MaaS Platform Features: An Exploration of their Relationship and Importance from Supply and Demand Perspective

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Abstract

Mobility as a Service (MaaS) aims to offer travelers easy and convenient access to transportation modes via a joint digital channel, often in a mobile application. MaaS has the potential to fundamentally change the way we commute as it encourages a more sustainable travel behavior. MaaS, as a business model, is an innovative concept that integrates a variety of these solutions and can significantly change the mobility environment by encouraging sustainable travel behavior. Despite the existing initiatives and efforts toward MaaS solutions, there is still no consensus on the essential features of MaaS platforms for actors from the supply and demand sides. This study explores the critical features of MaaS platforms from the perspective of mobility service providers - MSP (i.e., supply-side) and travelers (i.e., demand-side). We collected data via interviews with mobility experts for the supply side and a survey for the users' side. Based on a Gaussian Graphical Model, our results show that optimizing the number and use of the vehicles and appropriate data handling are the essential features of a MaaS platform for the MSPs. For the travelers, although retrieval of personal information and enhancing services, such as suggestions on local events and concert tickets, are expected, they are considered less significant. Our study provides insights into the features of MaaS platforms through synthesized and prioritized features - including their relationships - which would be helpful both for research and practice.

Keywords

Mobility as a Service, Requirements, Centrality Network, Partial Correlation Network, Urban Mobility

1. Introduction

Incremental technology advantages have created a digital-based economy where services like e-commerce platforms, digital health services, online distance learning portals, and mobility-related services are changing transportation needs and preferences (Vij et al., 2020). Due to the emerging demands, city authorities face many interconnected demographic, public health, and environmental challenges, such as climate change, traffic congestion, air pollution, and growing population (Zhao et al., 2020). Innovative mobility solutions based on the shared mobility concept have shown that they can address some of the mobility challenges of cities toward a sustainable society (Sochor et al., 2018). The increase in collaborative provision and consumption of shared mobility services demonstrates the shift from an ownership-based to an access-based economy (Shaheen et al., 2017; Vij et al., 2020).

Mobility as a Service (MaaS) is an integrated model of transportation. It can be described as 'systems
[that] offer consumers 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’ (Vij et al., 2020). It is a technological and social phenomenon that includes technical artifacts, processes, services, and business models (Mladenović & Haavisto, 2021) MaaS is expected to be a major disruptor of the mobility ecosystem (Polydoropoulou, Pagoni, & Tsirimpa, 2020), as it integrates various solutions and can significantly change the mobility environment by encouraging sustainable travel behavior (Reck et al., 2020), reducing traffic, and decreasing CO₂ emissions (Zhao et al., 2021). Despite the abovementioned potential benefits, there are uncertainties related to the societal implications, technology applicability, and social embedding of MaaS systems (Mladenović and Haavisto, 2021).

Besides the MaaS operators, Mobility Service Providers (MSPs) and end-users (i.e., commuters) hold the most critical roles in the core business of the MaaS ecosystem (Esztergár-Kiss & Kerényi, 2020). The end-users represent the demand side, expecting to use the commuting services. Furthermore, MSPs offer mobility-related services and expect added value in profits or societal/public gains. Therefore, MSPs represent the supply side, implementing and supplying MaaS platforms with various mobility services (Polydoropoulou et al., 2020). The integration and unified service provisioning is the responsibility undertaken by the MaaS operators, which are between the supply (i.e., MSPs) and demand (i.e., travelers) (Kamargianni et al., 2018). MaaS operators combine the offering of various MSPs and offer the integrated service often through a single interface -aka the MaaS platform- allowing the users to plan, use, and pay for their commute (Polydoropoulou et al., 2020). Therefore, the growth of the MaaS market is highly dependent on MSPs' and the end-user's acceptance of the MaaS platforms (Esztergár-Kiss & Kerényi, 2020). Fig 1. presents the three main MaaS stakeholders and their primary value exchange relationship.

![Fig 1. The three main MaaS stakeholders and their primary value exchange relationship.](image)

The potential of MaaS depends on various aspects, such as the integration of service-related information across different transport models through a single digital interface (Vij et al., 2020), the business models,
scalability, data privacy, and security of the user acceptance (Jittrapirom et al., 2017). Given these considerations, the development and implementation of MaaS is a complex task (Karlsson et al., 2020). Therefore, it is unclear how and into what configuration these objectives can be translated into the requirements and addressed in a single MaaS platform. The requirements are the necessary functions and features for designing, implementing, and operating a MaaS platform based on the diverse expectations of travelers, MSPs, and other stakeholders.

