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Review Article

MOBILITY-AS-A-SERVICE: LITERATURE AND TOOLS REVIEW WITH A FOCUS ON PERSONALIZATION

Francesco Maria TURNO, Irina YATSKIV (JACKIVA)✉

Faculty of Engineering, Transport and Telecommunication Institute, Riga, Latvia

Highlights:
- state-of-the-art in MaaS with focus on personalization;
- inclusive, user-friendly, personalized, and customizable MaaS solutions;
- high integration of data in human-centric manner and environmental awareness;
- taxonomy of HMD;
- interactive map of MaaS initiatives;
- technical, regulatory, financial, and social challenges to MaaS implementation.

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Abstract. In the coming years, mobility initiatives should focus on sustainability, safety, and social equity. This can be achieved by introducing innovative transportation methods, implementing novel approaches for end-users, and optimizing the utilization of traditional modes of transport. To achieve this goal, it is essential to utilize pervasive sensing and computing technologies, along with intelligent information processing systems, to assist decision makers, managers, and transport operators. To effectively address unforeseen events and disruptions, mobility services should promptly adapt and improve their flexibility. Furthermore, these services should be adaptable to meet the unique needs and evolving demands of individuals. Current research focuses on understanding how individuals make decisions about when and where they engage in walking, driving, and travel activities. Therefore, it is important to develop reliable human mobility models in this context. Big data and Artificial Intelligence (AI) are important in this context as they enable data generators to identify individual patterns and quickly adapt solutions. This paper aims to conduct a literature review on Mobility-as-a-Service (MaaS), focusing on personalization, to identify gaps in current MaaS initiatives. This assessment is essential for creating inclusive, user-friendly, personalized, and customizable MaaS solutions. To conclude, the existing challenges have been addressed in comprehending the characteristics of MaaS in terms of personalization. Additionally, they have been proposed further research questions to delve deeper into this aspect.

Keywords: mobility service, literature review, taxonomy, integration level, tools, personalization, human mobility data, gaps.

✉Corresponding author. E-mail: *jackiva.i@tsi.lv*

Notations

AFC – automated fare collection;
AI – artificial intelligence;
BRT – bus rapid transit;
CM – combined mobility;
DF – data fusion;
DRT – demand responsive transport;
ETC – electronic toll collection;
GPS – global positioning system;
HMD – human mobility data;
ICT – information and communication technologies;
IMS – integrated mobility services;
IT – information technology;
MaaS – mobility-as-a-service;
PT – public transport;
OD – origin–destination

Introduction

A city can be defined as "smart" according to (Schaffers *et al.* 2011) "when investments in human and social capital and traditional (transport) and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory government". The development of ICT and the digitalization of society are the basis for cities to respond to these challenges. But smart cities are much more than just technologies (ICT, smart applications, etc.), and sensors and technological devices do not make a city smart – rather, it is the impact of technology on improving the well-being and quality of life of its citizens (Komninos 2008), and we need to talk about the intelligent use of technology.

An important element that requires consideration in the smart city vision is smart mobility. So far, this term has been understood as the fusion of ICT with multimodal transportation including the new concepts and forms of ride-sharing, e-hailing, etc. Smart mobility in human-centric consideration is a people-driven multi-disciplinary collaboration that should include a holistic socio-technical approach, addressing different types of mobility for different social groups simultaneously in any city. One of the core elements in the value proposition of smart mobility is equity. We need more than a safe and sustainable net of mobility options for citizens, and it must also be a basis for equity considerations between the citizens to benefit (Klinger, Lanzendorf 2016). Moreover, it is needed to enable travellers' actual participation in urban management, empowering citizens through new kinds of technologies.

Mobility is not just function, it relates to social practices, interdependencies, relations (Manzini 2022), and it is often co-produced by (and with) citizens and communities, as shared mobility options for instance. Defining the guidelines of future European mobility (EC 2020), the mobility in the next decades should foster sustainability, safety and social equity by new modes of transportation (car-sharing, soft modes, etc.), new models for end-users (e.g., from ownership to MaaS), and new ways of using traditional transport modes through ubiquitous sensing and computing, and intelligent information processing (e.g., privacy-preserving data mining) for decision makers and managers. Thus, according to Van Audenhove *et al.* (2021), the mobility systems of the world's cities need to adapt quickly to become more environmentally sustainable, more resilient and adaptable to shocks and disruptions. They should be focused on people's needs, and not primarily determined by their technological infrastructure. MaaS can reduce social exclusion and create new opportunities for economic growth (MaaS Alliance 2017). Becoming more sustainable, resilient and human-centric should be the main goal of any modern urban mobility system.

In the past decade the concept of MaaS witnessed an exponential growth among public and private transport authorities. MaaS is characterized by the integration and access of various forms of transport services into an all-in-one mobility service, in the shape of a digital interface enabling multimodal travel possibilities (i.e., PT, car-sharing, ride-sharing, bike-sharing, scooter-sharing, ...), which allows the booking, payment, support and alteration of planned journeys. In other terms "MaaS is a user-centric, intelligent mobility management distribution system, in which an integrator brings together offerings of multiple mobility service providers and provides end-users access to them through a digital interface, allowing them to seamlessly plan and pay for mobility" (Kamargianni *et al.* 2015, 2016). The core characteristics of MaaS include integration of *multiple transport modes*, *various payment options*, and use of *various technologies* enabling the use of a single *interface* and platform, while catering for *personalization* and *customization* to offer *user-centric mobility services*. Despite the many research devoted to MaaS, some successful implementation of MaaS projects and positive feedback from users about MaaS projects, there are still a number of open questions.

One of the actual research questions is to understand how humans make decisions about when and where to walk/drive/travel and how to develop realistic human mobility models. For instance, perceived safety and mobility constraints are crucial in the decision to travellers with disabilities and not so important for others. Understanding where individuals actually wheel (that is not fully reliable from GPS data as they only capture people who carry smartphones), safety perception that is especially important in an ageing population and for people with reduced mobility, the different socio-demographic parameters in interaction with the urban layout and thermal comfort affecting walkability. Accordingly, research on individual mobility patterns (e.g., Hasanzadeh *et al.* 2021) has shown that individuals have differing distance thresholds that they consider acceptable, for instance, for active mobility (walking and cycling). These differences in individual requirements lead to diverse levels of perceived accessibility for different population groups (Pot *et al.* 2021, 2023; Lättman *et al.* 2018). User needs and habits should be analysed and used to support planning and development processes related to the entire urban mobility system, including MaaS (Gonzalez-Feliu *et al.* 2018). It plays the crucial role for creating tailored and suitable environment for different types of users with different expectations and it is the keystone of personalization. The solution of mobility personalization issues has become possible in the era of big data and AI (Servou *et al.* 2023; Diran *et al.* 2021) and it provides new models and tools to identify personal patterns and customize the solutions on-the-go.

The main goal of this paper is to conduct a literature review on MaaS, focusing on personalization and based on it to identify gaps in current MaaS initiatives. Section 1 provides a methodology of literature search and exploration of results; Section 2 includes a summary of literature findings on the MaaS concept, taxonomy of integration levels and focuses on aspects of personalization. Section 3 includes a discussion of gaps and challenges identified following the literature review of the MaaS. Section 4 contains a discussion and elaborates further research questions and lastly, Last section summarizes the main contributions and novelty of this research. One contribution includes comprehensive overview of existing MaaS solutions with a description of their characteristics, and it is provided in Appendix. For a better visualization purpose, the authors created an interactive atlas of MaaS application, accessible at this link: https://htmlview.glitch.me/?https://raw.githubusercontent.com/turnoworks/MaaSAtlas/main/MaaS_Atlas.html.

1. Literature review: search methodology and descriptive statistics

The above methodological framework outlines the process used to conduct a literature review on the topic of MaaS with a focus on personalization. The review process involves the use of a scientific database SCOPUS, to collect articles written in English and published in peer-reviewed journals. Present methodology excludes non-peer-reviewed literature, such as book chapters and project reports, as well as papers written in languages other than English. The review process is limited to research conducted between 1996 and March 2023, ensuring that the reviewed state-of-the-art is current and relevant. To search for the articles, several combinations of keywords are employed. The articles included in the review are selected based on relevance.

