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IMPReSS: A comprehensive method to classify MaaS systems

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ABSTRACT

Mobility as a Service (MaaS) has the potential to improve urban mobility by reducing car ownership and promoting multimodal transport through a single mobility app that provides trip planners, booking, ticketing, and payment for different modes and bundles. However, not all existing MaaS (or potential MaaS) systems provide a fully integrated system. Several authors have proposed different methodologies to assess MaaS integration. However, these approaches have some limitations regarding the scalability or characterization of the systems, making it hard to compare between them, as the current approaches are all incremental. In this work, we propose a new method called IMPReSS, a binary coding approach that assesses several dimensions of MaaS: Information, Multimodality, Payment, Reservation, Subscription, and Societal goals. It allows proper classification and comparison of different systems, using the societal goals as a cornerstone for its evaluation. Also, we propose a complementary scoring system based on the IMPReSS topology. This qualitative and quantitative methodology will allow practitioners and researchers to characterize, identify, and adequately assess transportation services and their potential to become a fully integrated MaaS system. Our results show that mature MaaS systems with public authorities involved, and some often excluded from MaaS discussion systems are ranked higher, while some wrongly called MaaS apps are ranked at the bottom. In summary, it assesses systems from a different and flexible perspective.

1. Introduction

Mobility as a Service (MaaS) has the potential to improve urban mobility by reducing car ownership and promoting multimodal transport through a single mobility app that provides trip planners, booking, ticketing, and payment for different transport modes and in some cases mobility bundles. According to the literature the basic features for an integrated multimodal system to be considered MaaS are clear: "*multiple modes of transport (public and private), one single application, user-oriented approach, mobility packages, real-time information, multimodal journey planner, and payment integration*" (Arias-Molinares and García-Palomares, 2020). Several authors (Arias-Molinares and García-Palomares, 2020; Jittrapirom et al., 2017; Sochor et al., 2018) have already studied the definition and scheme of MaaS. Nonetheless, the impacts of MaaS on mobility and accessibility are yet to be thoroughly analyzed and its concept is still evolving (Lopes et al., 2023).

Several classifications have been proposed to classify MaaS systems, allowing for the differentiation between complete and partial MaaS systems. The first, proposed by Kamargiani (2015), consisted of six incremental levels (regarding the features included): cooperation, integration of ticketing, payment, ICT, and tailored mobility packages. This scheme evolved into the topology proposed by Sochor et al. (2018) and is based on levels of integration to allow a "comparison" of different services and integrate the societal goals in the discussion. It considered *"0, in case of no integration; 1, integration of information; 2, integration of booking and payment; 3, integration of service offer subscription; and 4, integration of societal goals"*(Sochor et al., 2018). Based on this work, other authors proposed different methodologies or scales to qualify MaaS systems, adopting different perspectives and with different objectives (Bandeira et al., 2022; Ho et al., 2021; Lyons et al., 2019).

However, we contend that the incremental nature of these classifications limits the ability to correctly identify a system's characteristics solely by its "level of integration." For instance, according to Sochor (2018), a level 4 classification would mean that such a system encompasses all the characteristics of lower levels, which is not always true. Furthermore, the proposed methods that try to break with this echeloned classification (Bandeira et al., 2022) still give the same weight to all assessed dimensions. Therefore, we identified a gap in how to assess,

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classify and be able to compare mobility services. How do the current classification methods fit the concept of MaaS, given that the MaaS label should probably only be used to describe a fully integrated and sustainable system rather than just an enhanced travel planning app (Hensher et al., 2021). Therefore, this paper aims to propose a comprehensive classification method (designated IMPReSS) for comparison, classification, and clear identification of the characteristics of mobility services while addressing the main dimensions that compose the MaaS concept without the constraints of the bottom-up (incremental) approach.

To reach this objective, Section 2 presents the concept of MaaS and the existing classification schemes and topologies, highlighting their main shortcomings. In Section 3, we describe the proposed classification method in section 4, we apply our proposal to a few selected systems from different countries for illustration purposes. Section 5 discusses our findings, and Section 6 draws the main conclusions of our research.

