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Assessing the intention to uptake MaaS: the case of Randstad

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Abstract

Mobility as a Service (MaaS) has recently gained popularity as an opportunity to encourage a more sustainable mobility model and improve urban liveability. Today, it is still uncertain if travellers are willing to uptake MaaS and transform their habits. In the paper, we explore individuals' behavioural intention based on a survey comprising 418 respondents in the metropolitan area of Randstad (The Netherlands). The application of a Structural Equation Model allows to uncover a series of explanatory (attitudinal and personality) factors relevant for MaaS acceptance. Then, a cluster analysis determines four profiles of travellers in relation to their intention to embrace this new solution: 'Short-duration commuters', 'Active travellers', 'Traditional car-supporters', and 'MaaS admirers'. Overall, we identify three main barriers for the potential adoption of MaaS: low willingness to combine different modes of transport, low affinity with technology, and low reliability on the new mobility services. We also recognise that low environmental concerns seem to frustrate individuals' innovativeness.

Keywords Mobility-as-a-Service, Behavioural model, Technology acceptance, Behavioural change, Attitudinal change

1 Introduction

Urban mobility is currently going through some significant changes. In the past few years, the growing travel demand, together with global megatrends such as digitalisation and servitisation, have fostered the emergence of a wide palette of app-based mobility services (such as car-, bike- and scooter-sharing services) in many urban areas [2]. These new solutions, combined with "traditional" public transport, result in complex multimodal scenarios that challenge travellers and their decisions.

Within this context, Mobility as a Service (MaaS) is proposed as an innovative approach to seamlessly integrate all the mobility options available through a single digital interface (commonly a website or a smartphone) into travel "packages" or "bundles" [6]. MaaS relies on the application of Information and Communication Technologies (ICT) to place individuals at the core of the transport network, providing them with customised and on-demand solutions that satisfy their needs [16].

In recent years, MaaS has been hailed as a "game-changer with regards to the way people travel" [97]. Experts agree that it holds the potential to endorse a behavioural transition towards more sustainable mobility habits, while enhancing individuals' satisfaction [34, 49]. Consequently, MaaS has recently attracted much attention within and around the transport sector—as a socially, economically, and environmentally sustainable alternative to car dependency [77, 81].

Several MaaS schemes are currently operational around the world.[1] However, most of them are pilots or small-scale demonstrations. Today, despite the numerous opportunities expected from MaaS, it is still unknown whether the general population is willing to embrace the new mobility model. This means (i) adopting the new

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[1] The revision of these schemes is beyond the scope of the paper. The reader is referred to, e.g., 30, 95], or [32], for more detail.

digital technologies and (ii) changing travel behaviour. In this sense, previous research has noted that "public acceptance" is a pre-requisite for MaaS to be successfully deployed in our cities [16]. Throughout history, many technological innovations—such as MaaS, in this case—have failed to prosper due to their incapacity to attend users' expectations. Particularly for MaaS, with its inherent user-centric orientation, addressing individuals' perspective is of extreme relevance [21].

Are travellers ready to uptake MaaS? And if so, are they ready to transform their current behaviours in favour of sustainability? Considering the (relatively) novelty of the concept, individuals' intention to accept—or reject—MaaS remains unclear. And even if some studies have already explored this topic (see Sect. 2), further research is required to improve the still partial understanding of individuals' acceptance decision procedures. In agreement with Danquah & Amankwah-Amoah [25], we consider that—despite the growing research on the relationship between human capital and innovation—our knowledge of how human capital drives innovation and technology adoption remains limited.

In this study, we aim to gain deeper knowledge on who is willing to uptake MaaS by addressing the following three objectives: first, we explore the motivational factors behind travellers' intention to use MaaS; second, we define and characterise different segments of (potential) MaaS users, identifying which profiles are more (and less) likely to embrace the new mobility model; and finally, and based on the previous insights, we design some strategic recommendations to facilitate MaaS acceptance and, thus, more sustainable behaviours among travellers. Our ultimate goal is to contribute to the debate about the interrelationship between this innovative solution and the private car. Tailoring travel solutions to support individuals' expectations can possibly lead to a shift towards less car-oriented lifestyles [67]. The paper takes the Randstad Metropolitan Area (Randstad MA) (The Netherlands) as case study. Previous research has already focused on the Dutch context, where the implementation of MaaS is a national matter [35].

The structure of this paper is organised as follows. After this introduction, Sect. 2 presents the behavioural approach followed, and Sect. 3 describes the case study selected. Then, Sect. 4 explains the methodology, Sect. 5 evaluates the results, and Sect. 6 discusses the key findings and proposes future lines of investigation. Lastly, Sect. 7 summarises the main conclusions.

1.1 Travellers' intention to uptake MaaS

MaaS aspires to encourage more sustainable behaviours among travellers by providing them with an attractive "bundle" of multimodal alternatives. To achieve this behavioural change, individuals must first be open and ready to embrace the new mobility scheme.

Recently, well-established psychological theories—such as the Technology Acceptance Model (TAM) [27] and its extensions (TAM2 and TAM3), the Unified Theory of Acceptance and Use of Technology (UTAUT) and its extensions (UTAUT2 and UTAUT3) [104–106], and the Theory of Diffusion of Innovations (DOI) [88], among others—have been gaining popularity in the transport arena for evaluating the factors that affect individuals' intention to shift their conducts and adopt new technological solutions, such as ride-sharing services [108], bike-sharing applications [18], autonomous cars [59], autonomous road transport systems [70], shared-scooters [55], shared electric mobility hubs [13], and MaaS schemes [76, 91, 112]. These theories have in common that they aim to explain individuals' behaviour through the formation of behavioural intentions, which in turn are influenced by a set of motivational factors. In other words, they provide a theoretical framework to shed light on the processes underpinning adoption decisions, depending on the interaction between the personal characteristics of the decision-makers and the attributes of a particular technology. Their mechanisms derive from the Theory of Reasoned Action (TRA) [5, 36], stating that an individual's behavioural intention is the most immediate antecedent to his/her actual behaviour, and as such is a good predictor of it [1].

In their origins, all of the above theories focused on attitudinal factors as the core predictors of individuals' behavioural intentions. However, in the past years, several adaptations have been proposed with the objective of enhancing their explanatory power [19, 44, 83]. Particularly, some authors have incorporated personality traits as predictors [71, 79, 99]. Their findings have shown that individuals' attitudes and behaviours are affected by their personality character.

Personality traits refer to enduring affective, behavioural, and cognitive tendencies or dispositions that differentiate individuals [8]. They reflect characteristic patterns of thoughts, feelings, and behaviours (Gerlitz & Schupp, 2005). Psychologists have defined different sets of traits to explore the personality of individuals, as well as developed a variety of conceptual models to measure it—such as the 'Big Three' model or PEN (Psychoticism, Extraversion and Neuroticism) [33],the 'Big Five' model or OCEAN (Openness to experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism [22, 39],the Temperament and Character (seven-dimensional) Model [20],and the HEXACO (Honesty-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, and Openness to experience) model [58], among others.

