response to a travel recommendation system and to a wide variety of travel mode options. Research on travel behavior and human decision-making is vital and crucial. People have to make a lot of travel decisions every day about the mode, the route, the departure time, taking into account time and space constraints, the household needs, personal preferences and the availability of resources, in order to cover needs and desires. Many theories attempted to measure the relationship between spatial, socio-economic, psychological aspects and travel behavior, addressing theories, mechanisms and factors that influence this spectrum of activity generation and behavior. Considering that the people travel to satisfy a need, activity based approach focuses on explaining behavior rather than prediction, and major innovations in transport demand analysis were noted, bridging travel behavior and travel demand modelling. The behavioral inadequacy of the four-step models and the important limitations of the traditional approach to evaluate demand management policies and strategies, has led to the activity-based approach in modeling that views travel as a demand derived from the need to pursue activities distributed in space (Kitamura 1998; Timmermans et al. 2002; Bhat & Koppelman 2003; Ben-Akiva et al. 2007). The short term research aspect places emphasis on the decision to engage in an activity, the sequence of activities during a certain time interval and the household agendas, as engaging in an activity 'represents' a dynamic interaction of household needs, tasks and constraints (Rasouli & Timmermans 2014a; Rasouli & Timmermans 2014b).

Having described the two aspects of approaching MaaS, the complex and dynamic nature of this system becomes very prevalent, which makes the decision process fundamentally uncertain. It is difficult for users to estimate ex-ante their future mobility consumption, since it will depend on various predictable and unpredicted needs for conducting different activities. Moreover, since MaaS is fundamentally based on highly flexible, shared and on-demand mobility services, there is some uncertainty in the availability of the desired mobility option at the moment of the request (e.g. lack of available seats in a DRT service, inconvenient waiting time for a pickup by a taxi, unavailability of a shared car, etc.). Therefore, modelling either long-term or short-term decision process represents, indeed, a challenge task.

Thus, two first main research questions arise considering the long-term and the short-term decision problem:

1. What are the key factors affecting people's acceptance and adoption of MaaS to satisfy their future travel needs?

2. How do people use MaaS and are there any changes in travel behavior after its adoption?

Figure 1 conceptualizes the interdependence between long- and short-term perspectives when examining the demand side of such mobility services.

This paper is focused on the long-term decision-making problem. Public acceptance and consequent adoption of an innovative tech-enabled service model of transportation is crucial for its successful implementation and diffusion into urban environment.

Despite the increasing proliferation of research articles related to the MaaS concept in recent years (Hietanen 2014; Rantasila 2016; Sochor, Strömberg & I.C. Marianne Karlsson 2015; Giesecke et al. 2016; Holmberg et al. 2016; Kamargianni et al. 2016), no comprehensive framework has been suggested yet, although these studies offer important inspiring views on MaaS. For example, Sochor et al. (2014; 2015) offered some empirical evidences of the interest and the obstacles for joining MaaS, by collecting and analyzing data on a six-month field operational test of a the UbiGo. They used questionnaires, interviews and travel diaries to identify for what type of MaaS there is a demand, in order to better drive the future design decisions of MaaS. Results revealed that different users' group exist, differing for their motivations, expectations and behaviors, which in turn may change over time. Giesecke et al. (2016) identified the key issues to be taken into account when researching MaaS, suggesting that a segmentation of the end users is required on the basis on their personal internal factors (e.g. attitudes, social behavior, lifestyle). By reviewing the newly existing integrated mobility services, Kamargianni et al. (2016) underlined the importance of studying how each component of a MaaS system impacts the demand for this service and the willingness to pay for MaaS subscription and for buying a package (either as pay-as-you-go or a monthly/annually package).

To sum up, existing quantitative studies on MaaS impacts on users travel behavior are not yet developed, as highlighted by the European Commission (2016). Thus studying and modelling factors affecting users' adoption of MaaS represent an urgent area for further researches.