2. Literature review

While still largely unknown in terms of practical benefits and future consequences, MaaS has gained importance since its first official appearance in 2014 in Finland, promising a “one-fits-all” mobile solution that would, in theory, revolutionize urban mobility (Hietanen, 2014). In simple terms, MaaS is “*a system in which a comprehensive range of mobility services are provided to customers by mobility operators*” (Heikkilä, 2014, p. 8), which stresses the importance of stakeholders' interaction (such as customers and operators). A more detailed definition states that MaaS is “*a concept that integrates existing and new mobility services into one single digital platform, providing customized door-to-door transport and offering personalized trip planning and payment options*” (Durand and Kennisinstituut voor Mobiliteitsbeleid, 2018, p. 3). This definition stresses the importance of the user's needs, the multimodality, and the single interface, while having the potential to reduce car ownership.

While only a few fully integrated MaaS systems operate, several systems or platforms could be considered early or partial forms of MaaS. In general, these ‘partial’ MaaS systems offer some but not all the previously mentioned features and, as such, cannot be considered a complete MaaS system. Two well-known examples are Uber and Google Maps. Uber is a platform that allows users to plan, book, reserve, pay for, and access mobility services, but it is not multimodal nor integrated with other mobility services. Google Maps provides information and trip planning services but lacks other necessary features such as payment integration, mobility packages, etc.

In this sense, several authors have defined classification methods to characterize existing transportation systems regarding MaaS services' integration levels (Table 1). Five aspects are usually included in these systems: information access, multimodality, vehicle availability, payment and booking processes that facilitate access, and the contribution of the existing system to societal goals. All these aspects are assessed regarding their seamless integration into the proposed service.

After the first proposed MaaS classification (Kamargianni, 2015), several authors presented new approaches to help characterize transportation systems regarding MaaS services' integration levels. Sochor et al. (2018) identified four incremental levels and proposed the (to date) most known MaaS topology, encompassing the integration of information, booking and payment, bundle services, and societal values (Table 1). Ho et al. (2021) adopted and extended this topology by dividing level 2 (booking and payment) into two independent levels. These authors realize that the main limitation of existent MaaS initiatives is mainly related to the highest integration level, which is the integration of societal goals.

Alternatively, Lyons et al. (2019) interpreted integration from users' perspectives in terms of cognitive effort. They proposed a topological classification with five levels, with a bottom-up approach, starting from no integration and advancing with the integration of operational information, multimodal information, integration to limited modes, integration to all modes in certain circumstances, and integration to all modes under all circumstances. In other efforts found in the literature, Arias-Molinares et al. (2022) analyzed the different functions or characteristics of different “emerging” MaaS systems worldwide. However, the systems are neither compared nor ranked because of the lack of a comprehensive methodology. Also, they do not consider the systems' societal impact (Lopes et al., 2023). This hinders the ability to be able to identify the characteristics and “completeness” of the mobility services.

Table 1
Current propositions for MaaS integration levels characterization.

Level	Sochor et al. (2018)	Ho et al. (2021)	Lyons et al. (2019)
5	N.A.	N.A.	Full integration under all conditions: Full operational, informational, and transactional integration for all journeys
4	Societal goals integration: Policies, incentives, etc.	Societal goals integration: Policies, incentives, etc.	Full integration under certain conditions: Not all modal combinations available offer a fully integrated experience
3	Service offer integration: Contracts, bundles, subscription, etc.	Service offer integration: Contracts, bundles, subscription, etc.	Partial integration: some journeys offer a fully integrated experience
2	Integration of booking & payment: Single trip-find, book, and pay	Booking integration: No integration, public linking, deep linking, API integration Payment integration: Single to all providers, single to monthly trip	Limited integration: Informational integration across some modes with operation integration
1	Information Integration: Multimodal travel planner, price info	information integration: Multimodal travel planner, price info	Basic integration: Informational integration across (some) modes
0	No integration: single separate services	No integration: single separate services	No integration: No info on operations or transactional integration across modes