In the following paragraph, the results of the database search on date 31 March 2023 are presented. To search for the documents, several combinations of selected keywords are employed (Table 1).

1st input query containing "*Mobility-as-a-Service*" and "*MaaS*" keywords and searching results are shown in Table 1. The 1st keyword combination returned 468 documents including 268 articles, 162 conference papers and 13 review papers.

Figure 1 displays the publication of documents related to MaaS, from the foundation of the concept ("2014") until present day. It can be observed that the peak of publications has been reached between 2020 and 2022, counting a total of 316 papers.

SCOPUS, in addition, offers an analytical tool showing the quantity of documents published in several journals. In the Figure 2, it is evident that in 2020, a large number of articles were published in the *Transportation Research Part A: Policy and Practice* journal. The latter focuses on policy analysis, planning, interaction with the political, socioeconomic, and physical environments, and management and evaluation of transportation systems. Papers from various disciplines such as economics, engineering, psychology, sociology, and urbanism are welcome as long as they address a clear policy concern or are of interest for practice and are based on solid research and good quality data.

Besides, SCOPUS analytics presents top of 15 countries classifying the most published papers in the field (Figure 3), from 2014 until 2023. Although the list might not be extensive, it actually proves that the topic of MaaS captures the attention of many worldwide territories.

It is also worth noting that MaaS bridges several disciplines ranging from "Engineering" to "Social Sciences". Figure 4 shows the proportion of subjects covered by the keywords of interest.

4 new input queries with different sets of keywords were generated and the results including 1st one ("*Mobility-as-a-Service*" and "*MaaS*") are presented in Table 1. New keyword combinations are created, by appending for each query new terms such as "*User needs*", "*Integration levels*", "*Applicability*", "*Personalization*" and lastly "*Customization*".

As we see in Table 1 the 2nd keyword combination including "*User needs*" returned 69 documents including 43 articles, 25 conference papers and 1 review paper. The 3rd combination with "*Integration levels*" totally returned 23

Table 1. Results of input queries with different sets of keywords

No	Keywords	Input query	Search results		
			articles	conference papers	review papers
1	"*Mobility-as-a-Service*" and "*MaaS*"	*"TITLE-ABS-KEY (mobility-as-a-service AND maas) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))"*	268	162	13
2	"*Mobility-as-a-Service*", "*MaaS*" and "*User needs*"	*"TITLE-ABS-KEY (mobility-as-a-service AND maas AND user AND needs) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))"*	43	25	1
3	"*Mobility-as-a-Service*", "*MaaS*" and "*Integration levels*"	*"TITLE-ABS-KEY (mobility-as-a-service AND maas AND integration AND levels) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))"*	14	8	1
4	"*Mobility-as-a-Service*", "*MaaS*" and "*Applicability*"	*"TITLE-ABS-KEY (mobility-as-a-service AND maas AND applicability) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))"*	5	1	0
5	"*Mobility-as-a-Service*", "*MaaS*" and "*Personalization*"	*"TITLE-ABS-KEY (mobility-as-a-service AND maas AND personalization) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))"*	2	2	0
6	"*Mobility-as-a-Service*", "*MaaS*" and "*Customization*"	*"TITLE-ABS-KEY (mobility-as-a-service AND maas AND customization) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))"*	5	3	0

documents (14 articles, 8 conference papers and 1 review paper). The 4th combination with "*Applicability*" returned only 6 documents and no review papers. The keyword combination with "*Personalization*" returned 5 documents including 2 articles, 2 conference papers and 0 review papers. The last keyword combination with "*Customization*" returned 8 documents including 5 articles, 3 conference papers and 0 review papers. Moreover, it is interesting to notice a disparity of documents for the queries containing "*User needs*" (69) and "*Personalization*" (5), respectively.

2. Research findings

2.1. MaaS definitions

The concept of MaaS began to emerge in the 2010s, but its roots appeared early in discussions about integrated transportation systems. Tschanz & Zimmermann (1996), paved the way by proposing the 1st "intelligent information assistant" capable of searching and booking trips, hotels and eventually buying tickets. Although this idea was never brought to life, it pioneered future applications

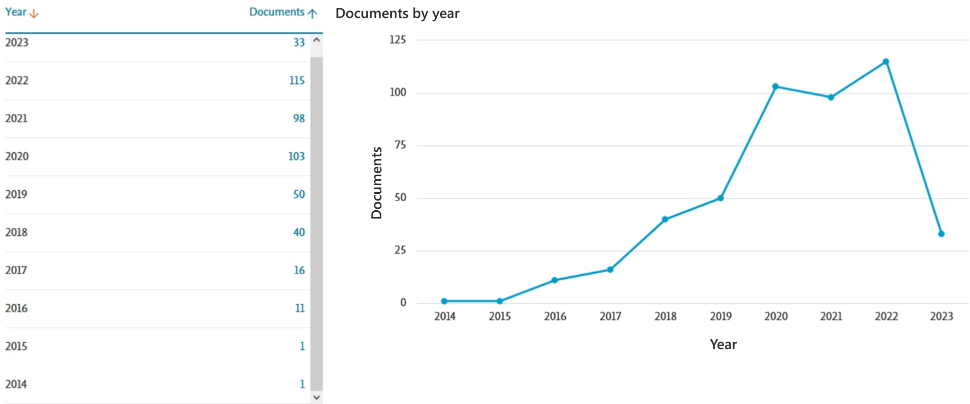

Figure 1. Time series depicting yearly publication history of MaaS related documents (created with SCOPUS Analyzer)

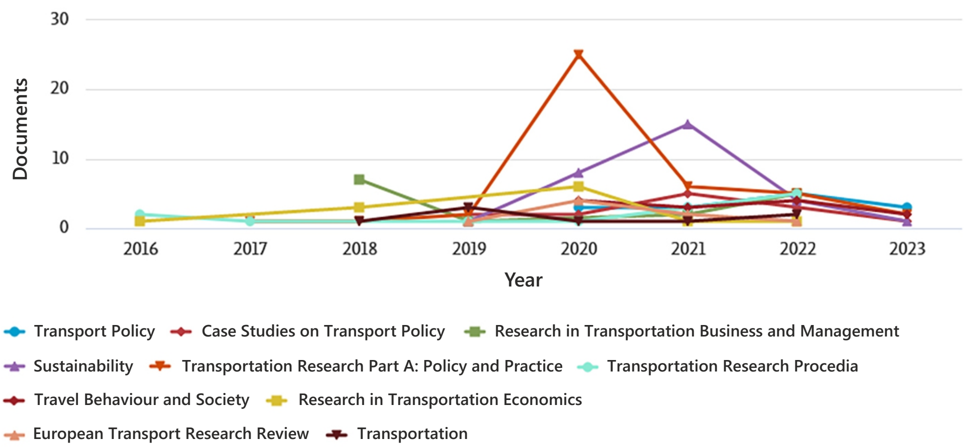

Figure 2. Number of yearly published documents by source (created with SCOPUS Analyzer)

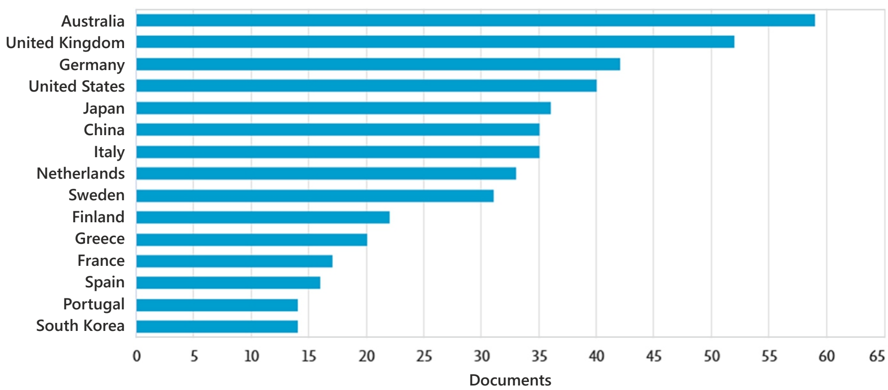

Figure 3. Published documents by country (created with SCOPUS Analyzer)

