

Are travellers willing to adopt MaaS? Exploring attitudinal and personality factors in the case of Madrid, Spain

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ABSTRACT

Mobility as a Service (MaaS) is expected to significantly change our mobility patterns. However, it is still not clear who will accept this new mobility paradigm and how it will affect travellers' behaviours. In this study, we identify a set of attitudinal and personality factors relevant for MaaS adoption based on a survey comprising 1,000 respondents in the metropolitan area of Madrid (Spain). The results show strong positive attitudes towards MaaS after being validated through a structural equation model. The higher the percentage of multimodal travellers, the more they are open to "new mobilities", the greater their technological capabilities and curiosity, and the lower their cost sensitivity, then the higher the adoption potential for MaaS. Our analysis reveals four clusters in terms of individuals' intention to use MaaS technologies (technological car-followers, unimodal travellers, MaaS-lovers and active public-transport supporters). Motivated by a significant environmental sensibility, MaaS-lovers appear to be the most likely to reduce their private car usage in favour of alternative modes. Overall, we recognise two main barriers that can frustrate MaaS adoption: low technology affinity and low openness to sharing-mobility services. Policies that focus on these two aspects can encourage MaaS acceptance.

1. Introduction

Urban mobility worldwide is changing rapidly, in line with the continuous development of digital technologies. In particular, new app-based mobility services – such as car-, bike- and scooter-sharing services – are increasingly being introduced in our cities to complement the "traditional" transport system, driven by a change in travellers' motivations. Individuals are seen to be ever more attracted by the transition from an "owner-ship" to a "user-ship" model (Jain et al., 2020).

Despite the social, environmental and economic benefits promised by the "new mobilities" (Durand et al., 2018; Dastjerdi et al., 2019), the wide range of available transport options presents a significant challenge to the users. Mobility as a Service (MaaS) is proposed to facilitate the adoption of all these alternatives and maximize their potential advantages when combined. The introduction of this concept is attributed to Sonja Heikkilä, who in 2014 described MaaS as "a system in which a comprehensive range of mobility services are provided to customers by mobility operators through one single digital interface" (commonly a mobile-application) (Heikkilä, 2014, p. 8). Today, MaaS is still in its infancy and, although there is no clear agreement on the definition of this notion (Arias-Molinare and García-Palomares, 2020b), all the

interpretations (e.g., Hamari et al., 2016; Grybaite and Stankeviciene, 2016; Jittrapirom et al., 2017; Smith et al., 2018; Esztergár-Kiss and Kerényi, 2019; MaaS Alliance, 2019; Alonso-Gonzalez et al., 2020; Caiati et al., 2020; Liljamo et al., 2020; Schikofsky et al., 2020; Storme et al., 2020) share the following three basic ideas: (i) MaaS relies on a user-centric scheme, offering tailored multimodal mobility solutions based on individuals' preferences through "customized-mobility-packages"; (ii) MaaS follows a mobility distribution model that integrates end-to-end trip planning, booking, e-ticketing, and payment services across all modes of transport available; and (iii) MaaS is provided to travellers through a user-friendly single digital platform (or mobile-application).

Based on a review of MaaS literature, we decided to adopt the definition given by the European MaaS Alliance, a public-private partnership responsible for establishing the foundations for a common and global approach to MaaS. According to this organization, "MaaS essentially constitutes the integration of various forms of transport services into a single mobility service accessible on demand" (MaaS Alliance, 2019, p. 1). The key concept behind this innovative model is to locate travellers at the centre of transport services and offer them tailored mobility solutions through a digital application. This means that easy

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access to the most appropriate transport mode (or service) is promoted by a “bundle” of flexible travel service options.

Experts agree that MaaS holds the potential to promote a more sustainable mobility paradigm (Alonso-Gonzalez et al., 2020; Caiati et al., 2020; Schikofsky et al., 2020). The combination of all the available mobility services (e.g., public transport, sharing-, or pooling-services) provides individuals with an attractive range of alternatives that encourage a behavioural change towards less car-oriented lifestyles, while increasing their satisfaction (Li and Voegel, 2017; Karlsson et al., 2020). As a result, MaaS has recently attracted much attention within and around the transport sector. Even cities that are already characterized by a well-structured transit offer are interested on increasing their efficiency, connectivity, flexibility and accessibility by incorporating demand-responsive solutions. Nevertheless, public transport services are expected to remain as the backbone of the new network (Utriainen and Pöllänen, 2018; Mulley et al., 2020).

The current state of practice includes several initiatives across the globe such as Whim in Europe and Asia; SoMo in Europe and America; and Mobility4All in North America (see, e.g., Durand et al., 2018). However, although the opportunities attached to MaaS are expected to be numerous (Jittrapirom et al., 2018), it is still uncertain whether the general population will replicate the engagement of individuals in these particular pilots. In accordance with Caiati et al. (2020), a pre-condition for the successful implementation of MaaS is its “public acceptance”. This is a frequent concern when an innovative service or product is introduced in the market. Historically, many innovations have failed “to achieve a widespread diffusion due to their inadequacy to address real user needs and preferences or because of their incompatibility with user values and past experiences” (Caiati et al., 2020, p. 125). Against this background, it is clear that an in-depth analysis of individuals’ expectations of MaaS, as well as their intention to accept such solutions, is needed.

Considering the (relatively) novelty of the concept, currently only a few studies have explored travellers’ willingness to adopt MaaS (see Section 2). Even if they represent a significant first step, further research is required to improve the still limited understanding of users’ adoption decision processes and, thus, develop a more comprehensive body of knowledge. Moreover, as the results tend to depend on the research design, model approach and the selection of the variables, additional research is a welcome contribution to the current scarcity of empirical awareness. Especially in the case of MaaS, with its inherent orientation to individuals’ needs, these insights are of the utmost importance.

All in all, the objectives of our study, and its novel contributions to the literature, are the following:

- i. First, we aim to increase the knowledge of MaaS by focusing on the motivational drivers affecting travellers’ willingness to adopt such mobile technologies. We carry out a comprehensive review of the literature to identify the corresponding attitudinal and personality factors. As far as we are aware, no previous research has simultaneously considered these two typologies of predictors in the field of MaaS.
- ii. Second, we explore how different population segments are more (or less) likely to engage in MaaS and identify “user clusters”. In particular, we analyse the potential relation between their current mobility patterns and inclinations towards MaaS solutions. The paper takes the metropolitan area of Madrid as a case study, being the first attempt to explore individuals’ MaaS acceptance in the Spanish context. Most studies are focused on European central-northern countries such as the Netherlands, Sweden, Finland and Germany.
- iii. Finally, and based on the previous findings, we define a series of recommendations to support the adoption of MaaS, tailored to the profiles of the different travellers. These insights will be of great importance for policy makers, public authorities, transport operators and mobility planners when considering the definition

and implementation of MaaS schemes and, thus, the promotion of a (socio-technical) transition towards more sustainable behaviours.

The remainder of the paper is organized as follows: Section 2 explores MaaS acceptability and establishes the behavioural framework for the study; Section 3 describes the methodological approach, which is applied to the case study of Madrid (Spain). Then, Section 4 analyses the results and Section 5 discusses the key findings, with an emphasis on policy implications. Lastly, Section 6 provides the final conclusions, exposes the limitations of the study and proposes future lines of research.

2. Acceptability of new technologies: individuals’ willingness to adopt MaaS

As noted above, the literature widely agrees that the success of MaaS depends significantly on travellers’ engagement. Until now, only some studies have explored why and how individuals adopt and use these innovative solutions (see Table 1). Their findings suggest a number of user (personal) characteristics and preferences that can be expected to shape the demand for MaaS.

By definition, MaaS requires an integrated application that provides individually tailored “algorithm-based travel management” (Schikofsky et al., 2020, p. 297). MaaS can therefore be regarded as a new digital technology. As a consequence, the Technology Acceptance Model (TAM) (Davis et al., 1989) is suggested as an appropriate initial framework for achieving our research purpose, namely to explain individuals’ willingness to adopt these innovations. TAM is the most influential and widely applied model for identifying the factors that affect individuals’ acceptance of a particular technology. Its validity, reliability and robustness have been demonstrated by extensive research. The model is originally an extension of the Theory of Planned Behaviour (TPB) (Ajzen, 1991), which states that a person’s intention to adopt a certain type of behaviour – in this case, adopting MaaS technologies – is the main predictor of whether or not he/she will engage in that behaviour. This psychological theory seeks to explain people’s actions by identifying the causal connections between beliefs, attitudes, intentions and behaviours.

TAM originally concentrated on attitudinal factors as central predictors that steer individuals’ adoption of technology. Davis et al. (1989) proposed that *perceived usefulness* and *perceived ease of use* determine the *behavioural intention* of an individual to use a specific technology. *Perceived usefulness* refers to the benefits expected from the new product or solution; while *perceived ease of use* describes the anticipated burden when using it. With a view to improving the TAM’s predictive power, some authors (e.g., Erdoğan and Esen, 2011; Svendsen et al., 2013) suggested a promising new approach that incorporates personality traits as predictors (or explanatory factors). Their studies have shown that individuals’ beliefs, attitudes, intentions and behaviours – across a variety of human life contexts – are influenced by fundamental personality traits. This means that these psychological predispositions may have relevant effects on a number of individual variables. According to Terborg (1981), simultaneous consideration of both the person and the situation is essential to understand behaviour. A more detailed description of the acceptance model is beyond the scope of this paper, and the reader is referred to e.g., Davis et al. (1989).