As an emerging phenomenon, academics have investigated different aspects of MaaS features, such as how transport system models can be incorporated to support the design of MaaS services (Musolino et al., 2022), consumer requirements and motivations (e.g., willingness to pay) (e.g., (Polydoropoulou et al., 2020; Feneri et al., 2020), or the expectations of mobility operators to join a MaaS platform (Vij & Dühr, 2022). Existing literature mainly focuses on identifying MaaS features by investigating end-user and (to a lesser extent) MSPs requirements in isolation, meaning without investigating their importance, relevance, and connection between and with other features. Adopting a network approach can give more valuable insights into the more central network features, have more connections, and bridge other features. Therefore, the objective of this exploratory study is (i) to identify relevant requirements for MSPs and end-users and cluster them under specific domains, and (ii) to identify the relationships and relevance of these domains for the design of a MaaS platform.

To address our research objective, first, we extracted features (i.e., requirements) from the literature. We grouped the requirements into Features Domains, fitting them on either the supply or demand side. Next, we elicited MSP-related MaaS requirements and performed an online survey to elicit travelers’ preferences on certain functionalities. Survey participants were asked for their preferences on the MaaS platform’s features for travelers. To capture the perspective of MSPs on requirements relevant to the supply side, we interviewed MaaS experts. We followed an exploratory analysis to understand how the requirements and variables are related. This explorative study can support MaaS operators and other stakeholders in identifying and implementing features based on their importance as travelers and MSPs perceive.

The rest of this paper is structured as follows. Section 2 provides a detailed description of our research design. Section 3 discusses the identified requirements clusters (under the label feature domains). Section 4 presents our analysis and findings regarding MSPs and end-users, and we discuss them in Section 5. Finally, we discuss the policy implications, limitations, and future research.

2. Research Design

We followed a four-step research approach. First, we performed desk research on literature (2017-2021) discussing MaaS features and requirements. Additionally, we reviewed the grey literature (i.e., practice-driven works, such as white papers and reports) and examined the features of the platforms implemented
by existing MaaS initiatives. We formulated search queries using a set of selected keywords, namely, 
("MaaS" and "MSPs") ("MaaS" and "mobility" operators), ("MaaS" and ("travelers' or "end-users"), 
("MaaS" and ("features" or "requirements" or "functionalities"). While reviewing the papers, the 
keywords string changed based on the relevant terms we found in the literature. In total, 40 research 
papers were found and analyzed. Additionally, we were interested in reviewing the features of existing 
MaaS initiatives. We focused on 12 initiatives, as discussed in Jittrapirom et al. (2017).

We clustered the requirements gathered from the literature based on two main MaaS stakeholder types: 
MSPs and travelers. Accordingly, we grouped the features into Feature Domains. Furthermore, for 
confirmation, we checked whether the identified feature domains are implemented in existing MaaS 
initiatives. Jittrapirom et al. (2017) reviewed twelve existing MaaS initiatives and indicated their 
functionalities. We compared our results and concluded that the features are implemented in existing 
MaaS initiatives and cover sufficient Feature Domains.

To better understand the features, we interviewed mobility experts in an online setting. We presented 
them, the Feature Domain, and features relevant to the MSPs. We asked them to indicate the services 
they consider as crucial for a MaaS platform. We provided the experts with a set of statements 
corresponding to each feature for each Feature Domain. The experts expressed their opinions regarding 
MaaS features that they find important (or less important). We target experts with 5-15 years of 
experience on relevant topics. Apart from their working experience, these experts were chosen as they 
were involved in a number of national and EU-funded projects focusing on designing, developing, and 
piloting MaaS platforms. During the interviews, we explicitly asked them to consider the preferences of 
a variety of possible suppliers on a MaaS (rather than reflecting solely their practical experience).

Furthermore, we developed a questionnaire to obtain data from a broader range of travelers/commuters 
for the features targeted at the travelers (demand side). The survey was distributed to the respondents 
through online platforms. As MaaS is not a well-known concept, a figure and accompanying text 
introducing the concept of MaaS platforms were included on the cover page of the questionnaire 
(Appendix: Introductory text and figure regarding MaaS in the survey). The questionnaire had 11 sections. 
One of these sections included questions concerning demographics, and the remaining sections were 
based on the Feature Domains and included statements relevant to the features. The link to the survey 
developed in Google Forms) was shared via social media (e.g., LinkedIn). The survey was conducted in 
February 2021. Before disseminating the survey, a pilot test was conducted to verify the completeness 
of the questionnaire. In retrieving our participants, we focused on the Netherlands for four reasons: 
the public transportation system is well advanced, (2) the mobility services and concepts such as shared 
mobility are of high interest, many services are already developed and offered, (3) MaaS initiatives are 
already under development, and (4) the majority of the Dutch population is extensively familiar with the
use of mobile apps \(^1\).

