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On the Necessity and Nature of E-Mobility Services – Towards a Service Description Framework

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Abstract. After years of focusing exclusively on the technological side of electric mobility (e-mobility), services are getting more and more in the focus of scientists. Many recent works concentrate on the identification and analysis of the potential of new business models in this field. Although the relevancy of services for the success of e-mobility is becoming more obvious among industry and science, there is still a lack in scientific contributions when asking for a comprehensive overview of existing e-mobility services. With this paper, we try to bridge this gap by providing a framework that enables the description and classification of services around the usage of an electric vehicle (EV). The framework captures six dimensions which allows to characterize and compare different services. This enables the identification of commonalities and differences between the services and provides an interdisciplinary playground for developing new services and further research in this field.

Keywords: E-Mobility Services Description framework Service dimension

1 Introduction

In order to limit global warming to 2 °C above pre-industrial levels, mitigation of greenhouse gas (GHG) emissions is on the agenda of many countries and organizations around the world [1, 2]. For Germany, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety has calculated that the GHG emissions of passenger cars should be reduced by 80 % between 2005 and 2050 [3].

This reduction target cannot be reached with efficiency improvements of conventional combustion engines alone. It can only be reached with a bundle of measures. One main measure is the electrification of vehicles [3] going along with an increase of electricity generation by renewable energy sources (e.g. [4, 5]).

Electric vehicles (EV) can generally be distinguished into three groups [6] (see Fig. 1): (a) vehicles relying on continuous electric supply from an off-board generation system, (b) vehicles relying on stored electricity from an off-board generation system, and (c) vehicles relying mainly on on-board electric generation to supply their needs. Examples for group (a) vehicles are electric trains or trolley buses powered by overhead wires. Group (b) includes battery-electric vehicles (BEV) and group (c) includes hybrid-electric vehicles (HEV) which have an electric motor and an internal combustion engine. Electric hybrids can be further distinguished into hybrids without a vehicle inlet for electricity, range-extended electric vehicles (REEV), and plug-in hybrid electric vehicles (PHEV). Thus, electric cars fall into groups (b) and (c).

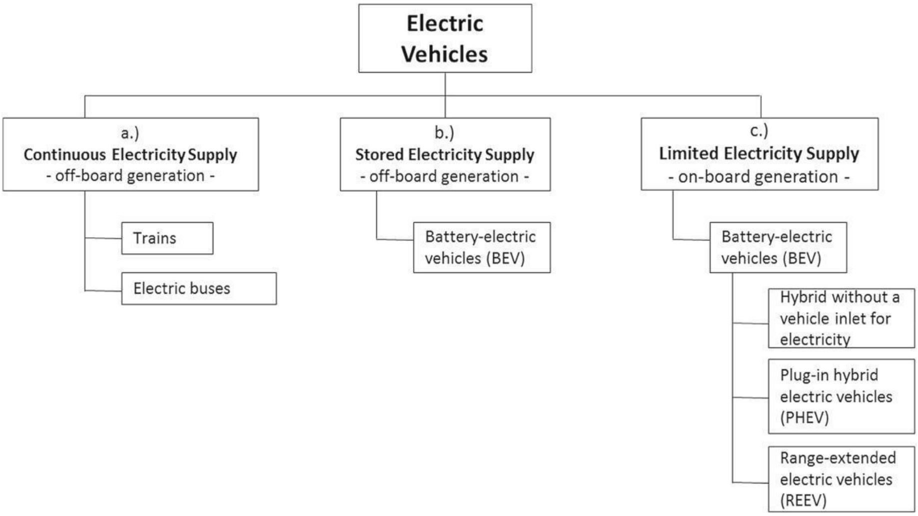

Fig. 1. Typology of electric vehicles (based on [6])

In the interest of this paper are plug-in electric vehicles (PEV) including BEV, REEV, and PHEV which allow a recharging of the battery from the external grid. Many governments have set targets for the market dissemination of PEV. For example, the United States are aiming for one million PEV on their roads by 2015 and Germany aims at one million PEV by 2020 [7].

In general, the success factors for market penetration of PEV are manifold. Some factors are (based on [8, 9]):

(a) adequate purchase prices of EV (highly dependent on battery prices), especially in comparison with traditional vehicle prices;
(b) similar total cost of ownership of EV vs. traditional vehicles (largely determined by gasoline, diesel, and battery prices);
(c) monetary and non-monetary incentives;
(d) reduction of driving range limitations, charging time, and increasing green image as well as adequate availability of a convenient charging network; and finally
(e) services which make the use of electric vehicles as easy and comfortable as possible.