In this study, we apply the TAM to explore individuals’ willingness to adopt MaaS, considering both attitudinal factors and personality traits as predictors. According to previous investigations (see Table 1), the identification of these (motivational) predictors is the first step for building the acceptance model. To this end, we carry out a systematic and comprehensive review of the literature published in the last six years. Specifically, the search was made in Scopus and ScienceDirect in May 2020, since these databases include a large amount of scientific papers. The exact keyword “Mobility as a Service” was searched in

Table 1
Individuals' willingness to adopt MaaS: identifying attitudinal factors.

Year, Author(s)		Case study	Objective of the research	Methodology (data collection, data analysis)	Attitudinal factors for MaaS adoption			
					Mobile applications	New mobility services	Mobility integration	Other factors ^a
2018	Ho et al.	Australia	Explore potential demand for MaaS and users' willingness to pay for mobility packages	Stated preference survey,Multi-Nomial Logit	–	–	Users' expectations ^b	–
	Polydoropoulou et al.	Hungary and United Kingdom	Evaluate users' opinions/ concerns on MaaS deployment and the services offered	Focus groups and Online survey, Exploratory analysis	Privacy concerns	Need for control, Need for flexibility	Users' expectations ^b	–
	Strömberg et al.	Sweden	Identify potential MaaS users, their expectations and travel behaviours	Online survey, Cluster analysis	–	–	Users' expectations ^b	–
2019	Fioreze et al.	The Netherlands	Investigate individuals' willingness to adopt MaaS technologies based on their attitudes	Focus groups and Online survey, Cluster analysis	Technophilia	–	Users' expectations ^b	–
	Hesselgren et al.	Sweden	Analyse how to lower the barriers to increase shared travel with MaaS	Interviews, Exploratory analysis	–	–	Users' expectations ^b	–
	Matyas and Kamargianni	United Kingdom	Explore individuals' preferences for fixed and flexible MaaS plans	Stated preference survey,Mix Multi-Nomial Logit	–	–	Users' expectations ^b	–
2020	Alonso-Gonzalez et al.	The Netherlands	Identify attitudinal factors relevant for MaaS adoption and characterise customers' profiles	Online survey, Latent Class Cluster Analysis	Technophilia, Privacy concerns,	Environmental awareness	Users' expectations ^b	Willingness to pay
	Caiati et al.	The Netherlands	Explore users' intention to subscribe to MaaS and preferences for bundle configurations	Stated preference survey,Mix Multi-Nomial Logit	–	–	Users' expectations ^b	–
	Feneri et al.	The Netherlands	Investigate the intended behavioural change (in transport mode) as a result of MaaS	Stated preference survey,Error Components Logit	–	–	Users' expectations ^b	–
	Liljamo et al.	Finland	Explore people's willingness to pay for MaaS services, and associate it to their mobility costs	Online survey, Linear regression model	–	Environmental awareness	Users' expectations ^b	–
	Schikofsky et al.	Germany	Identify motivational determinants that affect users' intention to adopt MaaS and their structural interrelations	Interviews and Online survey, Structural Equation Model	Technophilia	Need for control	Users' expectations ^b	Competence ^c , Relatedness ^d , Enjoyment ^e , Familiarity ^f
	Storme et al.	Belgium	Explore willingness to change travel behaviours: from private car to MaaS services	Online survey, Exploratory analysis	–	–	Users' expectations ^b	–
	Vij et al.	Australia	Understand consumers' demand and willingness to pay for MaaS	Online survey, Latent Class Choice Model	–	–	Users' expectations ^b	Willingness to pay
	Ye et al.	China	Identify key variables that affect MaaS acceptance	Online survey, Structural Equation Model	Technophilia	Individual innovation	Users' expectations ^b	Effort expectation, Social impact, Perceived risk

^a An additional category is considered for the factors that cannot be classified in accordance with Durand et al. (2018).

^b Users' expectations of the services integrated by MaaS applications (or mobile technologies).

^c Feeling of confidence.

^d Feeling connected to people.

^e Hedonic motives.

^f Habit-related motives.

documents written in English. Moreover, we limited the review to peer-reviewed journal articles, which restricted the focus of interest to a manageable and reputable search for literature

2.1. Identifying attitudinal factors for MaaS adoption

Durand et al. (2018) considered three main categories when analysing attitudinal factors for MaaS adoption: (i) mobile applications, (ii) new mobility services, and (iii) mobility integration. As shown in

Table 1, we followed this criterion to structure the attitudinal factors found in the literature and incorporated an additional category ("other factors") for the factors that cannot be classified in accordance with such authors.

This study selects those attitudinal factors aligned with the categorization of Durand et al. (2018) and which appear at least twice in the literature reviewed. Our research model therefore considers the following variables:

(i) Mobile applications. Given that travellers interact with MaaS via

an app interface, it is critical to explore their willingness to adopt the actual application (or mobile technology). This category includes two factors:

- **Technophilia (or personal technology affinity).** This factor refers to an individual's openness, interest in and competence with (new) technologies. Here, technophilia describes the degree of positive or negative attraction to MaaS applications. In line with previous research (Velazquez, 2019), our perspective is that higher levels of technophilia are correlated with higher rates of technology adoption. In the field of urban mobility, Astroza et al. (2017) also positively associated technophilia with the likelihood of using multiple modes of transport.
- **Privacy concerns.** This factor describes travellers' ability to control the collection of their personal information and its subsequent use by marketers. Privacy concerns have been considered a barrier for the acceptability and use of technological innovations such as MaaS, which compile, process and store user data as part of their regular operations (Polydoropoulou et al., 2018; Cottrill, 2020). The key is not the information disclosure *per se*, but rather the degree of control that is exercised by the consumers (Alonso-Gonzalez et al., 2020).

(ii) **New mobility services.** As a complementary offer to the public transport system, MaaS incorporates all the new mobility services available in the city. This category also comprises two factors:

- **Need for control.** Travellers today demand total control of the entire transport network. New mobility services (such as car- and bike-sharing) introduce some uncertainties for the user that “are inherent to their flexible and finite (scarce) nature” (e.g., local availability of services, possibility of parking at the destination) (Durand et al., 2018, p. 25). These uncertainties – if improperly managed – can negatively affect individuals' reliability on the “new mobilities” and hence the adoption and use of MaaS applications (Weckström et al., 2018).
- **Environmental awareness.** This factor describes the concern about the impact of human behaviours on the environment. It has been widely adopted in the scientific literature on travel behaviour, particularly when investigating new mobility services (Kamargianni et al., 2016). In general, environmentalists are less car-dependent and more easily motivated to use alternative mobility options. Considering the mobility shift that MaaS aims to introduce, it can be predicted that individuals with high environmental awareness are more inclined to embrace these new technologies.

(iii) **Mobility integration.** Integration of services is one of the key aspects of MaaS (Schikofsky et al., 2020). For users, MaaS provides an integrated travel management and payment system based on a single account. One factor represents this category:

- **Expectations of the services integrated by MaaS applications.** This factor refers to individuals' expectations of the level of integration (of the services) provided by MaaS applications. Individuals must be willing to combine different modes of transport as part of their travel patterns in order to exploit the benefits offered by these innovative technologies (Caiati et al., 2020). Multimodal mindsets are more disposed to adopt MaaS solutions (Fioreze et al., 2019; Alonso-Gonzalez et al., 2020).

A more detailed description of these attitudinal factors is beyond the scope of this paper, and the reader is referred to the literature listed in Table 1.

2.2. Identifying personality traits for MaaS adoption

Personality traits reflect individuals' characteristic patterns of

thoughts, feelings and behaviours (Gerlitz and Schupp, 2005). After developing a comprehensive literature review, we found that previous research into travellers' willingness to adopt MaaS technologies have not considered these factors as explanatory variables. In this regard, our paper represents an original contribution.

Psychologists have developed multiple conceptual models to measure personality. Among them, the Big Five is the most popular structure and has been widely applied to explain human behaviours and life outcomes. The Big Five model proposes the existence of five traits (or constructs), i.e., openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism (OCEAN), which capture the core personality domains. These broad trait dimensions can be applied to predict more specific attitudes and value orientations (Barnett et al., 2014). The first trait, *openness to experience*, represents a person's receptivity to consider alternatives, enjoy new activities (or ideas) and be curious. Second, *conscientiousness*, reflects the extent to which a person is organized, disciplined, cautious and goal-oriented. The third dimension, *extraversion*, reflects a person's tendency to exhibit social behaviour and to experience positive emotions. Trait four, *agreeableness*, indicates the degree to which an individual is trustworthy, compliant, sympathetic and cooperative. Last, *neuroticism*, represents a person's tendency to experience psychological distress and to be extremely sensitive to threats.

