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MyCorridor MaaS: A stakeholder-inclusive MaaS platform

Athanasios I. Salamanis[a]*, Theodoros Ioakeimidis[a], Dionysios Kehagias[a], Maria Gkemou[b], Dimitrios Tzovaras[a]

[a]*Information Technologies Institute, Centre for Research & Technology Hellas, P.O Box 60361, GR 57001 Thermi-Thessaloniki, Greece*
[b]*Hellenic Institute of Transport, Centre for Research & Technology Hellas, P.O Box 60361, GR 57001, Thermi-Thessaloniki, Greece*

Abstract

With the rapid growth of the global population and its concentration in large urban centres, the need for smart and sustainable mobility solutions has become more imperative than ever. Among the mobility paradigms advocating the shift from vehicle ownership to vehicle usership, the Mobility as a Service (MaaS) paradigm, namely the mobility system that brings together several heterogeneous mobility offerings from different service providers enabling end-users access on them via a single digital interface, seems as the most feasible solution. The acceptance of the MaaS paradigm by the vast majority of citizens requires putting people and their needs in the center of the MaaS design. This paper presents the MyCorridor MaaS, a user-centric MaaS delivery platform, which introduces design and implementation principles for the key components of a MaaS platform, aiming at maximizing the MaaS paradigm user acceptance.

Keywords: MaaS; urban mobility; MaaS API; MaaS platform

* Corresponding author. Tel.: +30 2311 257 736;
E-mail address: asal@iti.gr

1. Introduction

Modern societies are rapidly changing. Globalization, the need for better jobs and climate change are a few reasons for getting people gathered in large urban centers. Consequently, the need for new, smart, easy-to-use, green and sustainable mobility solutions, that will facilitate seamless trips of people and goods, has been rapidly increased. The innovations we have witnessed in the last few years in the IT and telecommunications sector have acted as a driving force to meet this need, leading to the design and development of new disruptive mobility models. Among them, the Mobility as a Service (MaaS) model has been distinguished.

There are several definitions of the MaaS concept. Kamargianni and Matyas (2017) defined MaaS as the user-centric, intelligent mobility distribution model in which all service providers' offerings are aggregated by a sole mobility provider, the MaaS provider, and supplied to users through a single digital platform. In addition, MaaS Alliance (2019), a public-private partnership created to promote the MaaS concept, defines MaaS as the integration of various forms of transport services into a single service accessible on demand. As these definitions indicate, MaaS integrates several heterogeneous services and provides them to users through a single platform aiming at the design of easy, seamless and sustainable trips. This concept goes one step beyond the existing sharing-mobility schemes like car-sharing (e.g. Car2Go from Daimler (2019), Drive Now from BMW) and bike-sharing (e.g. Mobike (2019), Motivate (2019)), in the sense that the services provided through a MaaS platform are interconnected and share useful information in order to better serve the users. For example, through a MaaS platform, a user can (at least theoretically) be informed for the available shared bicycles close to a bus stop, which s/he can use after getting off the bus at a particular stop.

MaaS has been advertised and promoted as the mobility paradigm that can tackle effectively many problems of modern mobility. However, as the concept is still very new, many of its challenges have not yet been thoroughly addressed. One aspect of these challenges concerns the technical difficulties of the process of integrating several services in one place. In theory, the integration of services within a MaaS platform is based on the availability of application programming interfaces (APIs). Yet, most of the services have no API, or, if they have one, it has very limited functionalities. Additionally, different services have completely different APIs. Therefore, the design and development of the appropriate mechanisms that will facilitate the interconnectivity of the available services' APIs within a MaaS platform is a major challenge.