The last success factor in the list, “services”, has been widely neglected in literature and research landscape so far [15, 16].

Traditional automotive mobility could be seen as a complex but rather static eco-system consisting of a product – the car – and a multitude of services surrounding this product. Examples are gas stations, maintenance and repair services, car wash services, but also insurance, financing, leasing, and services within the car like traffic information and navigation. We are typically not much concerned about these services, because they are widely available and functioning well. If we run short of gas, the next gas station is most often not far away.

This is quite different for electric mobility (e-mobility). Charging stations for PEV are not found at every arterial road or major intersection. This means that services have to be provided to locate charging stations – offline, or integrated into the navigation systems. Charging a PEV takes much longer than filling up gasoline today – even though fast charging stations allow an 80 % charging in less than 15 min. To make sure that an unoccupied charging station is available, a reservation is desirable. If someone wants to travel a larger distance with a PEV, the navigation system should consider stops that are necessary for charging. Intelligent systems might combine the stop with the recommendation of a restaurant or shopping mall, so that the battery could be recharged while the driver and companions make the best use of their time. These service scenarios are all related to travelling, but other services for e-mobility might be offered much earlier in the “PEV life cycle”. First, services are being offered that give the owner of a traditional automobile an indication, if a PEV would fit to his or her mobility needs. This indication can be based on GPS data from trips with a conventional car that the driver shares with the service provider and that are being statistically evaluated to characterize the driver’s mobility pattern (distances travelled, parking times and locations, geography). Thus recommendations for very individual mobility requirements can be given.

These examples demonstrate that for e-mobility new services need to be provided (e.g., reserving a charging station, evaluating the fit of a PEV) and existing services need to be extended (e.g., navigation considering charging locations and times). Many conventional services (e.g., maintenance and repair, financing) remain the same, but need to take the special characteristics of PEV into account. Furthermore, the current trend to intermodal mobility in many countries (and the increasing services in this field) seems to fit well to EV. Their low variable costs, local emission free driving in rural areas and their limited range makes them to a very attractive link within intermodal trip chains. Car sharing programs are a good example for an ideal application environment for PEVs. Combined with a train ride or flight, PEV are ideally suited to cover the “last mile”. Such an offering is more likely to be accepted if the customer can book the entire trip from one provider. Other mobility “bundles” are already offered by automotive companies for customers who buy a PEV: for weekend or vacation trips, they have the option to use a conventional (long-range) car.

A mobility system providing all necessary services for PEV differs strongly from the long-established conventional automotive system. It is a system that includes players from the automotive industry (e.g., car manufacturers, suppliers), the energy sector (e.g., utilities, grid operators), the public sector (e.g., public transportation, cities, authorities), other players in the transportation sector (e.g., rental car companies, logistics service providers), the IT industry and in the middle: the user (e.g., driver or owner of a car). Much more than the traditional system, it is more dynamically and an open system in which new players are continuing to enter. The system requires interaction between players which traditionally were not closely related (e.g. automotive and energy industry). New business models, pricing mechanisms and revenue sharing models need to be developed. Information and communication technology (ICT) plays an important role in providing platforms for connectivity and innovation and attractive end-user solutions. The availability and intelligent use of data becomes an important factor.

In this open system it is still not clear who will provide the individual services for e-mobility. The system is highly dynamic and competitive maneuvering can be observed. To understand these dynamics, it is first necessary to understand the nature of services around the use of PEVs. In this context, the following two research questions arise:

RQ 1: Which services are necessary for a convenient PEV usage?
RQ 2: How can they be described in a short and structured manner?

The description and mapping of services is an important basis for all forthcoming research. Further studies will be necessary to get clear of the impact services have on user acceptance and how far conventional companies will be able to offer these services by themselves or whether they need to form alliances.

The paper is organized as follows: Sect. 2 discusses several scientific works which focus on e-mobility and related services while Sect. 3 explains the exploratory study, we used for this work. In Sect. 4, the description framework is introduced by proposing relevant e-mobility services as well as dimensions to describe them in further detail. At the end, a summary and outlook section provides insight to limitations and further research potentials of this work.

