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MAASiFiE

Technology for MaaS

Deliverable Nr 5

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Executive summary

Internet-based and wireless technologies enable the main requirements for the provision of mobility services. Having identified the operational and business-related requirements resulting from the state-of-the-art analysis done within Work Package 3, Deliverable 5 highlights technological aspects including potentials and opportunities to be considered for the deployment of MaaS. Based on expert interviews, together with literature findings, a detailed analysis of required technologies for MaaS was conducted.

As the deployment of MaaS strongly relies on the provision of ICT technologies, the main focus within this deliverable was placed on related requirements, although user requirements (e.g. usability aspects and service design) were also discussed. Already employed technologies within MaaS and MaaS-related services were identified. All technology-related findings helped to develop a comprehensive MaaS system architecture, presented in this deliverable.

Required technologies along the value chain starting from data generation up to the final end-user service provision are studied in more detail. For instance the provision and integration of different mobility data sources open the way towards high quality MaaS systems. Therefore access to data is a main requirement presented in this document that highlights several state-of-the-art strategies. 'Open' data market places and the harmonized deployment of data standards are enablers for MaaS services, to mention but a few. Going one step further in the value chain, integrated service provision requires a comprehensive analysis of existing technical solutions, approaching the conceptual idea of implementing the one-stop-shop principle.

Technical solutions that are already mature and would give a major added value to MaaS service generation are analysed and reviewed in this document. This includes for instance the idea of interlinking different services by their subscriptions, supporting the provision of open application interfaces to developers and/or using common web-service standards simplifying the processes of integrating and combining different proprietary services.

Beside the elaboration of the MaaS system architecture and its technical requirements, the use of wireless networks as infrastructural requirements for MaaS allowing the seamless accessibility to mobility services is analysed. Both advantages and disadvantages in terms of availability for MaaS within different regions are discussed. For instance, new telecommunication technologies, like 5G, enabling an even higher quality service experience to users (based on e.g. higher data rates), seem to be promising for the extensive use of MaaS. Since mobile telecommunication provides an enabling key technology allowing individual access to information and digital services, new opportunities for digital transport service provision are highlighted. Both the telecommunication and transport industries show similar characteristics in approaching linking cross-border transport and mobile network services. In this respect, roaming requirements use other 'foreign' transport but also telecom providers, here discussed in the MaaS context.

An overview of prevailing technologies relevant for MaaS, dealing with data, service but also wireless network requirements, is presented. Wherever information could be derived from the state-of-the-art analyses, key technologies were assessed and opportunities highlighted.

In the final part of deliverable 5, recommendations derived from the resulting technology requirements are presented. Based on the main requirement issues, recommendations can be used as supporting implementation guidance for stakeholders, clustered into the following themes: Open Data-related specifications, Wireless Communication networks, Standardisation/Regulation/Management requirements and Licensing.

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1 Introduction

The trans-national research programme “**Call 2014: Mobility and ITS**” was launched by the Conference of European Directors of Roads (CEDR). CEDR is an organisation which brings together the road directors of 25 European countries. The aim of CEDR is to contribute to the development of road engineering as part of an integrated transport system under the social, economical and environmental aspects of sustainability and to promote co-operation between the National Road Administrations (NRA).

The participating NRAs in this Call are Finland, Germany, Norway, the Netherlands, Sweden, United Kingdom and Austria. As in previous collaborative research programmes, the participating members have established a Programme Executive Board (PEB) made up of experts in the topics to be covered. The research budget is jointly provided by the NRAs who provide participants to the PEB as listed above.

1.1 MAASiFiE project

Mobility as a Service for Linking Europe (MAASiFiE) is a two-year project that investigates the prerequisites for organizing user-oriented and ecological mobility services in order to provide consumers with flexible, efficient and user-friendly services covering multiple modes of transport on a one-stop-shop principle. In addition, the project examines the opportunities of combining passenger and freight transport operations, especially with respect to urban delivery and distribution in rural areas.

The project is organised in five work packages (Figure 1). The Roadmap 2025 for MaaS in Europe to be defined in WP2 is the main expected result of the project and can be considered as an umbrella for exchanging information, contributing and interacting with activities related to work packages 3, 4 and 5 (Figure 1). WP2 is performed in a series of four workshops held in three European countries – Austria, Finland, and Sweden – with the following themes:

- Creating a MaaS vision,
- Impact assessment based on existing cases,
- Building a Roadmap 2025, and
- Implementation and consolidation of MaaS.

The roadmap includes roles and responsibilities of different stakeholders, and legal enablers and challenges.

WP3 analyses state-of-the-art and future trends of MaaS including multimodal traveller information services, ticketing/payment systems and sharing concepts. It also analyses MaaS value networks, and develops business and operator models.

WP4 performs socio-economic and environmental impact assessments of MaaS and proposes a set of key performance indicators of MaaS.

WP5 analyses technological requirements and interoperability issues of MaaS, and gives recommendations supporting technical deployment of MaaS systems.

The project is coordinated by VTT Technical Research Centre of Finland Ltd., and the consortium partners are AustriaTech, Austria, and Chalmers University of Technology, Sweden. The steering committee consists of Asta Tuominen from the Finnish Transport Agency and Clas Roberg from the Swedish Transport Administration.

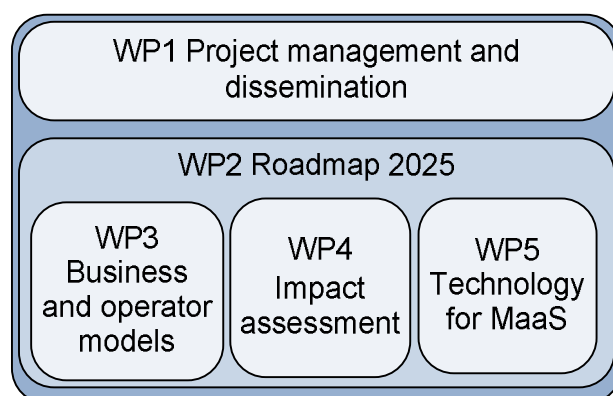


Figure 1: MAASiFiE Work Package structure.

1.2 Overview of WP 5 activities

Deliverable 5 presents technical requirements for the evolution of MaaS. Based on the results of the state-of-the-art analyses, required technologies for rolling-out MaaS, even on a large scale, were identified. Stakeholder interviews, in which new requirements were discussed in more detail, contributed considerably to the development of the technical system architecture. Additionally, literature findings and already published technical system architectures of MaaS-related mobility services supported the technology findings.

As the deployment of MaaS strongly relies on the provision of ICT technologies, the main focus within this deliverable was on the related requirements. In this respect, already employed technologies within MaaS and MaaS-related services were identified. All those findings helped to develop a comprehensive MaaS system architecture.

Based on the different value chain steps - from data up to service provision - different technology requirements arose for implementing MaaS. In this respect, this work package aimed to cover relevant technologies and their availability, with a strong focus on ICT networks and architectures required for MaaS.

Different existing and future planned technologies have been evaluated, showing, in particular, strengths and opportunities for supporting the proof-of-concept of MaaS and the different MaaS value chain steps. In detail, wireless networks play a decisive role for an area-wide MaaS service provision. Especially MaaS on an international level requires new technical/organisational solutions like adopted roaming principles and management of different subscriptions to different transport but also telecom providers. Therefore roaming principles in the telecommunication field are used as a basis for the studied system architecture (covering for instance 5G and location based service features as well).

In the final section, deployment recommendations are presented, mainly coming from derived technology findings and related requirements. Based on discussions during the final, consolidating project workshop on MaaS, both project group members and international stakeholders expediently worked on final recommendations.

1.3 Identification of MaaS Technologies

Even though MaaS has a strong orientation towards the implementation of new business models and requires new organisational concepts, as identified for instance in the online questionnaire results, technology is an important enabler in order to provide citizens with access to public and private real-time mobility services. It also enables further increased

transparency in terms of mobility costs.

Technology integration into mobility service planning and provision has become increasingly important for many new but also commonly applied transport-related process operations, including for instance infrastructure/vehicle management, route planning, ticketing/pricing and booking.

Based on the state-of-the-art analyses (including the online survey, interview results and literature review), wherever available, technologies required for MaaS services were identified and analysed in more detail.

2 MaaS Technology Requirements

With the provision of the simple value chain design, as defined in Deliverable 3, the identified technologies have been assigned to the different levels. Basically a simple framework design for depicting different value chains and roles is applied for the purpose of comparing different MaaS services. In detail this framework design provides different stages for generating added value for any MaaS service. The main value chain links represent the different stages of value generation, from data collection and information generation to service creation and provision. Figure 2 shows the general value chain, as elaborated in Work Package 3, relevant for the MaaS service provision. The value chain also provided the basis for setting up the technical system architecture.

2.1 MaaS Value Chain Requirements

Within the general value chain (as depicted in Figure 2) five modular levels/functions that fulfil the specific requirements can be defined:

- **Data Level:** One basic function is data collection. This encompasses the collection of all statistical data (such as timetables and departure times) as well as dynamic raw data (e.g. traffic or weather data measured using sensors). This should be done in strict compliance with data protection laws. Together with the collection of the (raw) data, processing of these data is done at this stage as well. For instance updating and validating data is done at this stage together with gathering data on pricing schemes.
- **Information Level:** Based on the processed data, information can be created. This information is further required for the MaaS service implementation. At this stage for instance information generation and maintenance such as storage/update of dynamic information is done together with cross-linking of information.
- **MaaS Service Creation:** The information is analysed, pooled and interpreted to generate a wide range of MaaS service features. For instance analysis of information, routing capability, and traffic forecasting processes are performed in this stage.
- **MaaS Service Provision:** Each MaaS service must be provided and accessed in a suitable form by respective end-user groups. Therefore appropriate HMI/MMI (Human-Machine/Machine-Machine) interfaces have to be available. In most cases, smartphone-based apps are established on this level. Ticketing and Payment procedures are defined at this level.
- **Mobility Market:** Describes the whole set of different available mobility services being provided to respective end-users/travellers/user groups.

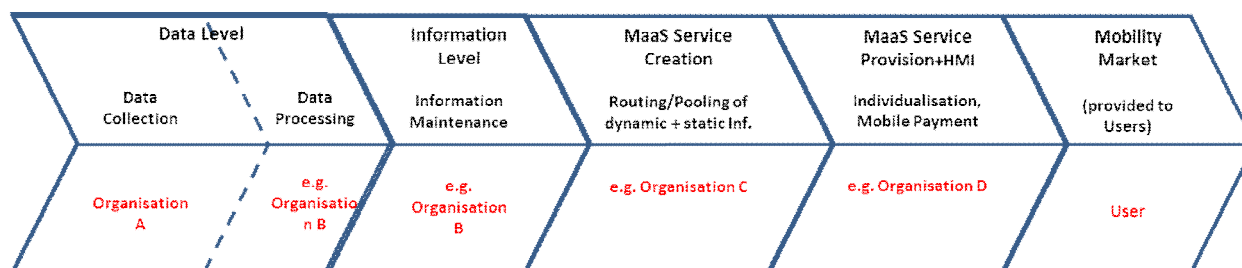


Figure 2: General MaaS value chain (Deliverable 3, MaaSFiE)

In order to find corresponding technologies most suitable for different value chain elements, different mobility services were analysed. The increased use of smartphones providing increased access to internet technologies is a major enabler of and requirement for MaaS. As such, technology findings were based on Internet and communication technology requirements for MaaS, following the value chain principle. Further communication networks/related physical interfaces and legal requirements were assessed. For the purpose of identifying technology requirements, the following simplified requirement themes derived from the value chain elements are used for further analyses:

- Data requirements: e.g. common data formats, applied standards/ specifications
- Service requirements: e.g. common interfaces, Open APIs, applied standards
- Physical requirements (wireless networks): e.g. WLAN availability, 5G technology
- Legal requirements: e.g. roaming regulations, security, privacy
- Usability requirements: e.g. Accessibility, interface design, usability

The most fundamental requirement for the provision of MaaS services is the provision of data for generating final end-user and transport operator services. With the number of available sensor data sources and with the level of data integrity, high-quality services can be achieved. Commonly used data formats facilitate the integration and exchange of different data and information content.

Service requirements mainly deal with the provision of common and open interface concepts, allowing service providers to opt to contribute to a jointly operated MaaS system. While data requirements focus on the provision of a common basis for embedding different data and information sources, service requirements concentrate on the provision of harmonized and agreed-upon information exchange and interface procedures, including usability requirements.

Accessibility to end-user devices is required for consuming final MaaS services and allows the provision of real-time interaction between end-users (travellers) and producers (e.g. transport operators and/or service providers). Wireless networks, especially, provide a key-enabling technology fulfilling the physical requirements. For instance the evolvement of 5G and 4G/3G mobile network technologies together with the integration and expansion of local wireless communication networks (e.g. WLAN and Bluetooth) pave the way towards a seamless access environment to MaaS systems.

Legal requirements influence general framework conditions and thus contribute to regulating use of different technologies for MaaS. Under these circumstances and wherever information was available, legal requirements in terms of data security and privacy are studied in more detail.

Usability requirements focus on the user needs, which must be tackled by the MaaS service, e.g. user interface design, accessibility and ease of use considering different user group

needs. More details on the technology requirements along the value chain and related aspects are analysed in the following sub-sections.

2.2 Data Requirements

The collection and provision of mobility data is indispensable for generating high-quality and real-time MaaS services. Stakeholders retaining mobility data need to be acquainted with providing data in standardised formats, enabling the refinement of mobility services and thus allowing increased transport efficiency. Service refinement is achieved by integrating added value data to existing value chains providing tailored data sets in standardised formats.

Based on the MaaS definition as elaborated within Work Package 3, specified data must be provided by corresponding stakeholders. Since it is often not clear which data can be provided and possibly made available to service providers, national data markets have been established issuing available data/metadata to interested parties. Registered users/organisations declaring their intentions are able to upload their data sets on commonly available and to some extent 'open' data platforms. As a consequence, added value services can be developed based on access to established data markets. As described under Legal Requirements (below) there are on-going European-wide activities fostering the provision of data to service providers. The following requirements were identified:

- Open data (e.g. open government data): strategies providing access to data
- Requirements on the data level: Real-time ability, harmonized data content specifications (common standards)
- Common data market places

In the following, different national strategies making data open and thus accessible to service providers were identified.

National Data Warehouse for Traffic Information (NDW): The Netherlands

The National Data Warehouse acts as a one-stop-shop for traffic data. The NDW database provides information on the current traffic situation on the motorways, secondary roads and urban thoroughfares of the participating authorities. The database also provides data on the operational status of the road (status information). The history of all data is available for traffic analyses.

The NDW is currently focused on the following data domains:

- Real-time traffic data - traffic flow, historic travel times, estimated travel times, traffic speeds and vehicle classes - national roads, provincial roads and municipal main roads - measured every minute; processed and distributed within 75 seconds - 20.000 measurement locations; 4500 km of road (end of 2011)
- Status information - road works and events (all roads) - reports of congestion, accidents and other incidents (national roads) - status (open/closed) of bridges (in 2012) - status (open/closed) of peak lanes and regular lanes (in 2012)

Mydata/ Midata: Finland, UK

British Midata is a voluntary co-operative program with industry aiming to give consumers increased access to their personal data in a portable, electronic format. The overall goal of

the program is to “benefit the economy, by stimulating innovation and growth, as well as companies and consumers”. According to UK governments officials [8]:

- midata will allow consumers to access their data in a secure way and aids them in making better informed decisions and managing their lives more efficiently reflecting their personal wants and needs. UK Government hopes midata will help individuals understand their own consumption behaviour and patterns and make more informed consumption decisions.
- midata will create opportunities for businesses through improved dialogue with consumers and increased trust, and the opportunity to provide innovative new personal information services and tools.
- midata will encourage sustainable economic growth by boosting competition between companies in terms of value and service, and driving innovation.

