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ScienceDirect

Transportation Research Procedia 82 (2025) 1896–1912

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2023 Montreal 17-21 July 2023

Can MaaS encourage travel behavior change? The role of cognitive, motivational factors in sustainable and pro-environmental choices.

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Abstract

Although several pilot projects and trials have been conducted to assess the impacts of implementing Mobility as a Service (MaaS), researchers still have doubts about whether such a system can actually influence the travel preferences of car users. While much emphasis has been placed on exploring the organizational and structural challenges of MaaS, fewer efforts have been made to investigate the "human" factors that could play a role in the cognitive process leading individuals to switch from using cars to adopting MaaS. Therefore, in this paper, we aim to understand which features should be included in MaaS to effectively encourage car users to modify their travel behavior. Based on an analysis of past literature, which highlighted the influence of behavioral and cognitive variables (such as habits, attitudes, and pro-environmental factors) on people's decisions to adopt sustainable transportation modes, we propose some actions that could add value to MaaS. Specifically, we argue that MaaS should not only focus on the digitalization of transportation services but also on the effective integration of public and private, shared, and individual modes of transport, considering factors such as fares and the availability of services. Additionally, due to the significant role played by cognitive factors in individuals' travel behavior choices, we suggest that the implementation of MaaS should be accompanied by Travel Demand Management strategies, such as feedback programs, incentives, rewards, and so on, to encourage car users to intentionally choose sustainable and integrated transportation modes. In conclusion, the article suggests that MaaS has the potential to reduce private car usage, but more effort should be devoted to developing soft measures that help individuals perceive the added value that MaaS can offer to their overall travel experience.

Keywords: "MaaS; Modal choice; Cognitive factors; Travel Demand Management"

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10.1016/j.trpro.2024.12.162

1. Introduction

One of the primary goals for decision-makers, practitioners, and researchers in the mobility sector is to encourage individuals to change their travel behavior. This shift can play a key role in addressing the climate crisis and promoting sustainable development. The pivotal challenge lies in introducing new forms of cleaner, cheaper, and healthier mobility by expanding the availability and simplifying access to sustainable transportation alternatives, particularly at the urban and metropolitan levels. This is essential to reduce carbon emissions from the transportation sector and align with the 90% emissions reduction goal of the European Green Deal (European Commission, 2019).

The extensive use of private vehicles is one of the main causes of the negative environmental and social impacts produced by the transportation sector. The dominant position of the traditional car, which is personally owned and runs on fossil fuels, remains the most significant obstacle in addressing this challenge. The private car's ability to be customized according to individual mobility needs, both in terms of time and location, is a key factor contributing to its prevailing position in the modal share.

To make sustainable mobility more attractive and competitive compared to private cars, an innovative form of transportation has emerged: Mobility as a Service (MaaS, Hensher et al., 2020). MaaS integrates existing and new public and private mobility services into a comprehensive and integrated system, with public transportation serving as its backbone. These services are accessible through a single, user-friendly digital platform. The platform offers a range of alternative travel options that can be purchased at advantageous costs and customized to individuals' needs.

Different studies have suggested that, by improving travel experience and offering a better and cheaper service, MaaS has the potential to make sustainable, integrated, and multimodal alternatives more attractive for those segments of population who currently use the car on a daily basis. For instance, users' travel experience could be enhanced by offering new additional services, including the possibility of planning customized trips, choosing from several options, integrating payments of various modes in a single ticket and with different forms of payment (subscription or pay-to-go), spending less than the sum of the individual tickets' values, and having real-time updates on the service. In other words, the concept of MaaS could speed up the transition from personal, single, and exclusive transportation means to multiple and shared transportation modes, leading to a shift from the possession to the use paradigm (Schikofsky et al., 2020; Hensher et al., 2020). In this situation, the use of the car (clean, small, and shared) could still be useful, but not for the entire journey and only when necessary.

It is possible that the expected results, both in terms of MaaS implementation in its broader integration and in terms of users' acceptability, will not happen in a few years. Indeed, studies on travel behavior changes and first MaaS trials agree on the complexity to change individuals' travel behavior, especially for those who habitually use private cars. Car use and ownership cultures are still strongly rooted and woven into lifestyles and activity-travel patterns (Scheiner & Kasper, 2003). Moreover, they have permeated individuals' personalities, values, attitudes, preferences, and habits.

There is a range of motivations ranging from contextual factors (supply side) to psychological and cognitive motivational aspects (demand side), which are the basis of individuals' transportation choices. The latter ones, however, are often overlooked. As shown by different researchers, a stronger involvement of citizens in terms of acceptance of technology and philosophy is required to reach a travel behavior change (Caiati et al., 2020). In addition, a more in-depth analysis of human aspects, such as values, preferences, interests, and intentions, will be needed for MaaS to lead to a more sustainable mobility paradigm (Strömberg et al., 2018; Feneri et al., 2022).

Given the above discussion, in the current work we aim to understand what MaaS systems should contain and how they should be structured to positively impact individuals' travel behavior and push them to move in a sustainable and pro-environmental way. By analyzing past literature on the impacts of MaaS, we try to discern what people would appreciate in such a new service and what is still missing to overcome its challenges. This knowledge could be useful for transportation operators and authorities seeking to apply a MaaS scheme which is not only an intervention aimed to improve the digitalization of transportation services, but also to integrate various travel alternatives within the urban context in which they operate.