For the data analysis, we included ten variables reflecting the Feature Domains. For the data analysis, we calculated the composite scores for each respondent and investigated the priorities of the Feature Domains. Furthermore, we investigated the relationships between Feature Domains that are Planning (my trip), Remember me, Payment, Booking (my trip), Ticketing, Share my trip, Help me (Assistance), Rate my trip, Enhanced service (I want more services), Non-Functional Requirement (Quality attributes).

To explore the relations (or the lack of) between the Feature Domains and their importance, we adopted a network perspective. We estimated a partial correlation network (a.k.a. Gaussian Graphical Model) using the qgraph statistical analysis package (Epskamp et al., 2012). The partial-correlation network shows correlations between pairs of nodes after controlling for the influence of all other variables in the network. A network comprises nodes representing variables (i.e., Feature Domains) connected by edges. Section 4 provides the details regarding the data analysis and our findings.

**Participants Profile**

Regarding the supply side, we interviewed five experts in an online focus group setting. The experts were practitioners from the industry (consultants from international private companies). Two experts were innovation consultants, one innovation manager, one R&D director, and one was innovation strategist. They have 5 to 15 years of experience on mobility-related projects. Four out of five participants argued that MaaS is a business opportunity, while one asserted that it is not clear to them whether MaaS is a business opportunity or not.

Table 1 presents the demographics of the survey. During the data collection, Dutch residents were discouraged from commuting by public or shared transportation during the data collection period due to the ongoing pandemic. The pool of active participants using MaaS platforms was significantly dropped. Eventually, data from 71 participants were analyzed. Most participants (37%) were between 18- and 34 years old. The majority of the participants lived in areas (58%). The majority of the participants argued that they are moderately familiar with MaaS as a concept, the transportation means of their choice, the most used transportation mode is the car, followed by bicycles, walking, and finally, public transportation.

Table 1. Demographics of the Survey. Percentages are rounded to the nearest integer.

<table>
<thead>
<tr>
<th>Age</th>
<th>Residency Area</th>
<th>Familiarity with MaaS</th>
<th>Public transport usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>18-34</td>
<td>37 Urban</td>
<td>Not at all familiar</td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td>34 Suburban</td>
<td>Slightly familiar</td>
<td>Once to several times a week</td>
</tr>
<tr>
<td>55+</td>
<td>29 Rural (including villages)</td>
<td>Somewhat familiar</td>
<td>Once or several times a month</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderately familiar</td>
<td>Several times per year</td>
</tr>
</tbody>
</table>

3. Feature Domains

3.1 Demand side

Table 2 presents the features and related domains for the demand sides. Focusing on the travelers, specific Feature Domains, such as planning (Sakai, 2019) (Sakai, 2019; Yeboah et al., 2019), ticketing (Mukhtar-Landgren & Smith, 2019; Wong et al., 2020), booking (Pangbourne et al., 2020), and payments (Vij et al., 2020) are considered essential for any MaaS platform. Studies have emphasized the importance of customization in the design of MaaS offerings (Vij et al., 2020). Personalized packages based on city characteristics, environmental, usage, and financial features are also considered essential aspects of a MaaS design (Ashkrof et al., 2020; Esztergár-Kiss et al., 2020; Jittrapirom et al., 2017). While the mentioned above are well established, other attributes are of interest too. Help me refers to forecasts, travel history reports, accessibility support, etc. (Jittrapirom et al., 2017; Reck et al., 2020). Ratings (e.g., of the service quality) is another feature domain considered relevant (Ashkrof et al., 2020). The ability to share the trip with specific people and on social media platforms is another that is considered. Recently, the need for enhancing services offered via MaaS platforms has also been pointed out. Some of these services are related to booking accommodation close to the users’ destination, information on touristic attractions, festivals, and other events (Turetken et al., 2021), as well as the ability to participate in the platform not only as a user but as a service provider too (Ashkrof et al., 2020). Finally, the quality attributes are critical when designing any digital artifact, as they describe ‘how well the system shall perform or offer its functionalities’ (Eckhardt et al., 2016). We defined ten feature domains that grouped the identified features.
Table 2. MaaS features related to the demand side – Travelers.