Table 1 The uptake of MaaS: identifying motivational factors in the literature

Literature	Attitudinal factors[1]			Other factors
References	**Mobility integration**	**ICT integration**	**'New mobilities'**	
Ho et al. [43]	Services integration[2]	-	-	-
Polydoropoulou et al. [85]	Services integration	Privacy issues[3]	Control concerns[5], Need for reliability[6], Need for flexibility	-
Strömberg et al. [98]	Services integration	-		-
Fioreze et al. [35]	Services integration	Tech-savviness[4]	-	-
Hesselgren et al. [42]	Services integration	-	-	-
Alonso-Gonzalez et al. [6]	Services integration	Tech-savviness, Privacy issues	Green values[7]	Willingness to pay (WTP)
Caiati et al. [16]	Services integration	-	-	-
Feneri et al. [34]	Services integration	-	-	-
Liljamo et al. [60]	Services integration	-	Green values	-
Loubser et al. [65]	Services integration	Tech-savviness	Green values, Need for reliability, Need for convenience	Attitude towards transport mode, Travel reason, WTP
Schikofsky et al. [91]	Services integration	Tech-savviness	Control concerns, Need for reliability	Competence, Relatedness, Enjoyment, Familiarity
Storme et al. [97]	Services integration	-	-	-
Vij et al. [107]	Services integration	-	-	WTP
Ye et al. [112]	Services integration	Tech-savviness	Innovativeness	Effort expectation, Social impact, Perceived risk
Zijlstra et al. [114]	Services integration	Tech-savviness	Innovativeness	
Hensher et al. [41]	Services integration	-	-	-
Kim et al. [53]		-	Openness, Need for reliability	Reluctance to drive, Resistance to mode transfers
Lopez-Carreiro et al. [63]	Services integration	Tech-savviness, Privacy issues	Green values, Control concerns	The "Big Five": OCEAN[8]
Matyas & Kamargianni [74]	Services integration	-	-	-
Hasselwander et al. [40]	Services integration	-	Green values, Need for reliability	-
Huang [45]	-	Privacy issues, Secondary use of personal information	Need for reliability	Perceived ease of use, Perceived risk of mobility information
Kayikci & Kabadurmus [50]	-	Tech-savviness, Privacy issues	-	Attitude towards car dependency
Kim & Rasouli [52]	-	Tech-savviness	-	Attitude towards multimodality, Introvert, Risk-taker
Macedo et al. [69]	Services integration	-	Green values	-
Zhang & Kamargiani [113]	Services integration	Tech-savviness, Privacy issues	Green values	-
Kriswardhana & Esztergár-Kiss [54]	-	-	-	Performance expectancy, Facilitating conditions, Technology readiness
Van't Veer et al. [102]	-	-	-	Utility, Perceived risk, Facilitating conditions, Effort expectancy, Scepticism

[1] Attitudinal factors grouped according to the categories established by Durand et al. [30]

[2] Individuals' expectations of the mobility services integrated by MaaS

[3] Individuals' need to control their personal data

[4] Affinity with technology

[5] Individuals' need to have full control over the mobility network

[6] Individuals' need to rely on the mobility network when travelling (i.e., need for trust)

[7] Green awareness

[8] OCEAN: Openness to experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism

According to previous research (see Table 1), the recognition of potential predictors is the first step in conceptualising any behavioural model. With the objective of identifying the motivational factors that could explain travellers' intention to uptake MaaS, in February 2023 we conducted a systematic revision of the literature published in the last nine years, since the emergence of the MaaS concept in 2014 [64]. Specifically, the keyword "Mobility as a Service" was examined in Scopus. Only papers written in English and published in peer-reviewed journals were considered, what allowed to limit the focus of interest to a handy number of documents.

As shown in Table 1, some authors have already addressed MaaS from the individuals' perspective, looking at their intention to embrace the new solution and the motivational factors behind it. Their investigations suggest complex processes underlying individuals' decisions. Durand et al. [30] established three categories when evaluating attitudinal factors regarding MaaS acceptance: (1) mobility integration, (2) ICT integration (or technological integration), and (3) 'new mobilities' (or new mobility services). We decided to adopt this criterion to organise the findings of our literature review. A fourth category was incorporated for those factors that cannot be included in this classification.

Given the extensive outcomes of the literature review carried out, we established the following criteria to limit the set of motivational factors—both attitudinal and personality—to be considered for achieving our research purposes. This helped us to restrict the focus of interest to a manageable number of variables. For the attitudinal factors, we selected those variables aligned with the classification of Durand et al. [30], and which appeared at least three times in previous investigations: individuals' expectations of the mobility services integrated by MaaS, tech-savviness, privacy issues, need for reliability, control concerns over the network, and green values. In the case of the personality factors, we opted for considering the 'Big Five' structure. This is a well-known and comprehensive taxonomy (or grouping) of personality traits that has been widely used in the transport field since its conception [46, 66].

The two sub-sections below describe the set of attitudinal and personality factors addressed in this paper to explore individuals' intention to uptake MaaS.

1.2 Attitudinal factors and the intention to uptake of MaaS

Based on the above criteria, we take into account the subsequent six attitudinal factors:

- Expectations of the mobility services integrated by MaaS. One of the pillars of MaaS is the integration of all the transport options available into a single digital platform [6]. This factor refers therefore to individuals' expectations of the level of integration provided by MaaS applications. Travellers should be disposed to combine a variety of alternatives in order to exploit the opportunities of the new model. Multimodal attitudes are positively associated with MaaS adoption and the reduction of (private) car dependency [48].
- Tech-savviness. This factor represents individuals' familiarity with (innovative) technologies. Here, it particularly refers to their (positive or negative) interest in accepting MaaS applications. In the field of urban mobility, different authors [26, 90, 103] indicate a positive relation between tech-savviness and the use of technology when travelling, e.g., use of the Internet for travel information or use of in-car navigation systems. Other researchers [10, 56] positively connect tech-savviness with the likelihood of using multiple modes of transport (i.e., adopting multimodal behaviours), and with the acceptance of the new app-based mobility services. Alonso-Gonzalez et al. [6] sustain that this factor is directly associated with MaaS adoption.
- Privacy issues. MaaS proposes a user-centric model that integrates multiple mobility options to respond to each individual's demand. With this objective, the collection of personal data is key, as it allows personalised services to be provided according to the expectations and preferences of the different travellers. In agreement with the findings of Matembaab & Li [72], we believe that the adoption of MaaS is positively associated with the willingness of individuals to disclose and share their personal information. In the same vein, several authors have already recognised data privacy concerns as an obstacle for the adoption of technological innovations [85, 87, 103].
- Need for reliability. In accordance with van Hagen & Bron (101, p.255), the concept of reliability refers to "the degree to which travellers receive what they expect". If the mobility service is not available how, when, and where individuals expect it, it will result in their being frustrated. In the (multimodal) mobility scenario that characterises our cities, travellers require reliability—in terms of, e.g., travel time, travel distance, or capacity of the service—to trust the network [17, 47]. Particularly, the emergence of app-based mobility services introduces a novel sense of this notion, associated to a wide variety of conditions such as the local unavailability of vehicles, the long response times, the unguaranteed availability upon departure, the anxiety of returning a shared vehicle on time, and the transfers within schedule-free modes, or from a schedule-free mode to a schedule-bound mode (and vice versa) [37, 109]. This

new understanding "differs from the usual meaning of reliability in conventional public transport" [30], p.25), driven by the changeableness and flexible nature of the new alternatives. MaaS aims to offer a seamless multimodal travel experience, with minimum uncertainties.

- Control concerns over the network. The incorporation of app-based mobility services to the "traditional" transport systems brings attractive opportunities, but also relevant challenges for individuals. Today, travellers aspire to have full control over the complex multimodal network in order to take the maximum advantage of its services and satisfy their personal expectations and preferences. In other words, each traveller aims to be provided with the "perfect" recommendation at the "precise" moment in the "appropriate" location, considering his/her emotional state (or attitudes), personality, current activity, habits, and past behaviours, among others [89]. Travel-planning applications—such as MaaS—aim to help individuals to have a "in real-time" control (in terms of, e.g., time, cost, crowding levels, or service incidences).
- Green values. This factor captures individuals' tendencies towards environmentally friendly behaviours. It has recently gained attention in the scientific literature on sustainable mobility behaviours, particularly when exploring the potential of new mobility services to encourage a transition towards "greener" habits [26]. According to previous studies [60], environmentalists are less inclined to the private car and are likely to adopt alternative mobility options. Based on the paradigm shift that MaaS proposes, we can predict a positive correlation between green values and the acceptance of these new technologies.

