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CATCHWORD

Intermodal Mobility

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1 Background

Cities around the world are facing a multitude of mobility challenges. Driven by an increase in the number of personal motor vehicles, traffic and traffic congestion are becoming more frequent, parking spaces are becoming more scarce (while also taking up public space), and the urban population is increasingly exposed to air pollution and noise with potentially negative health effects (Arnott and Inci 2006; Arnott and Small 1994; Barth and Boriboonsomsin 2008; Loukopoulos et al. 2005). In addition to producing CO_2 and other harmful emissions, personal cars are used inefficiently. It is estimated that they stand unused 95% of the time (Barter 2013) and, when driving, carry only 1.7 persons on average (US Department of Transportation 2011). At the same time, the number of people living in cities is expected to continually increase in both relative and absolute terms. The share of the urban population has been estimated to increase to 66% by 2050, up from 54% in 2014 (United Nations Department of Economic and Social Affairs 2014). Thus, the ongoing urbanization trend will likely exacerbate urban mobility challenges in the near future.

In recent years, the number of urban transportation modes – "the means by which people and freight achieve mobility" (Rodrigue et al. 2013, p 101) – including, for instance, bus, subway or personal car, has increased. Digitalization and Information Systems (IS) solutions have enabled new and more sustainable alternatives, such as carsharing (Firnkorn and Müller 2011), bikesharing (Shaheen et al. 2010), ride sharing (Teubner and Flath 2015) and e-hailing services (Greenwood and Wattal 2016), which hold the potential to alleviate the aforementioned challenges. The development and adoption of these modes has been aided by another socio-economic trend, the rise of the sharing economy, according to which access to and use of a good or service is increasingly valued over ownership of the same (Hamari et al. 2015). Especially for the millennial generation, the importance of cars as a status symbol has been decreasing (Belk 2014).

Thus, in urban areas personal car travel is partially being replaced by other modes of transportation. In a passenger transportation context, utilizing different transportation modes depending on one's momentary needs, as opposed to always travelling by personal car, is referred to as "multimodal behavior" (Kenyon and Lyons 2003). A special case of multimodality is intermodal mobility behavior, whereby two or more travel modes are combined within a single trip (Müller et al. 2004). These two terms are not always used in the same manner. In Sect. 2.1, therefore, we provide the different definitions and our reasons for utilizing the terms as mentioned above.

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Previously, transaction costs for intermodal travel behavior were often prohibitively high. Gathering timetables for the different modes and finding the best option, not to mention considering changeovers and varying ticket prices, was time-consuming and had to be done well in advance. The combination of different passenger transportation modes, however, has recently become simpler and more convenient thanks to advancements in IT and software solutions. Multiple websites and mobile apps offer trip-planning services by integrating information pertaining to different modes. Throughout the rest of this article we will refer to these web-based services as mobility platforms or mobility solutions.

Since public transportation providers often offer multiple modes, such as tram, subway or bus, they were the first to create intermodal mobility solutions, in which they bundle information about the different modes for their customers. Thus, for most large cities with a dominant public transportation provider, intermodal mobility solutions are already available (Masuch et al. 2013). Solutions that transcend public transportation and additionally integrate information from other providers, as well as "private" travel modes (bike or car), however, are more complex and have only recently been introduced, as a result of advancements in IS and better data integration. In some cases, these platforms even include booking and payment functionality, or real-time information during the trip regarding delays, the current traffic situation and the availability of bikesharing and carsharing vehicles in the vicinity of the user. Due to their relative novelty, and the enhanced range of choices they provide to travelers, we investigate these multi-provider mobility platforms in this article in greater detail.

The value which such solutions provide to travelers is easily recognizable. First and foremost, the mobility offering becomes more tailored to personal needs. For instance, users often have the option of choosing between the fastest, the cheapest, the most environmentally friendly, or even the most scenic route. The platforms provide travelers with flexibility and alternatives, which is especially useful in the context of real-time traffic information. Traveling becomes more efficient as algorithms calculate the fastest routes with minimal transfer times. Customers also save time in planning their trips and searching for the necessary information. Finally, multimodal travel, in most cases, is more economical than monomodal travel, since there is no large upfront investment as for personal vehicles (Christensen and Shaheen 2014). In the long run, price transparency for the different modes will likely lead to increased competition and lower journey prices overall. Mobility service providers also benefit from integrating their offering with other transportation modes, as this will likely increase their customer base and the additional customer information from browsing and mobility behavior can improve providers' customer targeting capabilities. Perhaps most importantly, society as a whole is predicted to benefit from the shift to multimodal travel as it reduces many of the aforementioned urban mobility challenges, namely air pollution, noise pollution, traffic congestion and a shortage in parking spaces. Overall, multimodality is expected to lead to a more environmentally friendly transportation paradigm (European Commission 2013; Spickermann et al. 2014; van Nes and Bovy 2004).