This paper is structured as follows: Section 2 shows the most relevant studies that assessed the critical issues encountered in past MaaS experiments and applications; Section 3 analyzes the factors that have been identified as a barrier to the use of MaaS and, in particular, to the modal shift of those who habitually use private cars; in Section 4 we describe the role of environmental factors in inducing intentional pro-environmental behaviors; Section 5 summarizes the drivers that could influence preferences, intentions, and behaviors toward a voluntary and conscious

sustainable travel behavior; in Section 6, we delve into the tools and techniques that MaaS services could employ in order to effectively foster a shift in travel behavior; finally, in Section 7, we draw the conclusions.

2. The concept of MaaS in current literature

Mobility as a Service (MaaS), when well-designed, promises to be inclusive of all social groups and an efficient mobility demand management tool to encourage behavioral change (Kamargianni & Matyas, 2017). This feature led to MaaS being defined in the literature as a "user-centric" paradigm (Karlsson et al., 2017; Giesecke et al., 2016; Jittrapirom et al., 2017). Nevertheless, despite the promising expectations surrounding MaaS, some researchers have expressed doubts regarding its potential positive impact. Many remain skeptical about its ability to reduce car usage (Ho et al., 2018; Alyavina et al., 2020; Herrlin, 2021). Currently, it seems more likely that these changes will occur in the long run, when MaaS systems operate at the highest level of integration (Lyons et al., 2020).

Though numerous studies, reports, guidelines, and first applications of MaaS have emphasized its role as a sustainable alternative to private car use (Ho et al., 2017), few have attempted to quantify the specific characteristics and factors needed for MaaS to steer a full travel behavior change (Matowicki et al., 2022; Smith & Hensher, 2020). According to Hensher et al. (2020), the limited sharing of results on MaaS experiments suggests these attempts have largely fallen short, struggling to demonstrate the effectiveness of the methodology and the MaaS system itself.

The analysis of past literature on the effectiveness of MaaS applications in generating a modal shift from the car to sustainable mobility has found mixed and conflicting opinions. For instance, Storme et al. (2020) report the results of a pilot study conducted in Ghent, Belgium, where a group of car-owning participants were offered mobility budgets to replace private car use. While respondents were happy to explore MaaS options, no reductions in private car use were recorded, suggesting that the interplay between MaaS and private car use may be more complex than expected.

On the other hand, the analysis of the results obtained by "UbiGo," one of the first and most documented MaaS experiments carried out in Gothenburg, Sweden, showed a contrasting picture (Karlsson et al., 2017). Participants substantially reduced car use and increased public transportation and shared mobility. The application proved particularly effective for families who might otherwise have purchased a second car and for those with high accessibility to public transport (stop proximity and frequency). However, the authors acknowledged that the positive results could be tied to the specific context and called for further field experiments.

As already underlined by Kamargianni and Matyas (2017), a significant portion of the existing literature is dedicated to delineating the concept of MaaS and addressing its organizational challenges (ecosystem, technologies, integration of modes). However, there is a need of in-depth analysis quantifying the impact of MaaS on preferences and travel behavior. Herrlin (2021) argues that there has been an imbalance in the focus on MaaS, with an excessive emphasis on the system itself rather than on addressing the underlying issues that MaaS aims to resolve. This imbalance has resulted in a neglect of the essential factors necessary for achieving sustainable mobility objectives. In essence, there has been too much focus on the technological aspects and too low on the "human" ones.

Current literature provides only very limited quantified guidance on which travelers might be interested in using MaaS instead of the car, and no quantification on the extent to which such changes in travel behavior might occur. The extent to which MaaS will be adopted among the general population remains uncertain. A deeper understanding of the necessary skills, values, and relevant factors like socioeconomic status, demographics, cultural attributes (including age and residential location), is crucial for designing MaaS systems that effectively promote travel behavior change. While some studies acknowledge the challenge of overcoming car attachment (Storme et al., 2020), further research is needed to fully grasp the decision-making processes driving individuals towards MaaS services.

In conclusion, previous studies show that MaaS has the potential to achieve sustainability goals, support the decrease in the use of the private car, and to stimulate sustainable travel models, but there is still no tangible proof of this. The frequent claims on the positive contributions that MaaS will make to the achievement of sustainability objectives are often based on limited, qualitative, and still unclear research results (Wong, 2017; Smith et al. 2022). Indeed, the magnitude of impact, the temporal sequence, and the direction of these changes remain relatively uncertain and require more quantitative results, both at the individual level (travel behavior, travel preferences) and at the societal level (social and environmental sustainability).

A rapid shift from private ownership to the sharing economy model underlying MaaS is unlikely without considering individual behavior and preferences. However, existing literature on travel behavior change offers

valuable insights. This knowledge can guide the development of MaaS features and address user needs more effectively.

3. Factors characterizing the resistance to travel behavior change

The challenges associated with MaaS usage stem from both the unique characteristics of the service itself and from broader barriers inherent in the process of altering travel behavior, especially when trying to stimulate a reduction in car usage.

Existing literature indicates numerous structural and behavioral impediments hindering the widespread adoption of MaaS as the preferred sustainable alternative to private vehicle ownership. Consequently, this section aims to outline the principal structural and behavioral barriers to the dissemination of MaaS.

3.1. Functional and performance characteristics

On the structural side, previous authors have observed that in numerous contexts, public transportation (which should serve as the "backbone" around which an effective MaaS service is constructed) has seen limited popularity in recent years. This is mainly because of the low level of integration it is able to offer. The integration between different modal alternatives should be, instead, one of the main strengths of MaaS.