1.3 Personality factors and the intention to uptake of MaaS

As noted above, we make use of the 'Big Five' structure for exploring the influence of individuals' personality on their intention to uptake MaaS. This model was ideated in the 1980s by D.W. Fiske and later expanded upon by other researchers including Norman [80], Smith [94], Goldberg [39], and Costa & McCrae [22]. It is based on the general consensus that there are five major traits—i.e., openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism (OCEAN)—underlying human behaviours, which capture the core personality domains. These trait dimensions can be applied to predict individuals' attitudes and intentions [11]. First, 'openness to experience' indicates an appreciation for adventure, unusual ideas, and imagination, and can be thought of as reflecting a "tendency toward complexity and flexibility in information processing" [28]. Second, 'conscientiousness' is a dimension that underlies traits such as impulse control, reliability, and punctuality [86], noting a tendency to show self-discipline and act dutifully. Third, 'extraversion' is characterised by pronounced engagement with the external world and is often interpreted as a tendency to focus on rewards and to experience positive affect [93]. Fourth, 'agreeableness' refers to individuals who value getting along with and care for others [100]. It underlies traits such as compassion, compliance, modesty, and trust. Finally, 'neuroticism', or 'emotional instability', is related to the tendency to experience negative emotions, such as anger, anxiety, stress, depression, and emotional volatility [92].

In recent years, the 'Big Five' has been considered an appropriate approach for exploring and predicting individuals' synergies with technological innovations [24, 111]. Several authors indicate a positive correspondence between openness, conscientiousness, extraversion, and agreeableness, and the acceptance of a new technology. However, previous studies do not reach a consensus when assessing the influence of neuroticism. In the case of MaaS, no previous research has addressed the relationship between each of these five personality traits and the intention to uptake such new solutions.

1.4 Case study: Randstad MA (The Netherlands)

The Randstad MA is a polycentric agglomeration in the central-western part of The Netherlands. Geographically, it is characterised by a mostly rural core (or 'Green Heart') with a low population density, surrounded by a ring of urban development. As shown in Fig. 1, this metropolitan area includes the four largest Dutch cities (i.e., the 'Big 4': Amsterdam, Rotterdam, The Hague, and Utrecht) (Table 2), and a series of medium-sized conurbations such as Almere, Delft, Haarlem, Leiden, and Zoetermeer, among others. Despite none of them has more than 1 million inhabitants, the Randstad MA hosts more than the 40% of the population of the country, with almost 6.55 million inhabitants. The territorial borders of this area are not strictly defined in the literature, but it covers around 5,130 square kilometres.

The Randstad MA is also the main focus of the Dutch economy, generating around the 50% of the country's Gross Domestic Product (GDP). Owing to the existence of independent cities, and different local and provincial governments, the political and administrative organisation is rather complex and can be characterised as fragmented and multilevel [6, 9].

Fig. 1 Case study: Randstad MA (The Netherlands)

Most of the travel within the Randstad MA takes place around its four major cities. Daily commuting distance in The Netherlands is (on average) 32 km. These trips are split across multiple modes, the main ones being private car (67.4%), public transport (13.9%), cycling (8.1%), and walking (2.4%) [14].

The Randstad MA has one of the densest motorway networks in the world which is heavily demanded and used. It is also served by a well-structured public transport system—including multiple alternatives such as rail, tram, metro, light-rail, and bus—and a robust cycling infrastructure [51]. While motorways and railways extend across the whole region, connecting its various centres and sub-centres, the tram, metro, and light-rail options are primarily contained in the so-called 'Big 4'. Bus services are present throughout the Randstad MA but are uncommon for long-distance travel. Overall, the tram, metro, light-rail, and bus networks play a complementary role in terms of coverage and converge in the mobility hubs located in the major cities, where they also interface with the rail system. Additionally, since the 1990's, a broad range of shared-mobility, micro-mobility, and ride-hailing services have been implemented to complement the "traditional" offer [68, 75, 78].

At the same time, several travel-planning applications (e.g., Google Maps, NS Reisplanner, HERE Maps, OpenStreetMap) are currently available to facilitate the use of the complex mobility scenario. In 2019, the Ministry of Infrastructure and Water Management in The Netherlands secured a framework agreement, in collaboration with some private entities, to deploy seven pilots of MaaS in different regions [35]. The selected locations were: The Zuidas in Amsterdam; Utrecht Leidsche Rijn, Vleuten, and De Meern; Twente; Groningen-Drenthe; Rotterdam-Den Haag (including Rotterdam and The Hague Airport); Eindhoven; and Limburg. Officially starting in 2020, the seven schemes were frustrated by the COVID-19 pandemic. And today, they are still under development.

At this point, it is relevant to note that previous authors [16, 34, 35, 114] have already highlighted a set of characteristics that make the Randstad MA a potential candidate for implementing MaaS: a solid public transport system, the interest in a growing offer of new mobility services, and the significant availability of travel planners.

Table 2 Characteristics of the Randstad MA (The Netherlands)

Randstad:	Population Inhabitants	Area covered Km^2	Population density (average) Inhabitants/Km^2	GDP per capita Euros
Region	8,403,915	11,372	739	45,000
Metropolitan Area	6,547,070	5129	1277	52,540
Main Cities (the "Big 4")				
Amsterdam	873,338	219	3988	60,855
Rotterdam	651,631	319	2043	51,455
The Hague	548,320	100	5483	48,010
Utrecht	359,355	100	3594	52,900

1.5 Methodology

Among all the alternatives identified in the literature, an extended version of the TAM[2] is suggested in this paper as a consistent framework for exploring travellers' intention to uptake MaaS mainly due to the following three reasons. First, the TAM offers a robust conceptual basis for responding the goals and scope of our investigation, given that it was conceived to predict the acceptance of a new technological solution (such as MaaS, in this case). Second, its validity and reliability for this work are supported by its widely application in studies on emerging mobilities and in the field of MaaS (see Sect. 2). It has been used in many empirical investigations and proven to be of quality and statistically reliable. And third, the flexible structure of the (original) TAM—which initially focused on attitudinal factors—is open to the inclusion of additional predictors that increase the explanatory capacity of the model [23, 38].

Following the theoretical assumptions of the TAM, we design an experiment comprising three stages: (i) the conceptualization of a behavioural model to explore travellers' intention to uptake MaaS in the Randstad MA, (ii) the development of a data collection campaign based on an online questionnaire, and (iii) the application of a three-step method analysis. Both the survey and the evaluation techniques are further explained in this Section.

1.6 Conceptualization of the behavioural model

We first define a behavioural model to investigate the (motivational) factors behind the intention to uptake MaaS. In line with the theoretical conventions of the TAM [27] and its extended versions, we hypothesise that attitudinal factors directly influence the 'behavioural intention' to uptake MaaS. And, at the same time, we hypothesise that these attitudes are affected by personality traits. Based on the work of DeYoung et al. [29], the five traits of personality—ncluded in the 'Big Five'—are grouped in two factors that represent two higher-order factors or meta-traits. On the one hand, the aggregation of openness and extraversion (labelled 'stability') appears to represent the propensity to explore or willingly engage with newness and may consequently be related to plasticity or flexibility in behaviour. The combination of conscientiousness, agreeableness, and the inverse of neuroticism (i.e., emotional stability) (labelled 'plasticity'), by contrast, appears to reflect stability in motivational, social, and emotional domains.

In summary, our model explores the following five hypotheses:

The case of Randstad MA is used to validate the hypothesized model. Given that MaaS technologies are still at an early stage of development in the area of study (see Sect. 3), we decide not to consider the "perceived ease of use" when designing the TAM [27]. We believe that including this factor might introduce a significant bias in our results due to the difficulty of ensuring a similar understanding of MaaS among the survey participants. MaaS is a (relatively) novel concept, which to date lacks even a single definition in the literature.

H1 Personality traits are directly correlated with the six selected attitudinal factors (Section 2.1). No directional effects are hypothesised due to the lack of evidence in previous literature on MaaS.

H2 Tech-savviness, privacy issues, need for reliability, control concerns over the network, and green values positively influence individuals' expectations of the mobility services integrated by MaaS.

H3 Need for reliability positively affects individuals' intention to uptake MaaS.

H4 Tech-savviness positively affects individuals' intention to uptake MaaS.

H5 Individuals' expectations of the mobility services integrated by MaaS positively affect their intention to uptake MaaS.