In the digital age, the Big Five is considered a powerful tool for predicting people's interactions with technology (e.g., participation in online social networking, trust in mobile technologies and e-shopping) (Chorley et al., 2015; Marshall et al., 2015; Stachl et al., 2017). We therefore consider this model appropriate for assessing our research purposes. Previous studies report a positive correlation between openness to experience, conscientiousness, extraversion and agreeableness, and the use of new technologies. The relationship between neuroticism and technology is less clear, and the results in the literature are contradictory (Svendsen et al., 2013).

3. Methodology

Driven by (i) the theoretical constructs of the TAM and (ii) the set of (motivational) factors recognised in the literature (Section 2), we conceptualize a research behavioural model (and propose a set of hypothesis) to explore individuals' willingness to adopt MaaS in the Madrid Metropolitan Area (Spain). Then, taking the model and its hypothesis as a reference, we design an experiment based on a data collection campaign using an online survey and a three stage mix-method analysis (exploratory factor analysis, structural equation model and cluster analysis). Fig. 1 summarises our methodological procedure, which is described in more detail below.

3.1. Research behavioural model and hypotheses

As indicated above, we conceptualize a behavioural model to capture motivational mechanisms underlying individuals' intention to adopt MaaS technologies (Fig. 2). Its quantitative validation is addressed in Section 4.

The literature review in Section 2 shows that the TAM is often adjusted and enhanced for each specific field of research. Following the assumptions of this theoretical model, we hypothesize that attitudinal factors (in this case, technophilia, privacy concerns, need for control, environmental awareness and users' expectations of the services integrated by MaaS) affect individuals' *behavioural intention* to adopt MaaS. In other terms, we hypothesize that the *perceived usefulness* of the MaaS offering positively influences travellers' willingness to adopt it. At the same time, we hypothesize that these attitudes are influenced by fundamental personality traits (openness to experience, conscientiousness, extraversion, agreeableness and neuroticism). The proposed model therefore allows us to explore the following hypotheses (Hs):

H1: Personality traits (i.e., openness to experience,

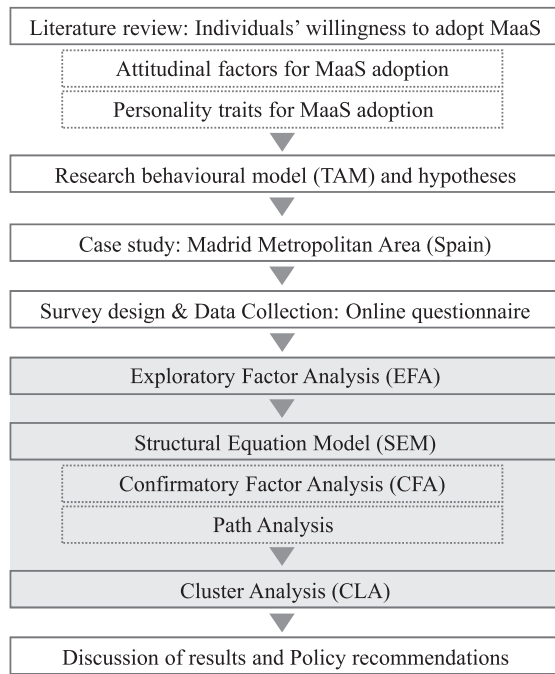


Fig. 1. Overview of the methodological procedure.

conscientiousness, extraversion, agreeableness and neuroticism) affect travellers' attitudes towards the adoption of MaaS.

H2: Technophilia, privacy concerns, need for control and environmental awareness explain users' expectations of the services integrated by MaaS applications.

H3: Technophilia directly explains individuals' intention to adopt MaaS, since users interact with these innovative services via a digital interface.

H4: Users' expectations of the services integrated by MaaS applications explain individuals' intention to adopt MaaS.

In summary, we adapt the TAM to the context of MaaS. *Perceived usefulness* and *behavioural intention* (Davis et al., 1989) describe the inner core constructs of our model. *Perceived ease of use* (Davis et al., 1989) is not considered since we are in an exploratory phase and MaaS technologies are not yet fully conceptualized. As suggested by the literature, personality factors are introduced as external variables to enhance the predictive power of the model for this business-to-consumer scenario. In the case of MaaS, personalized customization makes it easier to meet customers' individual preferences, stimulate their consumption and

attract potential users.

To validate the hypothesized behavioural model, we focus on the case study of Madrid (Spain), where the implementation of MaaS has recently been considered by the local authorities. One of our main motivations is therefore the real opportunity to deploy these technologies in the near future. In this line, Arias-Molinares and García-Palomares, (2020a) have already pointed out a set of conditions that make this metropolitan area a potential candidate for MaaS solutions: (i) a robust and well-structured public transport system, (ii) an increasing and varied offer of “new mobilities”, and (iii) high digital penetration rates.

3.2. Case study: Madrid metropolitan area (Spain)

The Madrid Metropolitan Area (Spain) is located at the core of the Madrid Region. It is a monocentric metropolitan area that has grown around the city of Madrid, the capital of the country (Fig. 3). Its main characteristics are summarised in Table 2 (Madrid City Council, 2020). In the last decades, this area has undergone rapid growth and a process of suburbanization, so many residents and jobs have moved out of the city to the outskirts.

Mobility in Madrid is characterised by a dense, highly-integrated and well-structured multimodal public transport system. It comprises 12 metro lines, 209 urban bus lines, 444 suburban bus lines, eight suburban rail lines (known as Cercanías) and four tram/light rail lines (Monzon et al., 2019). In accordance with the 2018 Madrid Mobility Survey (CRTM, 2019), there are 14.7 million trips on average in a working day in the metropolitan area, with an average trip length of 29 min. As shown in Table 2, they are split across multiple modes. Specifically, 14.2% of the trips in the city of Madrid are multimodal; while in the metropolitan area, this multimodality increases to 33.3%.

In recent years, the public transport system of Madrid has been complemented with a broad range of shared- and micro-mobility services (such as ride-hailing, car-, bike- and scooter-sharing). According to Arias-Molinares and García-Palomares (2020a), the city concentrates the largest number of shared-mobility operators worldwide, with 29 (public and private) companies and an approximate fleet of 30 thousand vehicles. Although most of these services do not provide accurate information on the number of subscribers, previous researches (Velazquez, 2019; Aguilera-García et al., 2020; Arias-Molinares and García Palomares, 2020a) have shown positive trends towards the demand of the “new mobilities”. In addition, several travel-planning applications are currently available in Madrid for moving through its metropolitan area (e.g., Google Maps, EMT App and Mi Transporte). However, none of these applications includes payment or e-ticketing services.

Local authorities have encouraged most of these alternative mobility options as a way of promoting more sustainable behaviours based on less

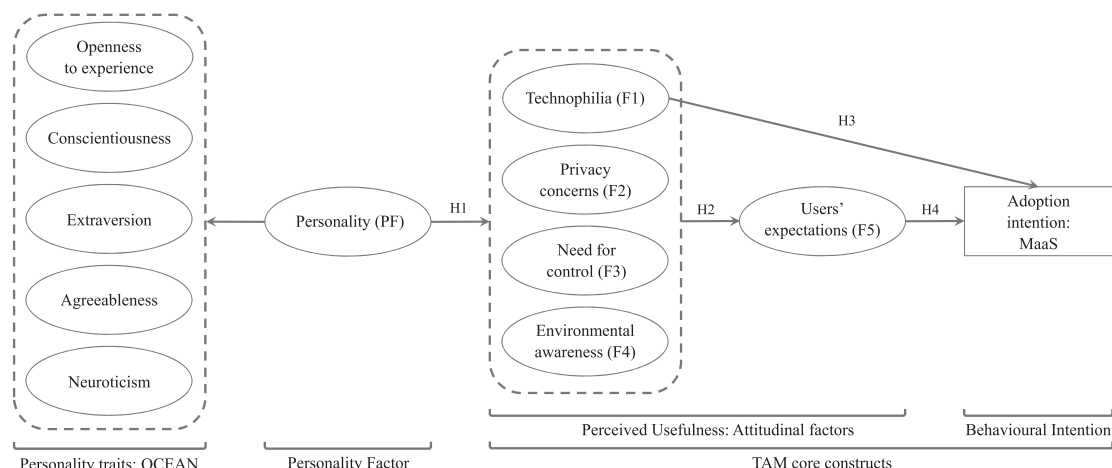


Fig. 2. Conceptual model of individuals' willingness to adopt MaaS technologies.