MaaS's lack of appeal might stem from unsatisfactory public transportation, leading to user dissatisfaction that is more contextual than a general disinterest in MaaS. For example, inadequate public transport options with limited modal choices and missing first/last mile solutions within a MaaS model are unlikely to attract users accustomed to private vehicles.

First experiences with MaaS have revealed that freedom of choice, customized offers, and increased travel comfort, particularly through high levels of integration, can positively impact the adoption of MaaS. However, it is necessary to verify the feasibility of a large-scale diffusion of MaaS, concerning its reliability issues and costs (Sochor et al., 2016). For instance, including shared mobility for the first and last mile can provide flexibility and freedom of choice. Nonetheless, these services are currently constrained by limited coverage and presence across the territory, raising concerns about their reliability.

The challenge of achieving travel behavior changes may be heightened in situations where MaaS solutions entail the utilization of numerous sustainable alternatives. Conversely, it could be less daunting when promoting the adoption of shared and ride-hailing services. Alyavina et al. (2020; p. 363) identify this potential drawback as the "Uberization of MaaS". Such solutions carry particular risks, as they may not only attract private transportation users to MaaS but also divert public transportation users toward less sustainable alternatives. This adverse scenario could inhibit the realization of anticipated outcomes and exacerbate the negative externalities associated with car usage.

Costs remain a critical concern, particularly when highly personalized services come at a higher price than what users are accustomed to. Hence, customizing the type of offer to suit individual users is likely to be pivotal, especially if it can be perceived as cost-effective.

In general, it is essential that MaaS does not require users to compromise, completely or at least partly, on their need for autonomy, flexibility, reliability, and economy.

In addition, the integration between public and private services, and therefore between public and private operators, is still difficult to guarantee due to the different strategies and approaches.

Besides, various researchers reveal that MaaS, in order to be effective as a tool for travel behavior change, must necessarily combine multiple levels of integration (Lyons et al., 2020). Only in this case, MaaS could encourage users to abandon the use of the car.

Unfortunately, an integrated and multimodal mobility is still a futuristic vision of mobility, especially at the urban level (Loose, 2010; Motta et al., 2013; Preston, 2012; Schade et al., 2014). From this standpoint, MaaS can also be considered a tool that stimulates and guides the overall offer of transportation to reach higher levels of modal integration, by which improving the efficiency and availability of the mobility service network (see also Wong et al., 2020). MaaS will be able to be activated and will have a higher probability of success if the integration of the services is guaranteed both on the spatial and the functional side. But until this is achieved, low levels of integration can be an important structural barrier to achieving the intended results.

3.2. Behavioral and cognitive-motivational factors

A series of non-secondary aspects that can be considered a barrier to the use of MaaS, regardless of the level of performance offered, are the behavioral and cognitive-motivational factors.

Changing travel behavior is not an easy process, especially for car users. In fact, there are a whole series of psychological-motivational obstacles and barriers, such as values, beliefs, norms, preferences, attitudes, sensations, tastes, emotions, judgements, affections, cultures, and habits, that could hinder the use of shared and integrated mobility.

Many field experiments and studies have explained that the reasons why many people still use their own car to make their daily trips, even when there are sustainable alternatives that are more advantageous in terms of time and cost, often refer to these factors. Furthermore, the fact that using the private car allows you to manage travel in an autonomously customizable way represents a further disincentive to the use of sustainable alternatives.

The culture of private car use that still characterizes travel behavior and mobility style of many citizens constitutes one of the main barriers from the demand side to the diffusion of MaaS services. In general, many researchers and studies have found that private vehicle users are identified as the social group that is least likely to adopt MaaS (Alonso-Gonzalez et al., 2020; Hoerler et al., 2020), less interested in searching for travel alternatives (Alonso-Gonzalez et al., 2020; Ho et al., 2018), and that perceives their modal choice as the only way to satisfy their mobility needs (Matyas, 2020; Sjöman et al., 2020).

3.2.1. Habits

Habit represents a very strong factor that makes the process of changing travel behavior complicated and complex (Gärling & Axhausen, 2003; Klöckner & Matthies, 2004; Gardner, 2009; Thomas & Walker, 2015). Merely possessing a car at one's disposal may suffice to dictate modal choices. Patterns of habitual behavior were found in various categories of people and in different modal choices, but in particular in the case of car users (Hoffmann et al. 2017; Lanzini & Khan 2017; Klöckner & Matthies 2004; Nordfjærn et al. 2014).

The automaticity of habit often prevents alternative behaviors. Consequently, a habitual car driver is likely not to consider collective transportation as a real alternative (Verplanken et al., 1998). Moreover, habitual car users tend to anticipate lower satisfaction with potential public transportation use (Pedersen et al., 2012) and exhibit reduced interest in information about available alternatives (Verplanken et al., 1997). Indeed, individuals often prioritize information that confirms their existing choices while disregarding information that contradicts their habitual behavior.

The lack of success of numerous interventions aimed at altering habitual travel behaviors underscores the necessity for combined and dynamic strategies to break car use habits. Consequently, future MaaS schemes must incorporate such strategies to attract new customers who currently rely on their cars on a daily base.

Various studies agree that it is particularly difficult to change habitual travel behavior when there is no trigger. It has been verified that many individuals generally reconsider their habitual behavior only when radical changes are introduced in their context of choice (shock effect). Such drastic changes stimulate the individual to reconsider the choices that they usually make.