2 State of Research and Related Work

Since the research on e-mobility services is still at its beginning, studies and publications in this domain are rare and distributed over various disciplines, often without linkages between them, e.g. automotive engineering, energy economics, information systems or transportation and logistics.

The research of e-mobility services is also a research of service systems. According to Maglio and Spohrer [10] a service system is "a configuration of people, technologies, organizations and shared information, able to create and deliver value to providers, users and other interested entities, through service" (p. 18). This is also defined in the main principles of service science introduced by Spohrer et al. [11], in which service systems are connections of service entities as nodes and value propositions as their ties. These networks are shaped by the exchange of resources, collaborative advantages as well as cooperative strategies [12, 13]. An example in the field of e-mobility networks and business models is the study by Kley et al. [14]. The authors provide a foundation for a structured analysis of business models. By listing and analyzing examples of existing business models, the authors state that there are a lot of initiatives in many domains which, however, are often in a too early stage. To address this problem, they use the methodology of morphological boxes to capture different aspects of the e-mobility business model and derive a descriptive model for a structured characterization of business models for e-mobility [14]. By explicitly addressing e-mobility services, Busse et al. [15] are the first who provide an overview of the research domain. However, they limit their work to information systems (IS) services only. In this context, they define service groups in a technical way as collections that "combine(s) a homogeneous concentration of properties required for operation, business and other additional support purposes" (p. 914). Furthermore, the unclear distinction and description of each service group makes it difficult to identify the different services which are allocated to the group. Driven by its IS-focus, the framework thus ignores services that are important for running e-mobility but are not touched by the IS domain as such. The customer as individual with needs and expectations is not captured by this work.

In contrast, the relevance of addressing the customer role in this field has been emphasized by Klör et al. [16]. Their approach does not have the goal to provide a description of the overall e-mobility ecosystem but rather strives for drawing a research agenda for future IS research. Nevertheless, their work is a valuable foundation for our study since the authors emphasize the missing system perspective in current publications on e-mobility services. They state that studies on e-mobility services are too often too much focused on the resources involved rather than on the system in which they are used. Klör et al. highlight the customer acceptance as one of the "core challenges" of e-mobility. Today, there is already a broad literature on this issue [17–20]. However, many studies are still analyzing ways to enhance customer acceptance only by focusing on price and overall usage costs or at least with a strong economic background. By this, the understanding of the customer is too often a picture of a completely rational individual ("homo oeconomicus") which could be convinced just by reducing price and total cost of ownership (TCO) and improving the charging infrastructure. In fact, the customer is far more than this – especially during the car purchase decision [21–24]. Every user is a human being whose decision for or against the use of e-mobility is influenced by various factors concerning his or her mindset. Besides economic considerations this is especially the social network, the income, the mobility patterns, the culture in which the customer grew up etc.

A missing point in all studies we analyzed is the comprehensive and interdisciplinary view on e-mobility services. Those services usually address many actors and activities whose interactions have not been considered by current research yet. To bridge this gap, we aim for providing a more comprehensive and service science-based view on the topic of e-mobility services. The core concept of the service science domain is the co-creation aspect between service provider and service consumer [11]. The provision of a service typically involves the contribution of the customer who expects the fulfillment of a value proposition made by the service provider. To address this issue, studies on e-mobility services which claim to give an overview of existing services have to include co-creation aspects in their service description.

3 Methodology

The framework we present in the following sections has been derived by insights gained within a small exploratory study of nine interviews with experts of the e-mobility industry and the research fields of service science, information systems and energy economics. All experts are either part of e-mobility service research projects or work in leading positions (e.g. head of business development, head of strategy) of the e-mobility actors. The expert sample consists of employees from one main car manufacturer, one IT-service provider, one roaming (billing) provider, one energy provider, one fleet software start-up as well as four representatives of research projects in this field, with background in different disciplines.

Each interview has been conducted by using a semi-structured interview guideline with questions concerning various aspects of e-mobility services. These were characteristics of successful e-mobility services, their network structure as well as the customer and provider aspect. The duration of all interviews varied between forty-five and ninety minutes. Each interview has been transcribed and analysed by using the open coding method of the grounded theory methodology. Open coding is defined as a systematic comparison of unstructured qualitative data in order to find conceptual similarities which allow a categorization in groups and related subgroups. Referring to our study, we tried to identify recurring e-mobility service characteristics in our interview material [25]. Afterwards, two workshops with a focus group of ten researchers from the domains of service science, energy economics and e-mobility were initiated to evaluate the characteristics collected in the interview phase and to derive suitable dimensions for the description framework.