<table>
<thead>
<tr>
<th>Features Domains</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning (my trip)</td>
<td>Departure times, Arrival times, Departure time change, Location selection, Directions to a location, Route favorites, Transfer time, Accessible transportation, Walking distance, Traffic changes.</td>
</tr>
<tr>
<td>Personalization (Remember me)</td>
<td>Cost, Time, User ratings, Transport mode, Environmental impact, Weather situation, Subscription allowance, Previous travels, Linked with calendar, Response’s personalization.</td>
</tr>
<tr>
<td>Payment</td>
<td>Single tickets, Pay-as-you-go, Mobility subscriptions, Payment terminals, Debit/credit schemes.</td>
</tr>
<tr>
<td>Booking (my trip)</td>
<td>Ticket confirmation, Coupons, QR-/barcodes, Tip, Anonymous/person-bound tickets switch, Ticket change, Ticket cancelation, Ticket refund.</td>
</tr>
<tr>
<td>Ticketing</td>
<td>Ticket/time slots, Use-restricted filters, Joint journey discount, Offer comparison (providers), Offers comparison (mobility subscriptions), Travel class, Seating options, Age group, Discount offers, Single ticket for all, Business to business payment.</td>
</tr>
<tr>
<td>Share my trip (in social media)</td>
<td>Trip sharing.</td>
</tr>
<tr>
<td>Assistance (Help me)</td>
<td>Journey changes notification, Departure time reminder, Step-by-step guidance, Text-to-speech directions, Offline navigation, Reporting an issue, Rating reminder, Audio function, Distinguishable pattern for color blind, Customer service via phone, Appropriate usable size, Customer service via live chat, Customer service via social media.</td>
</tr>
<tr>
<td>Rate my trip</td>
<td>Overall journey, Rating visible, Rate individual parts.</td>
</tr>
<tr>
<td>Enhanced service (I want more services)</td>
<td>Adapted travel options based on rating, Adapted travel options based on past travels, Entertainment booking, Accommodation booking, Event tickets purchase, Based on events tout recommendation, Tour plan recommendation, Recommmunication on the return trip, Car insurance subscription via an app, Facilities exploration, Travel insurance, Mobility service provider sign up.</td>
</tr>
<tr>
<td>Non-Functional Requirement (Quality attributes)</td>
<td>Quick response, Predictable response, Easy to learn, Easy to use, Unauthorized access protection.</td>
</tr>
</tbody>
</table>

3.2 Supply side

Table 3 provides an overview of the identified features and related domains for the supply side. Transportation refers to the requirements related to the number and types of necessary vehicles per case. For instance, Jittrapirom et al. (2017) indicate that it is essential to identify the optimal vehicles for a given transportation model and the best location for the cars for optimal usage. Another feature related to transportation is the possibility of alternating the offered services (UNECE, 2020), features that support the improvement of utilization of the transportation assets (MaaS Scotland, 2018) and features that allow the determination of needed vehicles for a specific event.

The analysis refers to the features that enable the analysis of users’ data for improved services, such as the user demand, the users’ response to prices and quality (Jittrapirom et al., 2017), the key performance indicators (Hernández et al., 2020) and the analysis of complaints about improved services. The management feature domain refers to the features that support service providers in managing their value.
creation, capture, and delivery. These features can help service providers to improve the traffic flow and traffic management (UNECE, 2020), optimize the existing infrastructure, to manage the parking places (and whether different parking places are necessary), manage to charge locations, and estimate insurance rates (MaaS Scotland, 2018). The interaction with the environment includes features such as the collection of insights to improve safety (MaaS Scotland, 2018), the communication between providers for decision-making processes (Turetken et al., 2021), air pollution level, and carbon emissions (Banister, 2008). The quality attributes (i.e., non-functional requirements) should also be considered for the supply-side perspective.

Table 3. MaaS attributes and entities related to the supply side – MSPs

<table>
<thead>
<tr>
<th>Features Domains</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>Optimal number of vehicles, Vehicle relocation for optimal usage, Changes in available services, utilization of transport assets, Number adjustment based on events.</td>
</tr>
<tr>
<td>Analysis</td>
<td>Users’ demands, Users’ response to prices, Users’ response on quality, Calculation of KPIs, Complaint analysis, Filtered results of the study based on the need.</td>
</tr>
<tr>
<td>Management</td>
<td>Traffic flow improvement, Traffic Management, Improvement of existing infrastructure, determination of the need for extra parking places, determination of the need for extra charging places, Insurance rates, management of existing parking places, management of existing charging places.</td>
</tr>
<tr>
<td>Interaction with the environment</td>
<td>Safety improvement, Communications with other providers, Data on air pollution, Data on carbon emission.</td>
</tr>
<tr>
<td>Quality attributes</td>
<td>Quick response, Predictable response, Unauthorized access protection, Easy to learn, Easy to use.</td>
</tr>
</tbody>
</table>