The midata type initiative has also been adopted in Finland strongly promoted by Open Knowledge Finland. In the report [11] published by Ministry of Traffic and Communications, Poikola et al. describe the role and benefits of PIMS (Personal Information Management Services) called My Data from the different stakeholders’ (individuals, companies and societies) perspectives. According to the authors [8], the goals of this initiative are similar to the UK midata:

- to provide individuals some practical means to handle their personal information stored among several sources and
- to encourage organizations holding users’ personal data to give the users themselves control over this data, extending beyond their minimum legal requirements to do so.

The intended benefits of the Finnish MyData approach are [7]:

- It provides tools for personal data management making it more transparent how organizations use personal data. The individuals might also gain access to new innovative services based on personal data. In practise these new offerings might be personalized recommendations, insight into one’s own behaviour, consumer empowerment and even monetization of personal data.
- It facilitates opportunities for new kinds of data-based businesses for companies when the individual is willing to give consent to use his/her personal data.
- For the whole society, MyData is supposed to create the practical structures, processes, and policies for protecting the rights of individuals and facilitating innovation and economic growth.

The key concept in the proposed MyData [7] infrastructure is the MyData account for personal data management. By using this account a person can give consent to service providers who are willing to access and use his or her personal data. The account stores information on how the individual’s personal data is connected to different services and the legal permissions and consents for using the data. After the consent is given to different parties in the MyData infrastructure, the data can be transferred directly among those parties (Data Sources and Sinks), as Figure 3 shows, by using suitable Application Programming Interfaces (APIs).

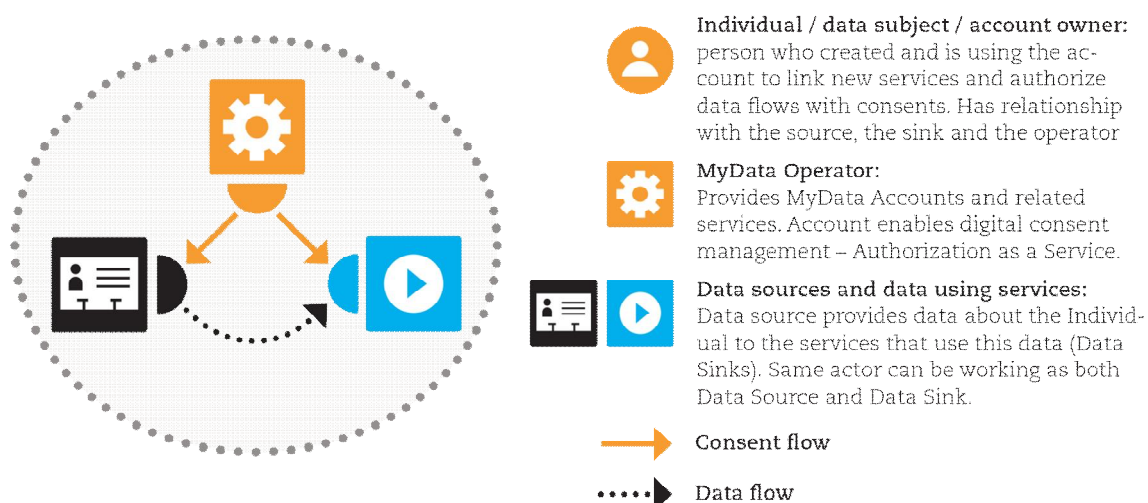


Figure 3: MyData working principle [7]

A MyData operator is an individual or an organization who maintains and hosts MyData account servers in a similar fashion like email or web servers. The MyData account server also includes a Service Registry that maintains a database of all services accessible with this operator and enables searching for other MyData-compliant services from the whole MyData infrastructure as well. Interfaces how to use the MyData services are described by using WADL (Web Application Description Language)¹.

The idea of MyData concept is not fully adopted or even properly understood among companies, even though the idea is getting more acceptance and attention. One of the problems is that the MyData infrastructure is not yet fully exploitable, so even those parties who have a positive attitude towards the MyData concept are still forced to wait for or develop practical solutions.

Currently, according to European privacy laws, users have an opportunity to request from a service provider what kind of personal information is collected related to them, but the format in which this information should be provided is not defined. Right now, a service provider can deliver this information as a bunch of paper that is pretty much useless for further machine-based processing. In the future, the same personal information should be given in a machine-readable format. Even though the exact data format is still freely selectable by a service provider, the digital form eases value added processing of this data and makes the MyData approach-based services far more feasible and practical.

Austrian National Access point (Mobilitätsdaten-platform): Austria

The Austrian National Access point provides information on available mobility data coming from transport operators and other data transport data contributors. The platform is an implementation of the national ITS law (National transferred law based on the European ITS Directive; further details can be read at the end of this section). It is a centralised, one-stop-shop to significantly simplify the connection of local data providers and international service providers by granting access to information on existing data and use conditions (metadata). In addition the access point is collecting truck parking data and transmitting it to the European truck parking access point.

¹ Further technical details related to the MyData architecture are described in the publicly available GitHub documents: <https://github.com/okffi/mydata>

The platform provides the possibility to present information about datasets (metadata) of public and private organisations and companies. As the platform is an implementation of the ITS directive, the metadata published contains only datasets listed in the directive and its delegated regulations.

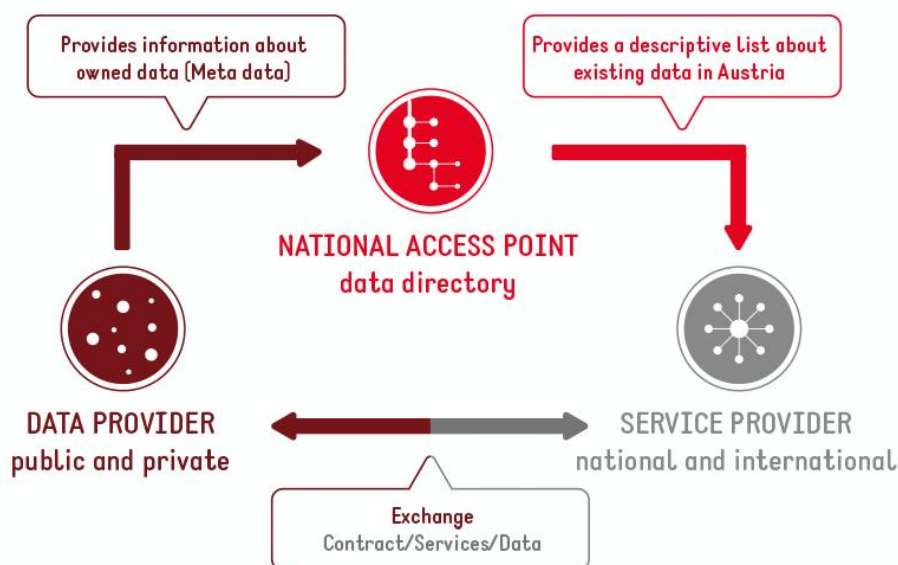


Figure 4: Austrian National Access Point setup²

The presentation and description of datasets on mobilitydata.gv.at is reducing the personnel resources that data providers previously needed to answer questions and requests concerning their datasets, accessibility and metadata information. It also helps service providers to improve services' data quality. Data providers can use mobilitydata.gv.at as simple data store for pull operations. In addition to just metadata information, data providers can upload complete datasets and have the possibility to reduce costs for their own IT infrastructure and web applications.

MDM: Germany³

The Mobility Data Marketplace MDM brings together providers, users and refiners of traffic data. As a neutral platform it ensures transparent terms and safe technical standards. This makes it simple to provide, search for and subscribe to traffic-related data. When providers and users want to do business with each other they can exchange data via standardised interfaces and proven communications procedures. Both parties benefit from MDM's technical and organisational support, exploiting the full potential of the data; here quality offers meet innovative ideas for use.

The Mobility Data Marketplace allows – via its Internet service MDM Platform – offering, searching and subscribing to traffic-relevant online data, as well as the distribution of online data between data suppliers and data clients. The platform forwards the data supplied by the data suppliers unchanged to the data clients.

2.3 Service Requirements

Service requirements are strongly triggered by the idea of allowing service scalability in

²Austrian National Access point for mobility data: <http://mobilitydata.gv.at>

³<http://www.mdm-portal.de/en/>

terms of adding, combining and integrating different individual, separate service products to one commonly accessible one. Common interface designs need to be made available and established within the required service environments to be used for developing a commonly accessible MaaS service being provided for instance over one common platform access.

Based on the literature findings and some expert interviews, there is a strong emphasis on and a high priority towards the implementation of “Open APIs”. Open APIs (Application-Programming-Interfaces) provide simplified linking of different digital web-based services.

By enabling Open API standards, even third party developers can be provided with the programmatic access to proprietary mobility service solutions. APIs basically represent, in this context, a set of requirements that govern the interaction and communication among different web-based services. Depending on the use of APIs (whether end-user oriented; publisher-client communication; operator-to-operator oriented services; or publisher to another publisher communication), different requirements on different technical levels arise. In this respect, depending on the way the services are linked, existing web interface languages prescribing the set of semantic rules to be used for exchanging relevant information need to be considered.

On the one hand, several possibilities for coming up with the provision of APIs can be obtained that are especially relevant for rolling-out MaaS system implementation. But on the other hand, technical requirements/standards allowing highly integrated service environments also need to be considered by the respective developers. The following main characteristics of providing Open API technologies could be derived:

- Simplified accessibility/connectivity between different proprietary service systems, having at least common interface specifications in use;
- The Open API is freely available and open data can be obtained mostly without any restrictions, but the publisher is able to limit the data access;
- Open APIs are based on an open standard. Thus, using this standard does not require any further licensing.

More details on available standards and service requirements are provided in Section 5.

2.4 Legal Requirements

With the collection, aggregation and provision of data and services, more legal requirements arise which need to be considered by all MaaS contributors. Especially use (storing/forwarding) of personalised data calls for a critical legal view. In this respect considerations could be identified that come into effect when deploying MaaS on different organisational and societal levels.

New EU regulation: GDPR General Data Protection Regulation

The basic business principle of MaaS operators is dealing with the provision of services to subscribers. Thus, handling of personal data is in an essential role in the MaaS operators' everyday business. MaaS operators need to store personal data and possibly provide personal data to transport providers, and also to other MaaS operators in case of roaming. This entails many responsibilities for MaaS operators in terms of data security and privacy. In order to unify data privacy regulation between EU countries and to address today's requirements for handling personal data, the EU has ratified a data privacy reform, called the General Data Protection Regulation (Regulation (EU) 2016/679). The previous directive is from 1995 (Directive 95/46/EC) and significant technological advances have been made

since then. The GDPR does not only affect European companies but all companies around the world that process the personal data of EU citizens. The GDPR necessitates a 'privacy by design' approach in software development, which means that compliance with the principles of data protection is already considered in the early design phase of software, systems, and processes. A system for detecting data breaches must also be deployed. For example, any data breach must be announced within 72 hours of detection. The GDPR extends liability to all organisations that have access to personal data. In the case of MaaS, this may also concern transport providers.

The GDPR gives EU citizens more power over their own personal data. The right to be forgotten, for example, enables citizens to demand that their personal data be deleted from any service in which they are stored. The reform also introduces a right to citizens that will enable data subjects to transfer their personal data in a commonly used electronic format from one data controller, e.g. a MaaS operator, to another without hindrance from the original controller.

European Data Economy

In January 2017, the European Commission has arranged a 'Communication on Building a European Data Economy' fostering a wide-range stakeholder dialogue on the issues of movement of free data, in particular dealing with data access and transfer, interoperability and liability. In this respect a Staff Working Document was published by the European Commission⁴ discussing new data policy frameworks and requirements to be implemented accordingly.

Some key interventions described in the communication document are providing stakeholder communities and organisations with support to make use of common data and service standards and fostering the provision of common machine-readable formats together with making use of access for public and scientific purposes of data and services [12]. Since MaaS relies on the accessibility and use/usability of transport/mobility-related data content as well, further data integration concepts fostered by the European Data Economy strategy will allow service improvements and enable high-end MaaS service provision. In this respect, this communication document (COM(2017) 9 final)⁵ provides common strategies relevant for MaaS as well, e.g. accessibility, interoperability and service harmonisation with the provision of data economy strategies.

2.5 User requirements (User experience, usability and acceptance)

Successful MaaS ultimately needs to have a service design that enables the user to manage their (and their household's) daily, weekly, monthly, and season travel in a way that provides added value compared to the user's current ways of organizing their travel. Part of this service design is a front-end that enables the user to accomplish various types of tasks (searching for information, accessing one's account, making bookings, contacting customer service, etc.). This section begins with some general information about usability, and then continues with more specific lessons regarding interface design (in the case of a multimodal traveller information service) as well as service design for MaaS.

Usability

ISO Standard 9241 on the Ergonomics of Human System Interaction defines usability as "the extent to which a product can be used by specified users to achieve specified goals with

⁴ <https://ec.europa.eu/digital-single-market/en/news/communication-building-european-data-economy>

⁵ http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=41205

effectiveness, efficiency and satisfaction in a specified context of use". In other words, usability is about: effectiveness (Can users do what they want to do?); efficiency (How much effort is required to do this?); and satisfaction (What do users think about the ease of use?); all three of which are affected by: the users (Who is the user, e.g. novice, expert?); the goals (What are the users trying to do? Does the product/service support what they want to do?); and the usage situation (Where and how is it being used?). Note the difference between functionality and usability, where the former is related to functions and features, but not whether or not those functions and features are usable. Nielsen⁶ argues that usability is also different from user satisfaction or user experience, as usability does not necessarily consider usefulness or utility. In other words, utility is about if the features the user needs are provided, while usability is about how easy and pleasant the features are to use (and useful = utility + usability). In the end, MaaS needs to be useful, i.e. providing both utility and usability.

Design and expectations of multimodal traveller information services: Lessons learned from the SmartMoov pilot

Although, as will be discussed below, MaaS is more than multimodality, and more than overlaying an app on existing modes of transport or an existing mobility service, multimodal traveller information apps are a piece of the MaaS puzzle; thus lessons for MaaS development can be drawn from examining such apps.

In the EU project Opticities, a multimodal urban traveller information service named SmartMoov, developed by HaCoN, was tested in Gothenburg in 2015-16. The app offered travellers information about all transport modes to travel from A to B, in other words, a useful component of a MaaS service. The information service considered traffic disturbances as well as changes to the infrastructure and included the following functionalities: timetables, real-time information, route maps, information on disruptions, information on infrastructure accessibility, and travel planner information (including public transport, bicycling, walking, driving, park+ride, bike+ride).

From Gothenburg's perspective, the goal for the development and implementation of the app was to encourage a shift from more to less energy demanding modes of transport, in particular from private cars – but also public transport (buses and trams) – to cycling and walking, i.e. similar to the vision for MaaS. Chalmers Division of Design and Human Factors administered the test and evaluation of the app, including ex-ante and ex-post focus groups, and ex-ante, in-itinere (2), and ex-post online questionnaires. In addition, a cognitive walkthrough of the app was performed prior to first release.

In the ex-ante focus groups, although the intention of the app was to be multimodal (including driving), it appeared as though this type of traveller information app is primarily associated with public transport, and their purpose to market public transport options, which implies that it is important to communicate that such apps also include information on and relevance for other modes of transport besides public transport.

Based on the focus groups, recommendations regarding the app development are summarized below. A more detailed description and analysis can be found in Annex I of this document, together with a discussion on the potential role of multimodal traveller information services in a behavioural change process (hint: likely necessary, but not sufficient).