These approaches are examples of characterization and classification attempts of MaaS integration levels, but they have limitations. For instance, they rely on incremental and ordinal logic. For example, it is unclear what a level 4 MaaS system means. Does a MaaS system considering societal goals (level 4) encompass all other levels? If so, to what extent? Indeed, this hierarchical perspective hinders its ability to correctly assess systems with characteristics belonging to the higher levels but missing some of the lower ones. Certainly, a system may lack one of the fundamental characteristics (i.e., route information) while incorporating full multimodality integration: most cities' PT cards that include train, ferry, bikes, buses, and metro tickets are good examples. Another example is Uber which allows for single trip booking and payment but has no multimodal planner.

Generally, these topological frameworks provide helpful information about the system and an overview of its development stage or integration level. However, Bandeira et al. (2022) state that the current MaaS integration levels neglect essential dimensions such as geographic coverage and contributions to sustainability. They propose six integration categories: environmental policy, social cohesion, personalization, IT integration, multimodality, and geographic area. The proposed methodology rates each category from 0 to 5 to provide a final score based on their sum, up to 30 points. However, while addressing the limitation of the hierarchical approach, this scoring method weights all dimensions equally, which implies a new limitation as it does not prioritize certain features, such as societal goals, for scoring purposes.

Moreover, the proposed numerical final scores are still hard to interpret, permitting only the numerical comparison between levels. This means that the number representing the level, or score, does not give information about the MaaS-like system's integration characteristics other than their position in a list, nor which category (or categories) is responsible for the final score. When these two limitations are combined, the result is a list that may categorize diverse mobility services as being at the same level, providing a misleading impression of homogeneity but not a straightforward way to assess or fix any discrepancies.

We identify at least three gaps by evaluating existing classification schemes and topologies. First, there is an informational gap, where schemes fail to inform the reader which characteristics belong to the classification method. Second, a cumulative gap when schemes assume that lower-level features are necessarily included in high-level ranked systems. Finally, a relevance gap, where assessment schemes ignore that specific dimensions of MaaS systems are more or less relevant than others.

3. Classification method

One of MaaS′ main objectives is to allow individuals to access relevant opportunities without the need to own a means of transport, thereby transforming mobility into a service that can be used whenever needed. Therefore, accessibility should be a key indicator when assessing a MaaS system. We propose a binary topology, which aims to classify any MaaS and MaaS-like *platforms* by scoring and ranking the system based on its features, dividing them into six features. These were defined based on the literature (Esztergár-Kiss et al., 2020; Ho et al., 2021; Kriswardhana and Esztergár-Kiss, 2023; Storme et al., 2021) but placed in an specific order related from the most simple to the most complex feature: (I) Information access, (M) Multimodal options included in the system, (P) Payment within the app (seamless), (Re) booking or Reservation capabilities, (S) Service subscriptions, and its association with (S) Societal goals and values. The tool was named after its features' initials: IMPReSS.

For simplicity, a Boolean classification awards 1 or 0 to each category whether the system includes the corresponding features. The symbology representing the classification is a binary sequence of six digits. Each position represents a feature rendering values between 000000, meaning a "zero" MaaS system, and 111111 for a full MaaS. This approach fills the gaps presented in chapter 2, as it clearly informs the reader which feature is available or missing on each system; it is not cumulative as having a higher-ranked feature does not imply that lower ones are included; and it allocates a different weight to each feature depending on its position within the binary chain.

The sequence of the features within IMPReSS was defined in ascendant order of implementation complexity and systemic relevance; the further to the right, the more its implementation is complex, and its systemic relevance increases. First, the most common and widely available feature among mobility apps is the provision of (I) information about transport supply, such as departure times, stops, charging stations, etc., and trip planning suggestions. In the second position, we placed the integration of (M) multimodal networks, which considers the number of modes available, followed by the option of (P) paying for (individual) services with the app.