4. Analysis and Findings
4.1 Demand side (End-users)

Table 4 presents the means and standard deviations of the ten FDs based on composite scores. The highest scored Feature Domain was quality attributes (non-functional requirements), (μ=4.51, σ=0.38) with relatively low uncertainty. Quality attributes are essential to ensure the usability and effectiveness of the entire system and increase user satisfaction. This indicates that travelers value non-functional requirements equally or even more than functional requirements (Eckhardt et al., 2016). Planning booking and payments were ordered higher than the rest regarding the Feature Domains. This is in line with the arguments that these attributes are essential for successful user adoption (Sakai, 2019; Yeboah et al., 2019).

At the same time, the rating system had the highest standard deviation among all features but with a relatively lower mean. This shows that the agreement among the participants on whether it is an important feature was low. Sharing their trips on social media was ordered as the least essential feature, followed by enhancing services. Both might be related to privacy issues due to the involvement of third parties (Ghazinour & Ponchak, 2017). This highlights the importance of a user-friendly platform where users can provide their inputs to the system (e.g., rating system, sharing) with features planning, booking,
and payments to improve user experience. The rest, well-established Feature Domains ‘Help me,’ ‘remember me’, and ticketing did not rank as high as hypothesized.

### Table 4. Standard deviations and Means of the Features Domains.

<table>
<thead>
<tr>
<th>Features Domains</th>
<th>Mean</th>
<th>Standard Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistance (Help me)</td>
<td>3.67</td>
<td>0.62</td>
</tr>
<tr>
<td>Booking (my trip)</td>
<td>4.06</td>
<td>0.45</td>
</tr>
<tr>
<td>Enhancing Services (I want more services)</td>
<td>2.76</td>
<td>0.74</td>
</tr>
<tr>
<td>Non-Functional Requirement (Quality attributes)</td>
<td>4.51</td>
<td>0.38</td>
</tr>
<tr>
<td>Payment</td>
<td>3.87</td>
<td>0.62</td>
</tr>
<tr>
<td>Personalization (Remember me)</td>
<td>3.38</td>
<td>0.55</td>
</tr>
<tr>
<td>Planning</td>
<td>4.25</td>
<td>0.36</td>
</tr>
<tr>
<td>Rate my trip</td>
<td>2.90</td>
<td>0.99</td>
</tr>
<tr>
<td>Social Media (Share my trip)</td>
<td>1.59</td>
<td>0.62</td>
</tr>
<tr>
<td>Ticketing</td>
<td>3.81</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Next, the survey data was analyzed to examine the network structure of the Feature Domains, their relationships and significance within the network. Fig 2. presents the partial correlation network of the feature domains. The size of the nodes corresponds to the nodes’ strength. Wider and more saturated nodes indicate partial correlations further away from zero. The absence of a line implies no or very weak relationships between the relevant items or variables (Epskamp et al., 2018). If the partial correlation is zero, no connection is available between the two variables. The absence of a connection indicates that these variables are independent, and that one variable cannot cause the other. Considering our content sampling size, we need to control the network’s sensitivity (true-positive rate) specificity (true-negative rate). Sensitivity increases with the sample size. However, a moderate sensitivity is acceptable as the strongest edges are discovered. In low specificity, edges that are not present might be detected (i.e., false positives). To address the issue of false positives and retain only meaningful associations, we applied a Lasso regularization (Epskamp & Fried, 2018) that shrinks small partial correlations, setting them to zero, so only the most robust partial correlations remain visible (McNally, 2016).

We can see that the strongest relationship is between enhancing services and social media. Furthermore, booking features and ticketing are closely linked. Planning and features related to previously stored data (‘remember me’) are well connected. On the contrary, the booking feature domain is not associated with the ‘remember me’ or payment domains.
Fig 2. Partial Correlation Network displays the relationships between Features Domains. Feature Domains are illustrated as nodes. Wider and more saturated lines indicate stronger partial correlations: Planning (PL), Remember me (PE), Payment (PA), Booking (BO), Ticketing (TI), Social Media (SO), Help me (AS), Ratings (RA), Enhancing Services (EN), Non-functional requirements (NF). R package qgraph was used.