4 Describing E-Mobility Services

Analyzing and designing e-mobility services require a profound knowledge about the different facets by which a service can be characterized. Description frameworks help to structure existing data and information about the entities of interest in a way that knowledge can emerge. The objective of this paper is to propose an intuitive, i.e. applicable and reasonable description framework for e-mobility services along several dimensions. This allows other researchers to test the framework by adding other services in the field of e-mobility and, thus, further validating and eventually improving this framework.

The intention of this work is to provide to give a comprehensive understanding of how the term “e-mobility service” can be described in a more tangible and applicable way than existing theoretical approaches may offer. This might be the basis for future research on the relationships between players and the overall system.

4.1 Identification of E-Mobility Services

The following list provides a collection of services which are useful for driving a PEV. The services have been sorted along four contexts in which a customer might get in touch with during the lifetime of the car. These service contexts are briefly described in the following section with a list of non-exhaustive examples that has been named in interviews and the focus group involved and repeatedly identified in literature research.

Group 1: Services in the context of buying a PEV are services concerning the acquisition of a PEV and managing the ownership either as proprietor or as user when choosing leasing contracts.

- Car leasing
- Car financing
- Battery leasing
- Insurance (traditional, pay-as-you-drive)
- Safety and theft protection

Group 2: Services in the context of using a PEV encompass all services around the direct usage of PEV.

- Battery changing/swapping
- Billing and roaming (of charging)
- Car usage information (private, fleet)
- Charging station finder
- Navigation (including charging)
- Reservation of charging station
- Roadside assistance
- Fleet analysis and consulting
- Information services (weather, sightseeing)
- Automatic emergency call in case of accident
- Entertainment services

Group 3: Services in the context of maintaining a PEV concern technical maintenance and battery care.

- Battery recycling, battery testing
- Car washing
- Car maintenance and repair

Group 4: EV services in a system context encompass all services which integrate the PEV in a larger system context such as Smart Grid or as part of a multimodal service offering.

- Intermodal navigation
- Vehicle-to-grid services (battery as storage)
- Conventional vehicle option for PEV owners
- Car sharing services
- Yard and plug sharing service platform (for private households)
- E-mobility consulting services (for private persons and fleet operators)

Since the services in the list are very heterogeneous, the current clustering approach is insufficient for a profound analysis. In order to better understand the services, i.e. its provider, customer and delivery structure, further dimensions seem to be necessary. The next section will introduce the fundamental framework approach as well as propositions for potential dimensions that have been emerged as a first appropriate foundation for an e-mobility service description.

4.2 A Multidimensional Approach for Describing E-Mobility Services

In this section, six exemplary dimensions are introduced which have been considered by the focus group as appropriate initialization of the framework. Appropriate literature has been selected to support the results of the focus group work. At the end of the section, two exemplary services have been chosen to show the dimensional functionality. As guiding principle for selecting the dimensions, established works in the field of service classification have been used.

Several approaches for description and categorization of services have been suggested by researchers in the past (e.g. [26, 27]). The intended result is to get a brief but clear description of each e-mobility service in the system. The selection of the dimensions is significant to ensure the applicability of the framework.

4.2.1 Description According to the Value Proposition

One essential part of service transactions is the value proposition which defines the service setting, its delivery and the expectations that customers have of the service [11]. This dimension is important to capture the fundamental intention that is aligned with the service, i.e. value added by delivering the service. A categorization of services according to their customer value has been suggested e.g. by Westphal et al. [28] who state that product-oriented services can add value through product individualization, improvement of the customer-supplier relationship, the support of customers regarding product-related processes such as vehicle usage, and through services in the context of product financing. Dimensional entities are "energy service", "mobility service", "installation service", "charging service", "financial service".

An alternative approach for assessing the service value might be to analyze whether the e-mobility service enables PEV a similar customer value known from conventional vehicles and thus compensating for current disadvantages of e-mobility or whether the service even increases the customer value with respect to current utility. Today, since most of the current e-mobility services rather can be allocated to the first category, e.g. the localisation of charging stations or an online estimation of the remaining range, this does not seem suitable for the description framework.