The fourth position refers to the possibility of (Re) reservation and booking different modes, including on-demand transport. Next, we placed the availability of bundles or (S) subscriptions, given the complexity of agreeing on margins and fees with the different providers and integrating subsidized and market-driven services in the same package, which also requires to consider city specific conditions or even tailored bundles based on the travel patterns (Esztergár-Kiss and Kerényi, 2020; Kriswardhana and Esztergár-Kiss, 2023), we assume that if the system offers bundling options it means that it has already solved the contracting, tariffs and fees issues with the operators involved. Finally, whether the system contributes to achieving transport-related (S) societal goals, which is simultaneously the most systemically relevant feature and complex to implement. The method proposed aims to classify any MaaS and partial MaaS system according to their features.

Table 2 presents a practical guide or criteria for coding each feature. We propose a question for each feature for which a positive answer awards '1' (True) or '0' (False) for a negative reply. For the multimodal category, we included public transport as a requirement for awarding "1". Accordingly, Hensher et al. (2020, p. 6) state that *"if public transport is to be at the heart of MaaS, then we need to create circumstances where is it natural for public transport to seamlessly integrate with first and last mile solution."*

According to IMPReSS, a full MaaS system would be a platform that provides real-time user information and multimodal trip planning options: seamless booking; unified payment; integrated ticketing; within a collaborative environment between public and private actors; and active commitment towards societal and collective agendas. The classification system proposed aims to score the systems based on their capabilities but does not address their performance. Hence the user experience or satisfaction is not being considered, which we discuss further in a later section.

Additionally, this ordered notation allows to easily identify what is missing and what's not by just looking at the binary sequence. For instance, a 010111 system means that the platform lacks booking & reservation feature in the digital platform (hereafter referred to as 'app') and that there is no involvement of the public authority, for a comprehensive understanding of the method we developed the infographic presented in Fig. 1. This qualitative approach has the potential to become a powerful planning tool as it highlights what do systems need to become a full-MaaS.

We argue that the closer a system is to a full-MaaS (111111) the better it will provide a comfortable and equitable mobility service to the user. It could be used by different stakeholders to identify exactly was missing or not on each system. Also, independent organizations could use it as benchmark, and it can tell cities how close they are to a full-MaaS and possibly to meet the expectations of their transport policy goals (Orozco-Fontalvo and Moura, 2023) or simply used by users to choose the most convenient option.

3.1. Preliminary completeness score proposal

As one of the flaws found in the current MaaS topologies is related with the impossibility to compare different systems, we propose a preliminary "completeness score" to be able to do this directly. Note that the qualitative classification (i.e. the binary chain) is the essential aspect of IMPReSS, allowing to identify immediately which of the six essential MaaS features are present or absent. This proposal is a complementary step for IMPReSS, that harnesses the order of complexity of the binary chain to our advantage, it is based on the idea that each system have a different level of completeness towards a full-MaaS and that some dimensions are more "important" than others as explained in the previous section.

After applying the IMPReSS scheme, we convert the binary sequence into a decimal number using its positional notation. We must multiply each bit by its corresponding power of 2 and then sum up the results. The mathematical equation for this conversion is:

$$IMPReSS_{decimal} = s_2 \bullet 2^5 + s_1 \bullet 2^4 + re \bullet 2^3 + p \bullet 2^2 + m \bullet 2^1 + i \bullet 2^0 \quad \text{Eq.1}$$

, where i is 1 or 0 if Information features are included in the MaaS system or not,

m is 1 or 0 if Multimodality features are included or not,
p is 1 or 0 if Payment features are included or not,
re is1 or 0 if Reservation or Booking features are included, or not,

Table 2
Features description.

Complexity/Relevance order	Feature	Question
1	Societal goals and values	Are local, regional and/or national policies and goals integrated into the service?
2	Service subscription	Does it offer more than one subscription option?
3	Booking & Reservation	Is it possible to book within the app?
4	Payment (Seamless)	Is it possible to pay within the app?
5	Multimodal options	Does it include public transport and other modes?
6	Information access	Does it include a multimodal trip planner, providing different travel alternatives?

Information access	Multimodal options	Payment (Seamless)	booking or Reservation	Service subscription	Societal goals and values
1 (included)	1 (included)	1 (Included)	0 (absent)	1 (included)	0 (absent)

Fig. 1. Example of an IMPReSS classification.

s_1 is1 or 0 if Subscription Services (bundling) features are included or not, and
s_2 is1 or 0 if Societal goals features are included or not.