3. MaaS Adoption Decision-Making Process

In order to study and model people decisions to adopt MaaS as an alternative to car ownership, a crucial step concerns the identification of the influential factors that need to be included into the model. A common approach used to identify the significant factors for the decision to adopt a certain service/product, is to systematically review previous qualitative and quantitative studies on consumers preferences for that product/service. Examples of this approach can be found in studies on electric vehicles (Rezvani et al. 2015; Rasouli & Timmermans 2016; Liao et al. 2017). However, applying this approach for studying MaaS adoption could not provide us with useful insights, due to the limited number of available studies on consumers' preferences for MaaS.

For this reason a theoretical abstraction of the MaaS concept is needed. In this way it is possible to identify the main theories and their relative constructs usable to explain the adoption decision-making process. MaaS can be considered as an example of the current paradigm shift in the conceptualization of transportation. This can be viewed as an information service giving access to physical transportation products and infrastructures instead of a physical system based on vehicles and infrastructure with additional services (European Parliament 2016). It is giving a new shape to the traditional transportation sectors, fostered by the technology penetration and the rise of new economic patterns, such as the

sharing economy and the "as a service" business model. It not only implies a change on how transport services are provided, but entails also a modification of people values and lifestyles. Thus, the first theoretical abstraction of MaaS consists in considering it as an innovation, since its adoption and diffusion could change people's conventional understanding of the way to satisfy their travel needs (Meijkamp 1998).

Considering that the users have to rely to their smartphones for the entire service experience (e.g. registration, journey planning, booking, ticketing, payment, access to transportation means), a second theoretical abstraction of MaaS consists in considering it as an information service based on the use of digital platform.
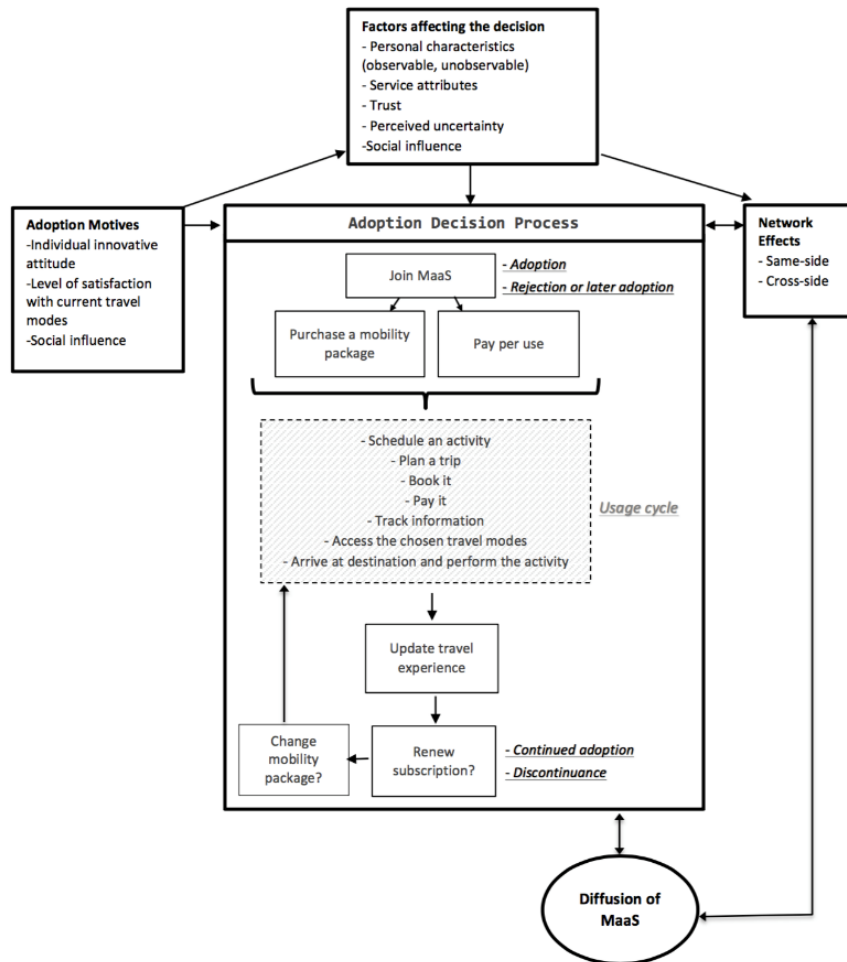