Some authors have suggested that even limited periods of enforced behavior change may present an opportunity to correct a misconception and promote sustainable behavior change (Fujii et al., 2001; Brown et al., 2003). For instance, many car users usually overestimate travel times by public transport. This overestimation can be corrected once public transportation is utilized, potentially leading to a "shock effect" that promotes more accurate perceptions and encourages sustained use of alternative modes of transportation.

Hence, we can discern two primary strategies that can be employed to disrupt habitual travel behaviors, which MaaS can leverage: (1) a substantial and radical change in the context in which the choice occurs, for instance, enhancing and innovating the transportation offer; (2) individual encouragement with appropriate, in-depth, and personalized actions to trigger intention to change.

3.2.2. Motivational and psychological factors

The decision to use a private car is influenced not only by its function as a mode of transportation but also by its status as a tangible asset desired by individuals (Paundra et al., 2017). This desire stems from the psychological and motivational factors associated with car ownership (Steg, 2005). Car acquisition and usage are believed to be driven

not only by practical considerations but also by symbolic and emotional factors. From a theoretical perspective, Steg (2005) categorized these elements into three types of motivational factors: instrumental, social (symbolic and ethical), and affective (sentimental).

- Instrumental motivations relate to personal advantages and objective consequences deriving from the use of the car (time and cost savings, speed, comfort, flexibility, availability, reliability, etc.).
- Symbolic motivations refer to the fact that, through the use of the private car, individuals express themselves, their identity, and their values. Also, car ownership plays a role in comparison with others (social identity). It is, indeed, one way in which people can express their social status in terms of prestige, distinction, and superiority.
- Affective motivations, which are a consequence of the first two, are those induced by the use of the car (freedom, driving pleasure, speed effect, vitality) and refer to several emotions and personal feelings that the car is able to evoke by procuring a different state of mind.

Steg (2005) found that these three types of motivations are perceived distinctly by commuters, and all influence car use. However, the effect of symbolic and affective reasons overcome the instrumental ones even when the trip has a highly functional characterization, such as reaching the workplace. Although many individuals justify the use of the car in a rational way, it has been demonstrated that psychological and emotional factors are extremely determining (Steg & Tertoolen, 1999; Steg et al., 2001; Storme et al., 2020).

What has been argued in this section suggests that, when dealing with change in travel behavior, and particularly when trying to reduce car usage, it is necessary to consider not only aspects related to utilitarian and practical convenience but also all the symbolic, psychological, and affective factors (Steg & Tertoolen, 1999; Steg, 2005).

4. Environmental factors inducing intentional pro-environmental behaviors

Since MaaS has been conceived to establish a new, innovative, and sustainable alternative to the use of the private car, it will need to immediately contemplate the presence of a combination of multiple structural and motivational requirements.

On the transportation side (supply side), it is necessary that the overall level of integration of all existing and available transportation services, particularly public transport, is of high quality and makes it possible to offer a product that is economically convenient compared to the car.

Nonetheless, as described in the previous paragraph, these characteristics may not be sufficient to induce a change in travel behavior and modal choice, especially for private car users. Indeed, several questions remain unsolved: “What is the added value perceived by the user when adopting a MaaS service? Do people recognize the added value offered by a MaaS service? What attributes of a MaaS service add value to the trip experience?”

For MaaS to effectively instigate a shift in users’ travel behavior, it is imperative to delve beyond the technological aspects and deeply consider the “human” elements. The adoption of MaaS centers on altering individuals’ travel behavior, necessitating a combination of various factors that influence people’s psychological and cognitive-motivational characteristics.

Indeed, psychological and cognitive motivational factors apply significant influence over travel choices, particularly in favor of private car usage. Harnessing these factors could pave the way for novel methods of promoting the adoption of sustainable travel modes. Such factors may be intertwined with sustainability, climate change, and environmental protection concerns. By addressing these factors, decision-makers and researchers have the opportunity to raise awareness and motivate individuals to alter their travel behavior. This can be achieved by promoting intentional, conscious, and voluntary utilization of sustainable transportation options, leveraging their inherent pro-environmental characteristics.

4.1. Sustainable and intentionally pro-environmental travel behaviors

Human decision-making is a mental process that translates the perception of options into choices. Analyzing the motivational and psychological factors behind travel behavior helps explain why many people continue to use cars even when sustainable alternatives are convenient. Studies show factors like habit, car attachment, and perceived control over travel choices complicate reducing car use in favor of sustainable modes. To promote this transition, the

desire to intentionally use sustainable transportation for its environmental benefits can play a crucial role (Kollmuss & Agyeman, 2002).

For the purposes of this study, sustainable travel behavior deserves to be specified in relation to its intentional or unintentional effects on the environment (Kollmuss & Agyeman, 2002). The substantial difference lies in the individual's motivation and awareness of the effects of their choices.

In the case of intentionally sustainable behaviors, individuals feel a personal responsibility for addressing the negative consequences associated with behaviors such as car usage. Consequently, their choices are driven by a desire to contribute positively to the environment, improve public health, and enhance the aesthetics of their city.

Conversely, unintentional sustainable behaviors involve actions taken to mitigate negative environmental impacts without the primary intention of doing so. Instead, these behaviors are motivated by personal needs, such as reducing expenses and saving time.