Despite all these benefits of integrated mobility platforms, several barriers to their implementation remain. Most notably, there are technical challenges such as different system architectures or different, non-standardized APIs. Secondly, paying for each mode individually is inconvenient, but different fee structures make centralized payment difficult (Christensen and Shaheen 2014). Thirdly, the market for multimodal solutions is highly fragmented with many city-specific solutions, even within a single country. This again causes inconvenience for customers and inhibits a rapid and more widespread adoption. And lastly, there are psychological impediments as conventional travel habits need to be overcome (Nobis 2007). Yet, several multi-provider multimodal mobility platforms are already active and in the next section we provide an overview of their functionalities and show how they differ from each other.

In summary, multi- and intermodal travel behavior is desirable as it enables more sustainable mobility behavior and can potentially relieve strained urban mobility systems. Well-functioning mobility solutions with easily accessible trip information and possibly on-the-go payment functionality are essential to encourage travelers to adopt this behavior. To facilitate the discussion on intermodal traveler behavior, this article shall provide an overview of this relatively new topic from both a practitioner and research perspective. Our contribution is thus twofold: first, we provide an overview of the multi- and intermodal mobility solutions that exist today, identifying dimensions along which their differences can be analyzed and giving an outlook on their future development. Second, we shed light on the topic from an IS research perspective, giving an outline of prior research streams and providing an outlook regarding the ways in which the business and information systems engineering research community can contribute to the advancement of multi- and intermodal travel behavior.

2 Different Perspectives on Current Multimodal Solutions

To create an overview of the market for multimodal mobility platforms, we have searched for active providers that offer at least two different modes of transportation. We concentrated on the European market, since there, the concept of intermodal transportation seems to be further advanced and more frequently discussed, which Marx et al. (2015) attribute to a pre-existing infrastructure that better supports new mobility initiatives, a greater public demand for mobility solutions, and more favorable institutional and legal conditions regarding public and private participation in mobility issues. Consequently, there is also more research into European, and often German, solutions.

In addition to the platforms mentioned in academic literature, we have conducted a web search of the iOS App store and Google Play and initially recorded 45 relevant mobility platforms. A more detailed assessment, however, led to the elimination of 31 platforms which were either not yet operational, no longer operational, acquired by competitors, or not truly multimodal. The remaining 14 active multimodal mobility platforms are shown in Fig. 1.

2.1 Classification of Marketplaces

An example of analyzing business model characteristics of multimodal mobility platforms can be found in Lisson et al. (2015). However, some of the identified categories in that paper are difficult to evaluate from an outside-in perspective. After an in-depth assessment and testing of the different solutions, we have decided to focus on four dimensions – namely geographic scope, breadth of offering, multi- versus intermodality, and depth of offering – to illustrate the differences between providers.

2.1.1 Geographic Scope

The providers' offerings can be grouped into three categories. Half of the providers offer their services only in select urban areas (1). Four providers, Moovel, Quixxit, Google Maps and Mobility Map, offer their services for urban and regional (2) trips where regional refers to national and international travel. For these platforms, the geographic scope of the individual mobility service providers (e.g., rail operator) determines the geographic scope of the overall platform. The remaining three solutions offer only regional (3) or medium- to long-distance trip comparison (Fig. 1). GoEuro and fromAtoB are only available in Europe, while Rome2rio offers its services worldwide. In this respect it is also interesting to note that GoEuro and fromAtoB are the only platforms in our sample which do not offer a smartphone app, probably because regional travel requires less spontaneous comparison. The longer the travel distance, the higher the likelihood that intermodal trips will be required to get from one place to another. Therefore, people should be more willing to use a combination of modes on longer-distance trips. Yet there are more platforms offering information for urban trips (11) than for regional trips (7).

