

# **Modularization of Digital Services for Urban Transportation**

*Full papers*

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## **Abstract**

The impact of digital mobility services on individual traffic behavior within cities has increased significantly over the last years. Therefore, the aim of this paper is to provide an overview of existing digital services for urban transportation. Towards this end, we analyze 59 digital mobility services available as smartphone applications or web services. Building on a framework for service system modularization, we identified the services' modules and data sources. While some service modules and data sources are integrated in various mobility services, others are only used in specific services, even though they would generate value in other services as well. This overview provides the basis for future design science research in the area of digital service systems for sustainable transportation. Based on the overview, practitioners from industry and public administration can identify potential for innovative service and foster co-creation and innovation within existing service systems.

## **Keywords**

Urban transportation, service systems, digital services, service modularization, digital platforms

## **Introduction**

Congestion costs in the U.S. urban areas have risen to \$160 billion in 2015 – this number has almost doubled since 2009 (Schrank et al. 2015; U.S. Department of Transportation 2009). Additionally, the increase in traffic and particular in congestion leads to an aggravation of air pollution and greenhouse gas emissions. This problem is not restricted to the U.S., cities around the globe face the same challenge: the highest rates of air pollution have been registered in metropolises such as Beijing, Shanghai or emerging cities such as Ulaanbaatar in Mongolia or Ludhiana in India (Statista 2016).

Individual mobility such as commuting is one of the most important reasons for the increase in urban traffic. In 2014, commuters in the U.S. spent an extra time of 42 hours traveling, wasting 19 gallons of fuel (Schrank et al. 2015). City administrations have been struggling to get the congestion problem under control since the 80s. While at the time, construction-based measures were the only way to manage traffic within cities, since then, IT has emerged as one of the key influencing factors on traffic (Wolter 2012). City administrations operate ITS that use IT to improve the safety, efficiency, and convenience of surface transportation (Weiland and Purser 2000). ITS analyze traffic data and influence the traffic flow using a variety of measures such as dynamic traffic signs and lights. It has been shown that ITS have a greater impact on energy and environmental benefits than construction-phase measures (Tupper et al. 2012). ITS are therefore suitable to optimize traffic in cities with regard to a global optimum. Researchers have discussed many aspects of IT within ITS that optimize mobility and logistics (Qiu et al. 2012). Smith et al. (1994) develop an approach based on neural networks to predict traffic flow, Vishwanath et al.

(2014) design a mobility model for urban transportation that leverages new developments in the IT sector, and Marrero-Almonte and Marin-Tordera (2015) discuss a cloud architecture to provide intelligent transportation systems.

Since the early 2000s, it has become possible to track mobile devices and to gather location data of users (Zhao 2000). Consequently, 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 (Forrester 2013). Most individuals use digital mobility services in their daily live and also small and medium-sized companies that cause traffic within cities start using mobility apps (Fries et al. 2016). As these services strive for the user's optimal mobility, they have a conflicting goal to ITS which strive for a system optimum for one city or region (Jonkers and Gorris 2015). For example, Google introduced Google Maps in 2005, offering digital maps to smartphone users. Over the years, Google gathered more and more data from the users to provide information on the traffic flow or on nearby points of interest (POIs). Google's map service is becoming more and more popular, ranking 6<sup>th</sup> among the most used apps on smartphones. Similar crowdsourcing approaches have emerged to gather information on traffic incidents, radar controls or pavement conditions (Yi et al. 2015). With the increasing spread of smartphones, further services such as car sharing and ride sharing (Teubner and Flath 2015) or parking (Caicedo et al. 2012) have been established.

While existing research on IS in traffic management focuses on ITS, it is essential to acknowledge the role of digital services used by individuals. From the viewpoint of the user, all these services are part of a service system for digital mobility services. However, the services are hardly related, the landscape of digital solutions is vast and unstructured. The development of structured service systems can help to overcome this challenge and to provide more useful and integrated services to the users. Service system engineering can foster the development of service systems with interoperable modular services enabling co-creation of value. As Böhmman et al. (2014) state in their call for future research, sustainable transportation is one area in which services can deliver greater value when they are part of a service system. In particular, a modular architecture of service systems has been shown to promote co-creation of value and innovation within service systems (Dörbecker and Böhmman 2015). Following the framework by Dörbecker and Böhmman (2015), we apply the perspective of modularization of service systems to digital mobility services.