To increase the ranking's intelligibility, we normalize the IMPReSS decimal by dividing by 63 the maximum possible IMPReSS score for the full-MaaS system, i.e., 111111. The IMPReSS score (I_S) indicates a MaaS completeness level calculated by Eq. (2).

$$I_s = \frac{IMPReSS_{Decimal}}{63} \qquad \text{Eq.2}$$

As an example, if a system obtains an 001110 IMPReSS binary, it means it lacks (I) in-app user information, but provides (M) multimodal services, (P) in-app seamless payment options, (Re) the possibility to book a ticket. Still, it does not offer (S) service bundles, such as subscriptions, and is not aligned with (S) collective and societal goals. For scoring and ranking, the binary sequence is converted into decimals (001110 = 14) for a final score or position of 14/63, or 22.2% of a "full MaaS system."

This proposal main limitation is that it needs validation to adequately define the formula specification and the weights of each dimension. Even though, we present this preliminary proposal to highlight the importance of allowing comparison between systems, expecting that other researchers would further explore this assessment or propose a different approach. For instance, instead of a geometric progression, we could have a linear combination of weighted dimensions that would be calibrated with a multicriteria analysis approach involving stakeholders and experts.

4. Results

To demonstrate the usefulness of IMPReSS, we applied it along with other classification schemes (see section 2) to MaaS platforms or "emerging" MaaS systems currently operating in different countries and compared the results. The application of IMPReSS allows more flexibility in describing the MaaS systems' functionalities. In some cases, it has no benefits compared to other ranking schemes. However, there are cases in which functionalities are not cumulative, and our proposed method presents some advantages. In this sense, a few operational transport integration solutions, or -MaaS-like systems, worldwide were selected to illustrate the application of the IMPReSS MaaS classification system.

4.1. *Comparing IMPReSS to other schemes*

4.1.1. *UbiGo (Stockholm)*

An example of a MaaS system to which IMPReSS brings limited benefits is the Swedish UbiGo service. The UbiGo was a MaaS initiative that started in Stockholm (Sweden). It offers a routing app with multiple transport modes (bus, metro, train, carsharing, rental, and taxi), an in-app payment and booking system, and mobility packages and subscriptions that permit limited personalization. There are no integrated incentives for customers to align with environmental or societal goals. According to Sochor et al. (2018) integration levels, UbiGo scores 3/5 (Table 3), 4/4 according to Lyons et al. (2019) scale, and 15/30 (overall 0.50) according to Bandeira et al. (2022). Finally, the IMPReSS classification is 011111.

In this example, IMPReSS clarifies which features are encompassed

Table 3
Comparing existing MaaS topologies with IMPReSS.

		Sochor/Ho	Lyons	Bandeira	IMPReSS
MaaS-like system	UbiGo (Gothenburg)	**3**	**4**	2.4.5.2.1.1(0.50)	011111
	Uber	**1** (+ lv 2, 3 items)	**2** (+ lv 3 items)	4.1.3.3.2.1(0.46)	001100
	Navegante (Lisbon)	**0** (Lacks lvs 1, 2)	**2** (Lacks lvs 1, 2)	2.3.2.1.1.5(0.46)	110010
	LexyPass (Helsinki)	**2** (Not multimodal)	**2**	1.3.3.1.1.1(0.33)	001101

Note: "lv" stands for level.

by UbiGo, or not, i.e., it does not include societal goals. Also, IMPReSS performs better at spotting more easily where the gap is. Conversely, it does not add value in identifying gaps in the hierarchical nature of other classification systems (hereafter referred to as a "Hierarchical gap"), as there are no missing in-between features.

4.1.2. Uber (international)

Uber is an international app-based mobility giant that offers point-to-point routing solutions with integrated payment and seamless booking. It operates in dozens of countries, covering both rural and urban settings, but is limited to unimodal routes based on a selection of motorized private vehicles, including privately hired rides, ride-sharing options, e-scooters, and bikes (in some countries). This MaaS-like system does not provide any incentives toward societal or environmental goals.