4.2.2 Description According to the Service Position in the Vehicle Lifecycle We base our understanding of the lifecycle according the German standard DIN 9241-210 for user experience with "product-related processes". The standard distinguishes three stages (entities): before usage, during usage and after usage. Since some services may affect the whole product lifecycle, we introduce a further dimension "concerning whole lifecycle" in our framework. Therefore, dimensional entities are "before usage", "during usage", "after usage", "whole lifecycle".

4.2.3 Description According to the Nature and Recipient of the Service Act According to Lovelock [27], services can be distinguished according to their nature and the consumer of the service. Similarly, Hill [29] mentions the categories services affecting persons vs. those affecting goods. Also Shostack [30] and Sasser et al. [31] use the share of goods or intangible services for categorizing a product. For the framework, the following three categories of [27] have been adapted.

Consequently, the dimensional entities are “tangible actions” (services directed at goods and other of the physical possessions, such as maintenance and repair), “intangible actions” (services directed at people’s minds, such as navigation/charging station finder), and “intangible services” (services directed at intangible assets such as financing or insurance).

4.2.4 Description According to the Nature of Provider and Recipient

Each service transaction is an exchange between a service provider and a service recipient. Rathmell [26] suggested the service categories type of seller, type of buyer, buying motives, buying practice and the degree of regulation. For this work, the first two categories “seller” and “buyer” have been adapted, since the knowledge on the market players involved in the transaction is a prerequisite for a later description of the whole e-mobility service system (e.g. alliance structures, business models). This dimension therefore describes the relationship of provider and customer regarding the question who offers and who receives the service. However, both service provider and service recipient can have more than one role for a service. For example: a plug sharing service platform can be offered by a small IT- Start up or an established energy provider. Dimensional entities are “IT services provider”, “OEM”, “auto repair shop”, “energy provider”, “charging service provider”, “roaming services provider”, “financial services provider”, “consultancy provider”, “fleet operator”, “driver” (normally end-user, but provider in a V2G context), “car owner”, “others”.

4.2.5 Description According to the End User Closeness

The fifth summarizes the overall closeness to the end user. This dimension is chosen since the knowledge about the service’s position in the service value chain is a pre-requisite for deriving a service network. Services which are directly addressing the end user need a different service setting than support services inside the service system. While in the first case the service delivery focuses more on the personal interaction and the customer experience aspect, the supporting (often business to business) service is more characterized by economic aspects and service level contracts. Dimensional entities are “supporting service”, “end user service”.

4.2.6 Description According to the Degree of Service Modification

Some of the services discussed and introduced for PEV are not transferrable to conventional vehicles, such as the reservation of a charging station, mainly because there is no need for them. However, other e-mobility services, e.g. separated leasing, rental or sales contracts for the vehicle and its battery, are already known from conventional vehicles but modified for the electric car. The sixth and last dimension “service modification degree” describes the degree of novelty of a service. Often e-mobility services are simply adaptations of classical car service offerings such as maintenance, navigation or insurance services. The framework distinguishes between two possible properties of a service: “developed for PEV” and “modified for PEV”.

To illustrate the principle of the framework, two selected services from the service groups of Sect. 4.1 are described and represented by using a morphological box [32]. In the morphological box, the leading dimensions are placed on the outer left side while the dimensional entities are organized on the right side (see Fig. 2). When describing a service, the corresponding dimensional entity (or entities) is marked for each dimension. For developing further services, potential contradictions of dimensional entities can be identified. This decreases the complexity of the problem. The working principle is illustrated in the following figures that show four selected description examples from the service groups of Sect. 4.1.

Description Dimensions	Dimensional Entities					
Value proposition	energy service	mobility service	(de)installation service	charging service	financial service	
Position in EV lifecycle	before usage	during usage	after usage	complete life cycle		
Nature of the service act	tangible action directed at goods	intangible actions directed at people	intangible actions directed at intangible assets			
Nature of service provider	OEM	IT services provider	auto repair shop	energy provider	charging service provider	roaming services provider
Nature of service recipient	car owner	driver	fleet operator	...		
Closeness to end user	supporting service	end user service				
Service modification degree	developed for PEV	modified for PEV				

Fig. 2. Description framework as morphological box

In an electric car, the battery is one of the most expensive parts. However, the lifetime of the battery does not necessarily correspond to the lifetime of the vehicle. In order to reduce the risks of the vehicle users, there is the option to rent the battery from a battery leasing company. This company might maintain, withdraw and replace (if necessary) the battery. This “Battery Leasing” service shall be the first illustrating example to demonstrate the framework application (cf. Fig. 3).