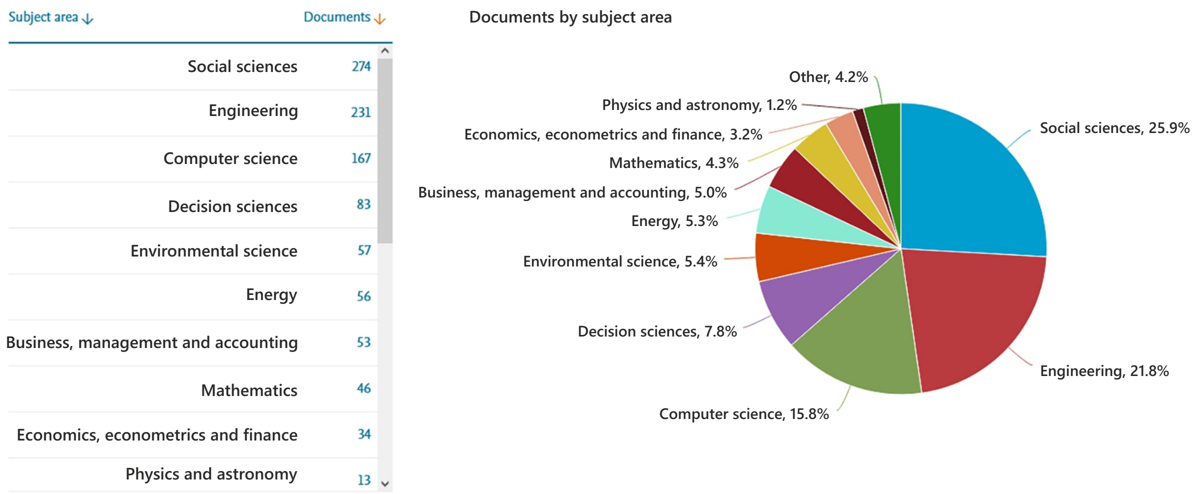

Figure 4. Number of published documents by discipline (created with SCOPUS Analyzer)

that started to exhibit MaaS characteristics. The French startup *BlaBlaCar* (Saxena *et al.* 2020), established in 2006, and developed a website for long-distance ride-sharing, facilitating connections between drivers and passengers who would share the cost of the journey. In 2008, the platform was further enhanced by the inclusion of a community module, enabling users to display their profiles and indicate their preferences. Eventually, in 2012, an online reservation service was added, providing additional convenience to the users. Another noteworthy example is Zimride, today known as Lyft, which was founded in San Francisco (US) in 2007 (Mitropoulos *et al.* 2021). The goal of this platform was to alleviate both drivers' and passengers' concerns about unfamiliarity by facilitating connections via social network services. In 2009, the *Uber* mobile application was created and had become widely popular around the world and in 2014 *Uber* introduced *UberPool*, a ride-sharing model that enables riders to "pool" their rides and split the fare between multiple parties.

The term of MaaS gained widespread publicity through the development of the so-called "Helsinki model", a vision, which was proposed by Heikkilä (2014). Later several countries unveiled the 1st iterations of a platform that "promised" to include integrated, user-friendly, seamless and inclusive mobility solutions for all; by fusing various forms of transportation and payment into a single interface, with the ultimate goal of decreasing reliance on personal vehicles and increasing use of sustainable transportation methods (Heikkilä 2014; Jittrapirom *et al.* 2017).

The pivotal moment in the development of MaaS occurred in 2015 at the *22nd Intelligent Transportation System Congress* (Bordeaux, France), which was attended by 20 European organizations, including transportation service and IT system providers, public transportation and MaaS service operators, user groups, and governmental organizations and when the 1st MaaS Alliance was established. Nowadays, MaaS Alliance counts more than 100 members worldwide and is working to create an open and sustainable MaaS ecosystem by improving interoperability, roaming of services, business scalability, providing 4 market insights, connecting problem-owners with solution providers, forging partnerships, fostering collaboration, and defining ecosystem principles (MaaS Alliance 2017).

As already mentioned above, there have been quite a lot of research in the frame of MaaS study over the years (in particular, in the SCOPUS database 468 documents), however the definition of MaaS is still in discussion and literature sources argue about the lack of a globally accepted definition between the different players. In Table 2 a range of MaaS definitions has been provided.

Therefore, the definition of MaaS can be factored into 3 interpretations: CM, MaaS and IMS:

- ***CM***: tends to focus on combining modes such as "facilitation of planners" and "purchasing functions" in terms of services, which may complement PTs or even substitute private cars (Smith *et al.* 2017, 2019; UITP 2011; Smith, Hensher 2020);
- ***MaaS***: tends to focus on the aspects of the "service" and "integration". This description is mostly agreed by (Hietanen, 2014; Kamargianni *et al.* 2015; Kamargianni, Matyas, 2017; König *et al.* 2016);
- ***IMS***: tends to concentrate on "integration of various services", in terms of multimodality, information, payment, deliveries and repairs via a single application (Kamargianni *et al.* 2015; Mukhtar-Landgren *et al.* 2016).

MaaS is an emerging idea that seeks to meet people's mobility demands in a sustainable way by combining several transportation options into seamless journeys (Utriainen, Pöllänen 2018), providing a desirable substitute for owning and operating a private vehicle (Lyons *et al.* 2019).

More recent definitions of the MaaS concept (Table 2) include fundamental aspects such as customers' needs, personalized and omni-comprehensive solutions, a graphical user interface, a mobility platform, an integrated payment, a contract/service offer, a common business model and eventually, a service provider. Jittrapirom *et al.* (2017) noted that one of the key characteristics of MaaS is personalization which means using traveler preferences, past behavior and based on it individual recommendations.