This distinction is of particular interest when planning the actions that can be implemented to foster MaaS usage. It emphasizes the importance of not only creating structural conditions that promote sustainable mobility but also of actively encouraging individuals to *intentionally* opt for sustainable travel options. In essence, the appeal of sustainable travel alternatives is amplified by factors directly linked to their intrinsic environmental sustainability. For example, individuals may derive satisfaction from using bicycles, knowing they are making a substantial contribution to environmental enhancement and carbon emission reduction. In certain cases, if these attributes are effectively promoted and valued, they can motivate individuals to opt for sustainable alternatives voluntarily and consciously, even when their functional characteristics are less appealing than those of a car.

This pro-environmental characterization that can promote MaaS usage should be strongly communicated, valued, and promoted in order to induce individuals to voluntarily change their travel behavior and overcome the barriers and obstacles of abandoning private cars.

5. Aspects that would add value to MaaS

In previous paragraphs, it has been noted that merely addressing structural aspects is insufficient to stimulate behavioral change towards sustainable transportation. Mobility as a Service (MaaS) must also encompass an integrated mixture of cognitive and motivational factors. The significance of the latter lies in their capacity to directly engage individuals, capitalizing on the sustainability features inherent in MaaS systems.

Specifically, the interventions required to foster shifts towards sustainable travel behavior are those acknowledged as "Travel Demand Management" measures (TDM, Litman, 2003; Loukopoulos, 2007). These measures encompass a range of actions and interventions aimed to modify travel behavior by affecting the different attributes that characterize them, both contextual (structural measures) and cognitive-motivational (informative and cognitive-motivational measures). Both attributes are exploited to reduce private car use by making it less attractive than other sustainable alternatives. These measures are then completed by informing individuals of the damage that car usage can cause to the environment and informing them of the benefits that sustainable alternatives can have on performance (times and costs) and individual/collective well-being. In summary, TDM measures can modify travel behavior by acting on the characteristics of the context of choice (structural factors) or on personal factors, such as preferences, judgments, attitudes, and environmental awareness, stimulating sustainable choices.

Many field experiments have indicated that the combined action on both factors has a higher efficacy than the individual ones (Piras et al., 2018a). Indeed, it is widely recognized that the combination of policies and measures that integrate structural measures with informative and motivational interventions record the highest levels of effectiveness in promoting travel behavior changes.

From this point of view, MaaS is able to encompass both actions in a combined and integrated way.

5.1. Structural factors

According to what was defined by Jittrapirom et al. (2017), the structural measures that a MaaS scheme should include in order to enhance its performance and, therefore, its attractiveness are the following:

1. the integration of different modes of transportation (existing, new, public, private, individual, collective, and shared);

2. the choice between multiple multimodal solutions;
3. tailored customization of the alternative offered in relation to the user's needs;
4. the use of a single travel ticket and the choice between several fare options (subscription or pay-to-go) that are more economically advantageous than the sum of the individual tickets;
5. a single platform, where users can plan, book, pay and get tickets for their trips;
6. the use of digital technologies (smartphones, ICT, etc.);
7. the presence of multiple actors (customers, suppliers, platform owners, authorities, etc.);
8. the obligation to register, to facilitate the use of the service and allow for its personalization.

5.2. Cognitive motivational factors

The cognitive motivational measures aimed to encourage people to adopt new sustainable and intentionally pro-environmental travel behaviors are those that refer to the methodologies and techniques of Voluntary Travel Behavior Change programs (VTBC) and, among these, the Personalized Travel Plans (PTP). MaaS and VTBC programs can, indeed, be compared in terms of user personalization and use of information and digital technologies.

The different applications of VTBC programs and PTP, both in the academic and professional fields, allow us to synthetically identify some key factors which, in the design of a MaaS system, should be considered important to achieve good levels of effectiveness. These factors are:

1. Identify a target mobility context. Identify a specific territorial and transportation context in which to offer MaaS services, recognizing the strengths and weaknesses of the transportation system that generated the current modal share: available sustainable modes of transport, first and last mile services, level of integration, service standards, reliability, and capacity. From this analysis it must emerge which contextual factors are causing a certain travel behavior and, furthermore, which sustainable transportation alternatives can be promoted through MaaS systems.
2. Identify one or more target behaviors. Select the most appropriate and achievable behavior change; it must be clear, easy to undertake, measurable, and not involve drastic changes. Identifying the alternatives to be promoted also depends on whether the current transportation system and the proposed MaaS scheme have the suitable requirements to make the promoted alternative acceptable.
3. Identify a specific user type ("receptive audience", Fogg, 2009). The alternative to be promoted must be feasible, acceptable, and sustainable for the individuals involved. With reference to the MaaS alternative to be promoted, the best target of individuals who can potentially undertake a certain behavior must be selected. Sometimes it is the population target that suggests the behavior to be promoted and not vice versa. Therefore, this phase can come before the previous one, even if a contextual execution is recommended. Population targeting involves in-depth knowledge of individuals' socioeconomic and attitudinal characteristics, their current activity and travel patterns, and possible barriers to behavior change. Usually, all this information can be acquired through an entry questionnaire to the use of MaaS.
4. Identify possible barriers and obstacles. They can be identified as territorial, economic, and transportation context barriers. Moreover, they can be associated with psychological-motivational barriers relating to current behavior, such as those associated with habitual travel choices.
5. Identify and specify the sustainable alternatives to be promoted. Identify and specify the right sustainable alternatives that the MaaS service must promote, in order to provide feasible, achievable, and acceptable solutions.
6. Personalization. The greater the level of customization, the more positive the response is likely to be.