Apart from the technical limitations, several business, legal and data restrictions have been identified within the MaaS ecosystem. The idea of bringing together several services with different characteristics (e.g. mode, pricing policy, operating rules), is based on the assumption that a framework exists that regulates the relationships between the partners and ensures both the smooth operation of the platform as a whole and the operation of each individual service within the platform. For example, the regulatory framework of the MaaS platform should ensure the equal provision of competitive services, either regarding the same or different modes of transport. Moreover, legal issues like the liability for the non-provision of a requested service, and data protection issues like the responsibility of handling users' sensitive information, should be fully clarified. The identification of such challenges and the design of a framework that will try to regulate them in a way acceptable to all stakeholders, are key enablers for the implementation of a successful MaaS ecosystem.

Several guidelines have been proposed to date in the relevant literature for the design of a successful MaaS platform. Although these studies describe in detail most of the aspects of the MaaS concept, they mostly investigate MaaS from a theoretical perspective rather than an implementation-oriented point of view. In this paper, we aim to strengthen the current MaaS literature by presenting a real world MaaS platform, namely *MyCorridor*. In particular, we focus on two main objectives: (a) the simplification of the technical requirements for the integration of different services, and (b) the maximization of inclusiveness of all the stakeholders involved. The rest of the paper is organized as follows. Section 2 reviews the current MaaS literature focusing mainly on real world MaaS implementations. Section 3 describes the MyCorridor MaaS platform from both the technical and business perspectives. Finally, Section 4 concludes the paper by reviewing its main contributions and proposes future research directions.

2. Literature review

MaaS is a very new concept of mobility that has been only addressed so far at a theoretical rather than a practical level. Most of the studies on MaaS, focus on topics such as how to shape a clear MaaS concept definition, what are its core elements, its restrictions and requirements for deployment, the associated business models, etc., targeting mainly on creating a better understanding of the MaaS concept and facilitate its wider adoption. For example, Kamargianni and Matyas (2017) proposed a preliminary definition of MaaS and described in detail the MaaS ecosystem and its actors. Also, Li and Voege (2017) summarized the conditions of operation of MaaS and developed a checklist for potential developers of MaaS to assess if they can implement MaaS in a city. Additionally, Jittrapirom et al. (2017) proposed an assessment framework to classify the unique characteristics of the MaaS core components, and based on this, they described existing MaaS schemes and applications. Moreover, Kamargianni et al. (2016) reviewed the existing shared transport services (e.g. car-sharing, bike-sharing), and developed an index to evaluate the level of mobility integration for each of them. Similarly, Goulding and Kamargianni (2018) introduced the MaaS Maturity Index, i.e., an index measuring the readiness of a city for MaaS implementation, based on several characteristics (e.g. transport operators data sharing and openness).

From a different point of view, Matyas and Kamargianni (2018) investigated the possibility of MaaS product bundles, i.e., monthly subscription plans, being used as a mobility management tool to promote share modes. Through a survey conducted in the Greater London area, the authors concluded there is concrete evidence that MaaS bundles can indeed introduce more travellers to shared modes. Additionally, Matyas and Kamargianni (2018) presented the design of a survey including a stated preference (SP) experiment that captures the complex decision-making process of purchasing MaaS products. Furthermore, Rantasila (2016) studied the potential impact of MaaS on land use in Finland. Finally, it would be an omission not to mention the already existing real-world MaaS applications, used by millions of travellers, such as Whim (2019), UbiGo (2019) and Moovit (2019), as well as the existing MaaS APIs like SkedGo (2019).

In contrast with most of the previous works in the MaaS literature, in this paper we present a real-world MaaS implementation. In particular, we describe the several aspects of a MaaS platform, from the initial conceptual architecture of the platform and the definition of the service data model, to the business rules and the booking and payment modules. Throughout the course of this endeavor, we try to shed light on all aspects of a real-world MaaS implementation, thus helping future professionals and researchers in the field of MaaS design and implement more advanced MaaS ecosystems.

3. MyCorridor MaaS platform

In this section, we describe the overall MyCorridor platform. Initially, we describe its conceptual architecture, and then its core components. Finally, the section briefly outlines the business model adopted by the MyCorridor platform.