Table 2. Overview of MaaS definitions

Reference	Definition
Heikkilä (2014)	System in which a comprehensive range of mobility services are provided to customers by mobility operators
Hietanen (2014)	Mobility distribution models in which a customer's major transportation needs are met over one interface and are offered by a service provider. Typically, services are bundled into a package
Burrows *et al.* (2015)	The provision of transport as a flexible, personalized on-demand service that integrates all types of mobility opportunities and presents them to the user in a completely integrated manner to enable them to get from A to B as easily as possible
Ghanbari *et al.* (2016)	A multi-actor environment that provides seamless door-to-door services for end-users by combining several modes of transportation
Kamargianni *et al.* (2015)	The term MaaS stands for buying mobility services based on consumers' needs instead of buying the means of transport. Via MaaS systems consumers can buy mobility services that are provided by the same or different operators by using just one platform and single payment
König *et al.* (2016)	Multimodal and sustainable mobility services addressing customers' transport needs by integrating planning and payment on a one-stop-shop principle
Mukhtar-Landgren *et al.* (2016)	A service that not only integrates a range of mobility services, both public and private, but also provides one-stop access to all services through a common interface (hence creating a seamless customer experience, i.e., the service). The service component could be developed, ranging from simply the possibility to find travel information and pay for different mobility services within one technical system, to providing more far-reaching mobility service offers such as subscriptions to different mobility packages, perhaps also involving other service components such as goods delivery or bicycle repair services
Datson (2016)	The *Catapult Transport Systems* has defined MaaS as using a digital interface to source and manage the provision of a transport related service(s), which meets the mobility requirements of a customer. The [mobility] service model is associated with understanding the "who?" and "why?" of customers' mobility requirements and only then is the transport solution offered as a "how?"
Johansson *et al.* (2017)	IMS mean that in one and the same service, one knits together many ways to move in the city (e.g., car-sharing, bus, tram, commuter train, bike-sharing, private vehicles) while one can offer payment of and information about the modes via one and the same interface. These new mobility services contribute to an increased freedom of choice and a reduced need to own a car, especially in larger cities or metropolitan areas
Kamargianni, Matyas (2017)	… a user-centric, intelligent mobility distribution model in which all mobility service providers' offerings are aggregated by a sole mobility operator and supplied to users through a single digital platform
Smith *et al.* (2017)	… services that facilitate traveling from A to B by different means of transport … the services can be anything from a multimodal travel planner to a full mobility subscription. The services can also include transport of goods as a complement to personal mobility. The common starting point is that the services should inspire and attract travellers to more sustainable travel and to reducing private car dependency
Harris (2018)	MaaS offers customers personalized access to multiple transport modes and services, owned and operated by different mobility service providers, through an integrated digital platform for planning, booking and payment
MaaS Alliance (2023)	… the integration of various forms of transport services into a single mobility service accessible on-demand
MaaS Alliance (2016)	The key concept behind MaaS is to put the users, both travellers, and goods, at the core of transport services, offering them tailor-made mobility solutions based on their individual needs. This means that, for the 1st time, easy access to the most appropriate transport mode or service will be included in a bundle of flexible travel service options for end-users
Van Audenhove *et al.* (2018)	The concept of MaaS aims to provide consumers with integrated, flexible, efficient, and user-oriented mobility services. It implies a shift away from the personal ownership of individual motorized transportation modes, and non-integrated means of transportation towards the use of integrated multimodal mobility solutions consumed as services. This shift is enabled by combining transportation services from public- and private-transportation providers through an "integrated mobility platform" that creates and manages the journey and integrates planning and payment (based on mobility packages tailored to the needs of each customer segment) on a one-stop-shop principle
Zijlstra *et al.* (2020)	… a transport concept integrating existing and new mobility services into one single digital online platform, providing customized door-to-door transport options. Instead of owning individual modes of transport, or to complement them, customers would purchase mobility service packages tailored to their individual needs, or simply pay per trip
Esztergár-Kiss *et al.* (2020)	MaaS is a new transport concept, which integrates, manages, and distributes private and public mobility alternatives by using intelligent digital technologies
Butler *et al.* (2021)	MaaS is an integrated system that through a single online interface enables commuters to plan, book, and pay for trips, which utilize a range of mobility providers
Lopez-Carreiro *et al.* (2023)	MaaS presents a mobility distribution model that integrates all the mobility services of a city, including ticketing, payment, and real-time information. MaaS is driven by servitization, encouraging a move from an "ownership-based paradigm" to an "access-based perspective" of mobility. MaaS is based on a user-centric scheme, providing on-demand tailored solutions according to individuals' needs, preferences, and expectations. MaaS is supplied through a single digital interface, underlining the importance of ICT for its deployment

Sochor *et al.* (2018) mentioned that half of considered definitions of MaaS define it as personalized service, catering the customer needs for planning/booking/paying/executing journeys.

It is a common misconception that personalization and customization would mean the same thing, but the study of Jittrapirom *et al.* (2017) highlighted an important difference. Customization gives users the option to make changes to fit their own needs and preferences. For example, in MaaS, users can choose how they want to travel, like by selecting the modes of transportation they want to use. This allows people to have more freedom, which makes the service more appealing and increases customer satisfaction and loyalty. On the other hand, personalization can be seen as a subset of customization, with the aim of improving user's experience by providing recommendations and solutions that are more relevant and effective for them. The result is a more satisfying and efficient data service that takes into account the individual's unique characteristics and additionally, less interaction efforts in finding the 'configuration items' they are interested in work by Tiihonen & Felfernig (2017). Personalization is the process of tailoring content to each individual user's needs, preferences, and behaviours. AI technologies, such as recommendation systems (Arnaoutaki *et al.* 2021), aid in this process by determining, which items to present to a user.

2.2. Integration levels in MaaS and distribution of MaaS initiatives

According to a number of sources (Kamargianni, Matyas 2017; König *et al.* 2016, etc.), a MaaS ecosystem is brought to life by different stakeholders:

- ***operator*** (MaaS provider), who cooperates with all stakeholders to create a diverse offering for customers;
- ***transport service providers***, who sell their capacity and access to vehicles to a MaaS provider – and share their data; ***technology providers***, who offer MaaS operator data management, analytical capabilities, technological solutions such as journey planning, ticketing, payment, cloud computing and ICT infrastructure;
- ***national and local authorities***, who provide regulations for open standards, interoperable data formats, policy frameworks and recommendations for sustainable development;
- ***end-users***, who consume mobility solutions provided by the MaaS Provider, on individual or company level.

Whereas several academics still debate about these differences, we believe that CM, MaaS and IMS are sharing some principles that could be truly qualified as a MaaS system, in the larger picture. Altogether they convene in offering a "service" with user needs as the focus; "mobility" rather than transport; and "integration" of several transport services, information, payment, and ticketing (Kamargianni *et al.* 2016). There are several taxonomies in that regard with the scope of classifying MaaS platforms according to several levels of "integration" (Table 3). Table 3 includes 2 more popular taxonomies and real initiatives followed it. The 1st suggested taxonomy in research by Sochor *et al.* (2018) is composed of following distinctive levels:

- ***level 0 (no integration)***: service providers offer separate services of transportation mode. There is no data interaction between different transportation modes (e.g., *Hertz*);
- ***level 1 (information integration)***: free, centralized information platform that can provide information comparison and travel recommendations of multiple 5 transportation modes. It helps the user by finding the optimal trip, but only acts as an information aggregator (e.g., *Google Maps*);
- ***level 2 (integration of booking and payment)***: application providing services from multiple operators and helping the users to search, book and pay a single trip via the same interface, but not directly responsible for the passenger mobility (e.g., *Moovit*);
- ***level 3 (integration of service offering)***: application focusing on the users' total mobility needs, rather than solely transportation from one place to another – it includes a MaaS operator taking responsibilities towards end-user and supplier, by delivering the best solutions based on information provided by transport service providers. Data such as user info, mobility patterns and mobility preferences are carefully integrated in the system. Nevertheless, since services of this level mostly depend on regional or local public authorities, it is still difficult to integrate technical information and find politically acceptable contract models (e.g., *Whim*);
- ***level 4 (integration of societal goals)***: ideally, it consists of a unified and flexible MaaS platform integrating local, regional, national policies and goals. In this context, MaaS operators would provide incentives for desired transport modes, to influence the travel behaviour of the user.

From another perspective an increasing level of integration entails a lower cognitive effort from the MaaS user. This latter interpretation introduces a different taxonomy (Lyons *et al.* 2019), based on 5 levels of integration, which tend to evaluate factors such as, emotional effort, familiarity, and predictability, that will eventually determine the adoption of a specific travel behaviour. Therefore, an integration of societal goals can be interpreted as a "modus operandi" that focuses on a more sustainable way of living, in terms of transportation efficiency, accessibility, high integration of data in human-centric manner and environmental awareness. On the other hand, this 2nd type of taxonomy draws attention to the user perspective and in a more particular way, its cognitive effort:

- ***level 0 (no integration)***: transport system is experienced as a series of discrete modes, in which services are separate and minimal;
- ***level 1 (basic integration)***: covers tasks as journey planning and search several different routes across some travel modes;
- ***level 2 (limited integration)***: built upon level 1, it also includes the possibility of purchasing a ticket - with interchange penalties for some transport modes;

- ***level 3 (partial integration)***: allows "some" journeys with multiple modes of transport to be planned, booked and paid through a unique interface, in limited circumstances;
- ***level 4 (full integration under certain circumstances)***: covers the same characteristics of level 3 – some door-to-door journeys cannot be accessed because of limited geographic coverage or transport service issues;
- ***level 5 (full integration under all conditions)***: provides full support of everyone's mobility needs. It supports flexible services that account for frequent short journeys, as well as less frequent longer distance travel with minimum interchange penalties, personalized bundles, and full geographic coverage.

