Improving Urban Transportation: an Open Platform for Digital Mobility Services

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Abstract

Due to the ubiquity of smartphones, the impact of digital mobility services on individual traffic behavior within cities has increased significantly over the last years. Companies, as for example Google, and city administrations or parastatal municipal transport providers issue digital mobility services. As a result, a heterogeneous landscape of digital mobility services has emerged. While the services serve different needs, they are based on similar service modules and data sources. By analyzing 59 digital mobility services available as smartphone applications or web services, we show that an integration of service modules and data sources can increase the value of digital mobility services. Based on this analysis, we propose a concept for the architecture of an open platform for digital mobility services that enables co-creation of value by making data sources and service modules available for developers. The concept developed for the platform architecture consists of the following elements: data sources, layers of modular services, an integration layer and solutions. We illustrated the concept by describing

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possible modular services and how they could be used to improve urban transportation. Our work supports practitioners from industry and public administration in identifying potential for innovative services and foster co-creation and innovation within existing systems for urban transportation.

43.1 Introduction[1,2]

Today, the traffic situation in many cities is challenging. Due to an increasing degree of urbanization and traffic complexity people lose more and more time in traffic jams and during the search for parking spots. It is estimated that European cities lose between 2.69 and 4.63% of their Gross Domestic Product (GDP) because of traffic congestions [1]. Additionally, the increase in congestion leads to an aggravation of air pollution and greenhouse gas emissions in cities all around the globe [2].

Recently, IT has emerged as one of the key influencing factors on traffic [3]. City administrators operate intelligent transportation systems (ITS) that use IT to improve the safety, efficiency, and convenience of surface transportation [4] and it has been shown that ITS have a greater impact on energy and environmental benefits than construction-phase measures [5]. In the last few years, mobility and location-based services emerged on smartphones as well as within cars. As a result, mobile services have become an important influencing factor on individual mobility in addition to existing ITS [6]. The variety of services that is used by end users include journey planning, ride-sharing matching, maps, navigation etc. and use a variety of data sources.

Many of these solutions are dependent on accurate data, e. g. the location of the users, time-schedule of public transportation or information on the current traffic or parking situation. However, it is difficult for developers of mobility solutions to gather this data, because there are only a few platforms, such as Google Maps or Bing Maps, that offer mobility data and services through standardized interfaces. Service providers only offer isolated services with a specific focus; access to their data and services is often limited and restricted. Furthermore, existing services are not yet integrated and the landscape of digital solutions is vast and unstructured. On the other hand, smart cities generate extensive mobility data such as floating car data of individual vehicles but this data is not offered to external providers nor is it standardized. Making this data accessible and offering standardized modular services that aggregate and analyze the available mobility data would

[1] This chapter is based on the following two publications: Schreieck, M.; Wiesche, M.; Krcmar, H. (2016). Modularization of Digital Services for Urban Transportation. Twenty-second Americas Conference on Information Systems (AMCIS), San Diego and Pflügler C.; Schreieck, M.; Hernandez, G.; Wiesche, M. and Krcmar, H. (2016). A concept for the architecture of an open platform for modular mobility services in the smart city. International Scientific Conference on Mobility and Transport (mobil.TUM), Munich.

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ease the effort for solution providers and foster further development of innovative mobility services. Especially in the case of small and middle-sized enterprises, this could lead to an increased use of mobility data since in these companies there often is a lack of highly specialized knowledge which would be required to analyze and make use of unstructured mobility data produced by smart cities [7]. However, until now it remains unclear what the concept for the architecture of an open and modular digital mobility services platform should look like.

In order to develop the requirements for a solution, we have conducted an analysis of already existing services [8]. We have identified distinct service modules and data sources that are used across these existing services in order to show that an integration of these can increase the value of digital mobility services. Based on our findings from the analysis, which will be presented in the next chapter, we developed a proposition of an architectural concept for an open digital mobility services platform, which we will present and discuss in the subsequent chapters. Our concept contributes to theory by giving guidance for future research on service platforms, especially in the context of mobility services. It also contributes to practice by showing how currently available mobility-related data can be made accessible for developers of digital mobility solutions.