Figure 1 : Research framework

Therefore, in studying MaaS adoption decision, theories on innovation adoption (Rogers 1962) and diffusion and acceptance and use of technology (Venkatesh, Thong & Xu, 2012) may potentially offer a significant theoretical basis, together with the theories and models of choice and decision making under uncertainty related to transportation demand research, for which we refer to Rasouli and Timmermans (2014). These theories can in fact provide us with a meaningful knowledge about the variables that could potentially affect the individual decision to adopt MaaS and with some inspirational considerations about individual behavior in choice decision context characterized by various degree of uncertainty. Overall, this multi-theoretical framework leads to the formulation of a comprehensive conceptual model for the decision-making process at the basis of MaaS adoption.

The following sections contain a brief overview of the theories of Innovation Diffusion and Acceptance and Use of Technologies.

3.1. Diffusion of Innovation Theory

The theory of diffusion of innovation (DOI) (Rogers, 1962) may offer valuable insights into MaaS adoption decision process. DOI is a theory that explains how, why and at what rate an innovation, defined as "an idea, practice and object that is perceived as new by an individual and other unit of adoption" (Rogers, 1962), becomes widely adopted by the members of a social system, after its creation. More specifically, five main steps characterize the innovation-decision process of a decision-maker. After an individual becomes aware of the existence of an innovation and of some of its characteristics (knowledge), she will develop a certain attitude towards it (persuasion). This positive or negative attitude could affect her choice to adopt or reject the innovation (decision). Finally, the decision-maker may put into use the adopted innovation (implementation) and consequently confirm her innovation-decision already made (confirmation), with the possibility to reverse the previous decision. The duration of this innovation-decision process may vary according to the degree of innovativeness of the decision makers, which can be classified into five adopter categories: innovators (*venturesome*), early adopters (*respectable*), early majority (*deliberate*), late majority (*skeptical*) and laggards (*traditional*). Each category plays a different role in the innovation diffusion process, and shows different abilities to cope with various degree of uncertainty about an innovation. Moreover the degree of innovativeness is related to other variables, such as socio-economic characteristics (e.g. education, social status), personality variables (e.g. attitude toward change, rationality) and communication behaviors (e.g. interconnectedness with the social system, cosmopoliteness). Besides the adopters differences in innovativeness, also the perceived attributes of an innovation may affect is rate of adoption. Rogers (1962) identified five main characteristics: *relative advantage*, *compatibility*, *complexity*, *trialability*, and *observability*. The relative advantage represents the degree to which an innovation is perceived to be better that an existing practice, measurable in terms of saving time, moneys and effort, or gain in comfort and social status. Compatibility represents the extent to which an innovation meets existing values and beliefs, past experiences and needs of potential adopters. Complexity is the degree to which an innovation is perceived to be more or less difficult to understand and use. Trialability is the degree to which an innovation can be tested before the full-scale use. Observability represents the degree to which the results of using an innovation are visible to others. This five attributes need to be explored in order to understand their relevance in rate of adoption and diffusion effect related to MaaS. It is important to underline that the relevance and dimension of these attributes may vary not only with the nature of the innovation, but also with the adopters categories, and thus with the diffusion stages. For example, trialability is assumed to be a relevant attribute for the earlier adopters as, differently form the laggards, they cannot relies on others experiences. Another example is the dimension of relative advantage. Individuals belonging to the innovators and earlier adopters categories may be more motivated by the desire to gain a social status, while the later majority and laggards may give more importance to time and money savings. The innovative nature of MaaS suggests that these considerations have to be included in the conceptual framework at the basis of this research.

Findings from previous studies on MaaS from Sochor et al. (2014) also indicated that the participants of the UbiGo six-month field operational test could be considered as innovators or early adopters. Afterward in Sochor et al. (2016) the results of the trial are discussed through the Roger's theory lens. They founded that the added value or relative advantage it's an essential attribute that MaaS should have to be adopted. It might concern various aspects, like economy, flexibility, accessibility and simplicity. Another intrinsic factor that they found, relates to the notion of complexity, since the service must be perceived as easy to understand and use. Finally trialability resulted as an essential factor for MaaS adoption, contributing also to gain new insights on the compatibility and observability aspects.