Table 3 shows taxonomy of MaaS and initiatives on different integration levels. The information about initiatives has been compiled using the studies of the following authors: Esztergár-Kiss *et al.* (2020); Sochor *et al.* (2018); UITP (2022); Lopes *et al.* (2023). It is worth noting that only one MaaS initiative, namely Umaji, from Taiwan, has reached the highest level of integration (Table 3).

A more comprehensive overview of existing MaaS applications including a full description their characteristics – integration level, transport modes, location, launch year and status – has been provided in Appendix. Moreover, for a better visualization purpose the authors created an interactive Atlas of MaaS application, accessible at this link: https://htmlview.glitch.me/?https://raw.githubusercontent.com/turnoworks/MaaSAtlas/main/MaaS_Atlas.html.

We can guess that a higher level of integration entails an ever-decreasing effort in engaging not only in the adoption of MaaS systems, but also an increasing ecological attitude and confidence towards PT modes. Hence, from this approach we can observe a superposition of visions, which coincide with the societal goals that we illustrated previously. From this analysis, it follows that only the highest levels of integration give us the possibility for formalizing an inclusive, secure, and adaptive user experience (MaaS Alliance 2023). Because of that, we wish to point out that current MaaS projects often lack high-level features such as personalization and customization, which can make it difficult for users to find the best options for their specific needs.

Table 3. Taxonomy of MaaS and initiatives on different integration levels

Level	MaaS taxonomy according to		MaaS initiatives
	Sochor *et al.* (2018)	Lyons *et al.* (2019)	
0	no integration	no integration	Transport for London (UK); Hertz (US); Sunfleet (Sweden)
1	information integration	basic integration	Moovit (Israel); Qixxit (Germany); Google Maps (US); Arevo (Australia); BlaBlaCar (France); Car2Go (Germany); Bird (US); Mobike (China); Quicko (Brazil); S'hail (UAE)
2	integration of booking and payment	limited integration	Moovel (Germany); MyCicero (Italy); NaviGoGo (Scotland); iDPASS (France); Tuup (Finland); Hanover Mobile (Germany); EMMA-TaM (France); Business Traveller Cards (Holland); Smile (Austria); WienMobil Lab (Austria), Lyft (US)
3	integration of service offering	partial integration	Shift (US); UbiGo (Sweden); Whim (Finland); Citymapper Ride (UK); Compte Mobilité (France); Fluidtime (Austria); GVH (Austria); Mobility Inside (Germany); Modalizy (Belgium)
4	integration of societal goals	full integration under certain circumstances	Umaji (Taiwan)
5	–	full integration under all conditions	–

2.3. Personalization in MaaS

This study is devoted to the aspect of personalization in MaaS. This decision is consistent with the United Nations Sustainable Development Goals (SDGS9 and SDGS11) and is dictated by the desire to meet the following criteria set out by Blom (2000): to provide access to information content; to consider user goals and individual differences; to elicit positive emotional reactions; and eventually to reflect individual identity.

In the heart of the MaaS concept in dimension of personalization is the user (travel) experience. User experience refers to the overall experience and satisfaction that a user has while interacting with service (system). Figure 5 depicts an ideal scenario, in which the complex intertwining of user experience layers forms an integrated system, purposefully designed to cater to diverse user requirements for optimal personalization. The initial level prioritizes activities and context, comprising elements such as individual significance, shareable experiences, and intuitiveness. On the other hand, the 2nd level encompasses more technical features like usability, dependability, and functionality.

1st and foremost, it should be smooth and seamless intermodal travel experience and a MaaS tool alone, without a supportive built environment, will likely not succeed in changing behaviour, whereas on the other hand changing the built environment may lead to changes in travel

Figure 5. Spectrum of user experience

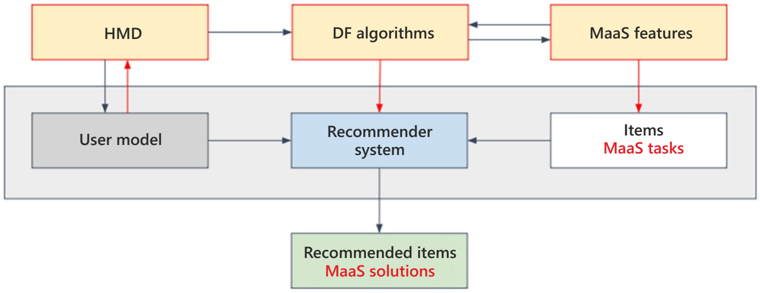

Figure 6. Conceptual MaaS Personalization environment

behaviour even without a MaaS tool (ITF 2021). An ideal MaaS application can be envisioned as a sophisticated platform that incorporates advanced technologies capable of analysing user data to understand their preferences and behaviours. It leverages powerful tools such as collaborative filtering, which offers recommendations based on the positive evaluations of similar users, and content-based recommendations, which are generated by analysing the items the user has previously expressed interest in. This platform would make use of knowledge-based recommenders, which identify relevant items through the application of specific filter constraints (Jannach *et al.* 2010).

So, the main characteristics of MaaS, which relate to the needs and expectations of users, are based on the characteristics defined in work by Jittrapirom *et al.* (2017): integration of modes of transport, tariff choice, single platform, multiple participants, technology use, demand orientation, registration requirements, personalization and customization. The key characteristics of MaaS from a user perspective, as presented in research (Zijlstra *et al.* 2020), result in 5 indicators, namely: travel information, multimodal mind set, choice within modes, tech-savvy and innovativeness.

Tiihonen & Felfernig (2017) proposed architecture for a recommendation environment, consisting of 2 horizontal layers. The 1st layer contains a "user model" module, in which are described user-related information such as needs, preferences, attributes, ratings or explicit requirements; the 2nd module include the "items" (or services), which are characterized by their rating and semantic meta-data; then, a "recommender system" module, which exploits the information of the user model and the item catalogue. The 2nd layer contains a unique module called "recommended items", which derives a ranked list of items that will be presented as the recommendation to the user.

Figure 6 presents a suggested by authors architecture that incorporates the integration of "DF algorithms" within the domain of personalization. The addition of a new component, "MaaS features", has also been incorporated into the design, whose significance will become clearer after a comprehensive explanation of "HMD". Additionally, the concept of "MaaS tasks" has emerged and will become clear afterwards, along with the notion of "MaaS solutions".

Maas Alliance (2019a, 2019b) proposed a set of requirements or best practices, that have fundamental importance to fulfilling individual user needs (Table 4). It is noteworthy, that the main pillars of a candidate application should include safety and security of data and travellers, convenience, accuracy and affordability of travel options, inclusivity and information about risks and environmental impact, and finally customer care.

Arnaoutaki *et al.* (2019) at 1st demonstrated user-focused study and included a suggestion for an optimal MaaS plan that matches the personal needs of the user and offered a filtered and ranked list of MaaS mobility packages. However, it did not include the user experience. The factors focused on the behavioural intention: the ease of use, the choices based on preferences, the feeling of control, and the anticipated enjoyment include and categorize firstly by Schikofsky *et al.* (2020). Esztergár-Kiss *et al.* (2020) considered 30 MaaS tools from 14 countries and suggested next personalization features with following ranks:

- preferable modes;
- stored trips;
- saved locations;
- service alerts;
- route planning preferences;
- traffic information.