43.2 Analysis of Existing Digital Mobility Services

For our analysis, we applied a methodology framework by Dörbecker and Böhmann [9] for the design of modular service systems. Based on service systems engineering theory, it helps with analyzing, designing, implementing and monitoring service modules as parts of a modular service system architecture. While previous research on modularity has focused mainly on products, recent studies have applied these concepts in the design of services [10]. Dörbecker and Böhmann [11] identified and analyzed 12 methods for designing modular service systems and, as a result, proposed their own iterative design framework. It addresses several limitations and weaknesses of the analyzed methods such as missing generalizability and introduces new aspects such as an iterative design approach across several distinct phases. Böhmann et al. [12] call for future research on service systems engineering in information systems and mention sustainable mobility as an area where services can generate significant benefits. With our analysis, we apply the second step of modularization within the mentioned framework, which comprises the identification and analysis of the service system's modules.

In order to provide an overview of existing mobility services for urban transportation, we conducted a broad search within app stores of mobile devices and tech blogs. All together, we identified 59 mobility services that we analyzed in more detail.

These services were first grouped into six categories, following a taxonomy development process described by Nickerson et al. [13]: Trip planners, ride and car sharing services, navigation services, smart logistics services, location-based services and parking services. A summary along with a description and example services is presented in Ta-

Table 43.1 Categories of Digital Mobility Services

Category	Description	Example service
Trip planners	Provide information for planning trips	moovel
Ride/Car sharing	Share cars and rides	flinc/drivy
Navigation	Follow a route by giving directions	Google Maps
Smart logistics	Facilitate the movement of goods	foodora
Location-based information	Provide location-relevant information	Services for radar controls
Parking	Provide information on parking lots	Parknav

ble 43.1. In a second step, we analyzed modules and data sources of all services. We will now further describe the results of our analysis.

Table 43.2 presents an overview of the modules that we identified. They can be structured according to the origin of their value proposition. One group of modules provides information, while a second group contributes analytics to enhance existing information. The modules map view, POIs, location sharing, traffic information and parking information provide the user with information he or she needs in a specific context. The modules routing and matching are based on analytic capabilities and combine existing information to derive new information.

An analysis of which service modules are included in which digital mobility service is shown in Fig. 43.1. Some service modules are integrated in most of the services. The map view, for example, is the most basic module and therefore integrated in almost all mobility services. Another important module is the routing module, which is integrated in navigation services and trip planners.

Some service modules are not yet integrated in many services although they might offer an additional benefit. The module that enables location sharing, for example, is mostly used in smart logistics services and car and ride sharing services. However, also trip planners or parking services could benefit from location sharing as it might be useful for users to know when a public transport vehicle is arriving or when a parking spot is left by another user. The matching module, as another example, is specific to services that match

Table 43.2 Modules of Digital Mobility Services

Module	Description	Example service
Map view	Show current location and surroundings, relevant information and directions	DriveNow
Routing	Provide suggestions on how to travel to a destination	Google Maps
POIs (Points of interest)	Provide information about relevant points of interest	ChargeNOW
Location sharing	Share location with other users	myTaxi
Traffic information	Provide information on the current traffic situation	Intrix Traffic
Parking information	Provide information on parking lots	Parknav
Matching	Match demand and supply	BlaBlaCar

	Service modules						
Category	Map view	Routing	POIs	Location Sharing	Traffic information	Parking information	Matching
Navigation	●	●	●	◔	◑	○	○
Trip planner	◕	●	◑	○	○	○	○
Smart logistics	◕	◔	○	◑	○	○	◑
Parking service	●	●	●	○	○	◕	◔
Car/ride sharing	●	◑	◑	◔	○	○	◑
Location-based info.	●	◑	◑	○	◕	○	○

Used in more than ● 80%, ◕ 60%, ◑ 40%, ◔ 20% of the services.

Fig. 43.1 Service modules of digital mobility services

supply and demand and is therefore mainly integrated in car and ride sharing services or smart logistics services that match free capacities with delivery requests.