- The app must offer added value compared to existing information services such as the local public transport operator's travel planner and Google maps.
 - The app should integrate different services into one – "all in one".

⁶ <https://www.nngroup.com/articles/ten-usability-heuristics/>

- The new app must offer information on all modes of transport.
- The app should provide 'best option' based on different prerequisites: cost, efficiency, environmental impact but also e.g. comfort and safety.
- The app must offer information on journeys to be undertaken "now" as well as journeys planned for later.
- The app must provide reliable information, i.e. information that is correct and that is perceived as correct.
- The new app must offer information in real time.
 - The app must offer information that takes into consideration the situation at hand, in terms of delays, disturbances etc.
 - The app should also inform the user about the reasons for delays and disturbances.
- The app must allow the user to customize information
 - The user should be able to filter information according to his/her preferences.
 - The user should be able to choose preferred mode of transport.
- The app must have a user interface (UI) adapted to the smartphone context in terms of screen size, possibilities for entering information as well as presentation of output.
 - Information presentation should take advantage of the whole screen but not require more than the available screen.
 - Legibility must be ensured (fonts, size of elements, use of colour etc.)
 - Colours should be used with care. Although colours can help highlight state etc. the design of the UI cannot depend upon the user being able to see colour.
 - Clarity must be provided for instance by using negative space, making important content more noticeable and easy to understand.
- The app should use as little battery as possible.

Service design: Lessons learned from the UbiGo pilot

Participants' expectations

In the UbiGo pilot, the expectations of the users were surveyed via an online questionnaire, and these expectations were subsequently followed up with during and end questionnaires to check to what degree their expectations were fulfilled. Expectations were generally high, but the greatest expectations had to do with being better able to pay for transport and keep track of transport expenditures, having more transport mode alternatives to from which to choose, and being better able to adapt one's mode choice to each individual trip, and these expectations were largely fulfilled. Other expectations regarded reduction in environmental impact and more effective planning, but not more time efficient travel, nor making the same mode choices as previously or having less physically demanding travel (see Annex I, Table 1) In other words, the users' expectations were not only about more, cheaper, and more environmentally friendly choices, but also about increased transparency, insight, and control over one's transport choices, planning, and expenditures.

Service and app features and functionalities

The UbiGo participants were also asked the importance of various service and app features and functionalities, which were later followed up with what extent they agreed or disagreed regarding such. Most of the features and functionalities were considered important, and thus only a selection will be discussed here. See Annex I for a more detailed breakdown of the

results and discussion of the themes, and Annex I, Table 2 for the rating results of the various items included in the themes.

Theme 1: Transport modes and travel guarantee. A good level of service with close, available and timely transport (particularly carsharing sites close by) including a working travel guarantee.

Theme 2: App use. Here one can see that ease of use is important (and more important than being fun to use). The app needs to be easy to use, instructions easy to find, and it should also be easy to check one's balance.

Theme 3: Subscription, bookings, bonus. Again, aspects related to ease of use are given the highest ratings, including ease of changing/cancelling bookings, modifying one's subscription and understanding the monthly invoice.

Theme 4: Customer service. Participants' highest priority was quick response time, however, most of the customer service errands were at the beginning and were related to downloading the app and placing it on one's home screen. Despite this, the 24/7 *centralized* customer service was highly appreciated by the participants, as was the travel guarantee even if this guarantee was hardly used.

Theme 5: Trust and security. Participants wanted to make sure their personal information was secure and not accessible to unauthorized persons/parties. Over the duration of the pilot, the participants also built up a high level of trust for the UbiGo team. Although people generally felt secure with a Gmail/Facebook login, when asked what they preferred, approximated one-third would have preferred a dedicated login, one-third did not care either way, and one-third preferred a Gmail/Facebook login.

Contributing service attributes

Based on participant questionnaires, interviews, and travel diaries, service attributes that contributed to the success of the UbiGo pilot were identified (see below, as well as a more thorough discussion with exemplifying quotes in Annex I). A discussion of the relationship between service design and (behavioural) impact can be found in Annex I.

Service Attribute 1: The 'transportation smorgasbord' concept, with the majority of one's travel needs offered in one package.

Service Attribute 2: The *simplicity* of the service. Several people could be included in one subscription with one monthly invoice; managing one's tickets and bookings via the smartphone made it easy to remember; easy up-/downgrades of public transport zones for a particular day; activating daily public transport tickets only once instead of a tap-in system; and paying according to use are some examples.

Service Attribute 3: Improved *access*. Participants felt that they had more transportation alternatives available to them. Not only did UbiGo enable access to car mode without ownership, it also provided access to improved public transport (daily tickets, expanded zones, etc.). Of note is that the alternatives also became more mentally accessible due to having to reflect on one's travel needs in order to set one's subscription level, as well as having to choose one's mode from a list in the app, which made participants stop and think about their trip choices and travel habits to a greater extent.

Service Attribute 4: Improved *flexibility*. No single mode can fulfil the requirements for all trips, but purchasing a car – or a public transport pass – can make people feel 'locked in' to choosing that mode no matter what the trip conditions. Beyond the flexibility of having multiple alternatives from which to choose (combined with reduced sunk costs), participants felt they could better adapt their choice of mode to the individual trip requirements.

Service Attribute 5: *Economy*, including pay-per-use. Although economy was rarely the main

motive for the participants (see Annex I, Table 3), it did act as a deterrent for some who were interested but decided not to join the trial. Participants expected their UbiGo transportation expenditures to at least not be more expensive than their current solutions, although many agreed that UbiGo led to reduced travel costs. Participants appreciated the pay-per-use concept (combined with the ability to roll over and top up credit); partly as this made travel costs more transparent (broken down per trip/day), and partly as not having sunk costs in a particular mode meant that they could more easily choose a mode according to each trip's requirements.

Service Attribute 6: Added value/Relative benefit. In UbiGo, the added value and/or relative benefits concerned the above mentioned aspects economy, flexibility, accessibility, and simplicity, although relative benefit is a matter of perception. The travel service cannot be more expensive than the user's existing solution, not without enough added value to outweigh the increase in price. Second it cannot be perceived as more 'inflexible' or 'inconvenient' compared to the user's existing solution. Public transportation and carsharing services can be perceived thus by those who are on call at their job, who live 'too far away' from a carsharing site, or who have small children. It is important to examine how for instance the carsharing network or the carsharing business model (especially pricing schemes) help or hinder use of the service, and the implications of this on facilitating a move away from privately owned vehicles in urban areas. Third, the infrastructure network (carsharing sites, public transportation stops/routes, etc.) must be extensive enough to reach the users. If a carsharing site is perceived as too far away, people will not join the scheme. Fourth, learning is yet another effort and the results indicate that travel service must be perceived as 'easy enough' to understand and use, as it is difficult for people to find time in their busy lives to go to informational meetings and read manuals about how to e.g. use an app or change their subscription. If it is perceived as too difficult or time consuming, potential users will be deterred.

Another factor of relevance for assessment of UbiGo and the results of the FOT was trialability (developed further in Strömberg et al., 2016⁷). UbiGo was not set up to stimulate behavioural change per se; it was primarily intended as a trial of the new type of service even though reduced environmental impact was a desired additional effect. Nonetheless, many participants used the service to actively trial new behaviour; to see whether they would still be able to carry out their daily activities. The trial lowered the risk, effort, and uncertainty connected with undertaking a behavioral change process.

A consequence of trialability was that participants gained new insights on convenience. UbiGo resulted in many participants evaluating the alternatives in new ways and determining what convenience meant for them. For some, convenience meant a private vehicle close at hand (e.g. for encumbered trips), while others felt that carsharing/rentals created convenience in terms of gaining access to a modern, varied car fleet (e.g. adapting the car size to the trip requirements), and not having to deal with maintenance, parking, etc.

In conclusion, MaaS is more than multimodality, and more than overlaying an app on existing modes of transport or an existing mobility service. While the UbiGo pilot demonstrated (and hopefully other MaaS services will soon demonstrate) the potential for MaaS, both conceptually and to change thought processes and behaviours, its success is not independent of the contributing service attributes identified above. A continued discussion on the implications of this can be found in Annex I.

⁷ Strömberg, H., Rexfelt, O., Karlsson, I.C.M., Sochor, J. (2016). "Trying on Change – Trialability as a Change Moderator for Sustainable Travel Behaviour", *Travel Behavior and Society*, Vol. 4, pp. 60-68. <http://dx.doi.org/10.1016/j.tbs.2016.01.002>

3 Technical System Architecture

MaaS can be presented in different ways (with different technologies and in different formats) to end-users no matter whether provided as smartphone applications or rather as an organisational construct to ease the organisation of the mobility of people. Main state-of-the-art findings and case study analyses within Work Package 3 have shown that web-based technologies represent a key driving technology for the provision of MaaS services.

Therefore, in this context, the focus of the technical system architecture is based on the use of web technologies, as those technologies show a profound basis for establishing new combined and integrated digital mobility services, following the identified definition and categorisation for MaaS systems. As a reference and modelling basis for setting up a common MaaS system architecture, ITS architectures were analysed and new MaaS-related requirements were identified. Basically, ITS architectures are strongly characterised by a high level of service integration, automation and connectivity. Going hand in hand with the deployment of ITS architectures, a higher degree of harmonization of services and provided data content is able to be achieved. In this case, very similar requirements arise with the provision of MaaS services in having different collaborating organisations synchronized and providing high-quality services to end-users. As a result, a conceptual system model for MaaS was developed taking all identified technical requirements into account.

The system architecture covers the same principles for service provision as identified within the service value chain. It represents a consistent approach to Work Package 3 developments. Even though the system architecture provides an overview of the technical MaaS system and related operations, there might be other technical solutions available and used that fulfil the same requirements. Technologies are able to be used in diverse ways and therefore only identified state-of-practice technologies applied to different available MaaS services were highlighted. It is foreseen that future technical solutions that are currently not offered commercially might enable even more sophisticated MaaS systems. For example augmented reality seems to be a promising future technology allowing optimised indoor routing as part of advanced traveller information system provision, but it is currently provided as part of R&D projects as it has not yet achieved a high degree of maturity.

Nevertheless, there is a strong focus on using internet-based technologies, in particular the use of mobile web-based devices like smartphones or tablets, as they already have a high penetration rate and enable cross-linking of different services, including common payment schemes.

In practice the system architecture analysis systematically links to the organisational background of the corresponding MaaS system. In other words, processes and technologies required for final MaaS service provision are highlighted in the technical system architecture (Figure 5), while roles and responsibilities are assigned to the business and operation models as developed in Deliverable 3 by the elaborated MaaS ecosystem and value chain analyses results.

As MaaS has a strong focus on the provision of flexible mobility services, having several transport modes included and combined in one common booking and information platform, a high target value of MaaS integration is triggered by the number of integrated transport modes allowing seamless mode transitions. From a technical viewpoint, both infrastructure and transport operators can represent both data as well as service providers as depicted in Figure 3.

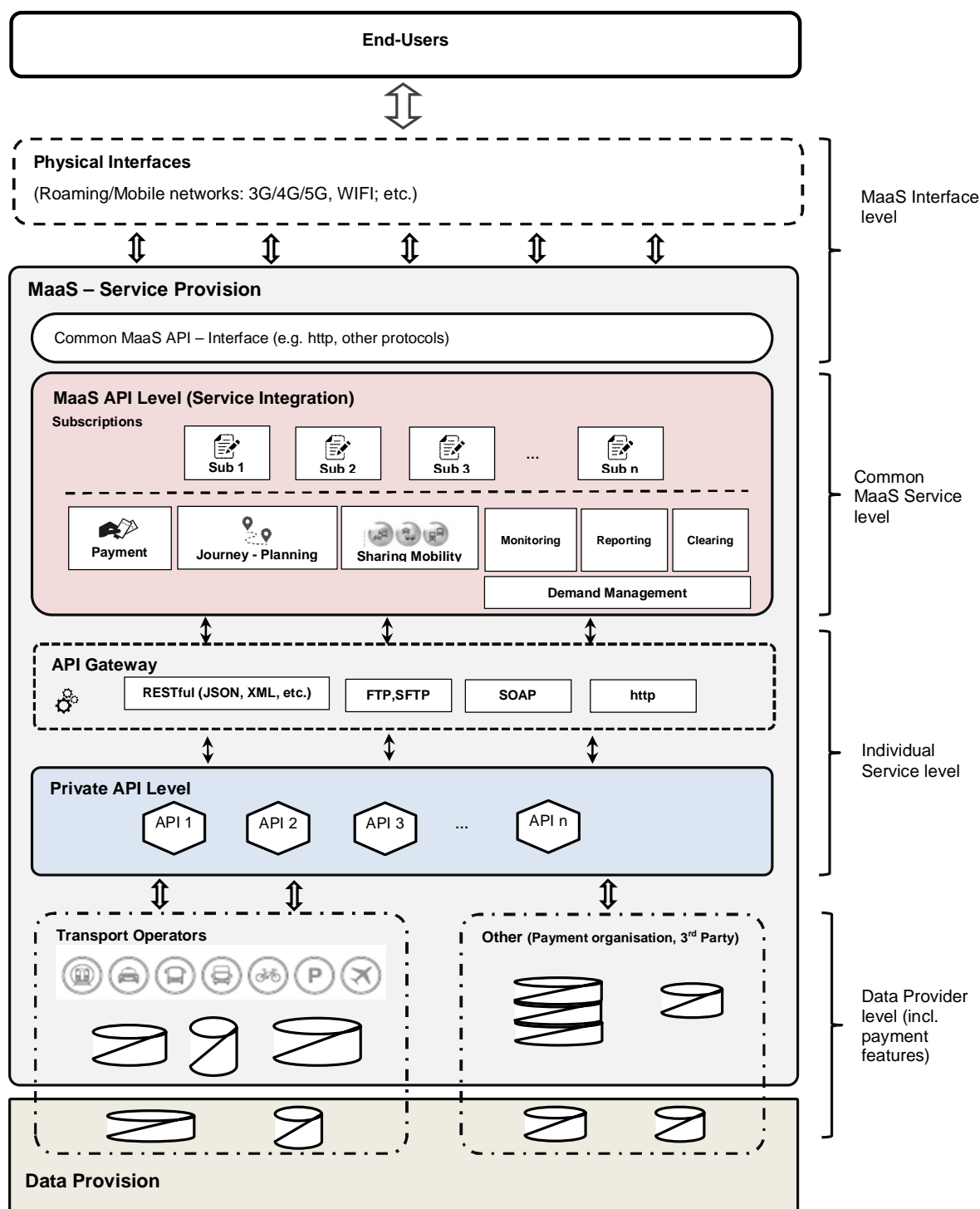


Figure 5: Technical MaaS system architecture

Following the one-stop-shop service principle, the system architecture depicts one technical solution showing associated key requirements needing to be fulfilled by the responsible assigned roles/responsibilities providing a reliable MaaS operation. Next, the different levels for final MaaS service provision are presented.

3.1 MaaS service provision

The main MaaS domain is represented by the new layer of the **MaaS API** (service integration). From the current perspective, only some existing (mobility) service providers allow the integration of different subscriptions on a commonly provided end-user application. For instance, in the follow-up project of SMILE (Wien Mobil-Lab), different service subscriptions of different API providers were able to be integrated and provided over one common mobility service interface. This means that for instance seasonal public transport tickets together with car-sharing payments were combined over one service interface allowing different 'foreign' subscriptions to actively run in the background and providing billing of transport rides on a separate accounting basis (covering e.g. public transport tickets, car sharing and/or parking fees).

Besides the availability of end-user service features like booking, sharing or journey planning, within the MaaS API level, several new administrative aspects arise with integration, covering mainly demand management issues. For example service monitoring, reporting of access, security and privacy issues (controlling terms of use conditions) for third party access, as well as clearing, as integral and neutral parts of the MaaS service, lead to some technical administration tasks. In this respect, clearing provides all participants involved in the MaaS service system with a neutral support, acting as a clearing site for service contributors.