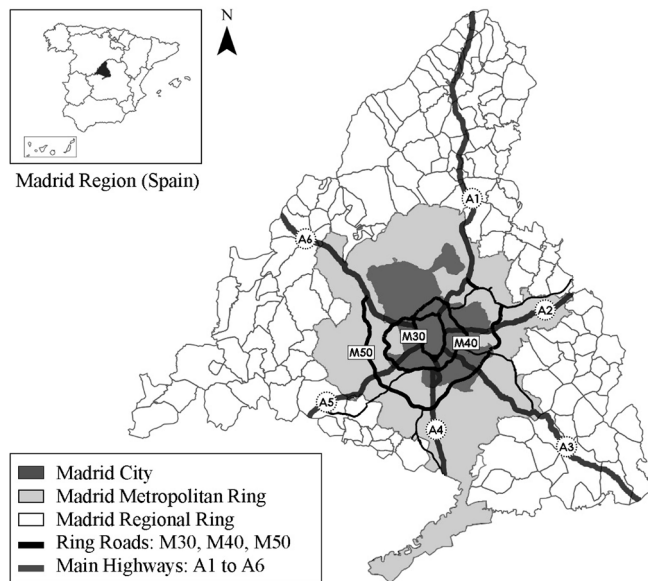


Fig. 3. Overview of the Madrid Metropolitan Area (Spain).

car-oriented lifestyles. Madrid, like other European cities, repeatedly exceeds the pollutant concentration limits established by the EU Air Quality Legislation (Directive 2008/50/EC). In order to comply with acceptable air quality levels, in 2015 the local government established an air-quality protocol to respond to high NO₂ pollution episodes. This protocol implemented restrictions on the use of private vehicles, on-street parking and an odd-even license plate control scheme. In 2018, a low emission zone of 4.7 km² was established in the city centre. All these measures are added to a generalized pay-per-use scheme for on-street parking in operation in the urban core since 2006.

3.3. Survey design and data collection

In response to the proposed behavioural framework, we design a tailor-made survey to assess potential MaaS users' perspective. MaaS relies on a user-centric model to provide travellers with individually customized mobility solutions. Understanding travellers' motivations is therefore essential for successfully defining and developing these innovative technologies.

The survey comprised the following seven blocks:

- i. **Block 1. Presentation of the research scope and the concept of MaaS.** After a short introduction participants are given a conceptual description of MaaS and a dummy application with user-centred preference settings, intermodal connections and an integrated account-based ticketing. They are then asked to assume that this MaaS application will be available on the market in the near future. The aim of this initial overview is to provide the

respondents with a realistic and reasonable level of knowledge. It is worth to highlight that, in the age of digitalization, individuals often do not have all the necessary data to fully understand certain innovations. In fact, "subjective behavioural intention does not necessarily require a deep understanding or rational evaluation of the new technology" (Schikofsky et al., 2020, p. 304).

- ii. **Block 2. General socioeconomic and demographic information:** gender, age, level of education, occupation, household structure, and residential location.
- iii. **Block 3. Adoption and use of technological tools.** Given that travellers interact with MaaS via a digital interface, we enquire about respondents' experience of using the predecessor of the MaaS application: the journey planner. Multimodal journey planners are considered Level 1 of MaaS solutions (Sochor et al., 2018).
- iv. **Block 4. Daily mobility trends and travel-related variables:** car ownership, car availability for frequent personal use, possession of driving license and public transport pass, and trip frequency on different means of transport. Since habits are important predictors of future transport behaviours (Lanzini and Khan, 2017), we also include questions related to individuals' current mobility patterns and their most frequent trips.
- v. **Block 5. Personal attitudes and lifestyle preferences.** To operationalize the five attitudinal (latent) constructs of our behavioural model (Section 2.1), we adapt validated items from the literature aimed at capturing individuals' beliefs, preferences and habits. For all the items, respondents are requested to rate their level of agreement on a five-point Likert scale (ranging from (1) "I strongly disagree" to (5) "I strongly agree").
- vi. **Block 6. Personality traits.** To capture the five major personality traits of each individual (Section 2.2), we apply the BFI-S (Soto and John, 2017), a 15-item version based on the original 44-item Big Five Inventory (BFI) (Gerlitz and Schupp, 2005). This shortened version has demonstrated good internal coherence and been validated against longer inventories. The complete formulation of each trait domain is detailed in Appendix A.
- vii. **Block 7. Willingness to adopt MaaS.** In this last block, participants are requested to rate on a five-point Likert scale (ranging from (1) "I strongly disagree" to (5) "I strongly agree") their intention to adopt MaaS. They also report their willingness to pay for using these innovations and their preferred subscription model (i.e., monthly subscription, annual subscription or pay-as-you-go).

In this study, an online survey is considered the most appropriate method for collecting the information, due to the following reasons. First, MaaS focuses on a target group that has access to the Internet. Second, web-based questionnaires make it possible to easily contact users of different means of transport. And third, online surveys are an approach that has already been selected in other previous research into willingness to adopt MaaS.

Table 2
Characteristics of the case study: Madrid (Spain).

Case study			Madrid Region	RegionalRing	MetropolitanRing	MadridCity
Population	(Inhabitants)		6,800,000	200,000	3,300,000	3,300,000
Administrative area	(Km ²)		8020	2685	4731	604
Population density	(Inhabitants/Km ²)		848	75	698	5464
GDP per capita	(Euros)		37,621	32,040	37,750	43,075
Mobility characteristics						
Modal share	Car/motorbike	(%)	39.0	56.2	47.7	20.3
	Active modes ^a	(%)	34.0	29.6	34.0	40.0
	Public transport	(%)	24.3	10.8	16.4	34.8
	Others	(%)	2.7	3.4	1.9	4.9

^a Walking, cycling.

The questionnaire was delivered between April and June 2019. Given that MaaS demands the integration of different transport options, our study focused on individuals living in the metropolitan area of Madrid, where the mobility offer includes a wide variety of services. For the sample recruitment, we partnered with a specialized online panel provider whose members are captured through multiple sources such as social media, email and web banners. The sample was controlled by quotas that ensure high representativeness for the population in terms of gender, age and frequency of public transport use.

A pilot survey with 300 respondents was conducted before the definitive survey in order to check the validity of the questionnaire and correct any possible drafting errors. Based on the pilot responses and recommendations, the content and graphic design of the questionnaire were refined and adjusted to certain time limits (approximately 20 min).

3.4. Data analysis

To analyse the data collected through the online survey and achieve our research objectives, we apply a mixed-method approach, comprising three steps: (i) an Explanatory Factor Analysis (EFA), (ii) a Structural Equation Model (SEM) and (iii) a Cluster Analysis (CLA). The combination of these techniques allows us to define customized recommendations based on each individual's attitudes and personality traits (Anable, 2005; Lois et al., 2018). Particularly in the case of MaaS, and due to its user-centric nature, these individual-tailored policies are key to achieve travellers' engagement.

All in all, the staged methodology applied is the following:

- i. First, an **Exploratory Factor Analysis** (EFA) is developed to identify the underlying structure of the attitudinal variables selected in Section 2.1, and to explore their theoretical constructs. Previous research has shown that “attitudinal approaches that are used as a base for mobility segmentation are advantageous as a starting point for related policy interventions” (Alonso-Gonzalez et al., 2020, p. 380). This structure is used to develop the subsequent SEM model.
- ii. Second, a **Structural Equation Model** (SEM) is used to investigate the behavioural model representing the research hypotheses (Section 3.1). The SEM involves two multivariate techniques: a Confirmatory Factor Analysis (CFA) and a path analysis, both of which test measurement and structural equations simultaneously (Schikofsky et al., 2020). An increasing number of recent studies apply SEM to examine travellers' willingness to adopt mobile applications or technologies (e.g., Assemi et al., 2018; Dastjerdi et al., 2019).
- iii. Finally, a **Cluster Analysis** (CLA) is applied to identify traveller segments that share similar attitudes towards the factors explored in the previous SEM. This analysis enables a set of “mobility profiles” to be defined, which are characterized by sociodemographic, mobility and technology-related variables. Among the different CLA methods, this study selects the agglomerative hierarchical clustering technique (also minimum variance or Ward's method), which aims to maximise inter-group heterogeneity and intra-group homogeneity, and has been identified as the most accurate of all the commonly used procedures (Esztergár-Kiss and Caesar, 2017). We also propose an unsupervised approach, in which a free interaction among the variables determines the number of clusters without any *a priori* restriction.

Prior to these analyses, the data collected through the survey have to be cleaned and filtered to guarantee the most successful results.

4. Results of behavioural modelling

4.1. Descriptive analysis of the online survey

A total of 1000 valid responses were collected. Table 3 shows a summary of the basic descriptive analysis for some of the variables and compares it with local statistics (Madrid City Council, 2020). The sample has certain characteristics that cannot be considered as fully representative of the case of Madrid, which seems reasonable given that the data collection method in the survey campaign requires the questionnaire to be completed online. However, it includes a sufficient level of heterogeneity for our modelling purposes.

It should be mentioned that although the majority of the respondents live in Madrid city (83.7%), some respondents living in the outskirts were also captured (163 observations). Consequently, the urban segment is over-represented in the sample. It is worth noting the significant share of multimodal travellers (41.5%) among the mobility-related variables.

4.2. Exploratory factor analysis (EFA): Identifying attitudinal factors

An EFA was applied to explore the latent structure underlying the set of attitudinal variables measured through the previous questionnaire, using the SPSSv26 software package. From a preliminary analysis of the descriptive statistics, we observed good internal consistency of the data and good sample adequacy. The determinant of the Spearman's correlation matrix indicated the absence of multi-collinearity, and the Bartlett's test for sphericity rejected the null hypothesis of an identity correlation matrix.

Principal axis factoring (PAF) with orthogonal “Varimax” rotation revealed five attitudinal factors: technophilia (F1), privacy concerns (F2), need for control (F3), environmental awareness (F4), and users' expectations of the services integrated by MaaS applications (F5). These latent constructs correspond to those identified in Section 2.1. Orthogonal rotation ensured that latent factors are uncorrelated and shows the order of importance of the factors extracted according to the percentage of variance (Field, 2009). The explained cumulative variance of the factors accounted for over 70%, so the underlying structure can be considered correct.