Table 43.3 presents an overview of the data sources that we identified. Most services are based on more than one data source. Especially navigation services and trip planners integrate data from private and public sources and enhance the data via sensor and crowd-sourced data. Data from public transportation providers and from public administration is not yet integrated throughout the categories of digital mobility services. An analysis of which service modules are included in which digital mobility service is shown in Fig. 43.2.

Our analysis provides an overview of existing mobility services showing that there is a large number of different services that need to be combined by the users in order to fulfill their individual needs. Users need to switch between apps and providers since most of the services are not integrated.

However, in this chapter we have shown that services can be structured based on their modules and data sources. We have also shown that a lot of distinct services use similar modules and data sources which suggests that there is a lot of potential for reusing certain components. This serves as further motivation and guidance for the development of

Table 43.3 Data Sources of Digital Mobility Services

Data source	Provided data
Google	Map, routing and traffic information
Device sensors	User location
Crowdsourced data	Data aggregated across users
Other private providers	Solution-specific data
Public transportation providers	Time tables, information on delays and incidents
Public administration	E. g. traffic situation, usage of public parking decks

Category	Data sources					
	Google	Device sensors	Crowdsourced	Other private provider	Public transp. provider	Public administration
Navigation	◑	●	◑	◔	◑	◑
Trip planner	◕	●	◔	◕	●	◔
Smart logistics	◕	●	◑	◑	○	○
Parking service	◕	●	●	●	○	●
Car/ride sharing	●	●	◑	◑	○	○
Location-based info.	●	●	◕	◔	○	◑

Data source used in more than ● 80%, ◕ 60%, ◑ 40%, ◔ 20% of the services.

Fig. 43.2 Data sources of digital mobility services

an open platform for digital mobility services which facilitates the development of new services by providing reusable modules and services and pre-structured data. In the next chapter, we will outline our architectural concept for such a platform.

43.3 Architectural Concept of an Open Platform for Digital Mobility Services

We will first further define the requirements for our platform based on the findings of our analysis in the preceding chapter. The platform should offer several modular mobility services with different levels of granularity. These services should access different data sources and refine their information. All services should be hosted in a secure and safe environment. As many of these mobility services are quite computation intensive, the platform needs to be able to handle sufficient parallel service calls. Additionally, each user should be identifiable by the platform. Furthermore, the platform should support developers that contribute services to the platform's ecosystem by providing access to raw or analyzed data, analysis tools and specifications on how to develop the services according to the platforms standards. The resources on the platform should be standardized so that similar datasets from different sources can be presented and interpreted in a similar way. The platform should provide a web-based interface which allows browsing through the different resources by providing user credentials. The proposed platform should furthermore support cooperation between the public and the private sector. They can create consortia or public-private partnerships and define who will operate the platform.

Fig. 43.3 shows the concept for the architecture of an open platform for digital mobility services. It consists of the following elements and layers which we will now explain in further detail.

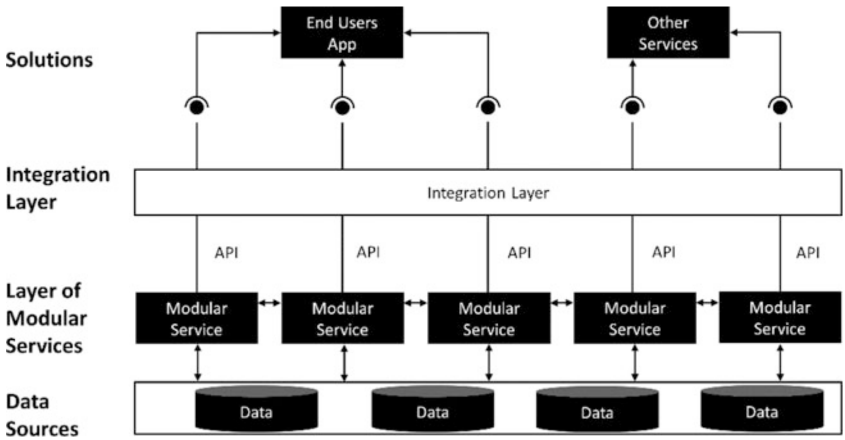

Fig. 43.3 Concept for the architecture of an open platform for digital mobility services

Data Sources The platform is based on several different data sets, for example floating car data or parking lot data. This data could be gathered through on board units within cars or through sensors in parking garages or on the streets. Additionally, data from public transportation providers and taxi corporations such as time tables or the positions of currently available cars could also be an important addition to the set of data sources.