To structure the landscape of mobility services and to identify the most important modules of digital mobility services, we evaluate the modules and data sources of 59 digital mobility services relevant for urban transportation. We identify modules that are already integrated in a variety of services and others that are integral parts of one dedicated service and are not designed in a modular way. This overview provides the basis for future design science research in the area of digital service systems for sustainable transportation and helps practitioners to develop modular mobility services as part of a platform ecosystem (Tiwana 2014). This is also relevant for public administrations that want to use the traffic data they gather to not only operate ITS but to provide digital mobility services for individuals.

The paper is structured as follows. First, we provide the theoretical background by summarizing research on digital mobility services, modularization of service systems and co-creation of value. Second, we present the results of our analysis of existing digital mobility services by laying out their modules and data sources. In the last part, we discuss the implications of our study for future research and future design of digital service systems for sustainable urban transportation.

## **Theoretical Background**

In this section we provide the theoretical background for this paper. First, we discuss service modularization and its benefit for service systems. Second, we describe concepts of co-creation value relevant for service systems. These two streams of research form the basis of our subsequent analysis of current digital services for urban transportation.

### ***Digital Service Systems and Service Modularization***

The landscape of digital services for urban transportation is vast and heterogeneous. This impedes an analysis of how these services impact urban mobility and how future digital services can be designed. A

first step is therefore to identify the most important modules of digital services as part of a service system. In order to illustrate the benefit modularization can have for service systems, we define the relevant terms and discuss recent literature.

Alter (2008) defines services as “[...] acts performed for others, including the provision of resources that others will use.” In the case of digital mobility services, an “act” could be the provision of information how an individual can get from A to B within a city most efficiently. A service system is “a work system that produces services”, while a work system is “a system in which human participants and/or machines perform work using information, technology, and other resources to produce products and/or services for internal or external customers” (Alter 2011). In the case of digital mobility services, traffic data, algorithms and software applications such as mobile apps build a work system that produces services related to mobility. Services and service systems have emerged as key concepts in IS (Alter 2011), as technology enables service systems in different industries, for example in healthcare, IT, and manufacturing. Effective architectures for service systems should “efficiently allow re-configuring and re-using these service systems to meet individual customer requirements and changing market opportunities” (Dörbecker and Böhmman 2015).

It has been shown that the modularization of systems is a concept supporting these desired characteristics for product as well as service systems (Baldwin and Clark 2000; Geum et al. 2012). Service modularization can be defined as “(a set of) activities being part of interactions between the components of service systems” (Leimeister 2012). Consequently, a modular architecture consists of modules and decoupled interfaces between modules. The interfaces facilitate co-creation of value and form the basis of the service system. Based on service systems engineering theory, Dörbecker and Böhmman (2015) propose a methodology framework for the design modular service systems. The framework helps to analyze, design, implement and monitor service modules as part of a modular service system architecture. Böhmman et al. (2014) call for future research on service systems engineering in IS and mention sustainable mobility as one promising area where services can generate significant benefits.

### ***Co-Creation of Value***

Inspired by modularization in software development (Sarkar et al. 2007), service systems enable co-creation of value and therefore leverage the capability of IS in different applications (Böhmman et al. 2014). Closely related to modular service systems, digital platforms are discussed as enabler for co-creation of value. Defined as “a set of stable components that supports variety and evolvability in a system by constraining the linkages among the other components” (Baldwin and Woodard 2008), platforms establish an ecosystem around a technological core (Jansen et al. 2009). Relevant actors on software platform ecosystems comprise the platform owner who provides the technological basis of the ecosystem, complementors that enhance the platform by adding complementary products as for example software applications and end-users that use the complementary products, i.e. the software applications available on the platform (Tiwana 2014).