1.7 Survey design and data collection

In response to the proposed behavioural model, we design a tailored-made survey to detect potential users of MaaS. A revision of previous studies focused on MaaS acceptability (Sect. 2) helps us to structure the questionnaire, which includes six parts: (1) Introduction of the study and the notion of MaaS, (2) Demographic and socio-economic characteristics, (3) Affinity with technology and use of travel-planning applications, (4) Travel-related characteristics, (5) Attitudinal factors and personality traits, and (6) Potential uptake of MaaS. In this last section, individuals are asked to rate their intention to uptake MaaS, which represents our dependent variable. It is worth noting the relevance of the first part of the questionnaire in providing individuals with a basic but reasonable understanding of MaaS before participating in the study. Specifically, the concept is presented as

[2] The (original) TAM consists of three core factors: perceived ease of use (PEU), perceived usefulness (PU), and intention to use (IU), which are connected with each other via causal relationships. PEU is "the degree to which a person believes that using a particular system would be free of effort", and PU is "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis & Venkatesh, 1996; p. 320). The reader is referred to, e.g., Davis et al. [27] for a more detailed description of the theoretical framework.

follows: *"MaaS is a new mobility model that allows users to plan, book, and pay for all the forms of transport available in the city through a single digital platform (generally, a smartphone application or a website). This platform also supplies real-time information before, during, and after the travel experiences (*e.g., *information about the travel mode, travel time, travel route, service disruptions,* etc.*) and therefore facilitates informed decisions".*

A web-based survey is regard as the most appropriate method of data collection. The questionnaire was distributed between April and June 2019 in the Randstad MA. For the sample recruitment, we subcontracted a specialised online panel-provider with broad experience on the performance of surveys in this region. We controlled the sample by quotas in terms of gender, age, and frequency of public transport use to ensure the appropriate representativeness for the purposes of the study. In total, the online panel-provider distributed around 5,000 questionnaires.

A pilot survey was carried out before the definitive one to check whether the questionnaire was comprehensible. On the basis of 300 (pilot) responses, we adjusted the structure, content, and graphic the design of the survey, as well as its time limits (around 25 min).

1.8 Analysis of the data: three-step method

To accomplish the research objectives, we propose a three-step method approach, involving an Explanatory Factor Analysis (EFA), a Structural Equation Model (SEM), and a Cluster Analysis (CA). This combination of techniques facilitates the design of customised recommendations according to the profile of each traveller. Given the user-centric nature of MaaS, individual-tailored strategies are key to achieve users' acceptance [16].

First, after cleaning the data collected, a EFA is developed for variable reduction. This technique has been widely applied when evaluating travellers' behaviours to identify the latent factors underlying a set of measured variables. In this case, the EFA allows us to determine if the six attitudinal factors under study (see Sect. 2.1) have statistical ground to be included in the subsequent SEM.

Second, a SEM is developed to explain travellers' intention to uptake MaaS, exploring the hypothesized behavioural model and its corresponding hypotheses. The SEM is a confirmatory analysis technique for testing models that are conceptually derived beforehand and assesses how well the theory fits the data collected [12]. Its foundations lie in two multivariate techniques: a Confirmatory Factor Analysis and a Path Analysis that examine measurement and structural equations all together. In recent years, the SEM has become significantly popular to evaluate individuals' likelihood to accept travel (mobile) applications [7, 31].

Finally, a CA is conducted for segmentation purposes to identify respondents who share similar positions on the factors addressed in the SEM. This approach is widely considered a consistent means to establish the basis for the definition of tailored-individual strategies aimed at behavioural change. In this study, the clustering technique allows us to distinguish a series of 'traveller profiles', which are then described in relation to a series of travel-related, demographic, socio-economic, technology-related, attitudinal, and personality characteristics. Among the multiple clustering methods, we select the Ward's method. Lastly, the Kruskal–Wallis test is applied to determine whether the characteristics considered are statistically different between the clusters [3].

2 Model estimation results

2.1 Descriptive analysis of the sample

In total, we collected 418 valid responses. Some sample characteristics are summarised in Table 3. Although we partnered with a specialised panel-provider to ensure representativeness, we recognise a possible bias in the sample that has to be taken into account when interpreting and discussing the results. For example, almost 40% of the respondents live in the highest density areas of the Randstad MA (>2500 addresses per Km^2) [15]. Overall, however, we detect a sufficient level of heterogeneity for our modelling purposes. It is worth noting the limited availability of personal public transport cards compared to the availability of car driving licences (55.3% vs. 84.9%).

2.2 EFA: exploring attitudinal factors.

We developed an EFA –using the SPSSv29 software— to extract the latent factors that underlie the attitudinal variables measured in the online survey. Prior to this analysis, we verified the internal consistency (Cronbach's alpha-α) and the sampling adequacy (Kaiser–Meyer–Olkin–KMO). The determinant of the Spearman correlations matrix noted the existence of correlations without multi-collinearity. And the Bartlett's test for sphericity indicated an appropriate covariance among variables. Explanatory Principal Axis Factor (PAF) analysis with 'Varimax rotation' uncovered six latent factors (Table 4), corresponding to those selected in Sect. 2.

The factor structure revealed by the EFA is used to perform the SEM model in the next Section, which also incorporates personality traits as predictors.

Table 3 Demographic, socio-economic, and travel-related characteristics of the sample

Characteristic	Category	Sample (%)
Demographic and socio-economic characteristics		
Gender	Female	49.0
	Male	51.0
Age (years old)[1]	18–24	10.3
	25–34	25.6
	35–44	15.6
	45–54	21.3
	55–64	15.6
	> 65	11.7
Education	University	38.0
	Non-university	62.0
Occupation	Student	5.7
	Part-time worker	20.1
	Full-time worker	45.9
	Retired	10.0
	Other	18.2
Household size	1 person	22.0
	2	39.5
	3	14.8
	4 or more	23.7
Residential location[2]	Level 4 of urbanization[3]	37.6
	Level 3	19.6
	Level 2	12.9
	Level 1	5.5
Travel-related characteristics		
Public transport card	Yes	55.3
Driving licence	Yes	84.9
MFT[4] frequency	Less than once a week	17.9
	One to three times a week	39.0
	More than three times a week	43.1
Modal share MFT[4]	Multimodal MFT	31.8
	Unimodal MFT:	
	Walking	2.4
	Cycling	13.9
	Car	34.2
	Motorbike/scooter	1.4
	Public transport	13.0
	Shared-mobility services	1.2
Vehicle ownership	Car ownership	77.5
	Bicycle ownership	93.8

[1] We considered individuals aged between 18 and 90

[2] 102 unknown cases

[3] In order to quantify the degree of urbanization in The Netherlands, the Central Bureau of Statistics (CBS—Centraal Bureau voor de Statistiek) establishes the following levels: Level 1: < 1,000 addresses/km^2; Level 2: 1000–1500; Level 3: 1,500–2,500; Level 4: > 2,500 [15]

[4] The Most Frequent Trip is the trip an individual makes most often, e.g., to go to school/work

(*) Characteristics of The Netherlands population [14]: Gender: 50.3% female, 49.7% male/Age: 21.9% < 20 years; 24.9% 20–40 years; 33.9% 40–65 years; 14.6% 65–80 years; 4.6% > 80 years/Education: 30.2% university; 69.8% non-university / Driving licence (yes): 64.7%/Car ownership (yes): 75.0%/Bicycle ownership (yes): 84.0%/Modal share: 67.4% private car; 13.9% public transport; 8.1% cycling; and 2.4% walking

2.3 SEM estimation results

To test and validate the behavioural hypotheses proposed in Sect. 4.1, we conducted a SEM with the AMOS26 software. We applied the 'maximum likelihood method' to estimate the model parameters and, thus, explain the influence of attitudinal and personality factors on the intention to uptake MaaS.