Layers of Modular Services Modular services represent the core of the platform. They can be structured into several layers where the level of granularity increases from the top to the bottom. Services at the bottom focus on analyzing and refining the data sources, whereas services on higher levels reuse the services from lower levels and integrate them using their results. Services that will be used by end users can be found on the highest level. Fig. 43.4 illustrates these different levels and shows several example services which we will now explain in further detail.

- **Parking situation** The parking situation service shows the current availability of parking spaces. It is based on data provided by the parking garages, sensors, or the crowd.
- **Prediction of parking situation** This service predicts the parking situation for a certain point of time in the future. It is based on the parking situation service and the traffic information service. This service processes the provided data with machine learning algorithms. Additionally, it is possible that this service also accesses other information such as weather data.
- **Traffic situation** The traffic information service collects the traffic data from different sources like floating car data, road sensors and road alerts. Then, it combines this data and estimates the current traffic situation.
- **Prediction of traffic situation** This service predicts the traffic situation for a certain point of time in the future. It is based on the traffic situation service and on other data

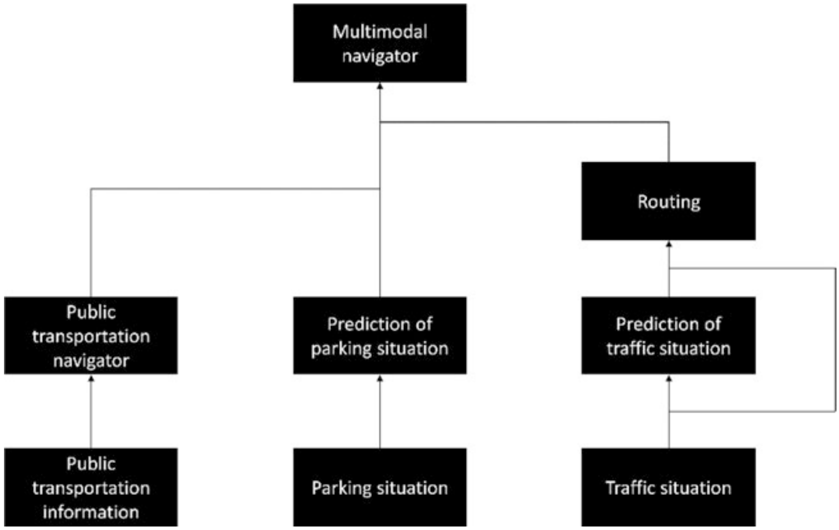

Fig. 43.4 Layer of modular services with example services

sources such as weather data. This service processes the data with machine learning algorithms.

- **Routing** The routing service calculates the best route between two points. The user can specify whether the current traffic situation or the predicted traffic situation for a certain point of time in the future should be considered.
- **Public transportation information** This service shows current and future time tables of trains, subways and buses. It also provides information about any failures or unforeseen situations.
- **Public transportation navigator** The public transportation navigator service suggests the best public transportation route between two points for a certain point of time. It is based on the public transportation information service.
- **Multimodal navigator** This service offers the optimal route within the city for car drivers. It considers the traffic situation for selecting the optimal route, but also checks where it is possible to find a parking space at the destination. Additionally, it checks whether it is better to park the car near a bus station and to use public transportation. This service is supposed to be used by end-users and is based on the previously described modular services.

Integration Layer The integration layer creates a secure and safe environment. Services can only be accessed through the integration layer which buffers service calls and acts as a load balancer. User management and access control also reside in this layer. Since all service calls have to pass this layer, it can also be used for analyzing service calls.