Following the principle of service bundling with multiple subscriptions over one common interface, users are provided with one common simple transaction interface via different registered subscriptions, thus giving users the choice to select preferred mobility offers.

From the current perspective, several different mobility services/applications coexist that have no interfaces/connections among each other. The standalone, proprietary services are highlighted in the blue box (Figure 5), referred to as the **Private API** level. The Private API level presents the sum of all available mobility services being potentially made available on the digital service markets and used for instance directly by travellers already. These services might be provided for instance by transport operators being in the role of service providers as well.

On the other hand services might be offered by third party organisations as well, capable of the provision of the whole virtual service architecture. Depending on the applied role model, some transport operators, as mentioned before, might act as both data and service providers therefore they are represented on both data and service level sites. Payment service provision requires billing and clearing between different stakeholder organisations (e.g. done via the MaaS operator) and information/booking and validation of user accounts. Mostly third party payment providers offer their add-on service features.

In order to connect different services (and/or features) to one common access platform, technical service interfaces are required to gather all available content/information sources. Figure 5 shows the **API Gateway** describing some interface examples using web-service-based distribution technologies. For instance Restful (Rest), simple HTTP, and/or SOAP specify when to access/exchange data between different sites (see Section 5.2 for further details). All those web-service technologies are mostly implemented as part of back-end systems. Since end-users interact only with the MaaS service front-end system, back-end systems need to be established between different data/service contributors.

3.2 MaaS data provision

From a technical point of view, several data sources form the basis providing high quality MaaS services. Very similar to the data level within the MaaS value chain, data content need to be available in commonly standardized machine-readable formats in order to allow harmonization and interoperability of different MaaS services.

In most cases, transport operators provide their own data and contribute to the digital MaaS architecture with their own 'opened' services or act as data providers. In some other cases, third parties or service providers are providing their data.

Provided data might for instance cover real-time information on schedules, information on stop locations, locations of Pols (Point of Interests), road network information, and/or road/public transport event information (e.g. traffic messages on incidents).

For both road and public transport-related data/information provision, different data standards are available. Open data platforms allow further utilisation and added value creation for MaaS services. More information on available data standards can be found in Section 5 of this document.

3.3 Physical Interface provision

The physical interface covers all wireless communication network aspects. With the increased number of handheld smart devices used by travellers, i.e. increased access to web-based services, new mobility service features arise. Both mobility service providers and travellers take advantage of consuming and producing data on a real-time basis and having area-wide access over wireless mobile networks. For instance, new mobile network technologies like 5G enable high data rates and thus enable the fast access conditions required (or at least desired) for MaaS as well.

3.4 Platform approach

Together with the rise of the digital economy, there are many new service-based platforms emerging in various sectors. Netflix, Spotify, and Amazon are a few famous representatives providing platform models to customers. Closely related to the technical characteristics of MaaS defined by the system architecture, a platform-based model for MaaS is proposed. With the provision of a platform-based approach, a pool of different stakeholder communities is able to be addressed so as to make synchronised contributions to MaaS. For instance cooperation agreements, legal framework conditions regulating the provision and access of data and services, promotional activities and provision of open service interfaces are some key enablers guiding platform development as commonly used tools for consuming MaaS. In terms of mobility service provision, platforms form the integral element of intermodal transport services. [4]

Standardization of payment procedures and information provision enable platform replication as well. Depending on the business model arrangement, platforms are able to be supervised by separate platform service providers, by transport/infrastructure operators, or by the mobility service providers.

4 Wireless communication as key technology for MaaS

Wireless communications form the basis for realising MaaS services. They allow using the services almost everywhere at any time. Wireless networks are heterogeneous with respect to capabilities, coverage area, terminal to be used, and usage cost. In addition, the cost of use differs widely. Some wireless networks are free of charge, while some charge fixed or usage-based rates possibly including additional charges to be added according to geographical location of usage (e.g. roaming charges). In this section, today's main wireless technologies that enable MaaS are introduced, providing also an outlook to future communications trends.

4.1 Mobile Networks

Currently deployed mobile network technologies are categorised as 2G (Global System for Mobile Communications, GSM), 3G (Universal Mobile Telecommunications System, UMTS) and 4G (Long Term Evolution, LTE), and are commonly used with handheld mobile devices. Within these technology categories, there are also sub-technologies that provide users with varying performance. Considering technology and related capabilities, today's mobile networks are very heterogeneous. However, all of these technologies are designed to provide users with uninterrupted service while they are on the move. Handovers, i.e. base station changes, are mostly seamless. The technologies are also backward compatible, which means that 4G users can also use 2G networks in areas where 4G is not available but 2G is.

2G, 3G, and 4G are very different with respect to data exchange performance, which is relevant to the use of MaaS services. The 2G technology was mainly designed for carrying voice and Short Message Service (SMS). However, IP data transfer was also developed for it, known as General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE). Practical data rates of 2G networks range from tens of kbit/s to 500 kbit/s. This makes the usage of many of today's web-based services annoying due to long load times even with relatively small amounts of data. Today's 3G networks are largely based on High-Speed Packet Access (HSPA) and Evolved High-Speed Packet Access (HSPA+), technologies that allow reaching data rates up to 20 and 40 Mbit/s in uplink (from device) and downlink (to device), respectively. In addition, one-way transmission delays are in the order of tens of milliseconds, which makes data requests and data uploads over the internet occur fast enough for most applications. 4G further improves the performance and all current applications that use internet can be used over the 4G network without problems, presuming that the network is not congested, which may often be the case, especially in densely populated areas.

Mobile networks based on 3G and 4G technologies do not currently restrict development and deployment of MaaS services. However, the next generation mobile networks, commonly known as 5G, will bring new possibilities for different types of MaaS services. Capacity, latencies, reliability, and availability will improve with 5G technology. Content and computing can be located close to users, which allows making services more efficient, location-based, and personalised. Wireless devices can then communicate directly between themselves, or relevant or much used data can be stored in and retrieved from just beyond base stations. When data is located close to users, there is no need to retrieve it over the internet every time. Different types of data, for example, about nearby environment and transport vehicles and opportunities in general can also be collected on a location basis without overloading back-end server systems over the internet. For example, a bus could notify persons waiting at a bus stop that this bus is going in another direction than they are heading in and ask them to wait for the next bus. This could happen automatically and without the need for the bus to stop at all, presuming there are no other passengers hopping in or out at that stop. The

technology evolution towards 5G also includes features that allow integrating WLAN networks with mobile networks. WLAN networks can be used simultaneously with mobile networks for obtaining high data rates, to extend the coverage area of mobile networks, to provide additional transmission capacity for mobile networks, and to allow users to switch to WLAN networks seamlessly, which are typically free of charge in many places.

Figure 6 shows different communication types that are possible in the future. Device-to-device (D2D) communications will allow devices to communicate directly among themselves. A mobile edge cloud solution (commonly known as Multi-access Edge Computing, MEC) allows storing location-specific data and data which is much used/retrieved in the geographical area close to users. The edge cloud logically resides just beyond the wireless base stations. Thus, there is no need to retrieve and send all the data over the internet. Thus, D2D communications can route via mobile edge or, e.g., Vehicle-to-Infrastructure (V2I), allowing communications to happen between device and mobile edge cloud server without needing to send packets over the internet.

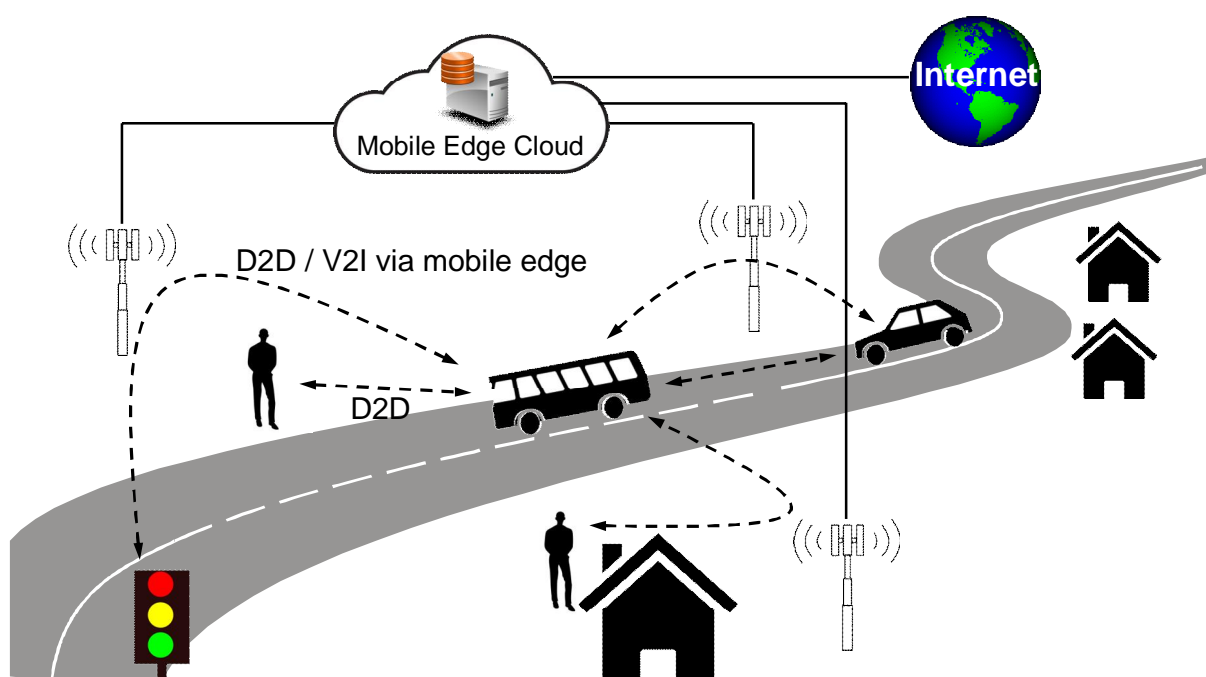


Figure 6. Wireless communications in the future. (copyright Piri, E., 2017).

4.2 Local Wireless Access Networks

In contrast to wireless networks, local wireless access networks provide connections within a more limited area (approximately 50 meters maximum distance between device and installed base station), provided for instance as in-vehicle, at public places, at public transport stations or indoors or locally. While access to mobile communication networks like 4G requires active subscriptions, local wireless access networks provide open, partly free-to-use, and in most cases contract-free access to web-based services. In most cases WLAN (Wireless Local Area Network) technologies are implied by these characteristics.

Since there are still other regions/areas where no WLAN can be accessed, some further, even offline technologies still enable the provision of some basic MaaS service features, like payment/ticketing and routing. The most important representatives of this group of local wireless access networks are NFC (Near-Field-Communication) and Bluetooth.

These technologies allow for instance wireless offline payments/registrations e.g. required for in-vehicle/station ticketing services, where no WLAN or mobile networks can be accessed.

Nevertheless online subscriptions are usually required beforehand in order to be registered on the operator's side. The most commonly used devices in this case are handheld devices like smartphones equipped with NFC and Bluetooth access points.

Wireless networks available for end-users do not cover all locations on the globe. Rural areas are especially problematic. HF radio systems, e.g. by KNL Networks, and satellite communications, for example, Inmarsat's network, provide extensive coverage for IP communications, but are not often directly available to end-users. They can be used to get internet access, which is then shared, for example, within a bus, train, airplane, and ship over, e.g. WLAN technology. However, the data rates of these long-range technologies do not reach the rates of mobile networks and WLAN networks. In addition to HF radio and satellite communications, low-power and long-range IoT technologies such as LoRA, NB-IoT and SigFox allow transmitting data with low data rates. Such technologies can be useful backup networks for mobility services that do not require sending or receiving large amounts of data, such as ticketing machines.

4.3 Coverage holes of wireless networks

Even though mobile networks cover most areas where people move, there are still many areas without connection. Network deployments are business-driven and areas with insufficient usage or population are prone to suffer from bad connections. For MaaS applications on mobile devices, it is important that the applications can be used without an internet connection. This necessitates storing all important information regarding tickets, schedules, addresses, maps, etc. for offline use. The applications should request information updates over the Internet immediately whenever a connection is found, keeping in mind that the connection may not be available for long or the user may not want to use the connection for a long time due to cost. Ticket machines, which may have internet connectivity, could also allow connecting the MaaS applications to the internet, i.e. that the ticket machine requests updates and passes the updated information along to the application over short-range communications technology such as Bluetooth or NFC. This could be useful especially for foreign travellers affected by mobile network roaming charges.

4.4 Collection, dissemination, and utilisation of geolocation-based data

Freight transport already utilises location-based information in their route and schedule optimisation. For example, courier companies plan parcel delivery routes and schedules according to delivery and pick-up addresses in order to minimise driving. Similar geographical information, if available in a single extensive data source, could be used to enhance the mobility of people and integrate it with freight transport.

Electric cars are becoming increasingly common. However, the current battery technology limits driving to similar distances to those possible with combustion engines (without stopping). Knowledge of charging station locations can already help electric vehicles optimise driving routes and schedules. In addition, timely information about rush hours, accidents, maintenance works, etc. provides further improvements on route planning. On a global level, an extensive set of geographical information enables the dynamic planning of lighting, smart energy grids, and speed limits in order to obtain greener and smoother traffic flows. Figure 7 illustrates an overall system where vehicles communicate between each other and with supporting infrastructure.

Wireless networks are an essential element for collecting and distributing location-based information. For example, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) are the basic communications types for road traffic. Furthermore, with the increasing number of

different web-based services, inter-service communication features allow an increased level of integration. For instance Cloud-2-Cloud communication channels used for information-distribution between different stakeholders coming from different mobility and service areas are very relevant to consider for MaaS planning as well. The current evolution of mobile networks moves towards allowing different entities and actors to be connected efficiently and fast, as described in Section 4.1. This enables whole new opportunities for realising the MaaS concept in different forms.