To align the actors within the ecosystem and to foster co-creation of value, the platform owner has to apply governance, defined by Tiwana (2014) as the “partitioning of decision-making authority between platform owners and [...] developers, control mechanisms, and pricing and pie-sharing structures”. The concept of digital platform ecosystems and their governance has been in particular discussed in the area of applications for mobile devices (e.g. Hein et al. 2016; Manner et al. 2013; Manner et al. 2012). As modular service systems represent a similar construct to digital platforms, insights on co-creation of value and governance discussed for digital platforms can be applied in the process of service systems engineering.

### **Analysis of Digital Mobility Services**

In this section, we analyze existing digital mobility services to identify their modules and data sources. In doing so, we apply the second step of modularization within the framework by Dörbecker and Böhmman (2015) which comprises the identification and analysis of the service system’s modules. Subsequently, we describe the data and method used for our analysis, then we present our results showing modules and data sources of digital services for urban transportation.

## **Data and Method**

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. To analyze a representative set of apps that are used by smartphone owners, we scanned the top 50 apps of the German Android Play Store's app category "traffic" and Apple App Store's category "navigation" for services that in some way facilitate mobility processes within cities. We enhanced this search by a key word search within a database of more than 80,000 tech blog articles gathered from October 2015 to February 2016. We used key words such as "traffic", "mobility" and "navigation" to identify suitable articles. By including tech blog articles, we identified newer services that are not yet in the top 50 of the app stores. All together, we identified 59 mobility services that we analyzed in more detail. We compared our sample with the overview provided by Motta et al. (2015) to identify missing services. In this paper, we provide aggregated results. A table comprising all mobility services is available from the authors upon request.

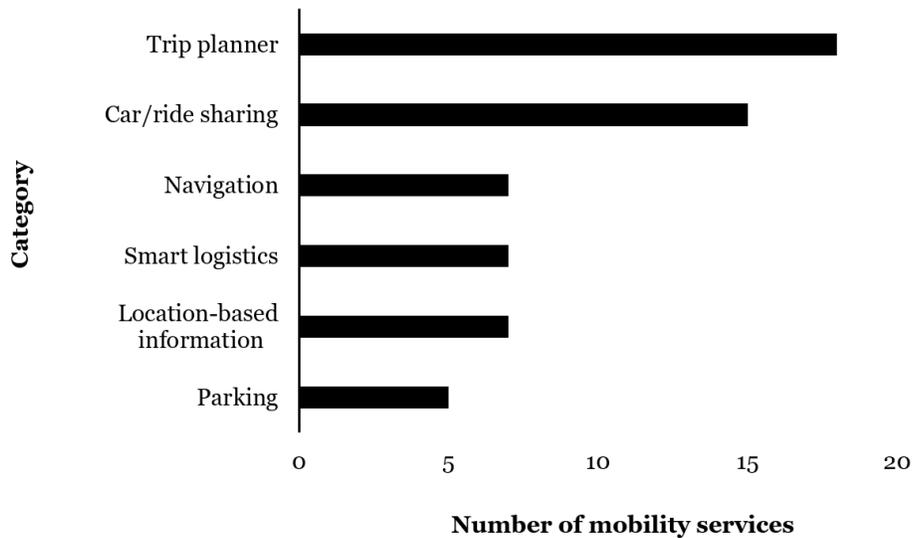
We first grouped the services to categories, following the taxonomy development process described by Nickerson et al. (2012). While we do not strive for the development of a complete taxonomy, the method helps to derive categories in a structured way. With the goal to differentiate services according to their main purpose, we followed an iterative, empirical-to-conceptual coding process (see also Lacity et al. 2010). In a first iteration, two researchers, one from IS research and one from transportation research, independently grouped the 59 services into categories. In the second iteration, the categories of both researchers were compared and differences were discussed. Based on the new group of categories, both researchers assigned the services to these categories in the third iteration. After that, services that were assigned differently or could not be assigned at all were discussed. The categories were again adapted and the researchers performed a last iteration assigning services to these categories. By converging towards the same categories of services, a final solution was created. The categories of mobility services we defined are trip planners, ride and car sharing services, navigation services, smart logistics services, location-based services and parking services (Figure 1).