In summary, all these factors must allow for the identification of the most suitable and acceptable sustainable alternatives to be promoted within the MaaS service: they must be feasible, achievable by operators, and have a high probability of acceptance by the user. Indeed, the first precondition for implementing these services is that the individual is offered an alternative with instrumental attributes (times and costs) that are better or do not differ much from the current ones. The proposed alternative may be slightly less advantageous but, in any case, have a good chance of being chosen if the personal and social benefits are adequately highlighted to make people intentionally adopt pro-environmental alternatives.

In this choice context, other incentives can also play an important role in overcoming the structural difference between the alternatives.

Furthermore, additional factors must be taken into account to retain users of Mobility as a Service. These include:

7. Information characterization. The dialogue between the user and the service provider takes place through an exchange of information. Information plays a crucial role in the process of behavioral change and should be characterized by the timing, technique, design, and overall organization with which it is delivered and implemented (see Section 6). Indeed, information, if well proposed, can directly influence psychological and cognitive motivational factors.
8. Use of specific communication channels. Identifying the most suitable channels for delivering information and communication (such as smartphone applications, social networks, etc.) is crucial for engaging people in using MaaS and making them aware of the active role they can play when opting for sustainable alternatives. Strong collective involvement and participation are essential for triggering behavioral change.
9. Use of mobile technology. The availability of a simple and intuitive smartphone application capable of communicating information and personalized advice in a direct, automatic, and dynamic way expands the opportunities for using MaaS services. In particular, it can play an important role in building social networks and comparing them with other individuals (gamification).
10. Rely on behavioral change theories. Success in using MaaS solutions may be more likely if the measures are based on behavioral theories and integrated into a behavioral change modelling process. Such theories may also derive from psychology research field: Theory of Planned Behavior (Ajzen, 1991), Norm Activation Model (Schwartz, 1977), Value-Belief-Norm (Stern, 2000), Theory of Interpersonal Behavior (Triandis, 1977), Trans Theoretical Model (Prochaska & DiClemente, 1982), Stage Model of Self-regulated Behavior Change (Bamberg, 2013).
11. Evaluation and monitoring techniques. Evaluation and monitoring have two important roles. The first is to inform, with reliable data, decision makers whether to invest financial resources in MaaS. The other is to inform users of the good results achieved, in order to activate forms of social norm. The evaluation consists in identifying the changes that have occurred as a result of the use of a MaaS service.

The key factors reported in this section must be investigated and used by those who plan to implement MaaS in their cities, so as to make it an effective tool in the direction of sustainability. Understanding the reasons behind individuals' choices is important because they provide indications for introducing innovative factors traditionally not considered in sustainable transport planning (Steg & Vlek, 2009).

From a practical standpoint, the design of a MaaS system should incorporate the most effective strategies to encourage behavioral change among potential users who have been previously carefully identified. Such strategies should be applied in combination with integrated pricing packages, informative feedback, incentives, rewarding schemes, persuasive messages, prizes, and gamification techniques.

6. The tools and operational techniques that can facilitate the use of MaaS

This section will provide a list of tools and techniques commonly utilized in interventions aimed at encouraging individuals to adopt new sustainable travel behaviors. These methods are rooted in the theories and psychological models outlined in the preceding sections, particularly focusing on information and communication strategies.

In recent years, information has become a primary research focus, likely due to its prominent role in interventions aimed at changing travel behavior (Abrahamse & Matthies, 2012). Many studies have tried to investigate the best form and means to provide it in an effective way. The need for meticulous attention in presenting information has been a recurring theme in past literature.

A critical first step in promoting pro-environmental behavior is addressing knowledge gaps. This approach assumes that people often lack awareness about the nature and consequences of environmental problems, or simply do not know what actions they can take to address them (Schultz, 2002).

Another more general aspect is the one linked to “satisficing behavior” (Simon, 1955). Some empirical evidence shows how, in making travel decisions, the level of individual satisfaction is inversely proportional to the amount of information used (“Bounded Rationality”).

Furthermore, Brög (2000) and Fujii and Taniguchi (2006) observed the importance of receiving only the necessary amount of information, avoiding information overload (limited rationality, Simon, 1982).

Information allows to provide users a real quantification of their behavior. Often, individuals do not know perfectly the characteristics associated with travel alternatives that have not been chosen (Schwanen & Lucas, 2011; Gaker & Walker, 2011) nor even those chosen (Gaker & Walker, 2011). In general, car users have a distorted perception of the characteristics of non-car alternatives. The same occurs when quantifying external costs and, in particular, the effects on the environment (Arnott & Small, 1994; Parry et al., 2007).

Many studies underline the problem of how, especially in travel choices, much of the provided information is systematically ignored. A first cause is related to the nature of the information, the method of communication and the content. They are often inaccessible, not visible, too detailed, difficult to understand, and not trustworthy because they are not sufficiently supported (ESRC, 2009).

A further fundamental aspect is that the information needs to be personalized in order to be effective (Abrahamse et al., 2007; Fujii & Taniguchi, 2006; Gärling & Fujii, 2009). Ampt (2003) argued that the importance of personalization is linked to the fact that different users have different needs, so it is essential to activate the right and specific motivational levers.

Finally, two non-negligible aspects, especially in travel information, are the reliability of the message, i.e., the role and importance of those who send the message ("brand" and "authority") and the way in which they are communicated, i.e., how they are formulated (design).