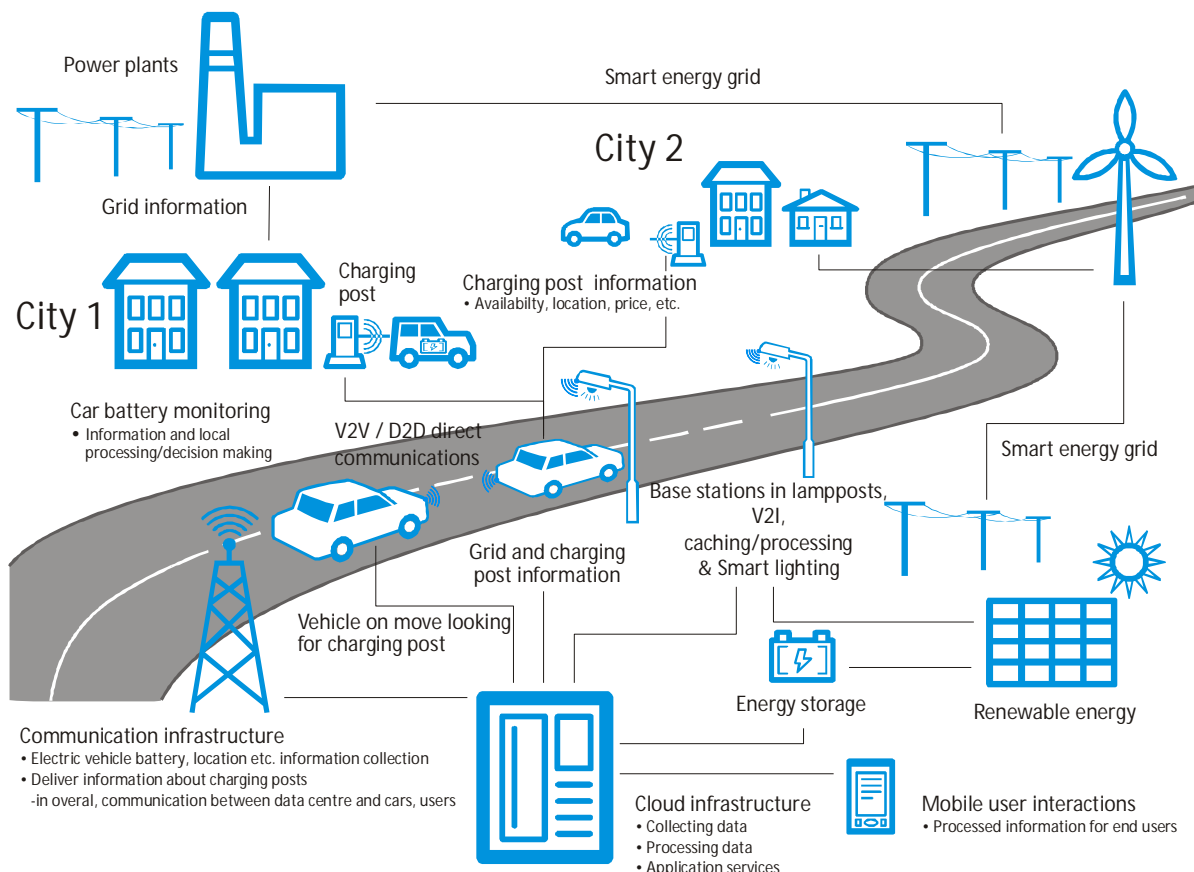


Figure 7: Road safety and optimisation with geolocation-based information and external power sources in case of electric vehicles. (copyright Huusko, J. and Piri, E., 2017)

5 Standardization aspects

As a main basis, enabling added value service features for MaaS systems, using available standards dealing with interface and data content specifications, plays a key role. Having common standards developed and applied, interlinking different available mobility services and providing access to data and information can all be simplified. With the agreement between different stakeholder organisations, using common standards along the value chain, will push the evolution of MaaS and simplify collaboration between different stakeholders. In this way, a higher degree of integration is able to be achieved as well.

Standardisation is required if more than two different operators/service providers are willing to exchange any related commonly understood content (e.g. pricing schemes, real-time information on road travel times, public transport timetables and/or information/booking on available shared facilities). Since MaaS focuses on the integration of different data and services, thus fostering the provision of an all-in-one accessible solution for end-users, common standards on different levels derived from the requirements coming from the technical system architecture need to be considered in order to provide scalable and easy to

access MaaS services.

As a basis for identifying relevant standards, the IP (Internet Protocol) architecture is used. Therefore adequate standards need to be transferable to the commonly used IP-based technology environment. The following example (figure 8) shows the idea and possible transmission aspects of content, shared among different clients/publisher sites.

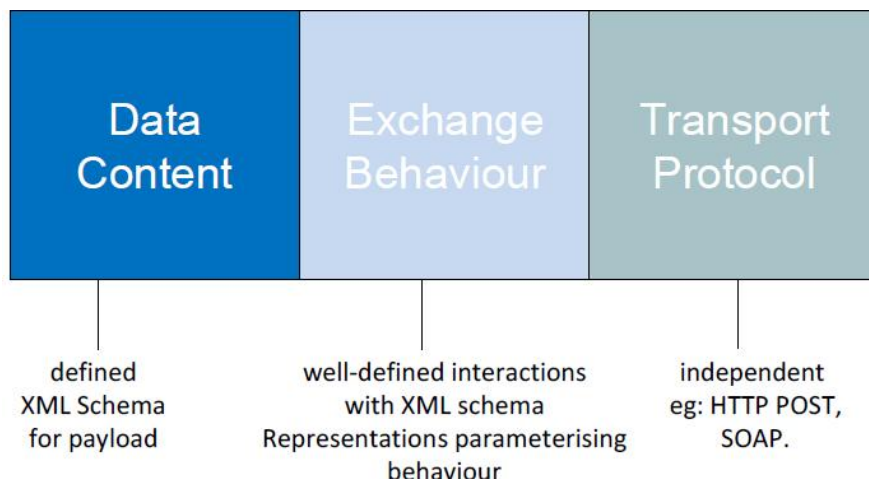


Figure 8: Provision of data content over the IP based architecture, [8]

In order to allow the synchronized distribution of information/data content, pre-defined formats specifying data elements need to be made available. Based on the literature findings, there are different data content specifications for different transport mode requirements available. For instance, for road transport-related data (e.g. travel time information, traffic messages, etc.) the DATEX II standard/format is applied. For public transport (PT) data, the NETEX provides a specification of required data content covering PT specific requirements (e.g. timetable formats, location of stops, etc.).

Having found the required data formats for the specified purposes, the required exchange specification for distributing information content over the internet needs to be determined. Since most standards (including DATEX II and NETEX) rely on XML-based technologies, XML-schemas derived from specific requirements coming from the standards are commonly used for pre-defining the exchange behaviour between different service applications.

In this respect, the XML (eXtensible Mark-up Language) provides the key technology for exchanging information complying with IP-based web-service logic. In other words the XML-specification works as a container for exchanging determined data.

Figure 9 provides an overview of the standards framework, identified by Slevin [8], with different available standards for data and service provision elaborated and divided into public and road transport.

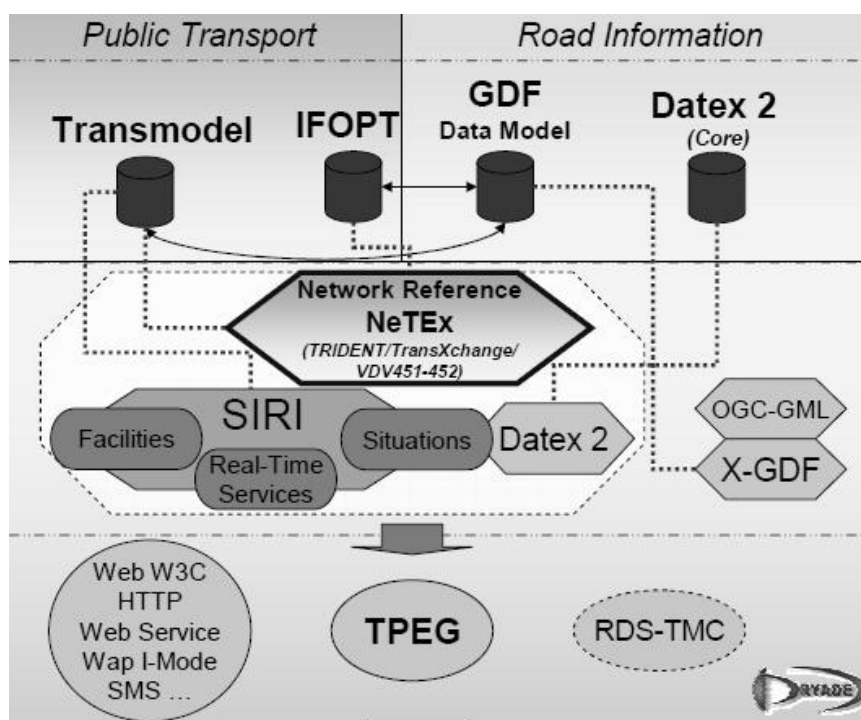


Figure 9: Overview of transport data standards, divided into related transport modes, [8]

On the left side, public transport data standards, including the Transmodel (similar to NETEX) together with the IFOPT (common standard for the provision of Identification of Fixed Objects in Public Transport) are shown. On the right side, road transport-related standards covering DATEX II together with the GDF (geographic data format standard, for coding transport networks relevant for routing) are shown.

Further interrelations between those standards and data models and possible overlaps are presented, which occur when having them all actively operating in a real-time based framework. 'SIRI' presents in this case a real-time-based PT data specification.

In the last step, the provision over different interfaces of aggregated information/service specifications to end-users is shown. For instance, the TPEG (Transport Protocol Experts Group) or RDS-TMC (Traffic Message Channel) standards are used to distribute road information (information on road status and incidents respectively road events) directly to road users' devices, e.g. over FM (radio).

As far as the final end-user service provision is concerned, the Web W3C standard for providing information/data content over the internet should be highlighted, covering the main requirements for MaaS. Further details on available standards (divided into data and service standards) are described in the following sub-sections.

5.1 Data content-related standards

The following standards for exchanging road and public transport related information were identified as state-of-the-art used for exchanging data/information:

DATEX II Standard: CEN/TS 1615 (Road traffic information)

DATEX II is a multi-part road transport standard, maintained by CEN Technical Committee

278, CEN/TC278, (Road Transport and Traffic Telematics).⁸ The first three parts of the CEN DATEX II series (CEN 16157) have already been approved as technical specifications. These three parts deal with the most mature and widely used parts of DATEX II: the modelling methodology (called Context and framework) as Part 1, Location referencing as Part 2 and the most widely used DATEX publication for traffic information messages (called Situation publication) as Part 3. A fourth part of CEN DATEX II series, VMS publications, is currently being prepared for standardization to CEN/TC278 and a fifth part on measured and elaborated data is currently proposed as work item. More parts are to follow as new content requirements emerge.

NETEX Standard: CEN/TS 16614 (Public transport information)

NeTEx is a CEN Technical Standard for exchanging public transport schedules and related data. It is divided into three parts, each covering a functional subset of the CEN Transmodel for Public Transport Information:

- Part 1 describes the Public Transport Network topology (CEN/TS 16614-1:2014);
- Part 2 describes Scheduled Timetables (CEN/TS 16614-2:2014);
- Part 3 covers Fare information (CEN/TS 16614-3:2015).

NeTEx is intended to be a general purpose XML format designed for the efficient, updateable exchange of complex transport data among distributed systems. This allows the data to be used in modern web-service architectures and to support a wide range of passenger information and operational applications. Whilst there are a number of existing standards available for timetables, NeTEx is the first systematically engineered standard that also covers multimodal fares. NeTEx is free to use under a GPL (General Public Licence) and the CEN standards process manages its development.

In addition, the INSPIRE⁹ standard, providing a common format for the provision of available digital transport networks, required for routing, also represents a fundamental basis for MaaS in order to foster common routing features for multimodal traveller information systems (an integral part of MaaS).

5.2 Service-related standards (web-service specifications)

A web service is a collection of open protocols and standards used for exchanging data between applications or systems. Software applications written in various programming languages and running on various platforms can use web services to exchange data over computer networks like the internet in a manner similar to inter-process communication on a single computer. With the implementation and provision of IP (Internet Protocol) based mobility services, the following general standards were identified.

W3C-XML

The eXtensible Markup Language (XML) is a simple text-based format for representing structured information: documents, data, configuration, books, transactions, invoices, and much more. The format was specified by the World Wide Web Consortium (W3C), which is the main international standards organisation for the internet (World Wide Web).

⁸ www.itsstandards.eu

⁹ <http://inspire.ec.europa.eu/>

Basically XML is one of the most widely used formats for sharing structured information between programs, between people, between computers and people, both locally and across networks. XML documents are made up of storage units called entities, which contain either parsed or unparsed data. Parsed data is made up of characters, some of which form character data, and some of which form markup. Markup encodes a description of the document's storage layout and logical structure. XML provides a mechanism to impose constraints on the storage layout and logical structure. Based on the following design goals of XML as a basis technology for coding data, several exchange formats have been specified.

SOAP web-services

SOAP (Simple Object Access Protocol) is a lightweight protocol for the exchange of information in a decentralized, distributed environment. It is an XML based protocol that consists of three parts: an envelope that defines a framework for describing what is in a message and how to process it; a set of encoding rules for expressing instances of application-defined datatypes; and a convention for representing remote procedure calls and responses. SOAP can potentially be used in combination with a variety of other protocols.

Rest web-services

REST stands for REpresentational State Transfer. REST is a web-standards based architecture and uses HTTP Protocol for data communication. It revolves around resources where every component is a resource and a resource is accessed by a common interface using HTTP standard methods. Instead of using the W3C based XML technology, Rest provides developers with an open container structure for specifying the exchanged content.

6 Roaming and MaaS

Roaming in the context of MaaS means using the transport services of other MaaS operator(s) than the operator to which one subscribes. The first MaaS pilots were carried out with a very limited set of transport providers and a limited geographical area. Although in the future some MaaS operators will cover many different transport providers and operate over large areas, even across country borders, any single MaaS operator will not be able to satisfy all the mobility requirements of all subscribers. Thus, cooperation between MaaS operators for expanding the coverage of their services and improving business opportunities becomes relevant.

Figure 10 illustrates the concept of roaming in the MaaS context. Different MaaS operators have made contracts with different transport service providers (TSPs) to sell their transport services within certain regions. The regions can cover whole countries or just some regions within a single country. The means of transports different MaaS operators support may also differ, which may be one another reason for a MaaS operator to establish a roaming connection to other operator(s).

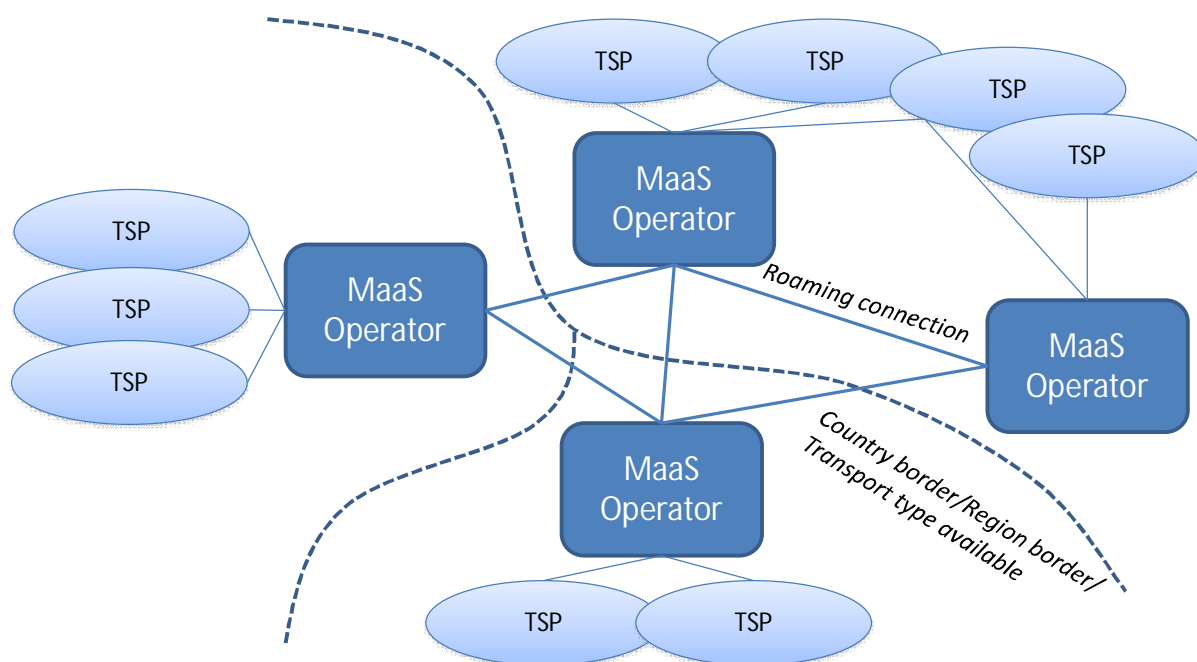


Figure 10. Overall concept of roaming of MaaS (copyright Piri, E. 2017).