3.1. Conceptual architecture

For the design and development of the MyCorridor platform, the *layer architecture* was adopted. The layer (or multitier) architectural style is a well-known and widely used model for large-scale software engineering projects, whose main feature is the physical separation of main system components (i.e., presentation, application processing, and data management). The different system components are, in general, independent from each other, i.e. they perform their own specific functions, and communicate with each other through appropriate interfaces (i.e. APIs). The system components in the layer architecture are organized in layers. In general, there are three layers: (a) the presentation layer that includes the components through which the end users interact with the system, (b) the application layer that provides the main functionalities of the system, and (c) the data layer that contains the several data repositories of the system. The components of all layers interact with each other through appropriate communication interfaces. Within a MaaS ecosystem, the several critical functions can be implemented by different system components, which can be organized on different layers. These components should be interconnected via secure communication interfaces, organized in what we call a *MaaS API*. Therefore, the choice of the layer architectural style for the design and development of a MaaS platform can be considered appropriate.

The main logical layers of the architecture of the MyCorridor platform are the presentation, the application and the data layer, surrounded by the communication/API layer. In the MyCorridor ecosystem, the identified end users are the travellers, the service providers, the data providers and the MaaS operator. Kamargianni and Matyas (2017) included these stakeholders into the core business layer of a MaaS ecosystem. The travellers interact with the platform via a mobile application, while the rest end users through appropriate web applications. All frontend applications belong to the presentation layer. Then, the application layer includes all modules that implement the several functions of a MaaS ecosystem. For example, the trip-planner provides multimodal trips to the travellers; the matchmaking module matches the travellers' mobility requirements with the available services, while the payment module implements the final steps of a MaaS service provision, namely the booking, the payment and the issuing of tickets for the purchased services. After the application layer, there is the data layer that accommodates the data repositories of the platform. In the MyCorridor platform, there are three data repositories, namely the travellers data repository, the services repository and the administrator repository. The travellers data repository contains all the data regarding the travellers, the services repository contains all the information that describe a service, and the administrators data repository contains information that are closely related to the management of the platform by the MaaS operator. Finally, all system components communicate with each other via the MaaS API.

3.2. Service data model

The key offering of a MaaS ecosystem is its services. In the context of the MyCorridor MaaS ecosystem, the term "service" is referred to the digital representation of a *mobility product*, which is defined as a real life, physical transportation service provided by a public, private or public-private transport company/authority. For example, a trip with a coach bus from one city to another can be considered as a mobility product, and when this mobility product is presented as an option to the traveller through the MyCorridor mobile application, it is called service. The services are classified into *clusters* and *subclusters*. The definitions of these categories and subcategories are presented in Table 1.

Table 1. Key definitions of MyCorridor services classification.

Type	*Definition*
Mobility services cluster: Services related to mobility products provided for a fee through MyCorridor mobile application.	**Vehicle related services subcluster**: MyCorridor services supporting purchase of mobility products for private use of cars (i.e. parking, rental, etc.).
	Vehicle (car/bike/e-car/e-bike/ride) sharing/pooling subcluster: MyCorridor services supporting purchase of sharing/pooling mobility products.
	Public transport subcluster: MyCorridor services supporting purchase of public transport mobility products (urban, interurban).
	Public transport (para transit) subcluster: MyCorridor services supporting purchase of para transit mobility products (i.e. taxi services, demand-responsive transport services).
	Tourist subcluster: Services targeting specifically at tourism.
	Vehicle related - Public transport subcluster: Services combining vehicle and public transport services (e.g. ferry services).
Traffic management services cluster: Services related to the online purchase of traffic management related mobility products and/or the use of advanced traffic management concepts within the MaaS framework.	**Advanced traffic management services subcluster**: Typical traffic management services, such as real time traffic state and forecast, event management, etc.
	Access control & tolling subcluster: MyCorridor services supporting purchase of traffic/demand management products, such as tolls, urban congestion pricing, and zone access control.
	C-ITS enabled traffic management services subcluster: Traffic management services such as traffic lights control and forecasting, etc.