The value proposition which comes along with the battery service is some kind of a charging service. The service is used usually while using the car actively, hence the field “during usage” is marked in the framework. Further is the service a tangible action which means that a car workshop or even the leasing provider itself put the old battery out of the car and the new one in. This is a visible action concerning a tangible good, the battery. The provider of the service is the battery leasing provider which is here understood as sort of a charging service provider. As service recipients, all “forms” of customers are possible so all of them are marked in the framework. The service itself is

Group 1: Battery Leasing						
Value proposition	energy service	mobility service	(de)installation service	charging service	financial service	
Position in EV lifecycle	before usage	during usage	after usage	complete life cycle		
Nature of the service act	tangible action directed at goods	intangible actions directed at people	intangible actions directed at intangible assets			
Nature of service provider	OEM	IT services provider	auto repair shop	energy provid er	charging service provider	roaming services provider
Nature of service recipient	car owner	driver	fleet operator	...		
Closeness to end user	supporting service	end user service				
Service modification degree	developed for PEV	modified for PEV				

Fig. 3. Description of “Battery Leasing”

a service provided for the end user – that means, it is not an intermediate and background service such as many IT services are. At least, leasing a battery is a service developed exclusively for electric cars. There is no equivalent offering so far for conventional cars.

In Fig. 4, one service of group 2 “Services in the context of using an EV” has been selected. The reservation of charging stations is an important tool to guarantee the charging process at the required time and at the desired place. Since there is usually a limited amount of charging stations at highly frequented places such as shopping malls or public parking slots, a well working reservation system is inevitable. Here, the value proposition of the service is to enable mobility for people by getting their electric cars charged while they are working, shopping etc. The service itself is offered via the internet and is characterized by its intangible accomplishment. The customers expect the service to be done when they arrive at the charging station. Usually, the service is offered by the charging service provider, i.e. owner of the charging stations. The service is especially relevant for the driver of the electric car but also important for car owner or fleet operators in the case of integrating the service in their own infrastructure. We consider the service as end user service since the customer directly interacts with the reservation system.

We applied our categorization framework exemplary with two services. It becomes obvious, that at least for these examples our framework delivers a good mapping of services and it might be used as a basis for further developments of the services. However, since the framework has not been evaluated by any empirical study, this will be the next step in the research process. Therefore, several case studies with existing e-mobility services may be a possibility to test the applicability of the framework.

Group 2: Reservation Service for Charging Stations						
Value proposition	energy service	**mobility service**	(de)installation service	charging service	financial service	
Position in EV lifecycle	before usage	**during usage**	after usage	complete life cycle		
Nature of the service act	tangible action directed at goods	**intangible actions directed at people**	intangible actions directed at intangible assets			
Nature of service provider	OEM	IT services provider	auto repair shop	energy provider	**charging service provider**	roaming services provider
Nature of service recipient	**car owner**	**driver**	**fleet operator**	...		
Closeness to end user	supporting service	**end user service**				
Service modification degree	**developed for PEV**	modified for PEV				

Fig. 4. Description of "Reservation Service for Charging Stations"

5 Summary and Outlook

This paper describes potential synergies of services and the usage of electric cars. We identified a research gap in the field of structured analysis of electric mobility services and develop a first framework for describing and categorizing them.

By using insights from a literature review and an exploratory study conducted with practitioners from industry and science, relevant e-mobility services have been identified and described. Building on these services, six appropriate categorization dimensions have been introduced and applied to two example e-mobility services. The development and application of the framework is an important step towards an e-mobility service system description model. By filtering the services along certain dimensions, new insights into the e-mobility service landscape, e.g. "white spots" or the identification of patterns in customer/provider relationships would be possible.

However, our exploratory study only consists of nine expert interviews. Thus, the insights gained may not be representative and comprehensive enough to sketch the current e-mobility service market. Consequently, we suggest the proposed framework as a first attempt of shedding light on the research agenda in this field.

Further expert interviews (from other sectors and disciplines) tests and refinements of our framework as well as the inclusion of further services and dimensions will complete this research. Further research could also focus on the relationships between the market players, i.e. the form of alliance building, existing business models between the players.

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