Table 4. MaaS applications: user needs and requirements (adapted from MaaS Alliance (2019b))

Safety and security	Convenience	Inclusivity	Customer care
▪ personal data; ▪ data security; ▪ safety during the journey	▪ contract and plans; ▪ seamless transit experience; ▪ flexibility; ▪ accurate display of travel options	▪ inclusive service; ▪ accessibility; ▪ information related to environmental and health benefits	▪ real-time assistance; ▪ information about liabilities; ▪ customer protection in event of insolvency of service provider

It is crucial to provide a clear understanding of the scope of HMD. This term encompasses data collected from various sources related to human movement and transportation and has become a crucial element in the advancement of MaaS solutions. Through the integration of advanced technologies, such as DF algorithms, this data can be analysed and processed to provide a comprehensive understanding of mobility patterns, preferences, and behaviours. This information can then be employed to design and execute personalized MaaS solutions, tailored to meet the unique requirements of each individual user. The sources of HMD are diverse and can include:

- *movement data* – user's mobility data from mobile phone network data, GPS, vehicle data from connected vehicles, including passenger cars, goods vehicles, and different types of survey;
- *transportation sensors* – traditional traffic count sites, Wi-Fi/Bluetooth vehicle counters, cameras capable of registration plate or facial recognition, etc.;
- *socioeconomic data* – demographic data and behavioural analysis, social activity data from smartphone apps, social media content and public/private cameras;
- *transaction data* – from credit cards and ticketing, including PT, taxi, and shared micro-mobility, etc.

Ma & Zhang (2022) addressed the problem of "sparse" HMD, which refers to the difficulty of obtaining complete, accurate and up-to-date information about individuals' movements and activities. This can be attributed to various reasons such as the limited availability of data sources, privacy concerns, and the difficulties in collecting, processing and integrating large amounts of data from diverse sources. The sparsity of HMD can impact the performance and accuracy of mobility-related decision-making processes, such as MaaS, that rely on such information.

Table 5 illustrates taxonomy, based on Zhou *et al.* (2018), to recognize potential "MaaS features" that can be extracted from peculiar data sources. In Table 5, we summarize the following 4 MaaS features most significant for personalization:

- *distance and duration distributions* – to model the probability distributions of certain attributes related to human mobility such as traveling distance and duration;
- *OD matrices* – include traffic volumes between key zones in transportation networks. The values obtained from OD matrices provide valuable insights into traffic patterns and can help transportation planners make informed decisions about how to optimize their networks;
- *individual activity-based mobility patterns* – aim at understanding an individual's daily activities through their visits to various locations. The objective is to categorize these activities (e.g., home, work, shopping). This information can be useful in predicting demand for transportation and other services, as well as personalizing user experiences;
- *individual transportation mode identification* – aims at identifying individual transportation modes (e.g., walking, driving, riding buses). The goal is to gain a better understanding of individuals' transportation behaviour and support transportation planning and management.

A comprehensive analysis of the features in MaaS reveals that tailoring the user experience requires a deeper understanding of individual mobility patterns and preferred modes of transportation. To this end, the most effective features are those that focus on capturing and processing *individual activity-based mobility patterns* and *individual transportation mode identification*. Then, it is apparent that these features provide critical information regarding users' individual habits and preferences, thus, allowing the personalization of their trip. In addition, Table 2 shows a high correspondence between the data sources used for the two MaaS features described earlier. For example, multiple data sources, such as: *social media*, *cellular network*, *mobile phone*, *Wi-Fi*, *GPS trajectory*, *online car-hailing orders*, *AFC*, and *ETC*, can be utilized to analyse human mobility patterns. Nevertheless, AFC and ETC are not crucial for determining a person's transportation modes.

Therefore, *travel recommendation* can be viewed as the main MaaS task in which humans become not only *data users*, but also *data providers* or "*soft sensors*" (Wang, Yang 2019). This task involves the *processing* of individuals' mobility patterns to gain insights into their preferred modes of transportation, preferred routes, and travel times. The information gathered is then integrated with real-time data, such as traffic conditions and current mode of transport, with the aim of providing more accurate, personalized, and efficient recommendations.

One final aspect that can be used to address the problem of Personalization is how to extract valuable knowledge from the HMD from various heterogeneous sources. AI has come in handy with a new collection of methods based on DF. This methodology focuses on the collection, cleaning, processing, transformation, and classification of large quantities of raw data. Moreover, MaaS can be seen as a composite (cyber-physical-social) system, which embeds "cyber-physical" and "cyber-social" intertwined dimensions, built upon the multivariate data sources that users can use and provide (Wang *et al.* 2019). Such conceptualization might help researchers in realizing specific

Table 5. Taxonomy of HMD data (based on Zhou *et al.* 2018)

Data source	Maas features			
	Distance and duration distributions	OD matrices	Individual activity-based mobility patterns	Individual transportation mode identification
Social media data (Mirzaee, Wang 2020)	✔	✔	✔	✕
Cellular network (CDR) data (Farooq, Imran 2017)	✔	✔	✔	✔
Mobile phone data (Jiang *et al.* 2017; Gjoreski *et al.* 2018)	✔	✔	✔	✔
WI-FI data (Li *et al.* 2017)	✕	✕	✔	✔
GPS trajectory data (Gambs *et al.* 2012)	✔	✔	✔	✔
AFC data (Xu *et al.* 2018; Zhou *et al.* 2018)	✔		✔	✕
ETC data (Yang *et al.* 2022)	✔	✔	✔	✕
Online car-hailing order data (Zhang *et al.* 2020)	✔	✔	✔	✔

MaaS tasks such as travel recommendation, based on individuals past trips, constraints (e.g., medical condition, pandemic, road infrastructure), preferences, points of interests and ideal transportation mode. For example, Kuang *et al.* (2014) proposed the use of a mathematical data structure, called tensor, to obtain a multi-dimensional representation of the user and their mobility pattern based on the combination of unstructured, semi-structured and structured data.

3. Identified gaps and challenges

The field of transportation research has increasingly focused on the concept of MaaS, which refers to the integration of various transportation modes into a single service, accessed through a mobile application.

Pagoni *et al.* (2022) describes various challenges to MaaS implementation including technical, regulatory, financial, and social issues, that should be implement in current and future transport policymaking.

After literature analysis we can set up that a significant gap exists in the current literature on MaaS with regards to user personalization. Despite the importance of Personalization in service design, many scientific papers on MaaS primarily focus on technical aspects, such as the development of the MaaS platform, the integration of various modes of transportation, and the use of mobile applications. ***The numerical papers tend to overlook the critical role of personalization in enhancing the user experience and promoting the adoption of the service.*** In addition, despite the proliferation of MaaS platforms, features such as personalization and customization have not yet been extensively implemented or elaborated in current practices (see Appendix for illustration of this gap).

Moreover, significant issues are ***to investigate and develop dynamic personalization issues due rapidly changed transportation landscape.*** Assessing the role of the MaaS concept of smart mobility and in achieving the sustainable development goals, the complex ways in which mobile service providers' offers interact with user demand in real-time are largely overlooked (Wong, Hensher 2021; Hensher *et al.* 2021). Matching supply and demand is critical to improving the efficiency and reliability of MaaS and involves 3 stages:

- forecasting, personalization and stimulation of end-user demand, including real-time user travel patterns;
- integration of the supply side of various mobile services, providers and infrastructure;
- optimization of the mobility system in real-time by matching supply and demand, which requires complex decisions that expand people's limited cognitive abilities (Banerjee *et al.* 2021; Diran *et al.* 2021).

Complex user preferences are influenced by various factors and based on own prioritization. Personalization is crucial in MaaS because users have unique needs, preferences, and behaviours. For instance, some users may prioritize reliability of service (Dinko *et al.* 2022), some - speed and convenience when choosing transportation modes, while others may prioritize cost-effectiveness or environmental sustainability. Therefore, a one-size-fits-all approach to MaaS is unlikely to satisfy all users, and customization is necessary to meet their specific needs. Despite its importance, personalization in MaaS is often neglected in scientific papers. For example, many papers do not explore the factors that influence users' mode choice, such as their income, age, or mobility needs and nor do they provide customized solutions that cater to these different user groups. To address this gap, future research on MaaS should focus more explicitly on user personalization.