Solutions Developers who are using the platform can use the service to create new mobility solutions. These solutions could be solutions targeted to end-users or they could be integrated into services outside of the platform. An example for a possible solution is a scheduling and routing service for small and medium-sized businesses with multiple appointments within one or several cities. By considering the routes between the appointments and the predicted traffic situation at that point in time, appointment scheduling can be optimized. For example, a nursing service could optimize its daily schedule using this solution and save driving time that could be dedicated to the patient care instead.

43.4 Discussion

Our architectural concept for an open platform for digital mobility services can be used to make data of smart cities available, such as data on public transportation, parking spaces and traffic situation. Such a platform creates a mobility ecosystem and fosters the development of innovative mobility solutions based on the provided modular services. Without it, each developer has to gather data on his own, which is difficult if at all possible.

In this context, another challenge arises: Due to the highly dynamic nature of the platform, caused by the different stakeholders and participants, extensive control, also known as platform governance is required as a precondition for further success of the platform [14]. For example, the data that is aggregated from different sources and then made public by our platform could be used by other developers to strengthen their own competitive position vis-à-vis the platform owner [15]. The platform's standards and interfaces should be carefully examined in order to control the data flow and to avoid misuse. Although effective governance is crucial for the success of a platform, many operators still struggle with designing and implementing a suitable governance concept. The work of Hein et al. [16] and Manner et al. [17] analyses different governance mechanisms and proposes core principles for the governance of mobile platforms. Their findings can give guidance for the design and implementation of a governance concept for our proposed platform.

The example services in the previous section demonstrate and clarify different layers of services. Each service can be offered to the end-user individually, but it is also possible for external developers to combine them to offer new services.

Data related to mobility is of a highly sensitive nature and requires special mechanism for preserving privacy [18]. Methods for preserving privacy while storing and managing mobility-related data are presented as an alternative to a trusted authority by Sucasas et al. [19]. Based on these findings, we suggest to give users as much control as possible by providing standardized processes for setting privacy requirements in order to ensure privacy and transparency in the provided services. For example, tracking data is anonymized and assigned to a regularly changing identifier. Data set owners can then see and track the use of their data.

Our proposed concept is subject to a few limitations. As of now, the architecture of the service platform has not been evaluated. Additionally, only a few exemplary services have been presented. For mobility solution providers, a comprehensive list of services would be more useful. In future research, the remaining steps of the methodology framework by Dörbecker and Böhmann [9], such as implementation and validation, could be applied to our findings. The architectural concept and a concrete implementation could be evaluated by using qualitative and quantitative approaches such as expert interviews and surveys.

Our findings contribute to both theory and practice. As for theoretical implications, our results give guidance on potential future research on service platforms, especially in the context of mobility-related applications. Additionally, they show how the framework of Dörbecker and Böhmann [9] can be applied for the modularization of service systems as presented in our analysis on existing mobility services.

As for practical implications, our concept presents a way of making already existing mobility-related data available for mobility solution developers by fulfilling several requirements related to safety, privacy and governance mechanisms. The proposed platform can be used for the creation of integrated and innovative services and identifying further potential among data source providers for collaboration and synergies. Furthermore, existing systems for urban transportation can benefit from the platform by using offered services to enhance their own solutions and in turn provide new data to the platform, thus further fostering co-creation and innovation.

43.5 Conclusion

Individual mobility is heavily impacted by digital mobility services. Therefore, research on digital mobility services can contribute to the efforts of companies and policy makers to make transportation more sustainable. We analyzed existing mobility services with regard to their modules and data sources. We showed that some modules and data sources are integrated throughout almost all categories while others are only available in highly specialized solutions. Our analysis shows that there is a large number of different services that need to be combined by the users in order to fulfill their individual needs.

In order to ease development of new, integrated mobility solutions, we designed an architectural concept for an open and modular digital mobility services platform. The platform supports the development of solutions by providing mobility data and services through open and standardized interfaces. A broad variety of services at different levels of complexity is offered by the platform which encourages reuse of existing service. Developers can find and pick the services that best fit their needs and goals.

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