Infomobility services cluster: Services related to the information and real-time support of the user both in the pre-trip phase (e.g. trip planning, support in decision of what mobility product to purchase, etc.), and on-trip phase (e.g. information regarding the available parking spots while travelling by car).	**Multimodal subcluster**: MyCorridor service combining multi modal information/route planning/guidance into a single feedback to the user.
	Public transport subcluster: MyCorridor services supporting use of public transport mobility products, prior or after their purchase, related to real time info, timetables, etc.
	Park & Ride subcluster: MyCorridor services supporting use of Park & Ride mobility products (i.e. real-time information for parking availability and public transport estimated time of arrival).
Added Value services cluster: Services giving added value to the user and enhancing user experience. These services can be closely associated to mobility or not.	**Touristic/Entertainment subcluster**: Services related to supply of touristic/cultural/entertainment information.
	Synthetic subcluster: Services that result as a synthesis of independent services.

The definition of the minimum information required for describing a service is of paramount importance. Within the MyCorridor MaaS platform, a specific service data model was designed, based on the insight (provided by the service providers of the project's consortium) that although the several services are, in general, different from each other, yet, they share some common characteristics that can be used for defining a data model. In particular, the service data model defined in the context of the MyCorridor platform contains the following attributes:

- **Name***: the name of the service
- **Cluster***: the cluster of the service
- **Subcluster***: the subcluster of the service
- **Mobility Product***: the mobility product represented by the service
- **Operating Areas***: a list of areas (cities or countries) in which the service operates
- **Operating Time Periods***: a list of time periods (days and/or hours within days) in which the service operates
- **Service provider***: the official name of the service provider
- **URL**: the URL of the official site of the service provider
- **API***: a Boolean denoting whether functions of the service (e.g. itineraries information) are provided through an appropriate API
- **API URL***: the base URL of the API of the service
- **API response***: the format in which the responses of the API are provided (e.g. JSON, XML)
- **Booking API***: a Boolean denoting whether the booking and ticketing functions of the service are provided through an appropriate API (which is usually different from the other functions API)
- **Booking API URL***: the base URL of the booking API of the service
- **Booking API response***: the form in which the responses of the booking API are provided (e.g. JSON, XML)
- **Business rules***: a set of rules (in textual form) describing several aspects of the business policy of the service (e.g. special discounts for trips on weekends or for the elderly)
- **Mode**: the transportation mode of the service (e.g. car, bus)
- **Paid***: a Boolean denoting whether a service is paid or free of charge
- **Currency**: the type of currency in which the service is paid (if the service is paid)
- **Cost**: the cost per trip of the service (if the service is paid)
- **Registration Status**: a code denoting the state of the service within the MaaS platform. This code can take one of the following values:
  - *Submitted*: The status code the service receives when it is first submitted to the MyCorridor MaaS platform
  - *Under Evaluation*: The status code of the service during the period considered for its suitability for the MyCorridor MaaS platform
  - *Registered*: The status code of the service after it was successfully evaluated. This status means that the service is provided to the end users (travellers) through the matchmaking process.
  - *Under Update*: The status code of the service, if the provider agrees to make the proposed changes to the service in order to successfully register it to the MyCorridor MaaS platform.
  - *Rejected*: The status code of the service when it has not passed the evaluation process.
- **Comments**: miscellaneous information of the service not described by the other attributes

Not all of the above attributes are required for successfully registering a service into the MyCorridor platform. In the above list, the required attributes are denoted by the (*) symbol.

3.3. Trip-planner

The trip-planner is responsible for providing itineraries for getting from point A to point B, combining different modes of transport (e.g. bus, car, rail, bicycle, scooter, etc.). In MyCorridor platform, a *hybrid* trip-planner was designed and implemented. In particular, the MyCorridor trip-planner combines the OpenTripPlanner, an open source software project that provides passenger information and transportation network analysis services, with proprietary trip-planners brought to the platform as registered services by the project's partners. When a trip search is performed in an area that is under the jurisdiction of a specific proprietary trip-planner, this particular trip-planner is used. Alternatively, the OpenTripPlanner is employed for trips that are out of any proprietary trip-planner's range.