3.2. **Unified Theory of Acceptance and Use of Technology**
Considering MaaS as a technology enabled service based on the use of digital platforms and smartphone apps, the extended Unified Theory of Acceptance and use of Technology (UTAUT2) (Venkatesh et al., 2012) may help to investigate and predict other key drivers of its adoption. This theory has been developed by Venkatesh as an extension of a previous theory named UTAUT (Venkatesh et al., 2003), which represents a comprehensive framework of eight theoretical models in information service adoption research, among which DOI theory and TAM model (Davis 1986), and applicable mainly at organizational contexts. The UTAUT2 extends the theory applicability to the consumer context, by integrating other important drivers to the main factors included in UTAUT. As a result, the key determinant factors affecting consumers' acceptance and use of ICTs are: *performance expectancy*, *effort expectancy*, *facilitating condition*, *social influence*, *hedonic motivation*, *price value* and *habit* as well as three moderating variables (age, gender and experience). Performance expectancy represents the extent to which consumers perceive that the use of technology to perform certain activities will provide benefits. Effort expectancy is the degree to which consumers perceive that using a technology is free of physical or mental effort. Facilitating conditions refer to resources and factors perceived as available by the consumers to perform their activity. Social influence are defined as the extent to which consumers perceive that important members of his social network (e.g. family, friends) believe they should use a certain technology. Hedonic motivation represents the enjoyment perceived by the customers in using a technology. Price value takes into account the monetary cost associated with the purchase and use of a certain technology confronted with the perceived benefits. Habit is conceived as consumers' tendency to automatically perform behavior because of learning. The effects of these seven factors on customers' behavioral intention and use of ICT to conduct a specific activity may vary and are moderated by customers' heterogeneity, in terms of age, gender and experience. This theory has already been used to study the acceptance and adoption of various technology- and web-based services, such as mobile payment (Slade et al. 2013; Morosan & DeFranco 2016), mobile learning (Yang 2013; Kang et al. 2015), location-based services (Chong & Ngai 2013), and recommender systems (Oechslein et al. 2014) Within the proposed research, the UTAUT2 may partially explain individual intention and use of smartphones and mobile applications to perform their door-to-door journey experiences (i.e. search for information, trip planning, booking, ticketing, payment, route tracking and real-time navigation, access to transport modes, invoicing). Although this could appear irrelevant considering that almost half of smartphone users (especially among the younger generations) already consider the smartphone as an indispensable instrument for their travel experience, technology acceptance could be considered as an important aspect to consider when we study the demand for the other population segments, that might not adopt such services if they perceive that they are more complicated than helpful (Transport Systems Catapult 2016). Thus, in MaaS context, we might assume that people will probably decide to adopt the service when, for example: they think that using their smartphones for organize and perform their travels will provide certain benefits (e.g. time savings, comfort, or social status); when they perceive that it will be easy and pleasant to use their smartphones to schedule their daily journeys and have access to the desired transportation mode; when they don't need any extra resource to use the services; when they perceive a significant social pressure.

4. **Conceptual modeling framework for MaaS adoption**

The majority of the factors included in the investigated theories and potentially influencing the choice process can be considered as unobservable variables. They mostly refer to latent characteristics of the decision maker, which can be grouped as attitudes and perceptions. Moreover the literature explained also that the relevance of each constructs might vary