Stakeholder engagement is difficult and challenging, but core condition of personalization. The potential benefits of MaaS can be realized only if the requirements of involved actors are satisfied, the needs and expectations of users are met, and the existing barriers are identified and overcome (Polydoropoulou *et al.* 2020). Butler *et al.* (2021) highlighted to design, develop and implement well-functioning service systems, it is important to view MaaS as a complex socio-technical system. It is essential to integrate the needs of different stakeholders, including the needs of the end-users, and enable evaluation of system impacts. Encouraging users to provide feedback, update references and actively participate in personalization features' development is challenging, but absolutely core condition of personalization.

Critical aspect for user experience in MaaS is ensuring users feel safe and secure using service. For better user adaptation we need clear and concise information and the research in that area should identify different user needs, preferences, and behaviours and develop customized MaaS solutions that cater to those needs. For instance, a MaaS service designed for older adults may prioritize accessibility, safety, and ease of use, while a service designed for commuters may prioritize speed and convenience. By providing customized solutions that cater to different user groups, MaaS services can better meet user needs, improve the user experience, and promote the adoption of the service.

Data Integration. MaaS exists only because of its data and requires the collection and integration this data among actors in the broader mobility ecosystem, to provide integrated services (Banerjee *et al.* 2021; Dinko *et al.* 2021). Data are collected from users, public and private mobility providers, and infrastructure (e.g., sensors, traffic lights) (Wu *et al.* 2018). It is necessary also explore complex relationships among different datasets to depict and predict macro trends for the future through its processing by AI algorithms (Liu, Dijk 2022). Nowadays, AI has come in handy with a new collection of methods based on DF. This methodology focuses on the collection, cleaning, processing, transformation, and classification of large quantities of raw data sourced from various heterogeneous sources. Thus, the ultimate objective of this approach will be to extract valuable knowledge from the processed data, which can be used to address the problem of Personalization. Only based on many data sources individual mobility predictions can obtained and provide personalized and anticipatory mobility services and recommendations to end-users.

Inclusivity and accessibility. Mitropoulos *et al.* (2023) concluded as most significant challenges in technical issues: unwillingness to share data; standardization of data among actors involved and data providers and aged travellers that may not be able to access MaaS services. Concerning the problem of data justice, lot of investigations ignore inequalities the certain groups of people use digital devices less than others and there is a lack of data from specific user groups. This way, MaaS runs the risk to facilitate accessibility only for "digital" users and reproduce existing mobility inequalities and injustice in cities, if data collection relies only on digital means (Servou *et al.* 2023).

4. Discussion and future research

The emergence of MaaS is characterized by its complex nature, which includes various interpretations, the importance of customization, and the essential role of HMD. This study highlights the significance of developing MaaS systems to cater to the ever-changing and varied requirements of different types of users.

The concept of MaaS does not possess a universally acknowledged definition. The existence of various interpretations of the term "MaaS" highlights the need for a flexible and adaptable approach in the development of MaaS solutions.

The integration of personalization within MaaS is becoming increasingly important, with the objective of tailoring services to suit the specific preferences, habits, and behaviours of individuals. The proposed architecture for a MaaS recommendation system showcases a novel strategy in attaining a user-centric experience by integrating various levels of user engagement and data analysis.

The utilization of HMD, which incorporates data from diverse digital sources, plays a crucial role in comprehending and forecasting individual mobility patterns. Therefore, it is important to formulate research questions related to personalization in MaaS that require further study. This study should be focused on next:

- *what is the MaaS user experience and how can we collect detailed information about a person's lifestyle and needs?*

  Predicting individual mobility, a feature of the MaaS solution, is challenging due to the dynamic, diverse and sometimes unpredictable nature of human behavior. In addition, the utilization of sensitive information gives rise to apprehensions pertaining to privacy and the security of data. Perhaps synthetic data presents a highly promising solution in the context of developing and evaluating MaaS systems, as it enables the process to be carried out while safeguarding the privacy of individuals involved. The desire to generate synthetic data that accurately reflects mobility behavior in the real world has great potential to improve the efficiency and ethical standards of MaaS systems.

  The introduction of AI, machine learning and specifically deep learning methods in MaaS is imperative for the efficient handling of heterogeneous data and the generation of synthetic data. The integration of such techniques plays a crucial role in ensuring predictable mobility, solving the problem of data scarcity and identifying individual mobility models to provide more individual service recommendations, all of which opens up the potential for further research by the authors;
- *eliminating the scarcity of HMD through synthetic data generation*;
- *defining individual mobility patterns for more personalized recommendations*;
- *enabling MaaS platforms to continually learn and adapt to changing user behaviour and preferences*:

  For this reason, future research should prioritize inclusivity as a fundamental aspect, guaranteeing that

MaaS solutions are fair and easily accessible to all users, including individuals who may face digital exclusion, by not only understanding their distinct travel habits and behaviours, but also value their individuality resulting in a more interconnected, personalized and user-centric urban mobility environment.

Conclusions

This research provides an in-depth examination of MaaS, focusing on the evolving nature of its definition, the critical role of personalization, the significance of HMD, and the development of a comprehensive personalization environment in the MaaS context.

Our investigation acknowledges by presenting a diverse range of MaaS definitions, demonstrating the diversity of perspectives from various researchers and institutions. MaaS interpretations are classified into 3 categories: CM, MaaS, and IMS. Each concept underscores a unique aspect, while CM focuses on combining transportation modes, MaaS emphasizes on service and integration and IMS draws attention on integrating various services through a single application.

Another significant contribution in this research is the study of a potential personalization environment in MaaS applications. We emphasize that MaaS should go beyond simply providing mobility options and should be tailored to individual user preferences, habits, and behaviours. This level of personalization is critical for user satisfaction and loyalty, but it is often underrepresented in current MaaS systems. Our research proposes an architecture for a MaaS recommendation system that includes multiple layers of user interaction and data processing. This environment is intended to provide a seamless and intuitive user experience by leveraging data from various sources, including HMD, to analyse and adapt to user needs and specific requirements.

This research reviews HMD as essential part in personalizing MaaS services. This data includes social media inputs, cellular network data, GPS trajectory data, and other sources. It is critical for understanding individual mobility patterns and preferences, which is essential for effective personalization in MaaS solutions. Moreover, our findings highlight the need for sophisticated data analysis and AI-driven technologies to process HMD, enabling tailored MaaS offerings that meet the needs of individual users.

A practical contribution of this research is the creation of an interactive map of MaaS initiatives (see Appendix). This tool provides a global overview of MaaS applications, detailing features such as integration levels, ranging from no integration to full integration under all conditions, transport modes, and geographical locations. It is a valuable resource for understanding the varying degrees of user engagement, environmental impacts associated with various MaaS systems but also understanding global MaaS adoption trends and identifying gaps in the MaaS ecosystem.

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Author contributions

All authors contributed to the study conception and design.

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The reviewed version of the manuscript and other sections was written by *Irina Yatskiv* (*Jackiva*).

All authors commented on previous versions and the final version of the manuscript.

All authors read and approved the final manuscript.