The statistical model confirmed the behavioural scheme and the five hypotheses proposed for the Randstad MA. Figure 2 summarises the estimation results, comprising the determination coefficients and the standardised path coefficients. Note that latent variables are represented by ellipses and observed variables are represented by rectangles. In agreement with Lois et al. [61], we certified the fit of the model through three parameters: the Standardized Root Mean Square Residuals (SRMR = 0.050), the Root Mean Square Error of Approximation (RMSEA = 0.079), and the Comparative Fit Index (CFI = 0.909). We also applied the chi-square test, which was found to be significant (78.7, df = 33, $p = 0.000$). Table 5 presents the outcomes of the hypothesis testing.

As shown in Fig. 2, the five traits of personality are grouped into two (higher-order) factors, which directly influence the six attitudinal factors considered, and therefore confirm H-1. We identify a positive effect of stability on (F1) individuals' expectations of the mobility services integrated by MaaS, (F2) tech-savviness, (F3) privacy issues, (F4) need for reliability, (F5) control concerns, and (F6) green values. On the other hand, plasticity has a negative effect on (F1) individuals' expectations of the mobility services integrated by MaaS, (F2) tech-savviness, (F3) privacy issues, (F5) control concerns, and (F6) green values; and a positive effect on (F4) need for reliability. Five of the attitudinal factors (F2 to F6) sequentially affect (F1) individuals' expectations of the mobility services integrated by MaaS, verifying H-2. In addition, the behavioural model confirms H-3, H-4, and H-5: (F1) individuals' expectations of the mobility services integrated by MaaS, (F2) tech-savviness, and (F4) need for reliability positively affect the intention to uptake MaaS. Regarding the determination coefficients, the model explained 47% of the variance in (F1), 30% in (F2), 42% in (F3), 30% in (F4), 48% in (F5), 31% in (F6), and 53% in the intention to uptake MaaS. The findings therefore endorse the relevance of attitudinal and personality factors as predictors for MaaS acceptance.

2.4 CA: Recognition of 'traveller profiles'

The application of a cluster analysis allows us to determine profiles of travellers in relation to their intention to uptake MaaS. This technique differentiates homogenous segments based on the (latent) factors included

Table 4 Attitudinal factors uncovered by the EFA

Category	Attitudinal factors—F[1]	Surveyed items	Loading
Mobility integration	F1. Individuals' expectations of the mobility services integrated by MaaS (α = 0.759)	MaaS integrates information on physical activity developed	0.778
		MaaS integrates information on parking at destination	0.770
		MaaS integrates information on accessibility	0.725
		MaaS integrates information on transport modes	0.725
ICT integration	F2. Tech-savviness (α = 0.889)	Apps help me in my daily life	0.856
		I regularly use apps for payment, reservations, etc	0.834
		I am enthusiastic about GPS and travel apps	0.811
		I find it exciting to try new apps	0.810
	F3. Privacy issues (α = 0.765)	I agree to share my profile, opinions, etc. with other users when using apps	0.750
		I agree to share my personal information with companies when using apps	0.730
		I agree to my personal information being checked to get personalized recommendations	0.599
'New mobilities'	F4. Need for reliability (α = 0.705)	For the same destination, I usually travel with the same mode of transportation	0.747
		I prefer a travel option that has predictable travel times	0.741
		I want to have the flexibility to go wherever I want, and to leave whenever I want	0.724
	F5. Control concerns over the network (α = 0.795)	Before travelling, I always check for real-time travel or route information	0.831
		During my trip, I always check for real-time travel or route information	0. 643
		I always check multiple sources of travel information to compare several travel options	0.536
	F6. Green values (α = 0.773)	I would switch to a different form of transport if it would help the environment	0.810
		I am willing to pay more for my trips if it would help the environment	0.810
		To help improve air quality I avoid travelling by car in the city	0.778

α = 0.868; KMO = 0.865; p = 0.000

[1] Following the "two-indicator rule" [12], we considered at least two items per factor, and set the cut off of 0.5

in the previous SEM: six attitudinal factors (individuals' expectations of the mobility services integrated by MaaS, tech-savviness, privacy issues, need for reliability, control concerns, and green values), and five personality traits (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism).

We identify four clusters (Table 6), namely 'traveller profiles': 'Short-duration commuters', 'Active travellers', 'Traditional car-supporters', and 'MaaS admirers', which are described below according to their travel-related (Table 7), demographic and socioeconomic (Table 8), technology-related (Table 9), and attitudinal and personality (Table 10) characteristics. 'MaaS admirers' is the cluster most likely to accept this innovative solution, followed by 'Short-duration commuters', 'Active travellers' and, lastly, 'Traditional car-supporters'.

2.5 Travel-related characteristics

As illustrated in Table 7, each of the clusters is distinguished by its travel-related attributes and mobility patterns. Given the scope of the paper, these characteristics are key to establish a comparison between the four groups.

By definition, MaaS relies on the combination of all the mobility services available to provide individuals with customised on-demand mobility solutions that encourage them to travel more sustainable [48]. Our analysis reveals a factor aligned with this approach: individuals' expectations of the mobility services integrated by MaaS (F1). The two clusters with the most positive attitude towards this integration ('MaaS admirers' and 'Short-duration commuters') are also the most intended to uptake MaaS.

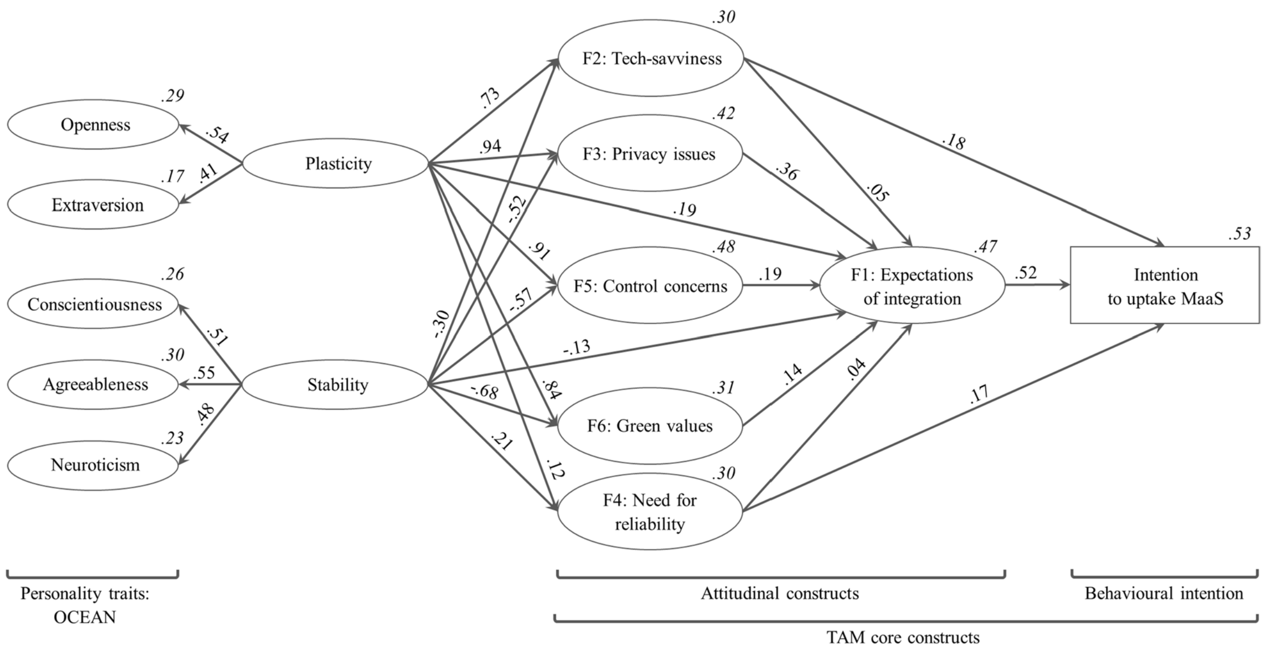

Fig. 2 Path analysis: intention to uptake MaaS

'MaaS admirers' include the highest proportion of multimodal travellers (85.3%). In the other clusters, this multimodality is (in comparison) significantly low (under 45%). In agreement with Alonso-Gonzalez et al. [6], our findings reveal that multimodal attitudes are positively related to public transit adoption and individuals' openness to 'new mobilities'. A significant share of 'MaaS admires' report using both public transport and shared-mobility services on a daily basis. The remaining clusters are less familiar with the 'new mobilities', and an important proportion of their members (more than 15%) have never used them.