To further investigate how vital the nodes are in the network, we used centrality indices, namely strength, closeness, and betweenness (Epskamp & Fried, 2018; Opsahl et al., 2010). Centrality indicates which nodes are more 'central' (Freeman, 1984). In strength centrality, we consider the edge weights (Newman, 2004). Strength centrality\(^2\) is calculated by taking the sum of all absolute edge weights of a node that is directly connected. Strength centrality denotes the sum of the weights (e.g., correlation coefficients) of the edges connected to a node. Therefore, a node with high strength is likely to activate many other nodes and may be a good target for 'intervention' (Fried et al., 2017). However, strength centrality only estimates the direct ties and does not consider the network as a whole or an indirect connection. A way to address the whole network is to estimate the betweenness and closeness centrality. Closeness centrality\(^3\) takes the inverse of the sum of distances from one node to all other nodes in the network. The higher the closeness centrality\(^3\) value is, the closer the node is to other nodes in the network. Betweenness centrality\(^4\) indicates how often a node is in the shortest paths between other nodes. A node with high betweenness centrality may influence the information passing between other nodes; therefore, it is critical to the network (Epskamp & Fried, 2018). A node with high betweenness centrality\(^4\) is of an essential role in the network, and the relationship with the other nodes have between them.

\[ S_{\text{strength}}(i) = C^D_B (i) = \sum_j^n W_{ij} \] where \( W_{ij} \) is the weighted adjacency matrix, in which \( W_{ij} \) is greater than 0 if the node \( i \) is connected to node \( j \), and the value represents the weight of the edge (Opsahl et al., 2010).

\[ S_{\text{closeness}}(i) = \left[ \sum_j d(i, j) \right]^{-1} \] (idem).

\[ S_{\text{betweenness}}(i) = \frac{g_{jk}(i)}{g_{jk}} \] where \( g_{jk} \) is the number of binary shortest paths between two nodes, and \( g_{jk}(i) \) is the number of those paths that go through a node (idem).
Fig 3. presents the centrality indices plots for the Features Domains' estimated network (nodes) regarding strength, betweenness, and closeness. Regarding centrality strength, we can see that the *remember me* feature domain has the highest strength indicating that it is directly connected with most other feature domains. Regarding betweenness, the χ-axis shows the number of shortest paths through a node. Regarding closeness, the χ-axis indicates the inverse of the sum of distances from one node to all other nodes in the network. R package qgraph was used. This indicates that it plays an important role in the network, and its activation has the strongest influence on the other nodes in the network. The payment, ratings, and quality attributes on the lowest centrality strength.

*Remember me* has the highest betweenness value meaning that it acts as the main bridge connecting the feature domains. Enhancing services and 'help me' follow with equal betweenness. We see that payment, ratings, and non-functional requirements do not serve as a bridge in the communities within the network. Finally, closeness centrality indicates that 'remember me' Feature Domains have the highest value again, meaning it is the Feature Domains with the most direct and indirect connections. Ticketing follows close by. Once more, payment and ratings have the lowest.

**4.2 Supply side (MSPs)**

As previously mentioned, regarding the demand side, we conduct interviews with experts. We presented them, the FDs, and features relevant to the MSPs. We asked them to indicate the services they consider as crucial for a MaaS platform. We provided the experts with a set of statements corresponding to each feature for each FD. The experts expressed their opinions regarding MaaS features that they find important (or less important). We asked them to place each statement on a scale from 1 (not important)
to 5 (important).

Regarding transportation, the experts indicated that determining the optimal number of vehicles for a given transportation mode and supporting the relocation of the vehicles to a location for optimal usage is of high importance. Additionally, four experts indicated that changing or altering the offered services is essential. All experts agreed that a successful MaaS platform should consider events at a specific location and adapt the number and the site of the provided vehicles. The above features can increase MSPs' attractiveness, decrease market fragmentation, and facilitate commuters' freedom of choice (Boijens et al., 2021). When the experts were presented with user data analysis statements, they all agreed that the users' demand data must be analyzed and presented via the platform.

The experts stated that it is critical for a MaaS platform to have features that allow the analysis of the users' response to the service quality and their complaints and to be able to calculate performance indicators. That indicates that the data-sharing agreements between the actors are critical (Kamargianni et al., 2018). The experts do not find features related to the management equally crucial to the features of the previous two categories. From the options we provided, the statement that they find more important is related to the performance optimization (possibly for the same reasons they find the transportation domain important).