In a second step, we analyzed modules and data sources of all services. To identify the services' key modules, we evaluated each mobility service included in the sample with data available on the website, the app stores for Android and iOS as well as additional sources that were found via a keyword search on the internet. To identify the data sources used by the services we also checked the license files and the general terms and conditions. Again, we used an iterative coding process, conducted by two researchers, grouping similar modules and data sources. The iterative process was continued, until the sets of modules and data sources converged.

## **Categories of Digital Mobility Services**

**Trip planners** provide information for the users to help them plan their itineraries within and between cities. One example is moovel, a platform for trip planning that consolidates information on multimodal means of transportation. Backed by Germany's second largest automotive company Daimler, it does not only include information on Daimler's own car sharing service car2go but tries to include all relevant means of transportation. In Stuttgart, moovel also offers the possibility to directly organize the transactions within the moovel app. Tickets for the public transportation or bookings of shared cars can directly be payed via the app (Preuss 2015). **Ride sharing and car sharing services** provide users with a platform to either share rides as for example with flinc or cars as for example with drivy. Finc is a ride sharing service that facilitates dynamic ride sharing. Instead of prearranging rides as in traditional ride sharing, drivers get notified in real-time whenever a request of a passenger fits their current route. While traditional ride sharing is mostly used for long-haul inter-city travelling, dynamic ride sharing as offered by flinc is also suitable for inner city ride shares. From January 2016 on, flinc integrates information on public transportation to enhance seamless intermodal travelling (Schumacher 2016). Drivy, a French startup founded in 2010, provides a platform for individuals to rent their cars to others whenever they do not need it. Drivy acquired its German competitor autonetzter in 2015 and has become Europe's largest platform for individual car sharing (Jacqué 2015). **Navigation services** support the user in following a route by giving directions. For example, Google Maps navigation feature is the most used navigation service on Android devices (Technology Unleashed 2015). Navigation services are mostly used in-car or by pedestrians and cyclists. In the last years, some navigation services have evolved to trip-planners by including different means of transportation. **Smart logistics services** cover all services that

facilitate the movement of goods within cities. One example for a smart logistics survey is foodora. Foodora, part of the online food delivery ecosystem of Delivery Hero, is different from traditional online food ordering services. Traditional services act as an agent between restaurants and customers, the restaurants are in charge of the delivery. Foodora, on the other hand, operates the delivery for the restaurants, thereby convincing high quality restaurants to participate (Rest 2016). **Location-based information services** provide information for the users that is relevant for them because of their current location. For example, dedicated services for radar controls or charging stations exist. **Parking services** offer information on free parking lots. Information on parking lots is very relevant for car drivers within cities as up to 40% of inner city traffic is caused by the search for parking lots (Giuffrè et al. 2012). For example, the service Parknav which is available in the US and Germany shows the probability that in a given road there will be available parking lots.



**Figure 1. Categories of digital mobility services (Source: own analysis)**

### **Modules of Digital Mobility Services**

According to Balzert (2009), modules comprise elements that are strongly interrelated but only weakly interrelated with elements outside of the module. We therefore interpret service modules as parts of the services that generate a distinct value for the user. We do not decompose services into their elements as we analyze the services from outside and do not have insights into their technical details. By iteratively coding the modules within existing mobility services, we identified the following modules.

Many mobility services provide a **map view** to show the location of the user, relevant information in his or her surroundings and the directions of the current route. In most cases, the map view is the service's main view. For example, the car sharing application DriveNow shows the user's position and all available cars on a map on the first screen after the login. Applications for public transportation show the nearest stations with additional information on the departure of the trains or busses. A **routing** module provides suggestions how the user should travel to his or her destination. Based on map data, a routing service includes algorithms that calculate shortest paths. Routing service modules may cover different means of transportation and even suggest intermodal itineraries. For example, Google Maps provides optimal routes for pedestrians, cyclists, car drivers and users of public transportation. A **POIs** service module provides information about points of interests (POIs) that are relevant for the user. As some points of interests are included in other service modules (such as parking lots as POIs in the parking information module), this module refers to additional POIs such as nearby gas stations or supermarkets. For example, ChargeNOW leads the way to nearby charging stations and Blitzer.de displays radar controls in the area. The module **location sharing** enables users to share their location with other users. For example, taxi drivers using myTaxi share their location with a customer that has requested a taxi. Thereby, the customer knows the estimated time of arrival and can see the taxi getting closer. A **traffic information** module provides information on the current state of traffic. Traffic is often affected by incidents, traffic jams or