'Traditional car-supporters' have the highest percentage of car ownership (almost 90%) and (on average) the highest number of cars per household (1.09). However, their use of the private car for the most frequent trip is similar to that of 'Short-duration commuters'. This latter group and the 'MaaS admires' show a similar share of car ownership (around 75%). Finally, it should be noted that 'MaaS admires' present the lowest proportion of unimodal car commuting (below 30%).

2.6 Demographic and socio-economic characteristics

Table 8 summarises the demographic and socioeconomic characteristics of the four clusters. Our findings show that 'MaaS admires' tend to be males, young (between 25 and 44 years old), and workers. This segment comprises an important proportion of individuals sharing a house among three or more people (52.9%). Moreover, and in line with previous studies [110], most of these 'admires' live in the most urbanized areas (almost 60%), where the mobility offer is comprehensive and well-structured. 'Short-duration commuters' contrast with the previous cluster in age distribution, occupation, and household composition. The most significant difference is the proportion of participants aged over 45 (56.2%).

'Active travellers' and 'Traditional car-supporters' are less likely to uptake MaaS. In agreement with various authors [35, 98], these clusters include a low proportion of high-educated and employed individuals. Specifically, it is worth to note that 'Active travellers' are characterised by a significant proportion of females (almost 60%), while 'Traditional car-supporters' have the highest percentage of respondents aged 55 + (34.9%). These two socio-demographic characteristics have been negatively associated with the adoption of innovative technologies in previous research [4, 103].

2.7 Technology-related characteristics

Table 9 presents the technology-related characteristics of the four clusters. We highlight that over 98% of the members in each cluster own a smartphone, a pre-requisite for using MaaS services given that they are distributed through a digital interface. Specifically, we evaluate the adoption of certain travel-planning applications, such as Google Maps and NS-Reisplanner. This variable and the acceptance of MaaS appear to be directly correlated. Nearly 95% of 'MaaS admires' use these tools on

Table 5 Outcomes of the hypothesis testing

Hypothesis	Path[1]	Effect (direction)	Path coefficient (β)	Findings[2]
H-1				
H-1-(i)-a	O + E (P) → TS	Positive	0.734***	-
H-1-(i)-b	O + E (P) → PI	Positive	0.938***	-
H-1-(i)-c	O + E (P) → CC	Positive	0.911***	-
H-1-(i)-d	O + E (P) → GV	Positive	0.844***	-
H-1-(i)-e	O + E (P) → NR	Positive	0.121***	-
H-1-(i)-f	O + E (P) → EI	Positive	0.194***	-
H-1-(ii)-a	C + A + N (S) → TS	Negative	− 0.304***	-
H-1-(ii)-b	C + A + N (S) → PI	Negative	− 0..518***	-
H-1-(ii)-c	C + A + N (S) → CC	Negative	− 0.568***	-
H-1-(ii)-d	C + A + N (S) → GV	Negative	− 0. 678***	-
H-1-(ii)-e	C + A + N (S) → NR	Positive	− 0.214***	-
H-1-(ii)-f	C + A + N (S) → EI	Negative	− 0.126***	-
H-2				
H2-a	TS → EI	Positive	0.047*	√
H2-b	PI → EI	Positive	0.363***	√
H2-c	CC → EI	Positive	0.187***	√
H2-d	GV → EI	Positive	0.141***	√
H2-e	NR → EI	Positive	0.044*	√
H-3				
-	NR → IU	Positive	0.174***	√
H-4				
-	TS → IU	Positive	0.176***	√
H-5				
-	EI → IU	Positive	0.525***	√

[1] O: Openness to experience; C: Conscientiousness; E: Extraversion; A: Agreeableness; N: Neuroticism (i.e., reversed Emotional Stability); S: Stability; P: Plasticity; EI: Expectations of integration; TS: Tech-savviness; PI: Privacy issues; CC: Control concerns (over the network); GV: Green values; NR: Need for reliability; IU: Intention to uptake MaaS

[2] √: The hypothesis is confirmed/-: As indicated in Sect. 4.1, no directional effects were hypothesised due to the lack of evidence in previous literature on MaaS

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 6 Identification of four 'traveller profiles'

Cluster (CL)	CL1	CL2	CL3	CL4
Traveller profile	Short-duration commuters	Active travellers	Traditional car-supporters	MaaS admires
	N = 119	N = 123	N = 106	N = 70
Intention to uptake MaaS				
Low	10.1%	8.2%	16.0%	0.0%
Medium	32.8%	39.0%	36.8%	8.8%
High	57.1%	52.8%	47.2%	91.1%
M(SD)[1]	3.66 (0.978)	3.55 (0.919)	3.32 (1.065)	4.44 (0.660)

[1] Mean (Standard Deviation): Likert scale 1–5

Table 7 Travel-related characteristics of the 'traveller profiles'

Cluster (CL)	**CL1**	**CL2**	**CL3**	**CL4**
Traveller profile	**Short-duration commuters**	**Active travellers**	**Traditional car-supporters**	**MaaS admires**
Travel-related characteristics (%)	**N = 119**	**N = 123**	**N = 106**	**N = 70**
Public transport card				
Yes	55.5	58.5	40.6	85.3
	Kruskal–Wallis significant (p < 0.01)			
Car license				
Yes	87.4	79.9	88.7	88.2
	Kruskal–Wallis not significant			
Car ownership				
Yes	77.3	71.7	86.8	76.5
No of cars/household: M(SD)[1]	0.93 (0.660)	0.86 (0.651)	1.09 (0.655)	1.03 (0.758)
	Kruskal–Wallis significant (p < 0.05)			
Reported PT frequency***				
4 days a week	21.8	20.8	17.0	61.8
1 day a week	27.7	30.8	20.8	20.6
1 day a month	29.4	22.6	27.4	17.6
1 day a year	13.4	13.2	15.1	0.0
Never	7.6	12.6	19.8	0.0
	Kruskal–Wallis significant (p < 0.01)			
Reported car-sharing frequency**				
4 days a week	0.8	1.9	3.8	29.4
1 day a week	5.9	6.9	2.8	8.8
1 day a moth	5.9	6.3	3.8	17.6
1 day a year	7.6	2.5	4.7	14.7
Never	63.9	59.7	64.2	17.6
Unknown the service	16.0	22.6	20.8	11.8
	Kruskal–Wallis significant (p < 0.01)			
Reported bike-sharing frequency**				
4 days a week	2.5	3.1	0.0	14.7
1 day a week	5.0	6.3	3.8	32.4
1 day a moth	5.0	9.4	6.6	23.5
1 day a year	17.6	8.8	4.7	0.0
Never	55.5	52.8	67.9	20.6
Unknown the service	14.3	19.5	17.0	8.8
	Kruskal–Wallis significant (p < 0.01)			
Multimodal MFT[2]				
Yes	33.6	43.4	30.2	85.3
	Kruskal–Wallis significant (p < 0.01)			
Use car in MFT[2]*				
Yes	44.5	34.0	47.2	29.4
	Kruskal–Wallis significant (p < 0.05)			
Use bike in MFT[2]				
Yes	26.1	34.0	26.4	35.3
	Kruskal–Wallis not significant			
MFT[2] reason ***				
Work/study	72.2	53.5	51.9	44.1
Shopping	11.8	17.6	19.8	38.2
Leisure	13.5	21.4	24.5	11.8

Table 7 (continued)

Cluster (CL)	CL1	CL2	CL3	CL4
Traveller profile	**Short-duration commuters**	**Active travellers**	**Traditional car-supporters**	**MaaS admires**
Travel-related characteristics (%)	**N = 119**	**N = 123**	**N = 106**	**N = 70**
Drop-off/pick-up someone	0.8	2.5	1.9	5.9
Other	1.7	5.0	1.9	0.0
	Kruskal–Wallis significant ($p < 0.05$)			
Duration of MFT				
Minutes: M(SD)	29.1 (22.4)	33.8 (27.4)	35.5 (50.8)	47.0 (60.0)
	Kruskal–Wallis not significant			

[1] Mean (standard deviation)

[2] The Most Frequent Trip is the trip an individual makes most often, e.g., to go to school/work

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$, when testing the relation with the variable 'intention to uptake MaaS' (Chi-Square test)

a frequent basis. Contrarily, 'Traditional car-supporters' result the least 'technologists' and around a 10% of these individuals never use travel planners for their trips.