Uber's setting is sufficiently complex, and Sochor/Ho and Lyons' classification methods do not classify this MaaS operator adequately due to its "Hierarchical gap." Bandeira's system scores Uber as 4.1.3.3.2.1 (0.46), clearly stating the important geographic dimension of Uber and its weak multimodality capability and lack of societal and environmental engagement. The IMPReSS classification is 001100, highlighting Uber's limitations regarding multimodality, even though the system allows in-app payments, reservations and supplying customers with some mobility packages (limited to the supported transport modes).

4.1.3. Navegante (Lisbon)

Lisbon's transit card, Navegante, provides access to all public transport modes with a single smartcard (including bike-sharing, buses, trains, trams, metro, and ferries), offering pay-as-you-go, daily tickets, and monthly subscriptions for an affordable price. It also provides free rides for students under 25 and elders (over 65), and it is aligned with the policies of the "Transporte Metropolitano de Lisboa" the transport public authority of the city. However, it does not give *in-app* user information (trip planning) or booking solutions.

IMPReSS classification would be 110010, while it would score an inconclusive score or even a zero, according to Sochor/Ho. Navegante has a clear societal orientation (which translates into a Sochor 4 score) while lacking basic dimensions, such as supply or routing information and booking capability. Lyons' score is also inconclusive (approximately 2) since it provides limited integration across some modes with operation integration but lacks all informational aspects. Bandeira would score Navegante 2.3.2.1.1.5(0.46). Importantly, Bandeira's scores for Navegante and Uber are similar (both at 0.46) but have very different characteristics, with Navegante being more sustainable and equitable.

4.1.4. LexyPass Helsinki

Another illustrative case is the Helsinki LexyPass service, which provided (in November of 2021) a real-time routing app that covers the region of Helsinki with limited modal combinations (only public transport) and allows for single trip payments and booking. The system claims to promote diminished sustainable footprints. Still, no active engagement solution exists (other than the customer's intention to use public transport included in the MaaS system).

The scores for both Sochor/Ho and Lyons' classification systems are also complex due to the non-hierarchical nature of MaaS features. They would both rank LexyPass in level 2. Due to its lack of societal goals integration and its impossibility of connecting customers and service operators via bundles or subscriptions (the two most relevant dimensions), IMPReSS classification for LExyPass is 001101.

4.1.5. Summary

IMPReSS brings a better understanding of all MaaS capabilities, as it clearly states the hierarchical gaps among the features addressed, which is unclear in Sochor/Ho and Lyons' classification systems. It also explicitly includes the relative relevance of MaaS features. Also, IMPReSS is more transparent on whether MaaS-like systems integrate seamlessly with societal goals (e.g., incentives to choose active mobility over motorized, full geographical coverage, or discounts to socially excluded groups and minorities, etc.) and therefore are more complex and advanced.

Among the selected systems (Table 3), Navegante seems the most complete because of its alignment with societal goals (including economically disadvantaged groups and exclusive incentives towards public transport usage), even though it was not even considered in the existing topologies. Our method allows to identify that Navegante has the most complex features, and it would be quite simple for it to become a full-MaaS just by adding information, payment, and reservation.

4.2. Application of the ranking system

To illustrate the flexibility of this ranking proposition, we classified 20 MaaS-like transport systems worldwide. The results are presented in Table 4, as expected companies who have all the assessed features are ranked first, followed by the ones with local or national policies integrated in the system (societal goals), this ranking clearly favor companies with more complex features.

With this additional step, IMPReSS ranking could solve the problem identified by Bandeira's false equivalence, where two systems present the same score. Within IMPReSS, equal scores mean systems with equal conditions.

Regarding the results, Ubigo scored 49% because it lacks societal goals, whereas Transport For London scored 87%, both have one feature missing but the impact is significantly different in the score. This is why IMPReSS is useful as it does not value what is making a system run but rather what it is running for. This also makes sense as in the end Ubigo was a pilot and ended a few years back, while systems who were awarded a 1 in societal goals are still running to this date – 12 out of our sample of 20 systems. One of the systems who were awarded a 100% was ZUM, a relatively new system created by the start-up Meep involving both the public authority and private operators, proves that deploying a complete MaaS system is also possible in small cities.