other unforeseeable events. The service helps the user to adapt his or her travel decision to the new situation. Traffic information mostly covers road traffic or public transport. For example, the Inrix Traffic App shows the current traffic state on a map and provides improved routing. A similar service is provided by Google Maps. A **parking information** module provides information on available parking lots in parking decks or on-street. For example, the applications Parkpocket and Parknav provide parking information. A **matching** module matches demand and supply for a certain mobility service. For example, a platform for ride sharing among individuals such as BlaBlaCar matches car owners and potential car renters.

The modules 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. For example, a dynamic matching module as in the ride-sharing application flinc dynamically combines the position of the driver with information on ride requests and calculates a new optimal route suggested to the driver to pick up one or more passengers.

An analysis of which service modules are included in which digital mobility service is shown in Table 1. Some service modules are integrated in most of the services. The map view is the most basic module which is integrated in almost all mobility services. Also routing is an important module. Naturally, a routing module is integrated in navigation services and trip planners. But also parking services, car and ride sharing services and services with location-based information offer routing functionalities to pilot the user towards his or her destination which might be the parking lot, a passenger to pick up or another point of interest. The module providing information on points of interests is integrated in many services as well. It allows to display additional information that might be useful. In some cases, this module is used to generate advertisement revenues by displaying sponsored POIs to the users.

Some service modules are not yet integrated in many services although they might offer an additional benefit. The module that enables location sharing 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 traffic information module has evolved to a key component of navigation services as information on the traffic situation is essential to plan routes. While traffic information plays a role in all mobility services, it is not integrated yet in smart logistics services, parking services or car and ride sharing services. The parking information module is only available in parking services and has not yet been integrated in other services such as navigation or trip planners, where it would produce added value. The matching module is a service specific to services that match 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.

### **Data Sources of Digital Mobility Services**

We analyzed which data sources feed the digital services (Table 1). As many mobility services are data-driven (Wolter 2012), this evaluation helps to understand the interdependencies of services and their modules and provide an indication for practitioners which data sources are necessary for which service.

The **Google** ecosystem emerged as one of the most important data sources. First of all, the map view that Google provides via an application programming interface (API) is widely used in mobility services of all categories. In addition, Google's routing and traffic information API is used in navigation services and trip planners. Overall, 40 out of 59 services use at least one Google API as data source. In addition to Google's data, almost all services use the **sensors** of the users' devices to enhance their services. Mostly, the sensors are used to localize the user on a map and to enable routing. If sensor data is aggregated across users or if users send data to the service provider manually, **crowdsourced** data becomes available. For example, radar control apps use crowdsourced information by users who spotted and reported radar controls. **Other private providers** of data also feed mobility services, but none of them is as dominant as Google. For example, NAVTEQ, now marketed under the label "here", builds the basis for in-car navigation services. Another important data source are **public transportation providers**. These providers often are parastatal companies that offer their own digital mobility services to the users. But

they also provide the timetable data and in some cases data on delays and incidents to third-parties. For example, the trip planner Quixxit uses information from public transportation providers to offer intermodal trip planning and routing. **Public administrations** offer information on the traffic situation or on the usage of public parking decks. Table 1 shows that mobility services build on a variety of data sources. Especially navigation services and trip planners integrate data from private and public sources and enhance the data via sensor data and crowdsourced data. Data from public transportation providers and from public administrations is not yet integrated throughout the categories of digital mobility services.