Furthermore, the experts indicated support for the charging infrastructure and parking places within the area of interest. Regarding the interaction of the platform with the environment domain, the experts denoted that it is relevant for MaaS platforms to provide features that help improve safety by including insights from places where the accident happened. Additionally, the experts suggested that the platform support close communication between the service providers (MSPs).

However, two statements related to the environmental impact: 'air pollution and 'carbon emissions,' are not considered essential features of a MaaS platform by the service providers. A reason for this might be that the experts do not consider that the services related to renewable energies would enable business model innovation (Athanasopoulou et al., 2019) and therefore considered less essential for the MSPs.

Finally, the experts indicated their views on the essential quality attributes. There was a consensus on ease of use. Other critical quality attributes are the quick response to the inputs (performance) and ease of learning. The final quality attribute considered necessary was security: protecting against unauthorized access to the platform and its data. Again, as with end-user data, privacy policies and data protection for MaaS platforms and their MSPs are considered highly important (Kamargianni et al., 2018).
5. Discussion

5.1 Supply side (MSPs)

Based on the interviews with the experts, we created and proposed the final version of the MaaS features important for the MSPs 28 features grouped in five feature domains, as seen in Fig 4. We ordered the features based on the score given by the experts for each feature domain.

Fig 4. MaaS feature domains and features (supply-side). The features are placed (top to bottom) based on the experts’ importance for each feature.

5.2 Demand-side (End-Users)

The network is characterized by a firm edge between social media and enhancing services. The second strongest edge is between booking and ticketing, while planning and remembering me are also strongly connected. Help me and enhancing services also have a strong connection. On the contrary, the network is characterized by weak connections between Help me, social media and ratings, payments, ticketing, and enhancing services. Remember me has the highest betweenness and strength centrality, indicating that, while it is ranked relatively low on importance, its absence could negatively affect the use of a MaaS platform for the whole network.

The results hint that the travelers do not highly value remember me (e.g., login account, previous session inputs saved, recommendations), but they do expect some form of personalization elements when using a MaaS platform (e.g., login page, store of language, and billing currency). The centralities of booking and ticketing were relatively high, confirming the existing literature (Pangbourne et al., 2020) on their importance. Payment has the lowest centrality, which might relate to the travelers’ demographics, such as their cultural background or age. In a study conducted by the European Central Bank (European Central Bank, 2021), 24% of the Europeans indicated that they prefer to pay cash which in some countries, that percentage exceeds one-third of respondents (e.g., in Germany, Cyprus, Austria). Even in countries where the participants prefer cashless transactions, such as in the Netherlands, for older consumers, or low-
cost transactions (as it can be considered a public transport ticket), cash is the preferred means of payment (van der Cruijsen et al., 2017). Our graphical model and the centralities indicate that the help me feature domain is medium to high centrality, with higher betweenness centrality than other feature domains. This might strongly affect perceived accessibility and transportation mode choice, even after including personal information (Scheepers et al., 2016).

5.3 Contributions and Policy Recommendations
This work contributes to the field of MaaS platform design and implementation by synthesizing, prioritizing, and uncovering the relationships and importance of MaaS platform requirements. The findings of this paper can be helpful for MaaS stakeholders, such as the mobility service providers, MaaS operators, or governmental authorities willing to participate in the MaaS ecosystem. More specifically, the results provide insights into the relationships and influence of well-established MaaS platform features on each other based on the preferences of the commuters and service providers. Our results can support stakeholders involved in the MaaS development projects by providing statistical-based insights via the centrality network (Reck et al., 2020). For instance, our results indicated that while environmental awareness and sustainability are essential (Storme et al., 2021), aspects of the environment and surroundings were considered less important for the MSPs. Furthermore, the findings deliver a better understanding of what MaaS platforms features commuters care about and thus how the involved stakeholders can create and deliver value to the stakeholders. Our results can support decision-makers regarding the design of MaaS platforms in addressing end-users’ preferences. By revealing the consumer expectations, MaaS operators and other stakeholders can design MaaS platforms that are more relevant and attractive to the commuters and potentially contribute to sustainable mobility efforts.

5.4 Limitations and Future Work
This research study has several limitations. First, the study included a limited number of participants from a certain geographical location. Further work should focus on validating the findings of this exploratory research with a larger and more representative sample size. It will be interesting to replicate the study in a more significant part of the population, located in different areas and with diverse characteristics, transportation habits, and cultures. While our study is the first to indicate relationships between the feature domains, a larger size will allow a stronger and better investigation of the relationships (or the absence of) within the features domains and between the features.