Table 4 shows the loadings of the dominant items for the factors obtained, together with their descriptions. Based on the “two-indicator rule” (Bollen, 1989), the analysis considered at least two items per factor, and 0.60 was set as the cut-off value to retain the items.

In the following Section, the factor structure extracted by the EFA is confirmed and applied to perform a SEM. The model also considers the influence of personality factors (Section 2.2).

4.3. Structural equation model (SEM)

With the aim of testing the hypotheses formulated in Section 3.1, we conducted a SEM using the maximum likelihood estimation method with the AMOS26 software. We considered that individuals' behavioural intention to adopt MaaS is directly affected by attitudinal factors, and that these attitudes are influenced by personality traits.

The statistical model confirmed the general behavioural framework and the four research hypotheses proposed for the case study of Madrid. Fig. 4 presents the results, including the estimated standardized path coefficients ($p < 0.001$) and the determination coefficients. Following Lois et al. (2019), we examined the goodness-of-fit of the model by using the root mean square error of approximation (RMSEA) and the standardized root mean square residuals (SRMR), and tested the incremental model fit with the comparative fit index (CFI). The overall model fit was satisfactory (RMSEA = 0.048; SRMR = 0.051; CFI = 0.988), and the chi-square test was also significant (98.1, $df = 30$, $p = 0.000$), although this index has an important limitation, since in the case of large samples (>400 cases) it leads to the rejection of the models (Kenny and

Table 3
Summary of the sample characteristics.

	Indicator	Category	Total sample Individuals	%	Comparison with the census data *
Sociodemographic characteristics	Place of residence	Madrid City	837	83.7	–
		Metropolitan area (outskirts)	163	16.3	–
	Gender	Male	500	50.0	46.0
		Female	500	50.0	54.0
	Age ^a	18–24 years old	109	10.9	8.0
		25–34	164	16.4	18.0
		35–44	216	21.6	22.0
		45–54	216	21.6	19.0
		55–64	216	21.6	14.0
		>65	79	7.9	19.0
	Education level	Non-university	414	41.4	65.5
		University studies	586	58.6	34.5
	Occupation	Student	65	6.5	–
		Part-time employee	106	10.6	–
		Full-time employee	621	62.1	–
		Retired	75	7.5	–
	Household size	Other	133	13.3	–
		1 person	164	16.4	–
		2 people	272	27.2	–
		3 people	267	26.7	–
		4 or more	297	29.7	–
Mobility-related characteristics	Public transport pass	(Yes)	685	68.5	64.0
	Car licence	(Yes)	785	78.5	–
	MFT ^b frequency	Less than once a week	97	9.7	–
		One to three times a week	278	27.8	–
		More than three times a week	625	62.5	–
	Modal share MFT ^b	Multimodal	415	41.5	–
		Walking	63	6.3	–
		Cycling	12	1.2	–
		Car	152	15.2	–
		Motorbike/scooter	14	1.4	–
		Public transport	336	33.6	–
	Vehicle ownership	Sharing services	8	0.8	–
		Car availability	794	79.4	–
		No car	206	20.6	–
		Bicycle availability	564	56.4	–
		No bicycle	436	43.6	–

^a The sample includes participants aged between 18 and 90 years (Mean = 44.3, Standard Deviation = 14.3 years).

^b MFT: Most Frequent Trip. It is the trip a person makes most often, for example, to go to work or school.

* The gap between our sample and the Madrid population may affect the results.

McCoach, 2003).

As presented in Fig. 4, the five personality traits (OCEAN) are grouped in one personality factor (FP). Conscientiousness shows the least relative influence on the composition of this latent construct, while the other factors display similar relative weights.

In accordance with H1 (H1a to H1d), the results indicate a strong and positive effect of the personality construct (FP) on four of the attitudinal factors: *technophilia* (F1), *privacy concerns* (F2), *need for control* (F3), and *environmental awareness* (F4). These variables sequentially influence *users' expectations of the services integrated by MaaS applications* (F5), and confirm H2 (H2a to H2d). *Privacy concerns* and *environmental awareness* show the strongest direct effect on *users' expectations*, followed by *technophilia* and the *need for control*. In addition, the results indicate that *technophilia* (F1) has a great influence on individuals' intention to adopt MaaS, which is also directly explained by *users' expectations* (F5). H3 and H4 are therefore confirmed. Finally, the analysis points out that *privacy concerns* (F2), *need for control* (F3), and *environmental awareness* (F4) also affect the behavioural intention to adopt MaaS, but mediated by *users' expectations* (F5).

For the determination coefficients, the model explains 49% of the variance in the *technophilia* factor (F1), 62% of *privacy concerns* (F2), 60% of *need for control* (F3), 42% of *environmental awareness* (F4), 56% of *users' expectations* (F5) and 64% of the adoption intention variable. The findings thus support the significant and important role of personality traits and attitudinal factors as influencing and motivational drivers for MaaS acceptance.

Finally, Table 5 summarizes the results of the hypothesis testing. In our behavioural model, all the relations identified are positive.

4.4. Cluster analysis

The cluster analysis identifies segments of travellers in terms of their willingness to adopt MaaS. It recognizes homogenous groups based on the ten latent variables included in the SEM (Section 4.3): *technophilia*, *privacy concerns*, *need for control*, *environmental awareness*, *users' expectations of the services integrated by MaaS applications*, *openness to experience*, *conscientiousness*, *extraversion*, *agreeableness* and *neuroticism*. Four clusters (CLs) are obtained, also called “mobility profiles” (Table 6): CL1 or “technological car-followers” (26.1% of the sample); CL2 or “unimodal travellers” (34.9% of the sample); CL3 or “MaaS-lovers” (14.6% of the sample); and CL4 or “active public-transport supporters” (24.4% of the sample).

The following sub-sections characterize the four clusters through sociodemographic, mobility and technology-related variables. In general, participants in the Madrid setting show positive attitudes towards MaaS. “MaaS-lovers” and “technological car-followers” are the clusters most inclined to adopt MaaS technologies, followed by “active public-transport supporters”; and, finally, “unimodal travellers”.

4.4.1. Sociodemographic characteristics

As shown in Table 7, different sociodemographic variables are assessed for a better understanding of the four clusters. The

Table 4
Rotated factor matrix for attitudinal variables.

Factor name ^a (Cronbach α)	Acronym	Item	Factor loadings
Mobile applications			
F1 (0.865)Technophilia	TC1	I find it exciting to try new apps	0.875
	TC2	I am enthusiastic about GPS and travel apps	0.842
	TC3	Apps help me in my daily life	0.836
	TC4	I regularly use apps for payment, reservations, etc.	0.833
F2 (0.757)Privacy concerns	PC1	I agree to share my profile, opinions, etc. with other users when using apps	0.858
	PC2	I agree to share my personal information with companies when using apps	0.813
	PC3	I agree to my personal information being checked to get personalized recommendations	0.794
New mobility services			
F3 (0.840)Need for control	NC1	During my trip, I always check for real-time travel or route information	0.831
	NC2	Before travelling, I always check for real-time travel or route information	0.824
	NC3	I always check multiple sources of travel information to compare several travel options	0.774
F4 (0.797)Environmental awareness	EA1	I would switch to a different form of transport if it would help the environment	0.842
	EA2	I am willing to pay more for my trips if it would help the environment	0.811
	EA3	To help improve air quality I avoid travelling by car in the city	0.725
Mobility integration			
F5 (0.824)Users' expectations of the services integrated by MaaS ^b	EX1	MaaS integrates information on accessibility	0.771
	EX2	MaaS integrates information on parking at destination	0.767
	EX3	MaaS integrates information on the environmental impact of travellers' behaviours	0.736
	EX4	MaaS integrates information on transport modes	0.731
	EX5	MaaS integrates information on service incidences (e.g., congestion, works)	0.706
	EX6	MaaS integrates information on physical activity developed	0.669

Cronbach's alpha (α) = 0.842; Kaiser-Meyer-Olkin (KMO) = 0.847; p = 0.000.

^a Each factor is described in Section 2.1.

^b Users' expectations of the services integrated by MaaS applications (or mobile technologies).

particularities of each group are explained below. Overall, gender shows no impact on propensity to adopt MaaS.

Our results show that “MaaS-lovers” tend to be highly educated, independent (living alone), and workers. This cluster includes a significant proportion of people aged over 55 (45.2%). This older segment appears to be highly attracted by MaaS applications, although their interest in innovative mobility services (e.g., car- or bike-sharing) seems low. Mulley et al. (2017) have already explored the opportunities that MaaS can bring to the older population, who tend to show a lack of affinity with ICT technologies such as travel planners. According to previous research, we were expecting “MaaS-lovers” to live in the most urbanized areas, but we found a high proportion (35.6%) living in high-

income zones in the metropolitan area. “Technological car-followers” mainly differ from the previous cluster in their household composition, residential location and age distribution. This group includes a low percentage of respondents aged 65+ (3.8%).