The information tools reported in this section are more effective when combined together (Stern & Gardner, 2002). Indeed, when applied individually, they are not completely effective and have weak effects in promoting behavioral change (Geller, 1992). Therefore, their ability to activate cognitive-motivational attributes could be enhanced by integrating them into a single technological platform, generating a high level of personalization. These platforms and applications can constitute a module to make MaaS a solid system to promote and stimulate intentionally sustainable and pro-environmental travel behavior changes.

6.1. Feedback programs

A specific type of information widely used in many travel behavior change interventions relates to feedback programs (Sanjust di Teulada et al., 2015; Sottile et al., 2015; Meloni et al., 2017; Piras et al., 2018a; Sottile et al., 2021; Giubergia et al., 2024). Feedback consists of giving people quantitative information about the performance of their travel behavior in terms of, for example, travel time, costs saved, CO_2 emitted, kcal consumed, etc. In accordance with the theory (Kluger & DeNisi, 1996), feedback influence behaviors because they make individuals clear and aware of the link between a certain result (reducing the distance travelled by car) and the behavioral change necessary to obtain it (taking the bus) (Dahlstrand & Biel, 1997). In particular, this quantitative information is aimed at (1) providing evidence of the observed behavior, (2) presenting the information associated with the suggested alternative (coping planning), and (3) encouraging behavioral change through the achievement of personal and social benefits (comparative feedback). Notably, comparative feedback is more effective when presented in terms of benefits and savings (Dahlstrand & Biel, 1997).

6.2. Goal-settings

Feedback is linked to another type of information: goal-setting. This type of persuasive communication is associated with the objectives that everyone can set out and is based on the desire to achieve them. Goal-setting is most effective when combined with feedback and in groups where goals are more ambitious (Abahamse & Matthies 2012). In addition, goal setting techniques are used in conjunction with commitment techniques, in which people formally commit to change their behavior.

6.3. Incentives and rewards

Behavioral change may be simplified with an incentive or a reward for achieving a particular goal. Incentives and rewards are being used in many applications in the field of transportation with good results, especially when combined with other measures. The theoretical basis of incentives and rewards is that people must be motivated by the promise of something they will get later (Skinner, 1974).

There are some techniques that can increase the desirability of the prize. Some authors indicate that consequences closer in time are more effective than those that are distant and difficult to verify. This aspect is very important in the context of intentionally sustainable travel behaviors, which, like pro-environmental ones, do not offer immediate rewards. It follows that adding positive consequences, such as short-term incentives and rewards, can be a good reinforcer (De Kruijf et al., 2018; Newson & Sloaman, 2019).

6.4. Gamification

Incentives and rewards are often combined with gamification. This is defined as the use of game elements in non-game contexts (Deterding et al., 2011). In the last 10 years it has gained wide popularity in different fields (education, marketing, welfare, health) and more recently also in transportation (Yen et al., 2019; Sanjust di Teulada and Meloni, 2016; Lieberoth et al., 2018). One example is Singapore's Travel Smart Network, where participants are encouraged to shift their travel schedules to off-peak periods. The more users participate in the scheme, the higher the chances of winning prizes (Land Transport Authority of Singapore, 2015).

6.5. Persuasive messages

Persuasion, i.e., the communication intended to change people's minds and behaviors without coercive means (Cialdini, 2001), acts on individuals' emotional and behavioral aspects. A persuasive message, for instance, could emphasize the choice to undertake a new behavior (applause message) or not do it (regret message). For simple tasks, another persuasive tool that could be used is prompting. They consist of a short-written message that draws attention to a specific behavior to adopt in a given situation.

Communication is an important factor in persuasion because it has pragmatic effects on the individuals to whom it is delivered. In this context, the diffusion of social media and mobile technology has further enhanced its potential.

Over the past 15 years, the inclusion of persuasion techniques in travel behavior change programs has been reaffirmed and strengthened in the field of behavioral economics (Thaler & Sustein, 2009; Avineri, 2009, 2011, 2012; Dolan & Metcalfe, 2012; Dolan et al., 2012; Bamberg, 2014; Sanjust di Teulada and Meloni, 2016; Sottile et al., 2021). The goal is to try to make individuals more aware of the importance of the negative effects that car use generates in terms of emissions and climate change.

6.6. Persuasive Technology

Information and digital technology play an important role in providing information, messages, feedback, incentives, and game dynamics. Technology represents, in fact, one of the main strengths of a MaaS system. In particular, several researchers analyzed the use of a particular form of technological information: "Persuasive Technology" (Fogg, 2003). Notably, Persuasive Technology helps motivational and informational approaches to be more effective in persuading individuals to adopt sustainable travel behaviors. Indeed, persuasive technology focuses on how interactive technology may be designed to influence people's attitudes and convince them to change behavior (Busch et al., 2012). In particular, it focuses on how to transform users' current cognitive state into a planned one (Torning & Oinas-Kukkonen, 2009).

More recently, thanks to the diffusion of smartphones equipped with increasingly accurate GPS systems, it has been possible to activate persuasive behavioral change strategies based on delivering feedback on the travel behaviors directly observed (Froehlich et al., 2009). In the past years, various smartphone applications have been developed with the aim to persuade people to change their unsustainable travel behaviors (Froehlich et al., 2009; Schrammel et al., 2012; Carreras et al., 2012; Bothos et al. 2012, 2013, 2015; Broll et al., 2012; Jariyasunant et al., 2015; Jylhä et

al., 2013; Gabrielli et al., 2013; Meloni & Sanjust, 2015; Sunio et al., 2017; Sunio & Schmocker 2017; Di Dio et al., 2018; Piras et al., 2018b; Anagnostopoulou et al., 2018; Dastjerdi et al., 2019).