During the design phase of a trip-planner integrated in a MaaS platform, particular attention should be paid to the trip-planner's data requirements. In particular, a trip-planner requires access to the GTFS data of the public transport services in order to be able to provide multimodal trips. This means that if a public transport service provider wants to be registered in MaaS platform, he should be willing to give access to the GTFS data of the service to the MaaS operator. Within the MyCorridor platform, this requirement is met in twofold way. In the areas covered by the OTP subcomponent, the GTFS data of the local public transport service providers has been provided and incorporated into the OTP. On the other hand, in the areas covered by the proprietary trip-planners of the project's partners, the required GTFS data are not given directly to the overall MyCorridor trip-planner (i.e., the MaaS operator does not have direct access to the data), but indirectly through the proprietary trip-planners (under specific individual agreements). In both cases, the final trip-planning services (i.e., the multimodal itineraries) are provided to the traveller in a seamless way.

It should be mentioned that the MyCorridor trip-planner was designed and implemented to meet the needs of travellers in the best possible way. In particular, the MyCorridor trip-planner covers the travellers' need for multimodal trips, in cases where OTP is used, but also in cases where the proprietary trip-planners are used. Additionally, in the design phase of the trip-planner, extensive research has been conducted in order to identify as many GTFS data sources as possible, in order for the trip-planner to cover as many areas as possible. Moreover, the MyCorridor trip-planner can support trips with intermediate points provided by the users (up to three intermediate points are supported). This feature can be very useful for travellers that want to include in their trips visits to places of cultural interest (e.g. museums, concert venues, restaurants, bars, etc.). Finally, from a technical point of view, the MyCorridor trip-Planner integrates an instance of the OTP as well as proprietary trip-planners. All these trip-planning solutions expose their functionalities through RESTful APIs, and the generated trips are provided in either JSON or XML format. Therefore, the overall trip-planner generates multimodal trips and provides them via a RESTful interface in JSON format.

3.4. Matchmaking module

The matchmaking module is responsible for matching the travellers' requirements with the services registered in the MaaS platform. The goal is to provide the traveller a mobility solution that is, at least, as comfortable as traveling with his own vehicle. Within the MyCorridor platform, the matchmaking process is carried out in two ways, i.e., with and without trip-planning. The "with" way is called *MaaS&Go* and refers to the case where a traveller wants an ad-hoc mobility solution for a particular trip from A to B. On the other hand, the "without" way (called *MaaSPacks*) refers to the case of a regular traveller (e.g. a commuter, a businessman, etc.) who wants to purchase a package of mobility solutions which will be consumed in a regular basis (e.g. daily) during a specific time period (e.g. a month).

In the MaaS&Go scenario, a traveller requests a trip from A to B. Initially, the trip-planner is invoked and it generates a set of multimodal trips based on the user's travel preferences. From this set of trips, the optimal trip is estimated based on the traveller's routing preference (e.g. the trip with the fewest number of interchanges). Then, the matchmaking module is invoked and for each leg of each of the generated trips (both the optimal and the non-optimal trips), it identifies a set of services that can serve this trip. These services come from the set of services that are registered in the MyCorridor platform at that time. A service is matched in a leg of a trip if it satisfies a set of rules. For example, the start and end points of the leg should lie within one of the operating areas of the service, and the mode of the service should be included in the list of the traveller's preferred transport modes. In this way, in each leg of each trip, more than one services can be matched. The traveller selects the preferred trip and the preferred services for each leg of it, thus creating a fully personalized mobility solution. The applicability of this solution is verified by the matchmaking module, and the traveller proceeds to the booking and payment process. On the other hand, in the MaaSPacks scenario the matchmaking process is simpler. The traveller just provides the origin, the destination, and the departure date and time (or the arrival date and time) of his/hers frequent trip/s. Then, the matchmaking module is invoked, without having to call the trip-planner. The matchmaking module matches the traveller's request and profile with the available services based on a set of rules, as in the MaaS&Go scenario, and a set of recommended services is returned to the traveller. The traveller bundles together the services he wants, thus creating a fully personalized mobility package. Within the same package, similar services provided by competing providers may coexist. After the package of services is assembled, the traveller proceeds with the booking and payment process.