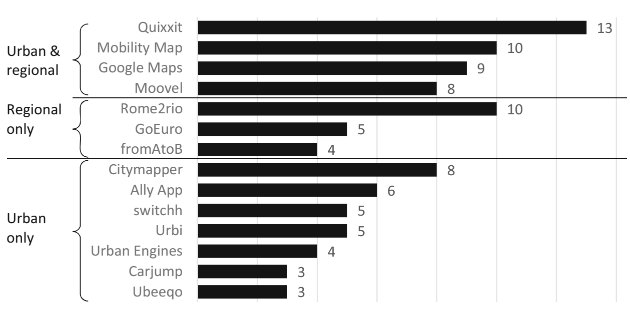

Fig. 1 Number of modes per mobility platform (breadth of services) clustered by geographic scope

2.1.2 Breadth of Services Offered

We define breadth of offering as *the number of different modes* offered on one platform. In a passenger context "mode of transport" refers to the means by which a person travels from one place to another (Christensen and Shaheen 2014; Rodrigue et al. 2013). The terms "mode" and "means" are thus used interchangeably. This is in contrast to freight transportation literature, which generally distinguishes between four different modes – air, water, road and rail, the last two sometimes being summarized as land (SteadieSeifi et al. 2014) – and the different vehicles (sometimes referred to as means) required to move the goods in each mode.

Following the passenger-related definition, we do not equate means of transport with vehicle type, as this would ignore important distinctions between the competing travel modes. For instance, carsharing, ridesharing, chauffeur services, car rental and private car all utilize an automobile as a vehicle, yet each mode presents a distinct option with unique characteristics that influence the traveler's choice (the same reasoning applies to bikesharing and personal bikes). Another implication of the passenger transport mode definition is that we regard public transport as a combination of different modes (local bus, subway and tram), because the different modes in a public transportation system are in some cases competing against each other and travelers can choose freely which one best suits their needs.

Figure 1 shows how many modes are offered on each platform, an average of 6.6 per provider and a maximum of 13 for Quixxit. Figure 2 shows the different modes ranked by how frequently they are offered, with the three public transport modes, chauffer/taxi services, carsharing, bikesharing and walking being the most common options.

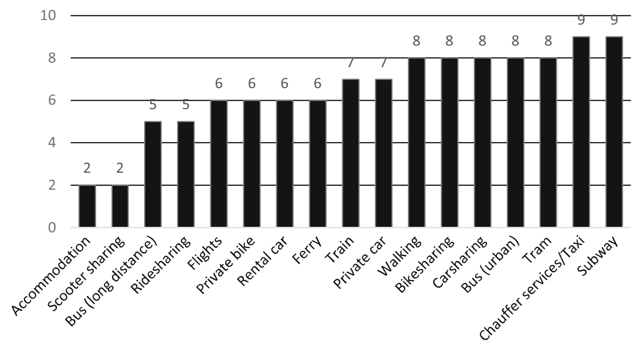

Fig. 2 Frequency of transportation modes within mobility platform sample ($n = 14$)

	Multimodal	**Intermodal**
Trip comparison only	▪ Ally App ▪ Citymapper ▪ GoEuro ▪ Google Maps ▪ Mobility Map ▪ Urban Engines	▪ Rome2rio
Trip comparison and booking	▪ Carjump ▪ fromAtoB ▪ switchh ▪ Ubeeqo ▪ Urbi	▪ Moovel ▪ Quixxit

Fig. 3 Classification of mobility solutions according to multi- versus intermodality and depth of services

2.1.3 Multimodality and Intermodality

The concepts of multimodality and intermodality are well established in the freight transportation context, but, due to the different nature of transportation and the diverging definitions of mode, their definition is not directly applicable to passenger transport. Multimodal freight transportation is defined as utilizing at least two modes, for instance sea and rail, and intermodality is regarded as a special form of multimodality whereby the goods do not change the unit of transportation (e.g., a container) (SteadieSeifi et al. 2014).

The European Commission (2013) applies the freight transportation definition to personal mobility and therefore uses intermodality and multimodality interchangeably to describe the combination of different modes. For personal mobility platforms, however, it can be useful to differentiate the between the two. Therefore, in this paper we follow Christensen and Shaheen (2014), who defined multimodal as “having access to multiple modes in making a trip” (p 1) and Müller et al. (2004), who defined passenger intermodality as “a policy and planning principle that aims to provide a passenger using different modes of transportation in a combined trip chain with a seamless journey” (p 2).