“Unimodal travellers” and “active public-transport supporters” are less willing to adopt MaaS. It is worth to note that these two clusters have a significant share of retired respondents (10.3% and 8.6% respectively). In accordance with Mulley et al. (2017), these individuals may not be appropriate candidates for MaaS type solutions due to their specific mobility needs and their usual habits.

4.4.2. Mobility patterns

Each of the four clusters shows rather different mobility patterns and travel characteristics, as summarised in Table 8.

“MaaS-lovers” is the cluster with the highest share of multimodal trips (56%), while “unimodal travellers” present the lowest percentage (30%). The shares of “technological car-followers” and “active public-transport supporters” are in the middle of the previous two groups, in line with their intermediate positions towards MaaS adoption. In agreement with previous studies, our results indicate that multimodal travel patterns are associated with positive attitudes towards public transit usage and with individuals' openness to new mobility services. A significant proportion of “MaaS-lovers” and “technological car-followers” appear to use shared mobility services on a weekly basis, while “unimodal travellers” and “active public-transport supporters” are less familiar with the “new mobilities”. In fact, a large share of these two clusters have never used shared mobility options. These results further illustrate the alignment between attitudes, personality and behaviour in the mobility context. Current unimodal travellers are the least likely to be attracted by MaaS and its flexible transport offer.

“Technological car-followers” have the highest share of household car ownership (almost 90%), the highest number of cars on average (1.21 cars per household), and the highest share of unimodal daily car behaviours. Conversely, “MaaS-lovers” show the lowest household car-ownership share, with the lowest number of cars on average (0.9 cars per household). In accordance with Alonso-Gonzalez et al. (2020), car usage resembles the trend in car ownership.

4.4.3. Technology-related characteristics

Table 9 summarises the technology-related variables, showing relevant differences among the four clusters. It is worth to highlight that over 98% of the individuals in each group own a smartphone, a prerequisite for using MaaS.

In the survey, respondents were faced with statements about their level of technophilia and attitudes towards technology innovations. Individuals' willingness to adopt MaaS is directly associated to these two indicators. “MaaS-lovers” have the highest technophilia, followed by “technological car-followers” and “active public-transport supporters”; while the lowest technophilia corresponds to “unimodal travellers”. Particularly, we analyse the use of travel planners (e.g., Google Maps, EMT and Mi Transporte) since they are considered Level 1 of MaaS applications (Sochor et al., 2018). The familiarity with these technologies appears to explain behavioural differences among the clusters, as well as their intention to adopt MaaS. Over 80% of “MaaS-lovers” and “technological car-followers” – the clusters most inclined towards MaaS adoption – declared to use travel information via their smartphones frequently, whereas “unimodal travellers” were the least engaged with these innovations.

5. Discussion of results and policy recommendations

In this section, we discuss our key findings and provide some policy recommendations specific for each of the clusters: “technological car-followers”, “unimodal travellers”, “MaaS-lovers”, and “active public-transport supporters”. Five attitudinal variables are found to explain 64% of individuals' willingness to adopt MaaS: *technophilia*, *need for*

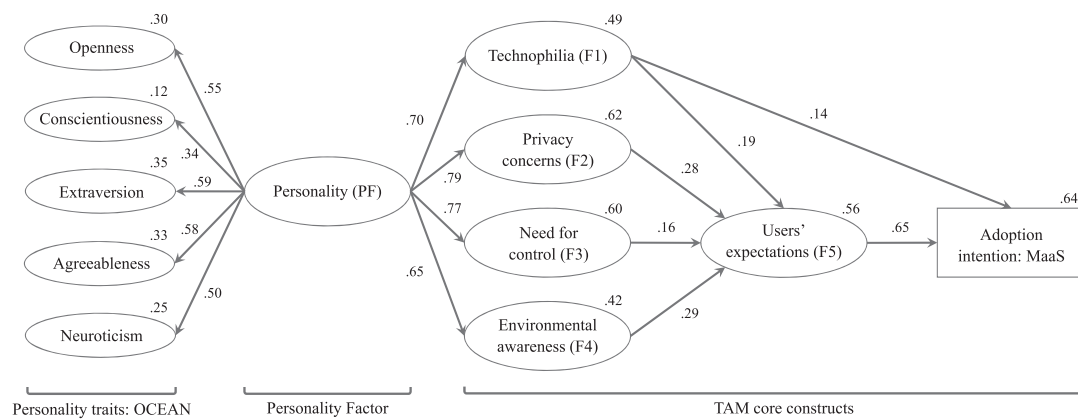


Fig. 4. Path analysis model related to individuals' willingness to adopt MaaS.

Table 5
Results of hypothesis testing.

Hypothesis		Path	Effect (direction)	Path coefficient (β)	Regression weights			Conclusion
					Estimate	S.E.	C.R.	
H1	H1a	PF $\rightarrow$ TE	positive	0.702***	0.598	0.038	15.575	Supported
—	H1b	PF $\rightarrow$ PC	positive	0.786***	0.646	0.039	16.482	Supported
	H1c	PF $\rightarrow$ NC	positive	0.774***	0.727	0.044	16.372	Supported
	H1d	PF $\rightarrow$ EA	positive	0.646***	0.576	0.039	14.836	Supported
	H2	H2a	TE $\rightarrow$ UE	positive	0.192***	0.165	0.023	7.088
—	H2b	PC $\rightarrow$ UE	positive	0.282***	0.253	0.026	9.735	Supported
	H2c	NC $\rightarrow$ UE	positive	0.156***	0.122	0.022	5.446	Supported
	H2d	EA $\rightarrow$ UE	positive	0.294***	0.243	0.021	11.374	Supported
	H3	TE $\rightarrow$ AI	positive	0.137***	0.160	0.030	5.251	Supported
H4	UE $\rightarrow$ AI	positive	0.646***	0.870	0.035	24.719	Supported	
—		PF $\rightarrow$ OP		0.551***				
—		PF $\rightarrow$ CO		0.344***				
—		PF $\rightarrow$ EX		0.590***				
—		PF $\rightarrow$ AG		0.576***				
—		PF $\rightarrow$ NE		0.504***				

Note: *** $p < 0.001$; ** $p < 0.01$.

PF: Personality Factor; TE: Technophilia; PC: Privacy Concerns; NC: Need for Control; EA: Environmental Awareness; UE: Users' Expectations (of the services integrated by MaaS); AI: Adoption Intention (MaaS); OP: Openness to experience; CO: Conscientiousness; EX: Extraversion; AG: Agreeableness; NE: Neuroticism.

Table 6
Profiles of the four clusters based on the variables included in the SEM.

Cluster		CL1	CL2	CL3	CL4
Mobility profile		Technological car-followers N = 261	Unimodal travellers N = 349	MaaSlovers N = 146	Active PT supporters N = 244
Willingness to adopt MaaS	High willingness	92.3%	61.6%	95.2%	76.2%
	Medium willingness	5.0%	24.9%	3.4%	18.0%
	Low willingness	2.7%	13.5%	1.4%	5.8%
	Likert 1–5: M (SD) ^a	4.54 (0.791)	3.63 (1.141)	4.67 (0.676)	4.12 (0.968)
SEM attitudinal variables					
Technophilia	Likert 1–5: M (SD) ^a	4.43 (0.679)	3.46 (0.879)	4.59 (0.602)	3.82 (0.803)
Privacy concerns		4.13 (0.687)	3.25 (0.825)	4.55 (0.490)	3.57 (0.720)
Need for control		4.03 (0.746)	2.96 (0.841)	4.58 (0.526)	3.41 (0.912)
Environmental awareness		3.73 (0.811)	3.03 (0.870)	4.49 (0.639)	3.33 (0.782)
Users' expectations ^b		4.25 (0.543)	3.46 (0.805)	4.60 (0.456)	3.82 (0.614)
SEM personality variables					
Openness to experience	Likert 1–5: M (SD) ^a	3.58 (0.436)	3.04 (0.451)	4.33 (0.629)	3.38 (0.456)
Conscientiousness		2.64 (0.395)	2.76 (0.484)	4.38 (0.590)	3.74 (0.458)
Extraversion		3.43 (0.558)	2.87 (0.500)	4.37 (0.615)	3.01 (0.565)
Agreeableness		3.30 (0.492)	2.97 (0.553)	4.28 (0.666)	3.33 (0.494)
Neuroticism		3.35 (0.493)	3.01 (0.520)	4.35 (0.610)	3.35 (0.470)

Note: The average of the latent variables was calculated by dividing the number of items on each variable for the purposes of comparison. High scores indicate satisfaction with the specific factor.

^a M (SD): Mean (Standard Deviation).

^b Users' expectations of the services integrated by MaaS applications (or mobile technologies).

Table 7
Sociodemographic characteristics of the clusters.