Category	Service modules							Data sources					
	Map view	Routing	POIs	Location Sharing	Traffic information	Parking information	Matching	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.	●	◐	◐	○	◐	○	○	●	●	◐	◐	○	◐

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

**Table 1. Service modules and data sources of digital mobility services (Source: own analysis)**

## Discussion and 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 59 existing mobility services with regard to their modules and data sources. First, we identified navigation services, trip planners, smart logistics, parking services, car and ride sharing services, and location-based services as most important categories of digital mobility services. Then, we identified the most prevalent modules for all categories. We laid out that some modules such as map view are integrated throughout all categories while others such as parking information are only available in dedicated parking solutions. In a second part of the analysis, we identified the predominant data sources used by digital mobility services. Some data sources such as the Google ecosystem were used throughout the categories of mobility services while others such as data from public administrations has not yet found its way into many mobility services. In summary, 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. This overview forms the basis for future design science work on modular service systems in the area of transportation. We therefore summarize the contributions to theory and practice below.

### Contribution to Theory

In our study, we apply a service system perspective on digital mobility services, bringing together research on service system engineering and research on digital mobility services. In doing so, we follow a call for research by Böhmann et al. (2014) who point out the potential of service systems in technology-driven domains such as sustainable mobility. We show that digital mobility services can be seen as part of larger service systems. As modularization is one of the key concepts in the design of service systems, we refer to the framework proposed by Dörbecker and Böhmann (2015) to identify and analyze modules of the

existing digital mobility services. This analysis provides a starting point for future research on the design of service systems for sustainable transportation. While several contributions provide technical solutions for a specific service system that integrates different mobility services (Marchetta et al. 2015; Pihlajamaa et al. 2013; Sassi et al. 2014), our study serves as basis for a more conceptual approach. This facilitates further analysis of services in several ways. First, by interpreting service components as distinct modules, boundaries of service modules are defined, creating delimitable units of analysis that are comparable. Second, interdependencies between service modules can be identified and help to understand why services need to comprise certain modules and data sources. Third, by building a framework of service modules and data sources, gaps in the framework become evident and can be filled by creating new services or combining existing ones.

Future research can firstly apply design science and action research methodologies to develop modular services as part of service systems for sustainable transportation and evaluate the impact of modularization on co-creation of value (Böhmman et al. 2014). Secondly, an empirical evaluation of the Google Maps ecosystem of mobility system with a focus on the co-creation and innovation enabled by openly available Google APIs and services would contribute to the understanding of service systems for sustainable transportation. Thirdly, research applying insights from the governance of digital platform ecosystems could contribute to the understanding of how to successfully establish service systems. Lastly, the concept of modular service systems could be applied to ITS research, linking ITS and digital mobility services. As both ITS and digital mobility services share similar data sources it would make sense to integrate them. As soon as connected cars will be established, this integrated view will be inevitable as road-side and in-car measures can no longer be differentiated.

### ***Contribution to Practice***

Public administrations such as city administrations may want to use the traffic and infrastructure data they gather to provide digital services for their citizens. As construction-based measures for traffic management often are protracted and costly, ITS and digital services may produce relief. However, road-side ITS lose impact with the predominance of digital services used in cars via smartphone or onboard units. Therefore, digital mobility services can help cities to stay in control with regard to the traffic management. Furthermore, by providing access to modular service and even data, cities can enhance co-creation of value and innovation. For example, New York provides a large amount of diverse data source via open interfaces within the NYC Open Data project (The City of New York 2016). Following the insights gained in our study, several guidelines can be derived for the development of modular service systems by public or private providers. First, every mobility services needs to be designed in a modular and interoperable way as part of the service system. Second, standardized data formats need to be used, in order to facilitate co-creation of value (Faouzi et al. 2011). By doing so, public data and data on public transportation systems will find its way into digital services further improving the quality and usefulness of digital mobility services. Third, interfaces need to be designed that deliver functionality to other service providers so that service modules can be combined to enable new, innovative mobility services. Fourth, the cooperation between public and private service providers needs to be deepened. Only by granting access to public data, private companies can leverage the data for innovative services. Without this cooperation, private companies generate data as basis for their services that is redundant to existing public services.

Our study entails several limitations. First, the selection of mobility services via app store rankings and tech blogs might not be representative. In-car apps that are not available on app stores might be neglected. The limitation to 59 services further impedes generalizability. Second, the coding process comes along with a loss of detail as similar but not identical services and modules are grouped. Third, our analysis covers one step out of the framework for the modularization of service systems by Dörbecker and Böhmman (2015), requiring further research to validate and apply the results.

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