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Appendix

No	Application	Integration level	Transport mode	Based in	Launch year	Status	Source
1	Arevo	1	train; bus; trams; bike; parking; petrol prices	Melbourne (Australia)	2019	active	*https://arevo.com.au*
2	BerlinMobil	1	car; bus; train, bike; flexible car-sharing	Berlin (Germany)	2019	active	*https://berlinmobil.de*
3	Bird	1	e-scooter-sharing	Miami (US)	2017	active	*https://www.bird.co*
4	BlaBlaCar	1	long-distance ride-sharing	Paris (France)	2006	active	*https://www.blablacar.fr/*
5	Car2go	1	car-sharing	Berlin (Germany)	2008	merged with DriveNow to form Share Now	*https://www.share-now.com*
6	Citen	2	bike-sharing; car-sharing; car renting; taxi; urban PT; regional PT	Paris (France)	2020	active	not available
7	Citymapper	2	bike-sharing; car-sharing; car renting; taxi; urban PT; regional PT	London (UK)	2011	active	*https://citymapper.com*
8	Citymapper Ride	3	PT; ride-sharing; bike-sharing; taxi	London (UK)	2017	active	*https://citymapper.com/news/1887/what-is-smart-ride*
9	Compte mobilité	3	PT (bus and tram); bicycles; car-sharing; parking; e-bikes	Mulhouse (France)	2017	active	*https://www.compte-mobilite.fr*
10	DerbyGo	2	PT (bus and tram); bicycles; cars; parking; e-bikes	Derby (UK)	2021	active	*https://www.derby.gov.uk/news/2021/september/derby-go-app/*
11	Didi Chuxing	2	ride-hailing; ride-sharing	Beijing (China)	2012	active	*https://www.didiglobal.com*
12	Divia Mobilités	2	bus; tram; bike; park and ride; car-sharing	Dijon (France)	2012	active	*https://www.divia.fr/bus-tram*
13	EMOT	2	on-demand shuttles; taxis; buses; car-sharing; bike-sharing	Tokyo (Japan)	2019	active	*https://www.emot.jp/service/detail/romancecar_online.eng.html*
14	Fluidtime	3	bike-sharing; car-sharing; car renting; taxi; urban PT	Vienna (Austria)	2013	active	*https://www.fluidtime.com/en/*

No	Application	Integration level	Transport mode	Based in	Launch year	Status	Source
15	Free2Move	1	car-sharing; car rental; parking with valet services; charging stations	Ulm (Germany)	2016	active	*https://www.free2move.com/*
16	Gaiyo	3	car-sharing; shared scooters; shared bicycles; PT; parking	Utrecht (Netherlands)	2008	active	*https://gaiyo.com/?lang=en*
17	Glimble	2	PT (buses and trams); bike-sharing; car-sharing; taxi; scooter-sharing	Heerenveen (Netherlands)	2021	active	*https://glimble.com*
18	Go-Hi	2	buses; trains; taxis; car hire; car clubs; bicycle hire; ferries; air travel; DRT	Inverness (Scotland)	2021	active	*https://gohi.app*
19	Gojek	2	ride-hailing; ride-sharing; food delivery; courier	Jakarta (Indonesia)	2010	active	*https://www.gojek.com/en-id/*
20	Grab	2	ride-hailing; ride-sharing; food delivery	Singapore (Singapore)	2012	active	*https://www.grab.com/sg/*
21	GVH	3	car-sharing; bike transport; park and ride; bike and ride; taxi	Hannover (Germany)	2004	active	*https://www.gvh.de/*
22	Hvv Switch	2	bus; train; ride; car-sharing	Hamburg (Germany)	2020	active	*https://www.hvv-switch.de/*
23	Imbric	2	taxi; bus; moto-sharing; parking	Madrid (Spain)	2011	active	*https://www.imbric.com*
24	Jak Lingko	2	train; trams; rail; BRT; buses; ride-sharing	Jakarta (Indonesia)	2021	active	*https://www.jaklingkoindonesia.co.id/id*
25	Jelbi	3	bus; train; e-moped; e-scooter; bike; car; taxi; shuttles; ride-sharing	Berlin (Germany)	2019	active	*https://www.jelbi.de/en/home/*
26	Lime	1	bike-sharing; e-scooter-sharing	San Francisco, US	2017	active	*https://www.li.me*

No	Application	Integration level	Transport mode	Based in	Launch year	Status	Source
27	Lyft	2	ride-hailing; ride-sharing	San Francisco, US	2012	active	*https://www.lyft.com*
28	MobiFlow	2	train; bus; tram; taxi; bike; charging stations	Ghent (Belgium)	2017	active	*http://www.mobiflow.be*
29	Mobike	1	bike-sharing	Beijing (China)	2015	active	not available
30	Mobiliteit	2	bicycles; buses; trains; tram; charging points; park and ride; car	Luxembourg (Luxembourg)	2019	active	*https://www.mobiliteit.lu/en/*
31	Mobility Inside	3	bus; train; car-sharing	Frankfurt am Main (Germany)	2020	active	*https://www.mobility-inside.de*
32	Modalizy	3	PT; Car-sharing; taxis; cycling; walking	Vilvoorde (Belgium)	2017	active	*https://www.modalizy.be*
33	Moovit	1	bike-sharing; car-sharing; car renting; taxi; urban PT; regional PT	Ness Ziona (Israel)	2012	active	*https://moovitapp.com/*
34	Moovizy	2	bus; coach; tram; train; bicycle; taxi; car-pooling; cars; car park information; trains	St. Etienne (France)	2016	active	*https://www.transdev.com/en/solutions/moovizy-maas/*
35	Good Move	2	PT; bike-sharing; scooters-sharing; car-sharing; taxi	Brussels (Belgium)	2020	active	*https://mobilite-mobiliteit.brussels/en/good-move*
36	MyCicero	2	urban PT; regional PT; parking; permit for urban congestion charging zones	Senigallia (Italy)	2015	active	*https://www.mycicero.it*
37	Ola	2	ride-hailing; ride-sharing	Bangalore (India)	2010	active	*https://www.olacabs.com*
38	Pick	2	metro; bus; train; ferry; bike-sharing; car transport; parking	Porto (Portugal)	2018	active	not available

No	Application	Integration level	Transport mode	Based in	Launch year	Status	Source
39	Quicko	1	public and private modes (municipal buses); trains; subways; trams; bike-sharing; parking	São Paulo (Brazil)	2018	active	*https://whimapp.com/news/maas-global-enters-brazil-by-acquiring-quicko/*
40	ReachNow	2	PT; taxis; cars; bikes; e-scooter	Hamburg (Germany)	2015	active	*https://www.your-now.com*
41	S'hail	1	metro; tram; taxi; bus	Dubai (UAE)	2017	active	*https://erticonetwork.com/shail-the-first-maas-solution-in-the-middle-east/*
42	Smile MaaS	3	PT; car-sharing; bike-sharing, taxi	Vienna (Austria)	2014	pilot ended	*https://smartcity.wien.gv.at/en/smile-2/*
43	SNCF Assistant	3	train; bus; taxi; car-sharing	Paris (France)	2019	active	*https://assistant.sncf*
44	Tarc	2	train; bus; ride-sharing; car-sharing; scooter-sharing	Louisville (US)	2019	active	*https://www.ridetarc.org*
45	Transit App	2	PT; bike-sharing; ride-sharing; taxi	Montreal (Canada)	2012	active	*https://transitapp.com*
46	Uber	2	ride-hailing; ride-sharing	San Francisco (US)	2009	active	*https://www.uber.com/*
47	UbiGo	3	PT; car-sharing; bike-sharing; taxi	Gothenburg (Sweden)	2013	pilot ended, relaunched in 2019	*https://www.fluidtime.com/en/ubigo/*
48	Umaji	4	buses; DRT; bike-sharing; car-sharing; scooters; taxi; rental cars	Taipei (Taiwan)	2020	active	*https://www.umaji.com.tw/*
49	ViaVan	3	ride-sharing; PT	New York (US)	2017	active	*https://ridewithvia.com*
50	Wegfinder	2	bus; tram; car-sharing; bike-sharing; e-scooter	Vienna (Austria)	2015	active	*https://wegfinder.at*
51	Whim	3	bike-sharing; car-sharing; car renting; taxi; urban PT; regional PT	Helsinki (Finland)	2017	active	*https://whimapp.com*

No	Application	Integration level	Transport mode	Based in	Launch year	Status	Source
52	WienMobil	2	bike-sharing; car-sharing; taxi, urban PT; parking	Vienna (Austria)	2018	active	*https://shop.wienmobil.at/products*
53	Yumuv	3	tram; e-bike; bus; e-scooter; car-sharing	Bern (Switzerland)	2020	active	*https://www.trafi.com/yumuv/*
54	Yuwway	2	bike-sharing; car-sharing; car renting; taxi; urban PT; regional PT	Cergy (France)	2019	active	*https://www.yuwway.com/en/*
55	Zipcar	1	car-sharing	Boston (US)	2000	active	*https://www.zipcar.com*

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