Cluster		CL1 Technological car-followers N = 261	CL2 Unimodal travellers N = 349	CL3 MaaS-lovers N = 146	CL4 Active PT supporters N = 244
Mobility profile					
Sociodemographic variables (%)					
Gender ***	Male	52.5	49.0	51.4	48.0
	Female	47.5	51.0	48.6	52.0
Age ***	18–34 years old	29.5	21.8	24.7	34.4
	35–44	23.0	22.6	14.4	23.0
	45–54	24.9	22.6	15.8	20.1
	55+	22.6	33.0	45.2	22.5
Education level *	Non University	39.5	42.4	38.4	43.9
	University	60.5	57.6	61.6	56.1
Occupation *	Student	3.8	5.7	4.8	11.5
	Employed	76.6	70.2	88.4	62.7
	Retired	5.7	10.3	2.1	8.6
	Other	13.9	13.8	4.7	17.2
Household structure ***	1 person	8.0	15.5	34.2	16.0
	2 people	24.9	34.7	15.1	26.2
	3 people or more	67.1	49.8	50.7	57.8
	N° of household members: M (SD) ^a	2.94 (0.961)	2.61 (1.038)	2.45 (1.232)	2.71 (1.055)
Place of residence	Madrid City	87.7	85.1	64.4	88.9
	Metropolitan Area (outskirts)	12.3	14.9	35.6	11.1

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$, when testing the relation with the variable “willingness to adopt MaaS” (Chi-Square test).

^a M (SD): Mean (Standard Deviation).

control, privacy concerns, environmental awareness, and users’ expectations of the services integrated by MaaS applications. The fitted path model of Section 4.3 also indicates a strong and positive effect of personality traits on such attitudinal factors, especially on travellers’ privacy concerns and need for control.

From the technological point of view, MaaS operates via a single digital interface to provide travellers with personalized recommendations that respond to their needs on-demand (Alonso-Gonzalez et al., 2020). The two most technological clusters (“MaaS-lovers” and “technological car-followers”) are also the two groups that are most inclined towards the adoption of MaaS. Both groups show a significant daily use of mobile technologies and mobility applications.

From the mobility perspective, MaaS combines all the available alternatives of transport and provides users with a wide variety of services (MaaS Alliance, 2019). The analysis reveals an underlying factor related to this mobility integration that involves a positive multimodal mindset. It also appears to be aligned with individuals’ mobility patterns, since multimodality is associated with a favourable attitude towards public transport and new mobility services (e.g., car- and bike-sharing). As a result, and in line with previous research (Alonso-Gonzalez et al., 2020; Karlsson et al., 2020), we find that individuals with unimodal behaviours seem less inclined to adopt MaaS than multimodal travellers.

Our two clusters with the most positive attitude towards mobility integration (“MaaS-lovers” and “technological car-followers”) are also the two most multimodal and most willing to adopt MaaS. Individuals in these two groups tend to rely on travel-planning applications for their transport choices, instead of directly considering their habitual or preferred mode(s). In accordance with Alonso-Gonzalez et al. (2020, p. 394), “multimodal individuals are known to have more complex strategies to choose transport modes and exercise weaker travel habits”, which encourages the acceptance of new mobility solutions such as MaaS. The analysis highlights another similarity between the previous two mobility profiles, who believed to have the highest daily travel costs. It might be questioned whether the interest of these individuals in adopting MaaS could be motivated by their expectation of reducing their overall travel costs and maintaining closer control over their expenses. However, it should be noted that there is a significant behavioural difference between “MaaS-lovers” and “technological car-followers”. The first cluster (14.6% of the sample) exhibits a greater positive attitude towards shared mobility services (such as car-, bike- and scooter-sharing) than the second one (26.1% of the sample), who prefers traditional transit or the private car.

“Active public-transport supporters” also show a positive attitude towards mobility integration and hence MaaS adoption. Nevertheless, the results indicate that this cluster strongly prefers traditional transit to new modes. Previous literature has already highlighted the fact that public transport users are less likely to adopt shared mobility services (Al-Ayyash et al., 2016). Ryley et al. (2014) suggest that this may be due to the (generally) high usage of public transport by low-income individuals, for whom the on-demand services included in MaaS might be regarded as an expensive option. In agreement with this assumption, we find that the percentage of “active public-transport supporters” who declare their willingness to pay for MaaS is lower than the share of “MaaS-lovers” and “technological car-followers”.

As described in Section 3.2, the public transport network in Madrid is characterised by a seamless and well-structured offer. The share of public transport users among the current population is therefore significantly higher than in other European cities (Velazquez, 2019), with most individuals using public transport on a daily basis. In this setting, (some) current public transport adepts may not perceive the need to complement their public transport usage with on-demand services. If this is the case, one of the additional values that MaaS is designed to introduce – i.e., the integration of new mobility services with “traditional” ones – could be worthless. However, MaaS could increase its attractiveness by expanding towards areas where the public transport offer is less effective (e.g., the outskirts or sub-urban areas). Lavieri and Bhat (2019) have already suggested this strategy for the American context.

Our findings also show that individuals’ differences in terms of personality traits may influence the acceptance of MaaS. In accordance with previous research (Jackson et al., 2013; Volkan et al., 2014), high levels of openness, extraversion and agreeableness are significantly related to a positive attitude towards personal innovativeness in information systems such as MaaS applications. In this study, conscientiousness and neuroticism are also positively correlated with the willingness to adopt the new technologies. This could be explained by the need for control expected by travel planner users.

Overall, we identify two main obstacles for the potential adoption of MaaS: (i) low technology usage, and (ii) low openness to “new mobilities” such as shared mobility services. In line with previous studies (Efthymiou et al., 2013), a low environmental awareness and a high cost sensitivity are also found as significant variables that deter individuals from accepting the new solutions. In summary, the higher the percentage of multimodal travellers, the more they are open to “new

Table 8
Mobility patterns of the clusters.

Cluster		CL1	CL2	CL3	CL4
Mobility profile		Technological car-followers	Unimodal travellers	MaaSlovers	Active PT supporters
Mobility-related variables (%)		N = 261	N = 349	N = 146	N = 244
Public transport pass	Yes	72.8	66.8	58.9	72.1
	No	27.2	33.2	41.1	27.9
Car licence	Yes	87.7	80.5	61.0	76.2
	No	12.3	19.5	39.0	23.8
Car availability	Yes	87.4	79.4	65.1	79.5
	No	12.6	20.6	34.9	20.5
Reported PT frequency ***	N° of cars/household: M (SD) ^a	1.21 (0.700)	1.03 (0.696)	0.90 (0.874)	1.03 (0.693)
	4 days a week	60.2	51.9	77.4	61.5
	1 day a week	25.3	25.5	15.8	23.8
	1 day a month	8.0	13.8	3.4	9.8
	1 day a year	3.4	5.7	2.1	4.5
Reported car-sharing frequency **	Never	3.1	3.2	1.4	0.4
	4 days a week	2.7	3.4	6.8	1.6
	1 day a week	19.2	5.7	24.0	8.6
	1 day a moth	22.6	12.6	12.3	20.1
	1 day a year	8.8	7.7	8.2	11.5
Reported bike-sharing frequency ***	Never	29.1	41.5	37.7	38.9
	Unknown the service	17.6	28.9	11.0	19.3
	4 days a week	3.1	4.0	5.5	2.9
	1 day a week	14.2	4.0	23.3	5.3
	1 day a moth	14.6	7.2	10.3	15.2
Multimodal MFT ^b	1 day a year	5.7	3.7	13.7	12.7
	Never	50.6	51.3	37.7	47.5
	Unknown the service	11.9	29.8	9.6	16.4
	Yes	46.7	30.9	56.2	42.2
	No	53.3	69.1	43.8	57.8
Use car in MFT ^b	Yes	34.5	28.7	29.5	25.0
	No	65.5	71.3	70.5	75.0
Use bike in MFT ^b	Yes	1.9	1.4	1.4	2.9
	No	98.1	98.6	98.6	97.1
MFT ^b reason ***	Work/Study	70.1	66.2	75.3	59.8
	Shopping	10.7	12.0	8.2	12.3
	Leisure	14.9	15.8	15.8	20.1
	Drop-off/pick-up someone	3.1	4.0	0.7	5.3
	Other	1.1	2.0	0	2.5
Origin-destination MFT ^b	Intro Madrid City ^c	20.3	15.8	26.7	16.4
	Intro Metropolitan Ring ^d	26.4	26.4	18.5	26.6
	Radial ^e	53.3	57.9	54.8	57.0

*** p < 0.001; ** p < 0.01; * p < 0.05, when testing the relation with the variable “willingness to adopt MaaS” (Chi-Square test).

^a M (SD): Mean (Standard Deviation).

^b MFT: Most Frequent Trip. It is the trip a person makes most often, for example, to go to work or school.

^c The origin and destination points of the MFT are located in the City of Madrid.

^d The origin and destination points of the MFT are located in the Metropolitan Ring.

^e The origin point of the MFT is located in the City and the destination point is located in the Metropolitan Ring, or vice-versa.

Table 9
Technology-related characteristics of the clusters.