As in the case of the MyCorridor trip-planner, the matchmaking module was designed and implemented to focus on the needs of travellers. In particular, an effort was made to gather as many services as possible in order for the matchmaking module to be able to match services in every leg of the provided trips. Additionally, special attention was paid to the case where a specific leg of a trip is not covered by any service in the platform. In this case the matchmaking module provides a suggestion to the traveller to either move on foot or use his/hers personal vehicle depending on the length of the leg. Moreover, considering a more technical perspective, particular importance was given on the performance of the module, which can greatly affect the user experience. Considering the fact that the matchmaking module tries to match services for each leg of each of the generated trips, and this process takes places for multiple calls from different travellers, it is understood that a considerable computation load is generated. Therefore, the matchmaking process was parallelized in the trip level by assigning the matchmaking process of each trip to a different core of the computer's processor. This choice considerably reduced the computation effort of the module, consequently reducing the waiting times for travellers, and thus enhancing the overall user experience. Finally, from a technical point of view, the matchmaking module was implemented as a native C++ application. Specifically, the module uses the C++ version of the cURL library for making RESTful calls to the MaaS API, it employs the C++ library RapidJSON for parsing data in JSON format, and it utilizes native C++ code to implement the rules based on which the services of the platform are assigned to the legs of the generated trips.

3.5. Big data analytics module

The big data analytics module provides data analytics services of the MaaS use. In particular, this module is responsible for:

- The collection of data relating to the use of the services within the MaaS ecosystem.
- Processing MaaS usage data, namely recognizing patterns that can be useful for either the MaaS operator or the service providers.

The results produced by the big data analytics module can be used either by the MaaS operator for improving the ways in which the services are offered to the travellers, or by the individual service providers for improving their own services. In the latter case, there should be a strict description of the data usership from the service provider's side, and this description should be included in the agreement signed between the MaaS operator and the service provider. In addition, in the terms and conditions document of the MaaS platform, it should be explicitly stated that information generated after processing MaaS usage data is likely to be shared with service providers to improve the services provided. The terms and conditions document should be always in place for informing the travellers for the type of data processing. This knowledge is very important for the travellers because it will make clear to them how their mobility history will be used by both the MyCorridor platform and the service providers, and it will alleviate users' concerns regarding the possible misuse of their personal data.

From a technical point of view, the big data analytics module uses native Python functions implementing specific filtering requests in the corresponding data repositories for calculating MaaS use meta-statistics, and it employs the pandas, the NumPy, and the scikit-learn Python libraries of the typical data science stack, in order to implement grouping of travellers based on their MaaS use characteristics and detection of MaaS use patterns. Finally, the big data analytics module communicates with the other modules of the MyCorridor platform via the MaaS API and exchanges data in JSON format.

3.6. Traveller feedback module

In a MaaS ecosystem, it is important for the MaaS operator to know the opinion of the travellers regarding the MaaS offerings. Hence, a module responsible for recording the travellers' feedback with the regard to the functionality of the MaaS platform and the quality of the services provided, can be considered as a useful addition to the platform. Within MyCorridor platform, this role has been taken over by the traveller feedback module. This module records the feedback of the travellers regarding the MaaS platform and the services, and calculates reputation scores for both of them. The module focuses on the satisfaction of the travellers' needs. In particular, the travellers' opinion regarding a service is one of the factors taken into account by the matchmaking module for deciding if this service will be recommended to a traveller or not (both for the MaaS&Go and the MaaSPacks scenario). Additionally, the feedbacks provided by travellers are useful to other travellers to assist them during their decision making process. Moreover, the feedbacks are used by loyalty and rewarding schemes, designed within the context of the MyCorridor platform for incentivisation and platform engagement purposes. Hence, a traveller is able to earn rewarding points based on his/her feedback for the platform or the services provided. From a technical point of view, the traveller feedback module communicates with the other modules of the MyCorridor platform via the MaaS API and exchanges data in JSON format. Moreover, the part of the module that calculate the reputation of the platform and the services based on the travellers' feedback is implemented as a native Python application.