Roaming in the MaaS concept has many similarities to roaming in mobile networks. When people travel abroad, their mobile devices are connected to a network of local mobile network operators. Mobile network operators have made roaming agreements with single or multiple operators in basically every country. A big, differing aspect in MaaS compared with mobile networks is that MaaS operators do not typically own the resources they are providing. Mobile network operators typically own and operate the network resources to which they provide subscribers with access. However, virtual mobile network operators are becoming more common in the future mobile network business. This means that virtual operators give their subscribers access to the resources owned and maintained by other companies, typically a mobile network operator as well. This is a more comparable situation with MaaS. When the actual resources are leased, all efforts can be put on creating different service concepts and business models.

Essential factors to enable roaming between MaaS operators are related to agreements between operators and well-specified open interfaces. Agreements form the basis for cooperation. Agreements may define, for example:

- Operational geographical area of MaaS operators involved in the agreement.
- Which transport modes that are allowed to be used when roaming.
- Possible additional expenses added to the price when roaming.
- How and for how long clients' personal information is handled and stored by the operator roamed. For data privacy, the ideal case is that no personal data (my data) needs to be exchanged between operators.
- Ticket reservation and cancellation policies.
- Detailed specification of the interface, which allows connecting to the services of the partner operator.

While the agreements form the basis for enabling roaming, open interfaces form the basis for realising the actual cooperation. The MaaS operator must have access to query for transport schedules and prices of the partner operator and handle ticketing. Ticketing can be handled by the home operator with support of the visited operator.

When subscriber information is moved between MaaS operators, issues related to data privacy need to be handled properly. It is important that as little personal information as possible is moved between operators. The reform of EU's data privacy directive defines many new aspects for data protection, briefly introduced in Section 2.4. The ideal case would be that no personal information needs to be exchanged between roaming partners.

6.1 Example service architecture for MaaS roaming

Figure 11 shows the high-level logical system architecture with interfaces and functions required by roaming. Essential elements regarding roaming functionality are the agreement database, storing roaming agreements negotiated between operators, and the interface, which allows connecting to the services of the partner operator. On the technological level, nothing else is needed compared to situations without roaming.

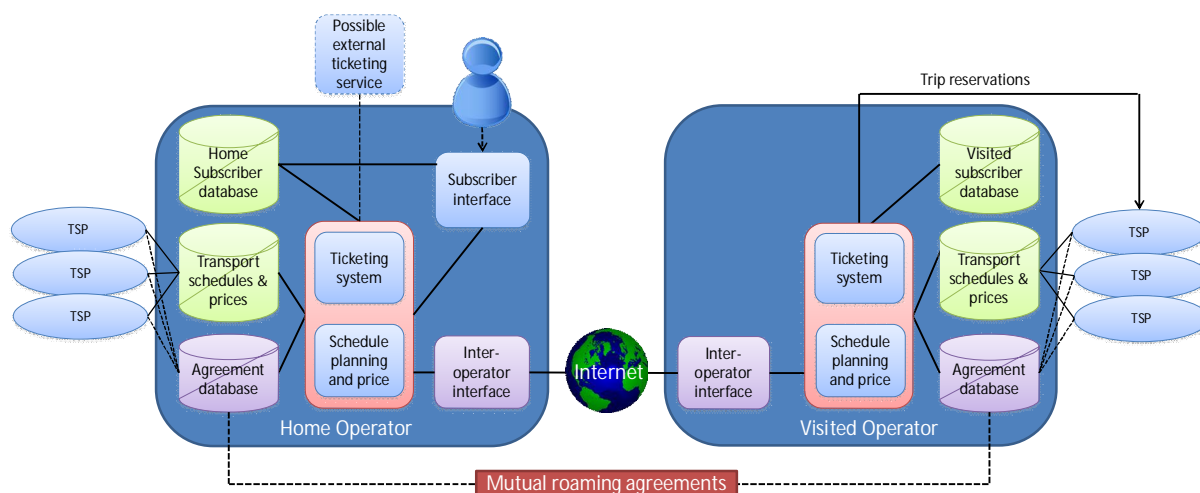


Figure 11. High-level architecture for roaming (copyright Piri, E., 2017).

Figure 12 shows an example diagram with message exchange between different function modules in the case of roaming. The acronyms in the diagram refer to Figure 11, and are: UI (User Interface), SPP (Schedule Planning and Price), TSP (Transport Schedules & Prices database), HSD (Home Subscriber Database), IOI (Inter-Operator Interface), and VSD (Visited Subscriber Database). The diagram does not attempt to provide guidelines or an optimal way on how message exchange should be done, but only adapts to the high-level example service architecture for MaaS operators shown in Figure 11. The message exchange between different architecture blocks is always architecture and service-specific.

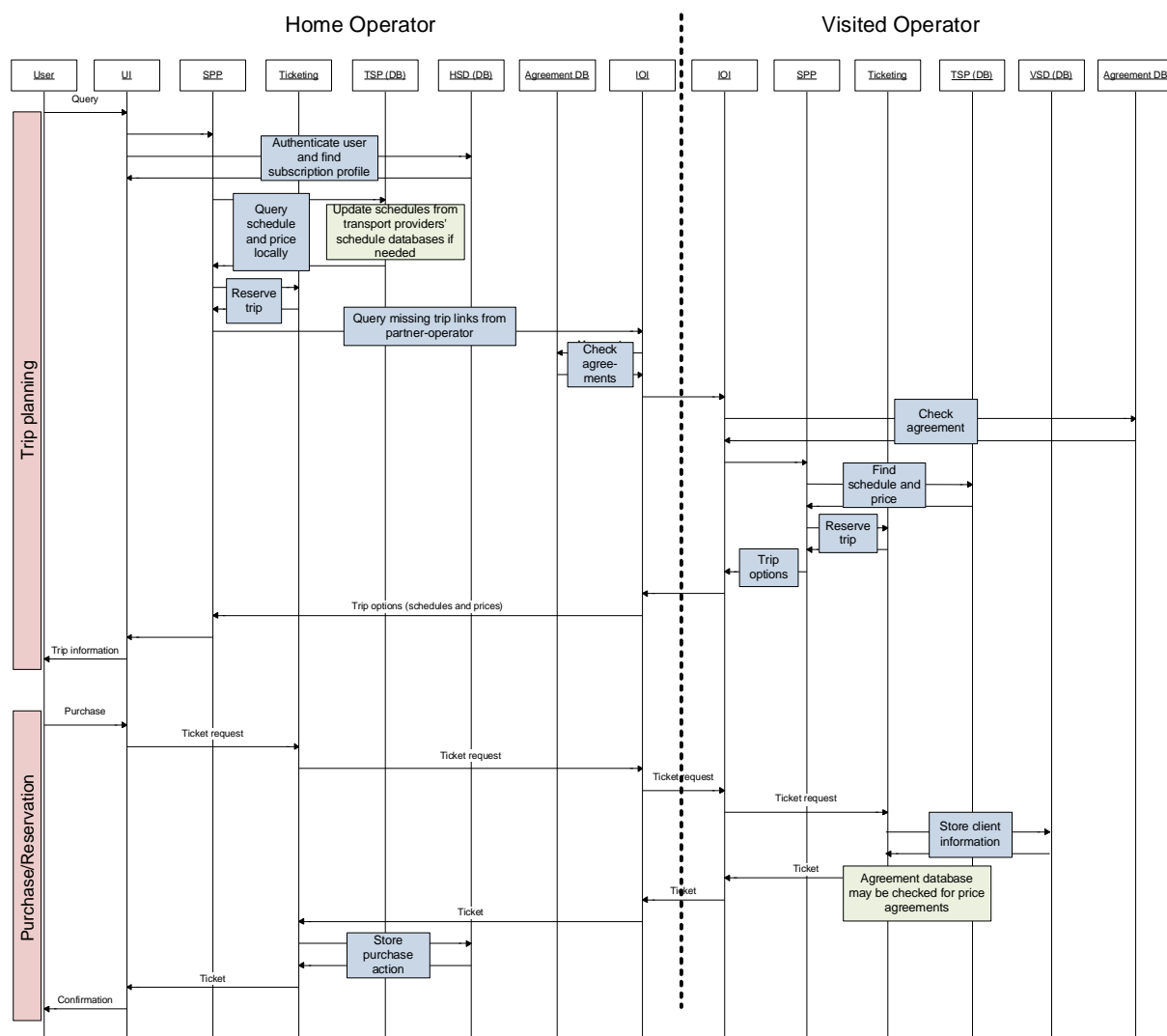


Figure 12. Sequence diagram with an example of trip reservation with roaming (copyright Piri, E., 2017).

7 Recommendations for MaaS deployment

Based on the state-of-the-art analyses and identification of the value chain, the technical system architecture was set up. Technical requirements that arise with the deployment of the MaaS system architecture were the basis for deriving recommendations following the value chain principle (User <-> MaaS Service <-> Individual/Common MaaS Service Levels <-> Information Generation <-> Data Provision). The following recommendations could be derived:

7.1 Open data/Service-related specifications

- Open and standardised interfaces for both, user and operator/publisher back-end communication.
- Access to transport data and real-time information: schedules, transport vehicles, provision of real-time information (delays, travel times, timetable changes), network data (lines, links, nodes) relevant routing

- Unified and increasingly centralised data structures in different data sources (different kinds of information need to be collected from a range of different sources)
- Unified machine readable protocols for updating (push) and retrieving (pull) transport information, e.g. with Restful (JSON), SOAP, other XML based protocols
- Merge differently available data pools coming from different transport sectors as basis for optimised route planning and transport safety, enabled by open data

7.2 Wireless communication networks

- Provision of communication alternatives in areas with reduced wireless access coverage with respect to user applications (reduced access to wireless communication networks requires alternative access conditions)
 - Making tickets, maps, schedules available for offline use
 - Utilize low-power and long-range IoT communication networks for low-rate data transfers
- Due to high roaming costs, alternative ways to be considered:
 - More extensive WLAN network coverage
 - WLAN hotspots in transport vehicles
- Utilize the upcoming mobile network technology (5G) to make services more personalised and location-based
 - Future communication technologies allow making more extensive use of connected and distributed systems
 - Data processing and data located close to users – low-delay services
- Technical deployment in different geographical areas: urban, rural, regional, national and international levels. (Other strong requirements coming from the tourism industry.)
- Currently WLAN already reaches capacity constraints in densely populated regions (e.g. in the case of the London Underground). High passenger traffic in frequency bands causes addition demand for 5G and new communication technologies.

7.3 Standardisation/Regulation/Management requirements

- Using common road transport data standard DATEX II is relevant for providing harmonized traffic data and related information exchange between road management centres, service providers and users
- Data content specifications applied to road and public transport modes for exchanging data: DATEX II, NETEX/Transmodel, SIRI. Both DATEX II (road transport) and NETEX/SIRI (public transport) allow the exchange of real-time transport information
- Fostering the deployment of data content specifications/standards on a national level
- Deployment of Cloud2Cloud communication standards
- Establishing a common data platform for exchanging data/information
- Digital networks/routing applications: common digital networks shared between

different MaaS actors. GIS-based network graph (links and nodes for routing) and exchanging transport information (e.g. based on INSPIRE standard),

- Technological solutions management: provision of expert groups supporting technical deployments within MaaS systems (taking new technologies into consideration for further MaaS system evolution, e.g. using Bluetooth and other location based applications)

7.4 Licensing

- Licensing gives users a higher certainty and fosters a common trust-based relationship
- With respect to standardisation, licensing enables the provision and availability of high-quality and open data services
- Provision of global licences fosters collaboration on an international level
- Harmonisation of licensing coming from public authorities
- Licenses for using open data should not restrict commercial use

8 Conclusions

Based on the setup of the MaaS system architecture, several technologies were identified so that a more comprehensible picture of technology requirements could be achieved. Even though there are many different, mostly ICT-based technologies (with a special focus on smartphone applications popping up on the market), only some have become established and represent true breakthrough innovations used by the large majority and thus need to be considered for rolling out MaaS on a broader scale.

As long as MaaS should be made accessible to the broader population, wireless communication networks present an inherent requirement to be made available. Thus mobile communication networks divided into local and wireless area networks were analysed with regard to the identified MaaS requirements. With the increase in bandwidth and increased wireless network coverages, higher accessibility and penetration of digital services can be achieved. Especially 5G, as the upcoming telecommunication network technology, seems to be promising as it can enable higher end-user service quality. In other words, by that, users are expected to gain a smoother service experience with reduced delay times and error rates. Also contributing to a smoother service experience is the development of useful (utility + usability), well-designed interfaces and quality service features based on user requirements.

Since MaaS fosters an area-wide mobility service accessibility, combining both urban and rural areas, some offline technologies like Bluetooth, NFC (Near-Field-Communication) or Infrared (as a more niche technology), are seen as bridge technologies filling up the gap between areas with lesser and greater internet access. However, offline-based service features, which will likely require subscriptions in advance, need to be available even though service accounting may be delayed. For instance, offline ticketing provided over NFC or Bluetooth can allow the use of some MaaS service features in areas with reduced internet access.

Since the implementation of the proposed MaaS system architecture strongly depends on the assigned business model, variations in the setup of required technologies for MaaS are conceivable and need to be manageable for the different service contributors. Nevertheless, common standards and technologies are seen as major requirements for implementing and synchronizing data exchange for final MaaS service provision.

Having common standards already at the data level in the form of data content specifications (e.g. DATEX II or NETEX) simplifies not just the physical exchange/transmission between different operators or service providers, but also provides a common machine readable 'language' format which can be understood by arbitrary third party providers also willing to participate in the MaaS distributed system.

The final recommendations should provide interested stakeholders with guidance on how to optimally cover identified technology requirements. With this respect, backward compatibility of technologies needs to be considered and managed within MaaS in order to allow high service level agreements.

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<https://www.w3.org/>

Annex I - Case studies on added value and behavioral change

1. Design and expectations of multimodal traveler information services: Lessons learned from the SmartMoov pilot

App “impression” and general technical wishes

Many of the participants stressed that in order for the app to be of interest to them it had to be “... better...” than those already existing and used (i.e. the local public transport operator's travel planner, Google Maps, Ways etc.): thus the new app has to provide additional value to users. Such an added value could be created by adding other information than what is provided by existing apps and/or by integrating different functions in one app. At the same time several participants expressed worries that an app providing a lot of functions would become more difficult to use and hence less user friendly than the existing ones. This would have a negative impact on acceptance and adoption.

The importance of the app being ‘user friendly’/easy to use was emphasized in discussions on positive features of apps in general as well as the traveller information app in particular. The app must offer good ‘learnability’ (i.e. easy to learn how to use), a readable screen (glasses should not be necessary in order to read text), good contrast, etc. and it must be easy to navigate, for instance menus. The design of the user interface (UI) must be adapted to the device and the available screen size so that one did not have to zoom in and zoom out too much. Some participants (primarily bicyclists) used navigation apps such as Google Maps with voice output. This feature was desired also for the new app.

An attractive app has to be ‘fast’, a request that referred to fast interaction (i.e. information entry etc.) as well as fast communication. It was important to get a quick response on a request (e.g. when is the next bus due?). Time to entry your request as well as response times must be as short as possible, if not “... You may miss the next bus and then what is the point?” as expressed by one participant. A fast way of entering information/request for information on route was for instance to be able to click on a map indicating “from ... – to ...” and then search, rather than having to add information on address or public transport (PT) stop. Another request was to be able to add one's favourite and/or most frequent trips as a link so that one only had to click the link to get information on next departure etc.

Furthermore the new app must be reliable. Reliability refers to the information provided which must be correct and updated. The suggestions for how to travel from A to B must also be interpreted as smart, preferable smarter than the individual user's own choices. Several participants commented that the information services used quite often suggest routes that one knows is not the best option: “If I takes the stairs to I can take bus X instead which I know will take me to where I want to go 10 minutes faster”.