5. Discussion

IMPReSS allows practitioners and researchers to characterize, identify, and adequately assess transportation services and their true potential to become a fully integrated MaaS system by identifying improvement opportunities. The proposed classification method also facilitates governance decisions, one of the prominent voids in MaaS literature, and incentivizes companies to climb the "ladder." The simplicity and objectivity of IMPReSS also brings flexibility and communication easiness to intermediate decision-making processes of private/public enterprises and public participation. In the end, for MaaS

Table 4
MaaS-oriented transport systems currently operating (non-exhaustive list).

MaaS	Country	City	IMPReSS	Decimal	Completeness	Infographic
Umaji	Taiwan	Taipei	111111	63	100%	
Whim	Finland	Helsinki	111111	63	100%	
Wikimove	Germany	Bamberg	111111	63	100%	
Jelbi	Germany	Berlin	111111	63	100%	
ZUM	Spain	Zaragoza	111111	63	100%	
Transport for London	England	London	110111	55	87%	
Navegante	Portugal	Lisbon	110010	50	79%	
Moovit	USA	San Francisco	101111	47	75%	
Cowlines	Canada	Vancouver	101011	43	68%	
Ualabee	Argentina	Buenos Aires	101011	43	68%	
Mobilitatsshop	Germany	Hannover	100011	35	56%	
WienMobil	Austria	Wien	100011	35	56%	
XXImo (Radiuz)	Netherlands	Utrecht	011111	31	49%	
Umo Mobility	USA	San Diego	011111	31	49%	
Ubigo	Sweden	Gothenburg	011111	31	49%	
Bolt	Estonia	Tallinn	001110	14	22%	
Freenow	Portugal	Lisbon	001110	14	22%	
LexyPass	Finland	Helsinki	001101	13	21%	
Uber	USA	San Francisco	011100	12	19%	
City Trips	Spain	Barcelona	000011	3	5%	

to fulfill its potential, it must show value in both sustainability (social and environmental) and profitability to be attractive to public authorities and private investors.

The main contribution of this paper is the classification tool, which from a qualitative approach fills the gaps of current MaaS topologies, however, as we dig deep and analyze each of the dimensions, it is possible to visualize that sublevels need to provide more detail about the system's structure (and perhaps consider the user experience). Nevertheless, this would increase the scheme's complexity making it more information-greedy, which to date, given the stage of most MaaS systems, would be impossible to obtain. This is especially true in the societal goals dimension as the actual impacts of these MaaS-like systems on accessibility, equity (Di Ciommo and Shiftan, 2017), and the environment are yet to be measured or identified.

The binary approach presents an explicit limitation, as it falls short of defining "to what extent?" a dimension is incorporated (in the case of a score of 1). For instance, in the societal goals dimension, some might argue that Uber deserves to be awarded a "1" given its geographic coverage and that it undoubtedly increases accessibility (Li et al., 2022). However, evidence corroborates that such ride-hailing services boost externalities like congestion (Tarduno, 2021), and pollution or exclude some population segments (Liu et al., 2020; Tirachini, 2020). At the same time, Whim has a "1" in the Societal goals category. However, besides changes in accessibility levels, it is working closely with the municipality and encouraging sustainable modes, which could mean a "solid 1" or higher than one.

The proposed method refrains from over-complicating the assessment in this stage, given that most systems are just initiatives or startups with little information available for a detailed score. Nonetheless, efforts to define detailed sub-levels are already being conducted, enabling a more detailed classification when more information, data, and impact results become available. Regarding the ranking proposal, we acknowledge the need for validation, which we will address in future works by conducting a Delphi study.