3.7. Business rules module

From a business perspective, a MaaS ecosystem involves multiple stakeholders coming from the public and private sectors and from many mobility related businesses, such as public transportation, para-transit, vehicle sharing, parking, city transport authorities, traffic management, data providers, application service providers, navigation service providers etc. These stakeholders are having different perceptions in terms of governance, business and customer care in the mobility. The main mobility stakeholders can be grouped as follows: (a) MaaS operator, (b) mobility service providers, (c) payment/ticketing service providers, (d) city authorities, and (e) traffic managers. On top of them, the *MaaS aggregator* can be added, i.e., an entity that operates on a global level managing multiple local MaaS operators. Each group of stakeholders has different objectives and may use different sets of incentives and methods to influence the behavior of the end users in favor of these objectives.

In the light of this fact, the MyCorridor platform was designed as an **<u>open tool for the multiple MaaS stakeholders to implement a variation of different incentive strategies</u>**. By "open", we mean a flexible mechanism that facilitates different objectives and respectively incentive strategies, such as those mentioned above. The fulfilment of this strategy is achieved through the appropriate prioritization of the services registered in the platform. This prioritization is performed by assigning a specific weight in each service. These weights are set by the MaaS operator following a discussion (and agreement) with the provider concerned. The values of the weights depend on the targeting of the MaaS operator during a specific period. For example, at a specific time period, the MaaS operator may want to promote the services that enable green mobility. In this case, services like urban buses and bike-sharing will receive higher weights than the car-renting services. On the other hand, during a different time period, the MaaS operator may wish to promote the less popular services (based on the travellers' recorded activity), and hence these services will receive higher weight values than the others. The prioritization process is an asynchronous process, which means it can take place at arbitrary times by the MaaS operator. The prioritization process of the services can be communicated to the travellers in two ways:

- At the output of the matchmaking module, i.e. the weight of a service is taken into account into the matchmaking process.
- The services are presented to the traveller (in the mobile application) with different semantics based on their weights. For example, the services with high weights can be colored with shades of green (and optionally having a star icon next to them), while those with low weights can be colored with shades of red.

The module responsible for implementing this business policy within the context of the MyCorridor platform is the business rules module. As can be understood from the above description, the business rules module can serve the needs of the different types of entities that want to have the role of MaaS operator. Public authorities may promote the use of eco-friendly mobility services, while private entities may promote the use of the most profitable services. In all cases, this design choice of the business rules module increases the acceptability of the MyCorridor platform. Finally, it should be noted that from a technical point of view, the business rules module is implemented as a native Python application that communicates with the other modules of the MyCorridor platform via the MaaS API and exchanges data in JSON format.

3.8. Booking and payment module

The booking and payment module is responsible for the completion of the MaaS offerings purchase process by connecting the travellers with the back-offices of the service providers. The module encapsulates common functionalities in the context of online payments (e.g. credit card tokenization, redemption, fee charging, etc.) provided through secure channels by a certified commercial entity. Within a MaaS ecosystem, having a certified payment service provider that can ensure the security of the transactions is of paramount importance. On one hand, the booking and payment module handles the payment process, namely the charging of the traveller with the amount that corresponds to the purchased services and the transfer of parts of this amount to the corresponding service providers. The payment process requires that travellers own a credit or debit card, and service providers have an account to the commercial entity, which offers the payment service. Although the MyCorridor platform has been developed in the context of a research project and therefore it has not specified fees for its services, yet in a commercial MaaS platform the MaaS services can be charged through a fee on each transaction. On the other hand, the module undertakes the processing of the reservation of seats for the services that allow this, and issuing of tickets. For the reservation of seats, it informs the service providers for the corresponding demand for seats, while it handles the distribution of tickets to the travellers. This means that the module does not issue tickets itself, but it distributes the tickets issued by each service provider. This point is very important considering the heterogeneity of the ticket issuing mechanisms among the service providers (e.g. QR codes, travel cards, etc.).