Accordingly, multimodal platforms are those offering multiple modes of transportation and intermodal solutions provide users with the opportunity to combine different modes of transportation within a single trip. Similar to freight transportation, personal intermodality is thus a special case of personal multimodality. Intermodality, in particular, has been deemed promising in its potential to relieve urban mobility systems, due to the more efficient use of individual modes (Christensen and Shaheen 2014). Yet the majority of platform providers in our set are simply multimodal while only three providers (Moovel, Rome2rio, Quixxit) offer intermodal services (cf. Fig. 3). This can likely be explained by the aforementioned technical barriers to seamless integration.

2.1.4 Depth of Offering

The fourth dimension can be used to assess the platforms’ technical sophistication. The main functionalities include trip comparison, payment for mobility services, and on-trip information or navigation services. The first two are depicted in Fig. 3. But there are also other functionalities; Rome2rio, for example, provides information about sights. The distinctions in this category are not as clear-cut as in the previous ones. While all providers offer trip comparison, the extent of the service varies. For instance, some platforms only provide price comparison while others offer a higher degree of customization (e.g., smartest, fastest or cleanest trip). Half of the platforms, seven, offer booking of or payment for mobility services, but only two providers offer on-trip information such as delays (Quixxit, Google Maps).

2.2 Observations and Outlook for Future Development

There were several interesting aspects in the assessment of the different solutions. First, surprisingly few providers offer truly intermodal solutions. Moreover, the market still seems very fragmented as many solutions are only city-specific. Third, the number of transport modes per platform does not necessarily provide information about the extent of the offering since the number of providers per mode also matters. Fourth, all government-backed solutions in our initial sample were either abandoned or are not yet in service. These include ASEAG Mobility Broker, econnect Germany, Superhub project, Wisetrip, Mobility as a Service (MaaS), and Intermodal Mobility Assistance for Megacities (IMA).

In the future, mobility platforms will likely continue to work on overcoming technical integration barriers to offer truly seamless intermodal mobility and provide a “one-stop shop” that fulfills all mobility needs. We also expect that with an increasing share of electric vehicles, electric infrastructure – in the form of charge points and designated parking spaces – will play a greater role and will potentially be integrated into the applications. And lastly, the fragmented market and location-specific solutions paired with the economies of scale of electronic markets will likely result in greater consolidation.

3 Research Focus and Trends

Previous research has pointed towards the importance of multimodality in urban systems to alleviate today's passenger transportation challenges. Yet multimodal mobility platforms are still in their infancy, and the corresponding body of literature is also still fairly limited.

3.1 Traveler Behavior

Getting travelers to adopt multimodal behavior requires overcoming psychological biases. Previous research has indicated that "the majority of travelers do not consider their modal choice for the majority of journeys" (Kenyon and Lyons 2003). But if presented with sufficient information, including information with regard to comfort and convenience, they might consider different, non-habitual travel modes. Preferences, however, vary with respect to age and place of residence, and multimodal behavior has been shown to be more frequent in younger generations and in an urban context (Nobis 2007).

Due to psychological and information barriers, most authors agree that the key to achieving multimodality is a well-functioning ICT solution (European Commission 2013). Spickermann et al. (2014) claim that a transition towards a truly sustainable multimodal transport system cannot be achieved by technological solutions alone, but requires more fundamental restructuring and integrated strategies (e.g., a diversification of public and private financing and the active involvement of the various stakeholders). In a pilot project with Palermo University students, Di Dio et al. (2015) show that adapting the urban infrastructure system is not necessarily a requirement. In their study, utilizing ICT succeeded in fostering a more sustainable multimodal transport behavior by incentivizing travelers and providing them with information via a smartphone app.

3.2 Multimodal Mobility Platform Design Challenges

Although the case study of Palermo shows promise, the technological implementation of combining multiple modes in a single platform is far from trivial and depends on the scope of the solution. Several years ago, Wicke (1999) described how the transport sector lacks transparency and the possibility to bundle different transport offers. As a remedy he imagined an electronic transport market with mobility exchanges – analogous to stock exchanges – which would enable the purchase of all forms of transportation, both freight and passenger, including the use of private cars. Since such a revolutionary approach to transportation would be difficult to implement, subsequent studies have instead focused on mobility platforms that combine some, but not all, modes of transportation. Nevertheless, the same barriers to implementation described by Wicke are also discussed in relation to the smaller mobility platforms.