2.8 Attitudinal and personality characteristics

Table 10 outlines the attitudinal and personality attributes of the clusters. The four groups are characterised by a high level of tech-savviness (on average). According to our results, this variable appears to be directly correlated with the likelihood of accepting MaaS. This seems reasonable given that the new scheme is delivered to travellers through a digital platform [9].

On the other hand, 'Short-duration commuters', 'Active travellers', and 'Traditional car-supporters' show a significant need for reliability; while 'MaaS admires' seem more focused on the integration (of mobility services) provided by MaaS. Individuals must be likely to combine different modes of transport as part of their travel patterns in order to exploit the benefits offered by this new solution [16].

In terms of personality, 'Short-duration commuters' appear to be characterised by their openness to new experiences; 'Traditional car-supporters' by their agreeableness, and 'MaaS admires' by their extraversion. According to our results, we cannot characterise 'Active travellers' by any particular personality trait.

2.9 Discussion of results: defining traveller-oriented strategies for MaaS uptake

The behavioural model adjusted in this investigation has revealed that 53% of the variance in travellers' intention to uptake MaaS in our study area is explained by six attitudinal factors, namely: individuals' expectations of the mobility services integrated by MaaS, tech-savviness, privacy issues, need for reliability, control concerns, and green values. Following a path model approach, these factors, combined with collected measurements of the five personality traits (the well-known 'Big Five') have proven their influence on the willingness to adopt MaaS.

These findings have set the basis for a cluster analysis, which has resulted in the definition of four groups of travellers: 'Short-duration commuters', 'Active travellers', 'Traditional car-supporters', and 'MaaS admirers'. In order to encourage them to use MaaS, each of these groups require customised strategies, as discussed below. Our ultimate goal is to stimulate a shift towards more sustainable travel habits.

- Cluster 1—'Short-duration commuters'—consists mainly of commuters (almost 75%), who show the shortest travel time (on average) of the four groups recognised. This cluster includes an important share of unimodal (66.4%) and car-dependent (44.5%) travellers. As shown in Table 10, these individuals aim to have a full control over the transport network, while giving a great importance to the availability of reliable data (see Table 9).

  According to their profile, we believe that 'Short-duration commuters' might be primarily interested in MaaS for the real-time information provided (on, e.g., incidents, accessibility, availability of parking at destination, modes of transport, etc.), which could help them to improve (i.e., make more efficient and effective) their daily commuting.

  In this case, the adoption of MaaS could be encouraged through tailored marketing campaigns that highlight the potential of the new travel-planning applications to facilitate a predictable and seamless travel experience through the provision of the

Table 8 Demographic and socio-economic characteristics of the 'traveller profiles'

Cluster (CL)	CL1	CL2	CL3	CL4
Traveller profile	**Short-duration commuters**	**Active travellers**	**Traditional car-supporters**	**MaaS admires**
Demographic and socio-economic characteristics (%)	**N = 119**	**N = 123**	**N = 106**	**N = 70**
Gender*				
Female	42.9	59.1	45.3	35.3
Male	57.1	40.9	54.7	64.7
	Kruskal–Wallis significant (p < 0.05)			
Age				
18–24 years old	12.6	10.7	6.6	11.8
25–34	17.6	25.8	29.2	41.2
35–44	13.4	15.1	15.1	26.5
45–54	27.7	23.9	14.2	8.8
55 +	28.5	24.5	34.9	11.8
	Kruskal–Wallis significant (p < 0.05)			
Education level				
University	45.4	35.8	29.2	50.0
Non university	54.6	64.2	70.8	50.0
	Kruskal–Wallis significant (p < 0.05)			
Occupation*				
Employed	69.8	63.0	58.5	91.2
Retired	11.8	8.2	14.2	0.0
Student	7.6	4.4	6.6	2.9
Other	10.8	24.4	20.7	5.9
	Kruskal–Wallis significant (p < 0.01)			
Household size**				
3 or more people	34.5	39.0	37.7	52.9
2 people	44.5	36.5	42.5	26.5
1 person	21.0	24.5	19.8	20.6
Number of household members: M(SD)[1]	2.34 (1.037)	2.37 (1.088)	2.42 (1.069)	2.68 (1.173)
	Kruskal–Wallis not significant			
Residential location				
Level 4 of urbanization[2]	42.9	34.1	22.6	57.1
Level 3 of urbanization[2]	5.9	16.3	37.7	21.4
Level 2 of urbanization[2]	10.1	17.9	18.9	0.0
Level 1 of urbanization [2]	4.2	4.1	12.3	0.0
Unknown	36.9	27.6	8.5	21.5
	Kruskal–Wallis not significant			

[1] Mean (Standard Deviation)

[2] In order to quantify the degree of urbanization in the Netherlands, the Central Bureau of Statistics (CBS—Centraal Bureau voor de Statistiek) establishes the following levels: Level 1: < 1000 addresses/km^2; Level 2: 1000–1500; Level 3: 1500–2500; Level 4: > 2500; [15]. (102 unknown cases)

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$, when testing the relation with the variable 'intention to uptake MaaS' (Chi-Square test)

abovementioned real-time data. Given that a significant number of the members of this group show car-dependent habits, it is crucial that these campaigns emphasise the reliability of alternative (and more sustainable) options, such as public transport services or the 'new mobilities'.

- Cluster 2—'Active travellers'—includes a significant share of frequent bicycle users (34%). This group also shows a positive inclination towards public transit, with almost 60% of its members in possession of a public transport pass, and towards multimodal behaviours. These individuals have the lowest share

Table 9 Technology-related characteristics of the 'traveller profiles'

Cluster (CL)	CL1	CL2	CL3	CL4
Traveller profile	**Short-duration commuters**	**Active travellers**	**Traditional car-supporters**	**MaaS admires**
Technology-related characteristics (%)	**N = 119**	**N = 123**	**N = 106**	**N = 70**
Smartphone availability *				
Yes	93.3	93.7	93.4	100
Kruskal–Wallis not significant				
Use of travel-planning applications***				
Never	1.7	5.7	9.4	0.0
Almost never	8.4	5.7	12.3	2.9
Sometimes	21.8	35.2	36.8	2.9
Frequently	49.6	38.4	34.0	58.8
Always	18.5	15.1	7.5	35.3
Kruskal–Wallis significant (p < 0.01)				
Type of information demanded***				
Mode of transport: M(SD) [1]	3.66 (0.978)	3.55 (0.919)	3.32 (1.065)	4.44 (0.660)
Incidences	3.82 (0.965)	3.69 (0.927)	3.40 (0.912)	4.24 (0.819)
Accessibility	2.84 (1.157)	2.74 (1.104)	2.68 (1.056)	4.38 (0.739)
Parking at destination	3.39 (1.144)	2.94 (1.187)	3.08 (1.006)	4.50 (0.615)
Environmental impact	2.73 (1.039)	2.81 (1.046)	2.64 (0.968)	4.21 (0.729)
Physical activity	2.78 (1.158)	2.92 (1.090)	2.48 (1.035)	4.15 (0.821)

[1] Mean (standard deviation): Likert scale 1–5

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$, when testing the relation with the variable 'intention to uptake MaaS' (Chi-Square test)

Table 10 Attitudinal and personality characteristics of the 'traveller profiles'