The "societal goals" category is the most difficult to classify, as no quantitative studies of MaaS impacts exist. However, there are some efforts (from some companies) to show their intention toward societal goals (CO_2 emissions, health conditions, awareness). Nonetheless, in the end, there are no clear incentives for choosing sustainable modes, which means people still choose their mode and route based on individual (and not collective) utility maximization. This is why we adopted the same criteria as Sochor et al. (2018) for awarding a 1 as presented in Table 2.

As a complementary step, we have put forth a scoring method aimed at facilitating the comparison of MaaS systems. It is important to note that this method is only a preliminary proposal and has a few limitations. We presented it with the intention of initiating a discussion and encouraging further development. The main limitation lies in the assignment of weights to the various features, which increases exponentially as we move towards the right in the binary number. We assert that assigning a significantly higher weight to the rightmost features may be justifiable given the complexity involved in achieving those levels. However, we recognize the importance of validation from experts and stakeholders, as there is currently no available evidence on how to appropriately weigh each dimension in the classification system in order to generate a final score.

As the scoring system and its results are in a preliminary stage, there are three main limitations. First, the results are based on a non-exhaustive list of systems to be assessed, meaning there is still space for expansion. Second, the binary assessment was adopted to guarantee an easy-to-read topology. However, there is still space for a more detailed evaluation, by adopting sublevels (e.g., instead of 0 and 1, the systems could adopt levels, such as (0) not included, (1) partially included, and (2) included), which can be addressed in future developments. This approach would increase the complexity of the method making it more information-greedy, which to date, given the stage of most MaaS systems, such information would be too difficult to obtain. Hence, our method could evolve along the development and information availability of MaaS systems. Third, it does not incorporate aspects associated with the user's experience, as it is focused on objectively and directly measurable characteristics of MaaS systems. This qualitative-oriented assessment might be useful when MaaS planning is committed to addressing users' well-being issues and to a more participatory approach, which impacts the equity (Di Ciommo and Shiftan, 2017) and willingness to use the service (Pangbourne et al., 2020; Tsouros et al., 2021).

6. Conclusions

The IMPReSS method proved to be a valuable tool to analyze different systems and identify opportunities for improvement by classifying and assessing both established and emerging MaaS systems and new and traditional mobility trends transitioning towards integrated services. This procedure was based on the previous MaaS classification schemes studies found in the literature and works as a complementary tool for providing a more comprehensive assessment. We evidenced that some dimensions are more important to reach an equitable MaaS and that different systems have different degrees of MaaS "completeness" but that it is not necessarily incremental. Existing topologies fail to identify and correctly assess these systems.

In addition to the theoretical contributions stemming from the conceptual debates surrounding the core components that make up a MaaS, the proposed classification scheme has the potential to assist in clearly distinguishing between complete and "emerging" or "aspiring" MaaS systems (Hensher et al., 2021), as well as recognizing their benefits. It can also aid decision-makers in evaluating the completeness of existing services, facilitating policymaking and regulation. Also, it proves that there exist transport services that could become a full-MaaS with small interventions and these are frequently disregarded when talking about MaaS, as is the case of Lisbon's Navegante who already has the more complex dimensions covered. Finally, it provides researchers with a tool for discussing the benefits of shared mobility services and comprehensively comparing them.

IMPReSS framework could also become a baseline for the classification of not only MaaS but also other transport systems such as smart or mobility hubs, who also face similar challenges in terms of integration, comparability, and assessment.

For future developments, the classification method should be extended by including different aspects that define in a more precise manner each feature that go beyond the binary approach if a more specific assessment is needed, e.g., payment and validation options, route criteria definition, specific modes included, etc.; on the other hand, the ranking system should address user satisfaction and willingness to use as criteria for scoring the MaaS system, also considering add-on services such as food delivery or vouchers could be integrated. Validation from stakeholders is also needed to provide adequate weights to the different features.

CRediT authorship contribution statement

Mauricio Orozco-Fontalvo: Conceptualization, Methodology, Writing – original draft. **André Soares Lopes:** Investigation, Writing – original draft. **David Vale:** Funding acquisition, Validation, Writing – review & editing. **Filipe Moura:** Conceptualization, Supervision, Writing – review & editing.

Data availability

No data was used for the research described in the article.

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