6.7. Normative information

Another effective information tool is the one based on standard behaviors. Such a strategy tries to persuade people by promoting those individuals who implemented the recommended behaviors. This strategy is based on the Learning Theory of Bandura (1977), whereby people shape their behavior by observing the behavior of others. Particularly, normative interventions (Cialdini, 2003; Goldstein et al., 2008; Piras et al. 2021; Giubergia et al., 2024) can rely on the observed behavior of others (descriptive norms) or on their opinions (injunctive norms). For instance, a possible normative intervention could be: "Many of your co-workers use a MaaS service for commuting from home to work at a truly convincing price".

7. Conclusions

To confirm that MaaS can be a tool to stimulate more sustainable travel behaviors, it is important to understand, on the basis of the scientific literature, the potential impacts of MaaS on travel preferences. More generally, it is necessary to understand what the fundamental components of a MaaS system are, so that it can lead to sustainable travel behaviors. In this perspective, this work reviewed some of the applications that have investigated the influence of MaaS on behavioral change.

Overall, the studies reviewed show that MaaS has the potential to support decreasing private car use. However, the magnitude and direction of these changes still remain uncertain. They require more quantitative results, both at the individual level (travel behavior, travel preferences) and the societal level (social and environmental sustainability). The exact type of potential users that will be initially interested also remains unclear, as does the timing for a wider adoption among the general population. Indeed, a drastic shift from the private car ownership paradigm to the MaaS paradigm is unlikely to occur within a few years.

However, the current literature on MaaS applications can inform us about the prerequisites for the adoption of MaaS, while also providing qualitative indications of potential users and impacts.

Studies agree that it is difficult to change travel behavior when there is no trigger or strong propensity, especially for regular trips. This indicates that, in the first phase, MaaS could have more possibilities of being used to make trips for non-systematic reasons. Then, if users are satisfied with the solution they used, spillover effects to everyday commuting trips may be expected. Nevertheless, people need actually to start using MaaS. Therefore, there is a need for strong awareness and promotion of the new system and the benefits it can generate for individuals and the community.

Besides the obvious transportation precondition, the adoption of MaaS will likely require a combination of multiple factors, not only structural. To stimulate users to change their travel behavior, it is important that MaaS will add value to their trip experience and will be perceived as such.

MaaS pilots demonstrated that freedom of choice, tailored offers, and increased travel convenience can positively impact MaaS adoption. The all-inclusive and personalized offers are particularly valid even if the price is higher than what individuals are used to. Costs, indeed, are an important aspect: to provide users with a viable and long-lasting behavior, the alternative offered must be economically feasible and perceived as cost-effective. Furthermore, MaaS must not require travelers to make too many compromises on their autonomy, flexibility, and reliability needs.

Combining modes of transportation is considered a strength of MaaS, but this is not always the case for car users who routinely use only one mode. Additionally, car sharing could provide flexibility to a MaaS system, but uncertainty remains about how much sustainable it is, especially when used to make the entire journey.

As previously argued, MaaS has to possess specific requirements to overcome the obstacles of users' travel behavior change. First of all, MaaS should be able to "sell" a mobility service that works well, and that is effectively characterized by a high degree of integration. High levels of integration are more likely to encourage passengers to use intermodal solutions. Furthermore, the personalization of the alternatives in relation to the user's needs represents a feature of primary importance.

However, these characteristics are necessary preconditions, but they may not be sufficient if not accompanied by other features that MaaS should possess.

For example, the current literature provides limited guidance on which target populations might be most interested in using MaaS. Furthermore, the analysis of the factors that can stimulate MaaS adoption has not yet been studied in depth. Nevertheless, it is certainly true that aspects related to attitude, values, environmental propensities, and other socio-economic, socio-demographic, and cultural characteristics play an important role in choosing to use a MaaS service.

It is clear that to make conclusive statements about MaaS effects there is a need for more research on its adoption and ability to change travel behavior, especially from a quantitative standpoint. Research and applications on travel behavior are very useful starting points that should be analyzed when implementing MaaS projects that try to steer sustainable and intentionally pro-environmental travel behavior.

This study has discussed the measures, especially the cognitive-motivational ones, which a MaaS service should necessarily contain. It also highlighted, through literature references, which informative, awareness and motivational tools, appropriately combined and integrated, can become part of the technological platforms used by Maas.

7.1. Future developments

While many authors are excited about what MaaS can accomplish, especially at the urban level, quantitative analyses are still very few. There is a need, therefore, for increased research into the effectiveness of MaaS and what it should contain. Only then will it be possible to understand what this new innovative system can offer in terms of sustainable mobility. Quantitative research could take place in the first phase by testing MaaS with the highest levels of integration in contexts, even limited, such as corridors and portions of cities, in which the transportation and social conditions exist for this service to be offered competitively.

In summary, MaaS research must focus on potential users who demonstrate a propensity for change. It would also be interesting to investigate the characteristics of those who did not change, what their obstacles have been, and, on the other hand, who are the ones who did choose to use MaaS, and what are the attributes that led them to choose it.

Perhaps one of the most subtle points is the willingness to pay for this service. Costs will require special attention and more research into what adds value within MaaS from a user perspective. In other words, understanding how much it is worth moving sustainably.

Acknowledgements

The third author gratefully acknowledges financial support provided by the Italian Ministry of University and Research (MIUR), within the Research and Innovation framework (Project code: CUP F25F21002180007).

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