Cluster (CL)	CL1	CL2	CL3	CL4
Traveller profile	**Short-duration commuters**	**Active travellers**	**Traditional car-supporters**	**MaaS admirers**
Attitudinal and personality characteristics	**N = 119**	**N = 123**	**N = 106**	**N = 70**
Attitudinal factors—M(SD)[1]				
Expectations of the services integrated by MaaS	3.17 (0.773)	2.94 (0.759)	2.89 (0.743)	4.37 (0.527)
Tech-savviness	3.73 (0.835)	3.45 (1.009)	3.11 (0.987)	4.40 (0.666)
Privacy issues	2.90 (0.874)	2.89 (0.826)	2.65 (0.920)	4.28 (0.593)
Need for reliability	3.76 (0.488)	3.77 (0.607)	3.71 (0.677)	4.14 (0.563)
Control concerns	3.29 (0.682)	3.18 (0.804)	2.95 (0.806)	4.31 (0.550)
Green values	2.88 (0.772)	2.96 (0.757)	2.73 (0.780)	4.18 (0.673)
Personality traits: OCEAN—M(SD)[1]				
Openness to experience	3.48 (0.352)	3.31 (0.422)	2.54 (0.373)	3.75 (0.632)
Conscientiousness	2.76 (0.475)	3.34 (0.508)	2.81 (0.422)	3.69 (0.686)
Extraversion	3.32 (0.363)	2.94 (0.361)	2.94 (0.482)	3.97 (0.565)
Agreeableness	3.37 (0.481)	3.32 (0.368)	3.14 (0.367)	3.91 (0.546)
Neuroticism	2.73 (0.366)	3.33 (0.424)	2.86 (0.450)	3.78 (0.531)

[1] Mean (standard deviation): Likert scale 1–5. In accordance with Lois et al. [62], the average of the latent factors was calculated by dividing the number of items on each variable for the purposes of comparison

of car licence availability (below 80%) and car ownership (around 70%). Moreover, their daily adoption of private car is scarce (34.0%). It is worth to point out that even if these values seem associated with non-sustainable practices, they are not negative for the particular case of The Netherlands, where the car has been detected to play a central role [35].

Based on the travel-related characteristics of these individuals and their high ecological values (Table 10), we propose to integrate financial bonuses (such as discounts, incentives, etc.) into MaaS "bundles" that reward their sustainable behaviours. As a result, MaaS might help to reinforce the current predisposition of these travellers to combine different public transport services, as well as these with active options (cycling or walking).

- Cluster 3—'Traditional car-supporters'—includes the highest proportion of daily car users among the profiles identified (almost 50%). This cluster is also characterised by a low use of travel-planning applications in comparison with the other groups: almost 10% of its members never use such technologies.

  For this case of car-dependent behaviours, and following the suggestions of Paundra et al. [84] and Alonso-Gonzalez et al. [6], we recommend supporting a modal shift only in those situations in which the (personal) car is not available. In particular, we believe that certain 'new mobilities'—such as car-sharing, car-pooling, and ride-hailing services—could be attractive to these individuals on such occasions. Therefore, we propose to design MaaS "bundles" that improve the visibility of these services, helping this group to experience the new system and move away from dependence on the (private) car.

  On the other hand, and to address the low level of technophile that characterises 'Traditional car-supporters', we believe that it is key for MaaS applications to be intuitive, user-friendly, and easy to use. Furthermore, given the privacy-conscious profile of this cluster, these technologies should assure individuals that their personal information is secured and protected.

- Cluster 4—'MaaS admirers'—is the most likely to uptake MaaS, with a strong inclination towards multimodal behaviours. Given their significant affinity with new technologies and their high interest for the 'new mobilities', and based on the findings of previous research [6], we could expect these individuals to (slightly) reduce their public transit usage by shifting to on-demand mobility services (such as car-, scooter-, and bike-sharing services), which might bring unintended adverse effects (i.e., an increase of environmental externalities such as congestion, greenhouse gases emissions, and noise and air pollution). If this were to occur, the switch could be addressed by appealing to the "green" sensibility of this group.

  In any case, here, the key seems to translate the intentions of this cluster into behaviours through effective and reliable MaaS applications that help to improve the travel experience of each person according to his/her preferences and expectations. In addition, financial bonuses (such as discounts, incentives, etc.) could be integrated into MaaS "bundles" and provided to those individuals who exhibit greener and healthier travel patterns.

On the basis of the above discussion, Table 11 outlines the proposal of four areas of action—and their suitability for each of the four clusters—to be considered when designing MaaS strategies that encourage the adoption of less car-dependent habits. In general, we believe that the implementation of a free trial scheme to test the new model is crucial for all the different clusters. This scheme could provide an opportunity to explore what might be of interest in a MaaS offering that aligns with travellers' perspective and contributes in a more comprehensive sense to the achievement of societal goals with a focus on sustainability.

Overall, we identify three main barriers for the potential acceptance of MaaS and the subsequent change of behaviour that it might facilitate: low willingness to combine different modes of transport (i.e., low openness to multimodal behaviours), low affinity with technology, and low reliability on the 'new mobilites' (i.e., new mobility services). In agreement with previous literature [57, 84], we also recognise that a strong sense of ownership and low environmental concerns seem to frustrate individuals' innovativeness.

Given that MaaS is not still implemented in the Randstad MA and our results are grounded on a dummy application, further research is needed to provide robust conclusions on the potential success of such innovative solutions. Thus, while the approach taken may be adequate as a first step, we propose the deployment of real-world pilots to gain better insights into the (possible) effects of MaaS on people's travel behaviours. These pilots might help the general population to become familiar with MaaS technologies. In addition, future studies could consider the incorporation of other (explanatory) variables (i.e., predictors) when designing behavioural models that assess the acceptance of MaaS.

Table 11 Areas of action to facilitate less car-dependent habits through MaaS

Area of action	Objective	Cluster			
		1	2	3	4
Implementation of free MaaS trials	Understand individuals' perspective (preferences, expectations, etc.)	√	√	√	√
Definition of marketing and promotion campaigns	Highlight the potential of MaaS to facilitate a predictable and seamless travel experience through the provision of real-time information	√			
	Reinforce the predisposition of travellers to combine different public transport services, as well as these with active options		√		
	Encourage the access to 'new mobilities' as complementary options	√		√	
Design of travel-planning applications	Provide individuals with an intuitive and user-friendly interface			√	√
	Ensure robust data protection and privacy			√	
Pricing schemes	Integrate incentives and bonuses into MaaS "bundles" to reward sustainable behaviours		√		√

3 Conclusions

The paper recognises four clusters according to individuals' intention to uptake MaaS in the Randstad MA (The Netherlands), considering a set of (underlying) attitudinal and personality factors. This segmentation helps us to articulate a user perspective on the adoption of MaaS. Despite the potential opportunities of the new solution, it might not achieve public acceptance on its own, so travellers must be presented with an appropriate change in circumstances. Pankratz et al. [82] have already pointed out that "just because a new technology –in this case, MaaS—offers benefits 'on paper' does not mean individuals will ultimately embrace it" [82], p. 96).

Previous literature highlighted the complex psychological processes behind people's travel behaviour, as well as the frequent prevalence of inertia. Given the user-centric nature of MaaS, experts agree that individually tailored approaches are key for defining strategic recommendations that support the transition towards more sustainable habits. In this line, our results outline a set of initiatives directed to different "traveller profiles", as well as five key areas of action to be taken into account by policymakers in the urban mobility arena.

Based on our findings, we cannot simply assume that MaaS will bring more sustainable mobility patterns that automatically decrease car possession and car distance travelled. Even if our results suggest the power of dealing with individuals' attitudes and personality traits for modifying travel behaviour, we cannot conclude to what extent it will change. This could only be found out with longitudinal research. In recent years, academia has been exploring the design and deployment of specific initiatives to encourage MaaS adoption. However, the modal transition promised by the new scheme must be supported with the broad availability of different mobility services, what will allow individuals to test and anticipate MaaS benefits.

Today, MaaS pilot investigations are still scarce mainly due to their high costs and time consuming. As a result, the recurrent claims about the positive contributions that MaaS will introduce towards the achievement of sustainability goals rely on a scattering of limited yet insightful scientific findings.

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