Additionally, more experts could help provide more conclusive results generalizable to a larger target stakeholder group. All involved in several MaaS initiatives, the experts we chose have already presented some patterns. However, a larger pool of experts would provide stronger evidence for the conclusions reached in this research study. Furthermore, the participants of the focus group meetings might have
reflected the views and preferences of international private companies. In the future, data should be collected that reflect the preferences of local companies and other stakeholders, which might prioritize the features differently.

Another limitation regards the limited number of stakeholder types we investigated. For our study, we only focused on the MSPs and travelers and did not investigate the platform requirements from the perspective of MaaS operators or other involved stakeholders, such as cities and governmental bodies. Hence, a similar analysis should be repeated in the future to elicit the requirements and priorities of different users or stakeholders to provide a complete picture of the main features of a MaaS platform.

Furthermore, we assumed that there is one type of end-user. However, previous research identifies different types of travelers, such as car shedders (i.e., users trying to give up car ownership for economic reasons), car accessors (users that do not own, are planning to buy but are not sure if they need it), simplifiers (no car owners, various mobility options users), and economizers (not car owners, public transport users) (Sochor et al., 2018). Future research should investigate if the requirements differ per different types of end-users.

This study implicitly assumed that travelers would use a MaaS app. However, we did not consider the features that could convince travelers to use MaaS and onboard the MaaS platform (e.g., a new app, new account). Aligned with the study by Zijlstra et al. (2020), a future study focusing on these features could answer whether users would like to use a single app for their trips to different counties or install a new app when visiting new places. It would be interesting to investigate the features of the existing platforms that the users dislike (and make them uninstall the apps). Answers to these questions can be significant for both academics and practitioners. This would allow them to uncover specific aspects of MaaS platform design that are important or valuable.

Future research can also focus on the MaaS-related business model innovation (Turetken et al., 2019). While we assume that stakeholders prefer features aligned with their business (and, therefore, their business models), it is not always clear what business model patterns and performance indicators should be used for added value from MaaS. This is especially evident when considering the motives behind a user's frequent use of the platform and choosing one service provider over the other. Future research considering the above views could lead to additional requirements for MaaS platform development and contribute to the emerging literature on the topic (e.g., Bocken et al., 2020; Boer, 2022; Polydoropoulou, et al., 2020).

6. Conclusion

This study explores the main features of MaaS platforms, including their relative importance and relationships. We focused both on the supply and demand side. While a ‘solution that fits all’ MaaS platform cannot be developed, our results provide strong indications of the main features essential for the main actors of the supply and demand side. Additionally, as end-users perceive, we further illustrate
the associations between the main features

Mobility experts expressed their preferences regarding the features of MaaS platforms. Accordingly, the features concerning the transportation modes and data analysis are considered the most important for MSPs. By exploring the MaaS features with the mobility experts, we present a categorization that groups relevant features into features domains and places them based on the scores indicated by the experts from most to least important. Industry stakeholders, academics, and other actors can use our findings to initiate discussions regarding MaaS initiatives considering the preferences of MSPs. Different actors can also use our findings to collaborate on the re-design of MaaS platforms, apps, and services. Furthermore, our work can trigger discussions on the more advanced services and features that can be implemented in the future.

Our results confirmed that booking, ticketing, and planning are essential for any MaaS platform. Additionally, we identify that the travelers value the non-features requirements higher than the Feature Domains because users prefer an easy-to-use app over a hard-to-learn platform with multiple features. From the results, we can understand that travelers do not find it essential that enhancing services (e.g., suggestions on events) be offered via a MaaS platform, but discounts and coupons for enhancing services should be offered during the booking and payment. Network analysis was used as it provides insight into the structural relations between the core MaaS features, and it has the potential to inform and trigger discussions among the involved stakeholders regarding the importance of specific MaaS features.

Acknowledgments
[Removed for reviewing process]
Appendix: Introductory text and figure regarding MaaS in the survey

Mobility as a Service

Mobility as a Service (MaaS) is the integration of, and access to, different transport services (such as private transport, public transport, ride-sharing, car-sharing, bike-sharing, scooter-sharing, taxi, car rental, ride-hailing and so on) in one single digital mobility platform. Through this platform it is possible to plan your trip, receive traffic information and pay for your travel. Examples of mobility as a service platforms are the NS reisplanner and Google Maps. The first image shows the purpose of mobility as a service. The second image shows the Google Maps example. In this image you see that there are different transportation modes available to choose, like your private car or public transportation.

Bibliography


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