Several participants argued that also the semantics (in terms of expression) of the app was important. It should communicate ‘modern’. A modern, aesthetic looking app would be used to a higher extent than an app that was interpreted as ‘old’ and considered ugly.

1.1.1.1.1 Information requested

The app must evidently provide information on how to travel from A to B. However, from A to B does not mean from one PT stop to another but information covering the whole trip. The app should also offer the possibility to specify a detour, i.e. from A to B but passed C. This was important if one for instance wanted to pass a particular store on the way home or pick up children at day care.

The app should offer alternative routes and/or mode of transport, i.e. trips by PT, by bicycle and walking. However it was desirable that it took into consideration for instance, the possibility to use the rental bike system (Styr & Ställ) and car sharing systems (e.g. Sunfleet) in Gothenburg. It should provide information on where bikes/cars are available and also where one can leave the bike/cars. It was considered very important that not only some but all travel modes available will be considered in the new app! This is also reflected in the desire to gain information about other alternative mode-related infrastructure, such as bike pumps to fill tires and charging stations for electric bikes and cars.

The participants also stressed the importance of having access to maps. Information on how to travel from A to B can be presented as a list but presenting it (also) in a map view (i.e. the route on a map) provides the user with a desired overview. However the maps must be of good quality – poor map views, and maps that take a long time to download, were quite common according to some participants. Google Maps and Waze were considered as examples of good map services whereas Eniro navigation and Apple navigation were considered poor examples.

Participants showed interest in the new app providing information on best travel option from the perspectives of cost, time, and/or environmental impact (CO₂ and/or other). This interest concerned in particular longer trips and less frequent trips. Also, even though one “knows” that walking and bicycling are the better options from an environmental perspective, it was considered difficult to assess the environmental impact of trips where different modes are combined. Other options mentioned were the best alternative from a health perspective (e.g. exercise). For bikers it was of interest to get information on the most comfortable choice (e.g. less hilly route, cf. Google maps), the shortest route as well as the safest route. This information could be based on statistics on accidents involving bicyclist, access to dedicated cycle lanes etc. And last but not least, basic accessibility information (e.g. accessible trams with no height difference between the tram and platform) is vital for travellers with baby carriages, wheelchairs, etc. Ideally one would also wish to get advance information regarding the current availability of baby carriage and wheelchair places in the vehicles (i.e. if these places are already occupied or not).

Most apps provide information on request. A majority of the focus groups desired a more proactive and ‘smart’ service that learned the user’s travel behaviour – “A smart app that recognize the users travel patterns” - and that suggested other alternatives than the one(s) commonly chosen. This proactivity could also include for instance alerts if there is some disturbance on the route you normally choose for your commuter trips. Such alerts should include information on delays, congestion, accidents, etc. along those routes that the traveller normally takes and/or for a route that the user requests to be kept informed about. To be informed not only that a disturbance exists but also the character and type of disturbance was considered important as this helped the user to judge the severity and duration of the disturbance. If the system could provide information on estimated duration of the disturbance, this would be an added value.

1.1.1.1.2 In-app services

In Gothenburg, travellers have the opportunity to pay their PT ticket via their mobile phone. Overall though, the fact that you have to register with the local PT operator in order to use this service has resulted in less use than before registration was required. Nevertheless several participants suggested that the new app should include this possibility.

In several focus groups weather information, or rather an integration of the weather forecast in the new app was desired. The wish was that the information provided on what mode to take or what road to take will take the weather situation into consideration.

A service mentioned several times across focus group interviews was that the app could

include information on interesting sights, where to find museums, libraries as well as for instance ATMs. Other information mentioned was where to find ride-and-park facilities and petrol stations.

1.1.1.1.3 Preference and customization

A very common request for the new app was that users must be able to customize the app to fit their own needs and preferences. This included primarily filtering the modes to be shown. Some participants mentioned that the desired mode of transport may differ over the year: bicycling being the preferred mode during summer and public transport during winter. However, the preferred mode may also be influenced by weather (rain, snow, wind) and road conditions (slippery) why a connection between the traveller information service and weather forecasts was desirable (cf. earlier comment).

1.1.1.1.4 Social media user interaction

Some participants suggested that it should be possible to share information on your travels with others, for instance information on that you are on the way and will arrive in x minutes. It was clear, however, that the participants differed in terms of their acceptance of such features. While some participants argued that one must accept certain risks in order to be able to gain certain benefits, other felt that sharing information this way was somewhat risky. There was a general agreement that one should always actively choose to activate this option.

1.1.1.1.5 Barriers

One aspect where the participants differed in opinion was their willingness to pay. However, most participants agreed that they expected a traveller information app to be free of charge. The main argument was that as one paid for the trip by PT or for renting the public bike one should not be charged for having access to information on the same service.

It was very important that the app did not drain your battery. Participants had experienced how animations, advertisements, etc. consumed excessive battery. It was also desirable that the app worked off-line as one cannot have access to the network all the time.

For most (but not all) participants it was important that the local public transport operator or another local authority was the 'owner' of the app and the 'sender' of the information. It appeared as though the participants felt that this type of organisation would be the least biased and the most neutral compared to a commercial company.

Outcome of and lessons learned from the SmartMoov pilot

A main goal for the development and implementation of the app was to encourage change, more in particular a shift from more energy demanding to less energy demanding modes of transport. However, there was nothing in the in-itinere surveys or the focus group interview results that indicate any radical, habitual changes in the participants' travel behaviour. Any impact of using the app on choice of mode of transport reported appears instead related to specific trips when the participant found it possible to take alternative routes etc. One way to explain the non-changes are consequently to argue that having access to the information did not change the participants' norms, motives or attitudes towards their existing travel behaviour and therefore no change in behaviour was achieved.

Analysing the ex-ante questionnaire results, the car users appeared somewhat less concerned about 'cost' than did public transport (PT) users and bicyclists; car users and

bicyclists seemed to judge 'time' and 'flexibility and independence' as more important than do PT users; and the share of car users who considered 'comfort' as important was larger than the share of other travellers in the sample. Attitudes towards the environment and environmental concern have been proposed as important factors in people's choice of transport modes. Even though most car users were aware of that their mobility patterns contributed to the emission of greenhouse gases, and that they agreed to having a personal responsibility to contribute to a reduction, environmental concern appeared to be less important to car users choosing the car than for other participants. Car users were also less willing, compared to PT users and bicyclists, to completely disagree with a statement that people should be allowed to use their cars as much as they like.

In order to cope with the vast number of decisions people need to make on a daily basis, different heuristics are used of which habit is one. However, these simplified rules result in biases and decisions are made based on pre-conceptions about a mode. Car users may for instance have misperceptions about how long a certain trip will take by PT or bicycling why travel information on the options may. Habit most certainly also played an important role, in particular in relation to commuter trips. It also seems as though habits influenced the way in which the participants accessed traveller information on, for instance, 'Next departure'. In the focus group interviews, the participants explained more than once how they had without much thought kept using their 'old' app, in particular in situations where they were in a hurry.

The Trans-theoretical Model (Prochaska & DiClemente, 1982¹⁰) asserts that people move through a series of stages when modifying behaviour: from pre-contemplation to contemplation, preparation, action and finally maintenance, and further that different types of support are needed for people at different stages of the process (Gatersleben & Appleton, 2006¹¹). Using this model as a basis for explaining the non-changes, one could note that 1/3 of the participants stated in the ex-ante phase that they had the intention to change their travel habits. It is possible that multimodal traveller information, easily available in an app, can play a role in this process (for instance to increase individuals' knowledge on alternative travel options, routes, times etc.) but additional information and/or other support is most probably needed in order for changes to happen.

Based on the results from the trial and the participants' comments on when and where they used the app and the impact it had (or not), it appears important to differentiate between different situations and time horizons in order to address, and assess, the possible impacts of different types of traveller information (cf. Skoglund & Karlsson, 2012¹²) as illustrated in the following examples:

Example 1: A public transport user searching for information on the next departure and a car user who wants to find out about which roads are congested in order to choose the quickest route to/from home/work may both use a multimodal information service. In this case, the travellers can be argued to have formulated conscious questions associated with travelling 'here and now' – 'When is the next bus 55 leaving the bus stop?'; 'Can I walk or should I run?'; and 'Is there a queue?'; 'Should I take route A or route B?' The choice of transport

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¹¹ Gatersleben, B. & Appleton, K.M. (2006): Contemplating cycling to work; attitudes and perceptions in different stages of change. *Transportation Research Part A, Policy and Practice*, 41:4, pp 302-312.

¹² Skoglund, T. & Karlsson, I.C.M. (2012). Appreciated - but with a fading grace of novelty! Traveller's assessment of, usage and behavioural change given access to a co-modal travel planner. *Procedia - Social and Behavioral Sciences*, 48, pp. 932–940.

mode has most probably already been defined and hence, the travellers are less likely to in this context contemplate different transport mode alternatives. Commuter journeys are most often accomplished without further thought or reflection why questions regarding what mode to choose or why may simply not emerge in the person's everyday life. There are consequently no motives to search for additional information.

Example 2: A public transport user searching for information on what route to choose for a less known or unknown destination OR a car user investigating the possibilities to take the bus home from a night 'on the town' can both use a multimodal travel planner which provides information on how to travel from A to B, as well as comply with its suggestions. Also in this situation the travellers have formulated questions to the information service but in this context the mode of transport may not be predefined. The public transport user may contemplate buses, trams, or, for example public bikes or car sharing provided that the multimodal travel planner offers this information and the car users may consider public transport but may also choose, for instance taxi, if the public transport options are not considered feasible.

In these situations, the multimodal travel planner will fulfil the main goal of reducing travellers' uncertainty (cf. Karlsson et al., 1994¹³). However, if the purpose of the service is not (only) to reduce any uncertainty associated with travelling 'here and now' or for a specific journey – but also to accomplish a long-term shift from less to more sustainable modes of transportation, there is no 'match' between the users' need for information and the information provided. Such a match exists only if a traveller uses the information service with the specific purpose of finding information to support such a change, i.e. 'Could I commute by bus or tram instead of driving?'. The multimodal traveller planner provides information on how to make the trip from A to Z, but it is still the individual traveller who will judge the 'could' based on a number of factors, actual conditions but also perceived action space (cf. Strömberg, 2015¹⁴). An app developed in order to support this and even more radical changes, i.e. 'Could I sell my car and rely on collective transport services instead?', probably needs to offer more than information than multimodal travel plans in terms of route and travel times. The participants suggested information on cost and CO2 emissions but earlier studies have shown that also travel planners including this information have not resulted in radical changes (e.g., Skoglund & Karlsson, 2012). In this case information needs to be accompanied by an interruption to the usual routine or habit, plus a motivation to change. An interruption to a usual routine is, for instance, when a person changes address.

However, also a single change in the choice of travel mode is a change. Single journeys may accumulate to chunks, and the information may still contribute to the changes desired by society. Information of the kind presented by the app might consequently have an effect on travel patterns in the long run, in particular when combined with other improvements of the public transport system and cycle and walking infrastructure, or as part of a MaaS service.

¹³ Karlsson M., Wikström L. & Béen, P. (1994): "Resenärens informationsbehov och -krav. Delrapport från GoTIC-projektet. (The travellers' need and requirement for information), Report. Consumer Technology, Chalmers University of Technology, Gothenburg,

¹⁴ Strömberg, H. (2015). Creating space for action - Supporting behaviour change by making sustainable transport opportunities available in the world and in the mind. Dissertation. Department of Product and Production Development, Chalmers University of Technology.

2. Service design: Lessons learned from the UbiGo pilot

Participants' expectations

TABLE 1: Initial expectations and fulfillment of expectations during the UbiGo pilot.

Question*	Average Rating (1-7) Disagree - Agree		
	Before	During	End
I expect it to become easier to pay for my transport and keep track of my transport expenditures.	5.59	5.40	5.74
I expect to have more transport mode alternatives to choose from.	5.49	5.32	5.44
I expect to be able to better adapt my choice of transport mode to the individual trip's conditions.	5.29	4.80	5.00
I expect my total transport expenditure to go down.	4.92	5.05	5.14
I expect my environmental impact to go down.	4.61	4.54	4.80
I expect my trip planning to become more effective.	4.46	4.38	4.79
I expect my travel patterns (e.g. times and destinations) to stay the same.	4.39	5.08	---
I expect my travel to become more time efficient.	3.66	3.83	4.14
I expect my choice of transport modes to stay the same.	3.63	4.40	---
I expect my travel to become less physically demanding.	3.10	3.68	3.81

Service and app features and functionalities

The UbiGo participants were also asked the importance of various service and app features and functionalities, which were later followed up with what extent they agreed or disagreed regarding such. Table 2 organizes these service and app features and functionalities into themes. As can be seen in the table, most of the features and functionalities were considered important, and thus only a selection will be discussed here.

Theme 1: Transport modes and travel guarantee. For this theme, one can see that it is important with a good level of service, with close, available, and timely transport including a working travel guarantee. In particular, it was considered highly important that carsharing sites be close by. This was also identified as one of the main obstacles for joining UbiGo, as some potential participants who did not join in the end just felt that the carsharing sites were too far away (Sochor et al., 2014¹⁵).

Theme 2: App use. Here one can see that ease of use is important (and more important than being fun to use). The app needs to be easy to use, instructions easy to find, and it should also be easy to check one's balance. This theme together with Theme 3 most highly

¹⁵ Sochor, J., Strömberg, H., and Karlsson, I.C.M. (2014). "Travelers' Motives for Adopting a New, Innovative Travel Service: Insights from the UbiGo Field Operational Test in Gothenburg, Sweden". Proceedings of the 21st World Congress on Intelligent Transportation Systems (Detroit, September 7-11, 2014).

correlates with the discussion of usability above.

Theme 3: Subscription, bookings, bonus. Again, aspects related to ease of use are given the highest ratings, including ease of changing/cancelling bookings, modifying one's subscription and understanding the monthly invoice. Contrary to the project team's expectations, rewards for sustainable travel turned out to be less interesting to the participants, with their feedback being linking bonus points to "internal rewards" (i.e. transport) rather than external rewards (exchanging points for rewards from local businesses).

Theme 4: Customer service. Participants' highest priority was quick response time, which is understandable if one's problem has to do with access to or using transport. However, in the UbiGo pilot, most of the customer service errands were at the beginning and were related to downloading the app and placing it on one's home screen. Despite this, the 24/7 centralized customer service was highly appreciated by the participants, as was the travel guarantee even if this guarantee was hardly used. Both of these contribute to a sense of reassurance on the part of the user.

Theme 5: Trust and security. Participants wanted to make sure their personal information was secure and not accessible to unauthorized persons/parties. Over the duration of the pilot, the participants also built up a high level of trust for the UbiGo team, which is likely at least partly related to the project partners comprising many well-known, local organizations. Also, the UbiGo app utilized a Gmail/Facebook login rather than a dedicated login. Although people generally felt secure with this, when asked what they preferred, approximated one-third would have preferred a dedicated login, one-third did not care either way, and one-third preferred a Gmail/Facebook login. This indicates that such customer preferences should be taking into consideration when designing security and access features.

Contributing service attributes

Based on participant questionnaires, interviews, and travel diaries, service attributes that contributed to the success of the UbiGo pilot were identified, including the 'transportation smorgasbord' concept, simplicity, improved access and flexibility, and economy. Although not a service attribute per se, the FOT also enabled the trialability of new behaviors and a reevaluation of convenience. Service design and impact are not independent of each other, and if a mobility service is to change behavior (i.e. achieve impact) as well as create added value, these goals need to drive design decisions and a deliberate and conscious development of service dimensions such as customization, bundling, and range of the offer.