Cluster		CL1	CL2	CL3	CL4
Mobility profile		Technological car-followers	Unimodal travellers	MaaSlovers	Active PT supporters
Technology-related variables (%)		N = 261	N = 349	N = 146	N = 244
Smartphone *	Yes	99.6	98.6	99.3	99.6
	No	0.4	1.4	0.7	0.4
Travel planner use ***	Always	25.3	8.0	47.3	13.5
	Frequently	55.9	33.2	40.4	42.6
	Sometimes	16.5	38.7	9.6	28.7
	Almost never	1.9	10.9	2.1	12.7
	Never	0.4	9.2	0.7	2.5
Type of information demanded ***	Mode of transport: M (SD) ^a	4.54 (0.791)	3.63 (1.141)	4.67 (0.676)	4.12 (0.968)
	Incidences	4.56 (0.652)	3.87 (1.104)	4.65 (0.570)	4.23 (0.881)
	Accessibility	4.17 (0.918)	3.37 (1.147)	4.54 (0.725)	3.69 (0.964)
	Parking at destination	4.34 (0.810)	3.51 (1.166)	4.60 (0.710)	3.89 (1.006)
	Environmental impact	3.92 (0.954)	3.09 (1.163)	4.53 (0.745)	3.48 (0.966)
	Physical activity	3.96 (1.015)	3.26 (1.061)	4.59 (0.66)	3.53 (1.083)

*** p < 0.001; ** p < 0.01; * p < 0.05, when testing the relation with the variable “willingness to adopt MaaS” (Chi-Square test).

^a M (SD): Mean (Standard Deviation).

mobilities”, the greater their technological capabilities and curiosity, and the lower their cost sensitivity, then the higher the adoption potential for MaaS.

Based on the outcomes of this study, we define some specific policy recommendations that can promote the adoption of (sustainable) MaaS initiatives in relation to the four profiles (or clusters):

- “Technological car-followers” (cluster 1) include the highest share of daily car users among the mobility profiles identified (around 35%). However, this proportion is still low. In the case of car-centred attitudes, previous studies propose “promoting new mobility modes to these individuals solely as an alternative for the occasions in which the car is unavailable instead of suggesting to replace it altogether” (Alonso-Gonzalez et al., 2020, p. 395). This can help “car-followers” to experience the new system and attract them on the basis of their high technological affinity (Paundra et al., 2017). Special attention should be focused on providing mobility alternatives that satisfy the needs of families with children, which are more prevalent in this cluster.
- “Unimodal travellers” (cluster 2) probably represent the laggards in terms of mobility innovations. These individuals are the least inclined to adopt MaaS, showing significant unimodal attitudes and low environmental concerns. Their low technological affinity can also prevent them from embracing new mobility trends (Alonso-Gonzalez et al., 2020). In order to encourage MaaS use among this group, it is suggested to implement a mixed ticketing system that combines a mobile application with a smartcard. In addition, the incorporation of a traditional call centre for personalized support may make it easier for these individuals to access on-demand services and real-time information. Nevertheless, “unimodal travellers” appear unlikely to adopt MaaS in the short-term.
- “MaaS-lovers” (cluster 3) are the individuals that are most inclined to adopt MaaS. In comparison with “technological car-followers”, this cluster shows a stronger positive attitude towards new mobility services (such as car- or bike- sharing). Motivated by their high environmental sensibility, “MaaS-lovers” seem more likely to reduce their private car-usage in favour of alternative and more sustainable modes. In this scenario, travel awareness-raising initiatives seem an effective strategy to highlight the functional benefits of MaaS (e.g., in terms of time and cost savings) and promote its use. These mechanisms are intended to appeal to the “green” concerns of this cluster, and can help to induce its modal shift away from private vehicles, while preventing a significant shift from traditional public transit.
- “Active public-transport supporters” (cluster 4) show positive attitudes towards scheduled public transport and active modes. Despite their low interest in new mobility services (below average), previous studies (Sochor et al., 2018; Karlsson et al., 2020) suggest that these transit-supporters might be attracted by MaaS since they are already familiar with multimodal travel. In accordance with Alonso-Gonzalez et al. (2020), new mobility modes should be promoted among these individuals, who could become “the most sustainable MaaS users” by recognising public transport as their core mode and on-demand services as complementary options. “Traditional” public transport operators should provide these travellers with user-friendly applications, ensuring a reliable and convenient environment that motivate MaaS adoption. Their public transport subscription could facilitate their access to shared-mobility services to entice them out of their comfort zone.

In short, we detect six main strategic lines of action that should be considered when defining policies to stimulate the adoption of MaaS in metropolitan areas: (i) promoting the use of new mobility services (or “new mobilities”), (ii) encouraging multimodal travel behaviours, (iii) enhancing individuals’ affinity with smart technologies, (iv) developing environmental awareness campaigns, (v) developing travel awareness initiatives (in terms of providing, e.g., the time and cost savings per trip),

Table 10

Strategic lines of action to stimulate the adoption of MaaS.

Strategic lines of action	CL1 Technological car-followers	CL2 Unimodal travellers	CL3 MaaS-lovers	CL4 Active PT supporters
Promote the use of new mobility services	✓	✓		✓
Encourage multimodal travel behaviours	✓	✓		✓
Enhance individuals’ affinity with smart technologies		✓		✓
Develop environmental awareness campaigns	✓	✓		
Develop travel awareness initiatives ^a			✓	
Integrate urban and mobility planning tactics	✓	✓	✓	✓

^a In terms of providing, e.g., the time and cost savings per trip.

and (vi) integrating urban and mobility planning tactics. To summarise and further illustrate our findings, Table 10 relates these six lines to the four clusters identified.

At this point, it is worth noting that the recommendations proposed for travellers in the metropolitan area of Madrid show the way to promote the adoption of MaaS in other European and worldwide regions. The transferability of our results might bring important opportunities for those areas aiming to encourage a shift towards more sustainable mobility practices. In this process, it is relevant to highlight that each local context should be taken into account, especially in terms of urban configuration and mobility services offered. The consideration of the particular social, economic and environmental conditions of each region is also key to ensure the successful acceptance of MaaS.

6. Conclusions

The paper identifies four clusters in relation to their willingness to adopt MaaS, based on a set of attitudinal and personality factors. Previous research has shown that these findings are a key starting point for defining policy recommendations that foster a change towards more sustainable travel behaviours. In general, individuals in the metropolitan area of Madrid (Spain) show positive attitudes towards MaaS adoption. In accordance with Fioreze et al. (2019), we find that travel habits and attitudes towards transport modes are stronger predictors for the uptake of MaaS than sociodemographic variables (e.g., gender, age or education level). This is probably the result of the specific characteristics of the case study area, with a high share of public transport and pedestrian trips.

Understanding the latent acceptance factors and mechanisms behind MaaS adoption is very important for designing successful user-oriented strategies. The relevance of psychological needs for strategic (market) communication and policy campaigns was already explored in other fields such as recycling or healthier consumption habits (Silva-Ramos et al., 2020). The cluster segmentation applied in this research is also a valuable source of knowledge for developing tailored – and thus more persuasive – schemes for each group of users.

However, based on the evidence from this investigation, it cannot be confirmed whether MaaS solutions will ensure more sustainable mobility patterns. Although attitudes and personality traits are closely linked to individuals’ behaviours, our findings do not allow us to

conclude to what extent they produce behavioural changes, which could only be determined with longitudinal studies. Urban authorities and research institutions should critically evaluate how MaaS policies are defined and implemented in order to ensure the maximum benefit to society and the environment. Nevertheless, the sufficient availability of new mobility services must be guaranteed before any modal shifts are materialised. This will help individuals to anticipate the opportunities that MaaS offers.

Given that MaaS technologies are not yet deployed in the Madrid Metropolitan Area (Spain), we point out that our findings correspond to a dummy MaaS application, explained in the survey. While this approach may be appropriate for identifying fundamental motivational mechanisms, it should be followed up by future research on choice behaviour, based on real applications. The results are also dependent on the attitudinal statements presented to the respondents, and future studies could consider the incorporation of other (explanatory) variables.

The market development of new technologies requires long-term observations of user behaviour that must be the subject of future research. Potential adopters can only approximate the opportunities of MaaS when they actually use it, and their long-term assessment may be closely related to their life experiences. The present insights into

motivational factors may therefore be helpful for understanding post-adoption loyalty or explaining the success of the policy measures implemented.

CRedit authorship contribution statement

Iria Lopez-Carreiro: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Andres Monzon:** Conceptualization, Writing - review & editing, Supervision. **David Lois:** Methodology, Formal analysis, Writing - original draft. **Maria E. Lopez-Lambas:** Writing - original draft, Supervision.

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Appendix A. . Personality traits: BFI-S

The BFI-S is a shorten version of the 44-item BFI designed by Soto and John (2017). Each trait domain is represented by three descriptive statements.

Personality trait	Area	I am a person who ...
Openness	Aesthetic Sensitivity	Is fascinated by art, music or literature
	Intellectual Curiosity	Has little interest in abstract ideas
	Creative Imagination	Is original, puts forward new ideas
Conscientiousness	Organization	Tends to be disorganized
	Productiveness	Finds it hard to start doing tasks
	Responsibility	Is dependable, someone people can always rely on
Extraversion	Social Engagement	Tends not to talk much
	Assertiveness	Is dominant, acts like a leader
	Energy level	Is full of energy
Agreeableness	Compassion	Is sympathetic, with a big heart
	Respectfulness	Is sometimes rude to other people
	Acceptance of Others	Thinks well of people
Neuroticism	Anxiety	Worries a lot
	Depression	Tends to feel depressed, melancholic
	Emotional Volatility	Is emotionally stable, doesn't get upset easily

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