Seamless integration of the different services seems to be the greatest challenge, one that is fueled by differing sources of data and incompatible protocols. As a result of incoherent and incompatible data sources, most currently-active intermodal travel solutions only combine different modes within the public transport offering (Masuch et al. 2013). After a review of the current state of intermodal planning algorithms and their providers, Masuch et al. present the open platform "Intermodal Mobility Assistance for Megacities" (IMA), their own solution to integrating infrastructure providers. Looking at the example of integrating eMobility providers (e-carsharing, charging and parking), Strasser et al. (2015) show that a lack of standard protocols is the main reason for the lack of interconnection between the individual providers. Consequently, they describe different possible architectures to facilitate interconnection and present their own solution to integrated services, the eMobility MarketPlace. Another example of the system architecture behind a multimodal platform is described by Beutel et al. (2014a) for the German government-funded "Mobility Broker" project. The authors discuss the protocols that are necessary to integrate different functions, such as routing and payment, and the different mobility providers. The platform itself, they propose, should be run by an independent third party which does not offer any mobility services. A fourth approach to integrating different providers, in this case for the purpose of international multimodal journey planning, is an EU-funded project called WISETRIP (Aditjandra et al. 2009). Also in this case, common and standardized data, as well as the incorporation of real-time information, were mentioned as the main obstacles to be overcome.

3.3 Business Model Approaches to Multimodal Mobility Platforms

Aside from system architecture and technical prerequisites, there have been some studies investigating the appropriate business model approaches and functionalities of multimodal mobility platforms. Beutel et al. (2014b) describe the key building blocks for the business model of virtual marketplaces that offer different mobility services. A virtual currency and payment mechanism is one of these keys and is described as essential to the platforms' success. With regard to e-mobility, the business model approach becomes slightly more complex if electric infrastructure providers become integrated with electric transport mode providers such as electric cars, e-bikes and e-scooters (Buchinger et al. 2013). A recent overview of the different business model approaches and the features and attributes of web-based mobility services, including solutions that offer only a single mode, is provided by Lisson et al. (2015).

A crucial prerequisite to developing a mobility platform is the consideration of customer needs. Grotenhuis et al. (2007) focus on which information is most relevant to travelers during a trip and cluster the different types of information according to user groups and the different stages of a trip. Accordingly, several authors have discussed on-trip information as a central feature of mobility platforms.

Birth et al. (2015) have developed an intermodal route guide app which detects external factors that lead to deviations from the standard route, such as weather changes, or user-induced deviations such as walking too slowly to reach the next stage of the route. Based on an event-driven architecture (EDA), and complex event procession (CEP), their service informs users about these deviations and adapts the route accordingly in real time. A similar solution is presented by Motta et al. (2015), who have developed an integrated real-time mobility assistant (IRMA), which integrates different sources of real-time data, including open data such as timetables, but also crowd data (e.g., user device data), sensor data and social media data.

4 How Business and Information Systems Engineering can Enable and Support Intermodal Mobility

The objective of IS research is to be close to current practice, as well as to current research. In each of these areas, intermodal mobility is still in its infancy. Therefore, there are several promising possibilities for the IS community to support the transition towards a sustainability-enhancing intermodal mobility paradigm. For instance, IS researchers can help to identify and define *what constitutes a good intermodal value proposition* regarding platform design and the definition of standards. Intermodality requires interoperability and constant information exchange between the individual transportation providers and the platform. Different approaches to interoperability have been discussed in an enterprise architecture context (Bidan et al. 2012). With regard to interoperability on IT platforms, it has been shown that independent software vendors benefit financially from joining a major platform. IS research can investigate whether the same is true for mobility providers and platforms.

Evaluating the quality and the success factors of the different intermodal solutions, can provide insight into the above question from a business model perspective and will open up further opportunities for IS researchers to work towards the seamless integration of modes. A third approach to determining a good intermodal offering might come from the point of view of the customer. Investigating how people use mobility apps and how they interact with intermodal platforms could provide information necessary for improving multimodal and intermodal solutions or for developing new ones. Moreover, studying people's mobility behavior across time and space (Willing et al. 2016) can provide valuable insight for the design of an efficient intermodal solution. We hope the IS community will further contribute to these efforts as they have the potential to provide relief to city infrastructures and make transportation more sustainable.

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