according to the context and the time of measurement (i.e. stages of individual experience). For example, the "complexity" attribute in DOI (comparable to the "effort expectancy attribute in UTUAT2) might be more significant when individuals have already tried the service and they face the decision of continuing or not to use the service based on their direct experience with it (i.e. adoption confirmation and discontinuance decision in Roger's theory). It is not easy to quantify the effects of these factors on the choice to adopt or not MaaS, due to the fact that they are not directly measurable and that they change over the time and across the individuals. However they need to be studied in order to generate models that can be considered as a satisfying behavioral representation of the adoption decision process. Zooming into the choice modeling field, in the past decades considerable progress has been made in incorporating latent factors into discrete choice model, together with observable factors, including individual characteristics (e.g. socio-economics, demographics, etc.) and directly measurable attributes of alternative (e.g. price) (McFadden 1986; Ben-Akiva et al. 1999; Walker 2001; Ben-Akiva et al. 2002; Bolduc et al. 2005). The Hybrid Choice Model (HCM) represents an integrated modeling framework resulting from the combination of two main components, a discrete choice model and a latent variable model. They are estimated simultaneously using maximum likelihood techniques based on likelihood functions including complex multi-dimensional integrals (Ben-Akiva et al. 2002). Through the latent variable model, it is possible to capture the casual relationship between observable explanatory variables and unobservable variables, which are identified as a function of a set of measurable behavioral indicators (e.g. attitudinal indicators, perceptual indicators). For this reason we could claim that MaaS adoption decision can be study with HCM, in order to enrich the choice model with all the latent constructs that derive from the multi-theoretical behavioral framework. It will allow us to capture the effects of individual characteristics, satisfaction with current travel modes and MaaS attributes on the adoption process.

Moreover, it is also possible to identify different subgroups within a population, which exhibit similar attributes in terms of attitudes, perceptions, preferences and decision rules. Specifically, Roger's theory (1962) identifies five categories of adopters that can be distinguished according to their attitudes in terms of their degree of innovativeness and their ability to cope with various level of uncertainty about an innovation. In turn, these are related to other variables, such as socio-economic characteristics and other latent variables. Reflecting on the description of the adopter's categories, it is possible to identify also a distinction about the motivations that may lead to the adoption decision. People with a strong innovative attitude may adopt an innovation since they are motivated by the curiosity to adopt a new service, thinking that they will gain in terms of social status, caring less about the risk and uncertainty characterizing the initial phase of the innovation diffusion. On the other hand, people with a less innovative attitude will perceive a higher degree of uncertainty around the innovation adoption decision and may decide to adopt the service lead by the desire to mimic important others' or in case they are not satisfied anymore with their current practices. This means that the motivations of adoption decision and the decision rules may vary with the various stages of the diffusion process. The adopters' subgroups can be considered as latent classes characterized by membership probabilities that may depend on observable and unobservable individual characteristics. The probability that an individual choose to adopt or not the new service at a certain time period after its introduction will be conditional on individual-class membership, as well as on service attributes and individual characteristics at that time. Therefore, a latent class model should be incorporated in the HCM in order to capture the unobserved segmentation in the population (Walker 2001; Ben-Akiva et al. 2002). Within this modeling framework, latent classes are linked through a measurement relationship with psychometric indicators and with structural relationship with observable variables and latent variables. We refer to Kim et al. (2014) for a review of the main principles underlying the HCMs and the specifications used in previous and more recent applications of the model.