Service Attribute 1: The 'transportation smorgasbord' concept, with the majority of one's travel needs offered in one package. Interview results revealed that even participants who were already using car- and bikesharing appreciated the packaged concept, as it was convenient to have only one subscription, one customer support number, etc. "The best part is the package; getting a unified solution to get by without a [private] car." (IP11).

Service Attribute 2: The simplicity of the service. Several people could be included in one subscription with one monthly invoice; managing one's tickets and bookings via the smartphone made it easy to remember – "I can forget my public transportation card, but I cannot forget my phone"; easy up-/downgrades of public transport zones for a particular day; activating daily public transport tickets only once instead of a tap-in system; and paying according to use. Participants felt that it became easier to pay for their travel as well as keep track of their (household's) transportation expenditures (5.74 of 7, EQ End Questionnaire). To be clear, participants also had many constructive comments on how to make the service even easier, e.g. decision support, particularly regarding choosing between car modes (carsharing, rental, taxi), and a pay-per-use system based on money rather than different forms of credit (hours of car and days of public transport).

TABLE 2: Ratings of importance of and agreement with various service and app features and functionalities in UbiGo.

Question*	Average Rating (1-7)		
	Before Unimportant - Critical	During Disagree - Agree	End Disagree - Agree
Theme 1: Transport modes and travel guarantee			
Carsharing sites are close by.	5.20	5.93	5.73
Public transport sticks to the timetable.	4.83	5.07	4.87
Carsharing cars are available whenever I need one.	4.61	5.63	5.87
The travel guarantee works as promised.	4.61	4.80	4.53
Taxis are at the right place at the right time.	4.16	5.63	5.23
Bikesharing bikes are available at the docking stations I use.	4.14	5.36	5.14
The vehicles (bus, rental cars, carsharing cars) are electric or hybrids.	3.33	---	---
Theme 2: App use			
The app is easy to use.	5.51	5.75	5.51
Instructions for how to use the app are easy to find.	4.88	5.40	4.96
It's easy to keep track of my subscription balance.	4.88	5.08	4.80
The app is fun to use.	3.13	4.24	4.22
Instructions for how to use the app are easy to understand.	---	5.40	5.28
The app is easy to download.	---	5.28	4.95
It is easy to log in to the app.	---	4.67	4.35
The app is stable.	---	4.31	4.09
Theme 3: Subscription, bookings, bonus			
It is easy to change a booking.	5.08	4.48	4.67
It is easy to cancel a booking.	4.94	4.58	4.93
It is easy to modify my subscription.	4.85	5.13	5.01
The subscription invoice is easy to understand.	4.74	5.43	5.12
It is easy to cancel my subscription.	4.59	---	---
I trust that the subscription invoice is correct.	---	5.61	5.70
I am sure that I do not pay for more trips than what I can use during the pilot.	---	4.92	4.82
I am rewarded for sustainable travel.	3.50	---	---
It is easy to use my bonus points.	---	3.96	4.41
Theme 4: Customer service			
Customer service can quickly answer my questions.	4.69	5.53	5.38

Customer service is available 24/7.	3.74	6.04	5.72
Customer service's answers were helpful	---	---	5.72
Theme 5: Trust and security			
No third party can access my account.	5.11	5.84	5.38
My personal information is secure.	5.06	5.27	5.05
I trust UbiGo to deliver the transport I have booked/requested.	---	6.34	6.15
I trust the UbiGo team to fix problems that arise.	---	6.26	6.16
I feel safe using Gmail/Facebook to log in to the UbiGo app	---	5.86	5.29
I would rather have a dedicated UbiGo login than use Gmail/Facebook to log in.	---	---	4.75
I trust UbiGo regarding technology and the app	---	5.59	5.33
I am sure that I have paid for a trip.	4.89	---	
I am sure I can show a ticket controller that I have paid for a trip	---	5.58	5.05

Service Attribute 3: Improved access. Participants felt that they had more transportation alternatives available to them (5.44 of 7, EQ); “One gets easier access to more modes” (IP10). Not only did UbiGo enable access to car mode without ownership, it also provided access to improved public transit (daily tickets, expanded zones, etc.). Of note is that the alternatives also became more mentally accessible due to having to reflect on one’s travel needs in order to set one’s subscription level, as well as having to choose one’s mode from a list in the app, which made participants stop and think about their trip choices and travel habits to a greater extent. As one participant noted: “I don’t take the tram just to take the tram. I stop and think – should I bike instead? It’s not much but it means that one thinks in a different way” (IPsRI).

Service Attribute 4: Improved flexibility. No single mode can fulfill the requirements for all trips, but purchasing a car – or a public transport pass – can make people feel ‘locked in’ to choosing that mode no matter what the trip conditions. Beyond the flexibility of having multiple alternatives from which to choose (combined with reduced sunk costs), participants felt they could better adapt their choice of mode to the individual trip requirements (5.00 of 7, EQ); “It’s not about being a bus user or a walker or; it’s that you’re everything. And having reasonable proportions of each [mode]. To be able to see when I need one and when I need the other. And that was really important. ... And the threshold was low enough to easily cross, to see what [mode] is good for me today?” (IP7). Another participant commented on a greater flexibility on his/her own part: “UbiGo resulted in my being more spontaneous in the way I travel. Even just going to town has become easier. If a tram isn’t leaving within seven minutes, I bike instead as it’s more flexible” (IP14). However, in the FOT, the participants’ perceived need for flexibility was even greater than what the UbiGo service offered, or, participants got a taste for flexibility and then desired even more. For instance, the participants desired a more flexible pay-per-use system based on money rather than credit (hours of car and days of public transport); they wanted more transport providers included in the offer, e.g. multiple taxi companies from which they could choose; and they particularly wanted their UbiGo subscription to cover all their travel needs, e.g. long-distance buses and trains, and even travel in other cities and countries. This desire for flexibility resulted in participants trying other types of new services as well, such as home delivery of groceries, which also conveniently eliminates a trip; “We found an alternative to [the weekly shopping trip]. We started ordering groceries online and having them home delivered. You know, having more means wanting more. When you get a taste for something new, you want to try

everything” (IP4).

Service Attribute 5: Economy, including pay-per-use. Although economy was rarely the main motive for the participants (see Table 3), it did act as a deterrent for some who were interested but decided not to join the trial (Sochor et al., 2014). Participants expected their UbiGo transportation expenditures to at least not be more expensive than their current solutions, although many agreed that UbiGo led to reduced travel costs (5.14 of 7, EQ). Whether or not participants saved money by using UbiGo, participants appreciated the pay-per-use concept (combined with the ability to roll over and top up credit); partly as this made travel costs more transparent (broken down per trip/day), and partly as not having sunk costs in a particular mode meant that they could more easily choose a mode according to each trip’s requirements. UbiGo’s daily public transport tickets (which were not otherwise offered) were also highly appreciated, although some lock-in effects were observed for these as well (if users had chosen to activate a daily ticket for public transport earlier in the day, they were more prone to choose public transport for the rest of that day’s trips). Some comments made were; “It became cheaper [to use public transport instead of a car]. Then it becomes convenient as well, if one has not seen that possibility before and then tries it and gets into it” (IP12); and “When you live in the inner city, it costs a lot just to have [a private car] standing there, parked. Then one realizes how little one needs it” (IP11).

TABLE 3: Overview of changes in UbiGo participants’ motives and satisfaction.

		Self-Reported Motives and Satisfaction			
		Before (n = 164)	During (n = 161)	End (n = 160)	6 months later (n = 109)
Main Motive to Use UbiGo	Curiosity	63%	25%	21%	n/a
	Convenience/Flexibility	7%	22%	30%	n/a
	Economy	8%	14%	14%	n/a
	Environment	6%	8%	4%	n/a
	FamilyMember	9%	11%	13%	n/a
	Gain/Lose Car	2%	12%	11%	n/a
Satisfaction with Current Travel*		77% satisfied 19% very satisfied	88% satisfied 40% very satisfied	93% satisfied 51% very satisfied	75% satisfied 16% very satisfied
* satisfied = rating 5-7 of 7; very satisfied = rating 7 of 7					

Service Attribute 6: Added value/Relative benefit. According to Rogers¹⁶, an important attribute for rapid adoption of an innovation (in the case of UbiGo, the service as well as behaviors) is that the innovation offers relative benefits compared to the existing solution. From a business perspective this can be described as offering additional value. The results of the trial support the notion that the innovation must offer some added value or relative benefit, cf. (Rogers, 2003), in order to be adopted, i.e. the service must appeal to the users on a practical level and facilitate their daily travel, as it is practicalities that will keep the users incentivized to continue using the service after the novelty and curiosity fade. Relative benefit is however a matter of perception as different individuals may assess the same offer differently, depending for instance upon how they assess the effort associated with adopting

¹⁶Rogers, E.M. *Diffusion of Innovations*, 5E, Simon and Schuster, New York, 2003.

the innovation. In terms of UbiGo, the added value and/or relative benefits concerned the above mentioned aspects economy, flexibility, accessibility, and simplicity. The travel service cannot be more expensive than the user's existing solution, not without enough added value to outweigh the increase in price. Second it cannot be perceived as more 'inflexible' or 'inconvenient' compared to the user's existing solution. Public transportation and carsharing services can be perceived thus by those who are on call at their job, who live 'too far away' from a carsharing site, or who have small children. It is important to examine how for instance the carsharing network or the carsharing business model (especially pricing schemes) help or hinder use of the service, and the implications of this on facilitating a move away from privately owned vehicles in urban areas. Third, the infrastructure network (carsharing sites, public transportation stops/routes, etc.) must be extensive enough to reach the users. If a carsharing site is perceived as too far away, people will not join the scheme. Fourth, learning is yet another effort and the results indicate that travel service must be perceived as 'easy enough' to understand and use (cf. Roger's notion of complexity/simplicity as an intrinsic factor of the innovation (Rogers, 2003)) as it is difficult for people to find time in their busy lives to go to informational meetings and read manuals about how to e.g. use an app or change their subscription. If it is perceived as too difficult or time consuming, potential users will be deterred.

Another factor of relevance for assessment of UbiGo and the results of the FOT was trialability (developed further in Strömberg et al., 2016¹⁷). UbiGo was not set up to stimulate behavioral change per se; it was primarily intended as a trial of the new type of service even though reduced environmental impact was a desired additional effect. Nonetheless, many participants used the service to actively trial new behavior; to see whether they would still be able to carry out their daily activities. One of the participants said; "I've made use of new modes that I hadn't tried before" (IP14) and another; "It was a way to test carsharing that I might not have tested otherwise" (IP13). One example concerns car ownership. Some wanted to try to manage daily life without the economic, environmental, and practical demands of private car ownership; "We don't use our car so very much. I've been irritated by people saying 'now that we have kids, we have to have a car'. I've thought that we really don't" (IP3). The trial allowed such participants to set aside their car temporarily and be compensated for parking, insurance, etc., while testing whether other available modes were viable options. Others wanted to test having access to a car without having to purchase one; "[UbiGo] was a way for us to try having a car, to see if we need a car" (IP13). The trial let such participants to test non-private car modes and explore to what extent their perceived need for a (privately owned) car was genuine. In both cases, the trial made it possible to revert back to one's original behavior by lowering the risk, effort, and uncertainty connected with undertaking a behavioral change process.

A consequence of trialability was that participants gained new insights on convenience. UbiGo resulted in many participants evaluating the alternatives in new ways and determining what convenience meant for them. For some, convenience meant a private vehicle close at hand (e.g. for encumbered trips), while others felt that carsharing/rentals created convenience in terms of gaining access to a modern, varied car fleet (e.g. adapting the car size to the trip requirements), and not having to deal with maintenance, parking, etc. After the trial, one family decided to only own a private car during the summer.

At the end of the UbiGo pilot, only 3% did not want to continue as UbiGo customers, and of those 64% who had reported behavioral changes (including mode choice 43%, pre-trip planning 34%, trip chaining 21%, destination 21%, route 19%), only 3% were dissatisfied with the changes (EQ). That the changes were not considered negative is also illustrated by

¹⁷ Strömberg, H., Rexfelt, O., Karlsson, I.C.M., Sochor, J. (2016). "Trying on Change – Trialability as a Change Moderator for Sustainable Travel Behaviour", *Travel Behavior and Society*, Vol. 4, pp. 60-68. <http://dx.doi.org/10.1016/j.tbs.2016.01.002>

satisfaction levels as participants became more satisfied with their travel as the trial progressed, with satisfaction rates increasing from 77% (Before), to 88% (During), and 93% (End). Six months after the trial ended (and the service no longer available), satisfaction rates had dropped back to pre-trial levels (75%), although admittedly there is no control group with which to compare: “It’s noticeable now that we’re not in [UbiGo anymore] that it’s like, it feels awkward to travel in the usual way.” (IPsPL). Of note is the attitude changes towards the various travel modes, where participants became less positive towards private car (23%) and more positive towards alternative modes (carsharing 61%, bus/tram 52%, bikesharing 42%, etc.).

In conclusion, MaaS is more than multimodality, and more than overlaying an app on existing modes of transport or an existing mobility service. While the UbiGo pilot demonstrated (and hopefully other MaaS services will soon demonstrate) the potential for MaaS, both conceptually and to change thought processes and behaviors (and hence types and patterns of demand), its success is not independent of the contributing service attributes identified above. In the service literature, it has been argued that “compared to physical products, services are generally under-designed and inefficiently developed”¹⁸. Given these points, one must emphasize the importance of developing the service concept, as it not only “defines the how and what of the service design, and helps mediate between customer needs and an organization’s strategic intent” (19 p. 121), but also “can be the key driver of service design decisions at all levels of planning” (ibid., p. 122). If a mobility service concept is to change behavior (i.e. achieve impact) as well as create added value, these goals need to drive design decisions; for example, a MaaS concept designed with high flexibility and few lock-in effects (at a reasonable price) can demonstrably provide a low-risk environment to trial new travel behaviors, generating new types and patterns of demand, whereas an alternative concept with less flexibility and more lock-in effects (and/or at higher prices) may not provide such a low-risk environment and/or change behavior (or demand) to the same extent.

Another way to compare mobility services is in terms of service development dimensions by which a service provider positions itself in relation to others. Three examples are: customization, bundling, and the range of the offer²⁰. UbiGo, as an example of what MaaS can be, offers relatively higher levels of all three – customization via the need-determined, flexible subscription for the entire household with bookings and tickets managed via an app, etc.; bundling via the one-stop shop, ‘transportation smorgasbord’ package; and the range of the offering – compared to other types of mobility services such as public transport, sharing services, and peer-to-peer services. Although focusing only on bundling, More²¹ observes that: “A product/service super-bundle is created when your integrated solution creates your customers’ most differentiated and desired choice/rejection/experience process. You become the mirror image of the customer’s solution process and life cycle. Looking at your solution, your customers see themselves” (ibid., p. 33). MaaS can offer customers a greater opportunity to create tailor-made mobility solutions that mirror their needs and solution processes, which played a fundamental role in changing behavior and demand.

¹⁸ Cavalieri, S. and G. Pezzotta. Product-Service Systems Engineering: State of the art and research challenges. *Computers in Industry*, Vol. 63, 2012, pp. 278–288.

¹⁹ Goldstein, S.M., R. Johnston, J. Duffy, and J. Rao. The service concept: the missing link in service design research? *Journal of Operations Management*, Vol. 20, 2002, pp. 121–134.

²⁰ Nordin, F., D. Kindström, C. Kowalkowski, and J. Rehme. The risks of providing services: Differential risk effects of the service-development strategies of customisation, bundling, and range. *Journal of Service Management*, Vol. 22(3), 2011, pp. 390–408.

²¹ More, R. *Marketing High Profit Product/Service Solutions*, Ashgate – Gower, Farnham, UK, 2013.