The booking and payment facilities are considered as some of the most crucial services of a MaaS platform. In the context of the MyCorridor platform, an effort was made for serving the needs of both the travellers and the service providers as much as possible in terms of booking and payment. Regarding the travellers, at the time this text is written, there is support for payment with credit and debit cards. However, supporting payments through the PayPal services is within the development plans of the future versions of the MyCorridor platform. Regarding the service providers, the main support of the MyCorridor platform is about the integration of different types of mobility tokens, including QR codes, Aztec codes and username/password pairs. Moreover, there is a plan for incorporating more types of mobility tokens in future versions of the platform. Finally, from a technical point of view, the booking and payment module was implemented using the Java EE framework, and it utilizes Spring MVC for inversion of control container, Maven for build automation and MyBatis as database communication framework. In addition, the module communicates with the payment services provider and the other modules via the MaaS API and exchanges data in JSON format.

3.9. MaaS API

The MaaS API comprises a RESTful API that enables the communication between the components of the MyCorridor platform, as well as between the MyCorridor platform and the outside world. In particular, the MaaS API interconnects:

- **The MaaS platform components**: The several components of the MyCorridor platform communicate with each other and exchange data through the MaaS API.
- **The MaaS platform components and the data repositories**: The several components of the MyCorridor platform can access the data repositories in order to retrieve or store data.
- **The MaaS platform and external applications**: the MaaS API exposes the MaaS logic and functionality to external applications, which want to build on these functionalities and potentially extend them.

From a technical point of view, the MaaS API was developed on top of the Eve Python REST API framework. The selection of this platform was based mainly to its simplicity (which in the long-run leads to maintainability) and to its native support for MongoDB data store. For more information regarding the suitability of the Eve framework for ITS applications, the reader can refer to Tsoukalas et al. (2018). The communication is implemented on top of the HTTP communication protocol (HTTPS for sensitive data). The JSON data schema was selected for data exchange as it is completely language independent, human readable (and therefore, more easily maintainable), and due to its small size it is ideal for transferring data in a communication network with limited bandwidth, thus ensuring real-time communication even in extreme network conditions. Regarding the security of the information exchanged, the MaaS API currently supports basic HTTP authentication. This means that along with each request (POST, GET, PUT, PATCH, DELETE), the client must sent a proper authentication header that will contain the credentials of a traveller or a service provider registered in the platform. All operations require authentication except for the creation of a new user of the platform. Regarding authorization, the users can modify or delete only the objects they have created. Each object has a unique 'owner' and only this user can modify the object. Finally, the endpoints of the MaaS API implement all the CRUD operations on the defined data models. The complete documentation of the endpoints of the MaaS API can be found online (MyCorridor MaaS API (2019)). From all the above description it is understood that the MaaS API was designed and implemented in a way that meets all users' needs in terms of performance, data security, seamless service delivery user experience.

4. Conclusion

MaaS is a new mobility paradigm that already disrupts the established transportation industry. However, as a new concept, there are gray areas in several of its aspects waiting to be clarified. The main purpose of this paper was to serve this endeavour by describing in detail a real implementation of a MaaS platform with its core components, from both a technical and business points of view. The immediate plans include the evaluation of the presented platform in real-world scenarios, through deployment in several European cities, and the qualitative and quantitative analysis of the evaluation results. Future research directions include the benchmarking of the technology stack used for the development of the MyCorridor platform, and its comparison with other possible technological solutions, as well as the investigation (mainly from a business perspective) of ways of integration of the emerging micromobility services (e.g. Lyft (2019)) in the MaaS ecosystem.

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