The modeling framework that we intend to adopt for investigating MaaS adoption decision process is depicted in Figure 2. As emphasized by Ben-Akiva et al. (1999), adequate and successful applications of these methods involve not only a good definition of the comprehensive behavioral framework at the basis of the choice process, reinforced by a convincing explanations for the added complexity, but also an accurate design of the data collection experiment for identifying the indicators and the casual variables needed to support the framework. The indicators incorporated in the HCM framework may include choice indicators such as revealed and stated preferences and psychometric indicators related to the behavioral process, provided by responses to survey questions about attitudes, perception and motivations. The most widely used approach is to consider indicators as ordered categorical variables. Thus, Likert scales can be used to measure respondents' attitudes, perceptions and other relevant latent variables.
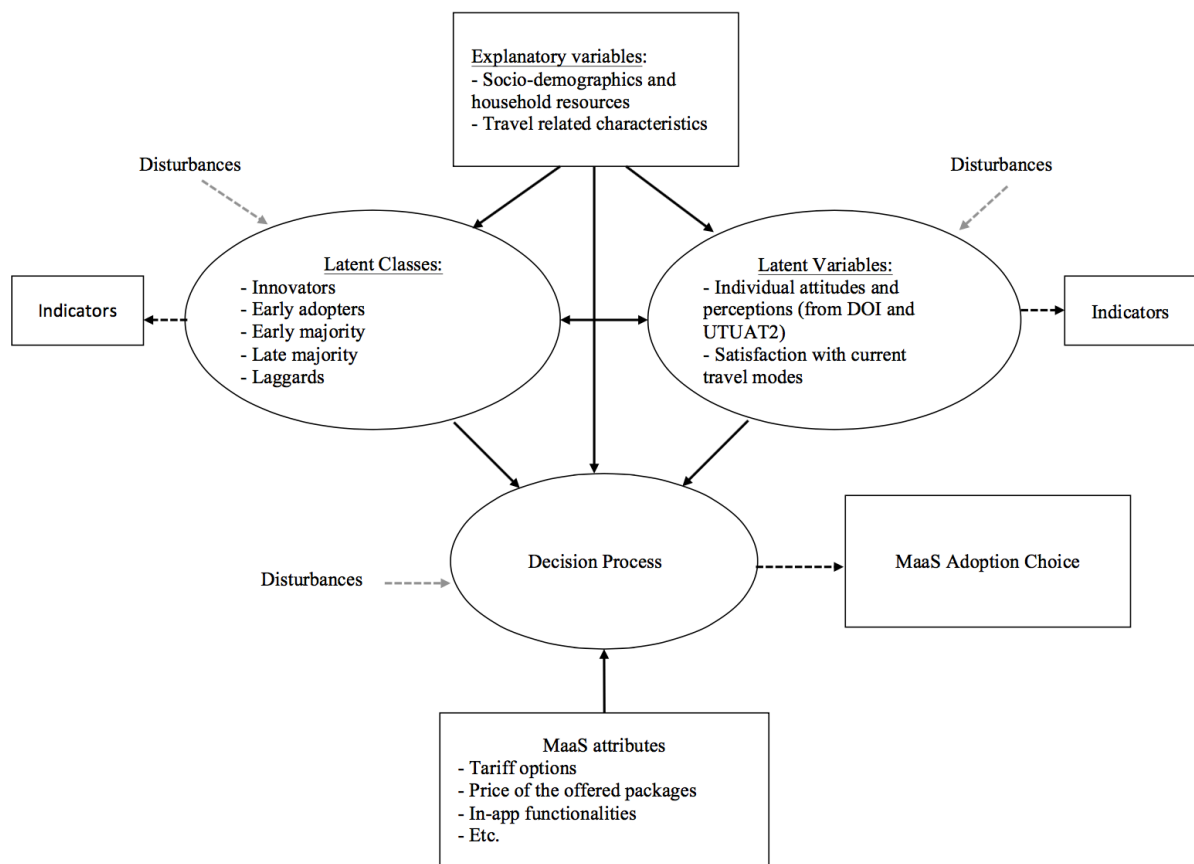

Figure 2 : HCM framework for MaaS adoption decision (adapted from Ben-Akiva et al. 2002)

5. Conclusions

To conclude, this study sits at the confluence of three research sub-streams (travel choice modelling, innovation and technology acceptance) to form an inclusive model of factors affecting the long-term decision-making process related to MaaS. It aims at providing first conceptual insights necessary to (i) investigate the relevance of the influencing factors from DOI theory and UTUAT2 within MaaS context and (ii) estimating concurrently their impacts in a single integrated modelling framework of MaaS adoption. Considering the core characteristics of MaaS system, other theories should be explored to generate a behaviorally richer model of the adoption of such services. Important notions may derive from social influence, social comparison and social learning theories (Festinger 1954; Bandura 1977; Kelman 1974; Conlisk 1980; Manski 1999), trust theories (Mayer et al. 1995; McKnight et al.

2002) and economics in multi-sided markets (Evans 2003; Rochet & Tirole 2004; Gawer 2014). This will lead in gaining useful insights about choice behavior as well as providing valuable information for policy making and marketing strategies.

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