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Economic incentives for the adoption of electric vehicles: A classification and review of e-vehicle services

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ABSTRACT

Policymakers primarily rely on both subsidies and non-economic incentives to support the adoption of electric vehicles. Nevertheless one of the major barriers to widespread adoption is still given by consumer concerns about the economic benefit of electric vehicle ownership. In this work, we propose economic incentives to ownership in terms of electric vehicle services. We use the concepts of service science to propose a definition of e-vehicle service, and we identify microgrid operation, energy trading and vehicle sharing as general service contexts. We derive the service types within each context by reviewing state-of-the-art approaches to service realization. The resulting service classification provides a complete overview of opportunities to leverage the full economic potential of electric vehicles. As such it indicates which business models and technologies should be supported by policy measures to accelerate the adoption of electric vehicles.

1. Introduction

Electric vehicles (e-vehicles) are considered as a promising low emission alternative to vehicles with internal combustion engines (e.g., Hawkins et al., 2013; Giordano et al., in press). Consequently, many governments and cities aim at reducing air pollution from transportation by developing policy measures to support e-vehicle adoption (Bakker and Trip, 2013). However, enabling the widespread adoption of e-vehicles still requires significant barriers to be resolved. Studies underline that one major barrier is represented by consumer concerns about the economic benefit of e-vehicle ownership (Dumortier et al., 2015; Berkeley et al., 2017), and that so far only few e-vehicles are economical without subsidies (Letmathe and Suares, 2017). Currently both private consumers and commercial fleet managers have to rely on subsidies and on non-economic incentives for e-vehicle adoption (Sierzchula, 2014; Taefi et al., 2016; Globisch et al., in press; White and Sintov, 2017; Ensslen et al., in press).

In this work, we propose e-vehicle services as economic incentives for the adoption of electric vehicles. We take into account the fact that e-vehicles are able to create value beyond their standard use as means of transportation, and conclude that both supporting and providing e-vehicle services is indispensable for leveraging the vehicles' full economic potential. To this end we introduce a comprehensive and complete e-vehicle service classification, and support this classification by reviewing state-of-the-art approaches to service realization. We identify microgrid operation, energy trading and vehicle sharing as general service contexts, and we derive all types of e-vehicle services in each of the contexts. Our main contributions are as follows:

1. We provide a definition of e-vehicle services by using the concepts of service science.

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2. We identify three e-vehicle service contexts, and specify all service types in each context.
3. We review state-of-the-art approaches to service realization with respect to the service types.
4. For each service type, we compare the approaches to service realization with respect to both key technology requirements and operational management decisions.

The remainder of this paper is organized as follows. In Section 2, we derive a definition of e-vehicle service, and we introduce three e-vehicle service contexts. In Section 3 we specify the different service types in each context. With these types we discuss and classify works from the literature on e-vehicle services in the subsequent sections. Section 4 elaborates on e-vehicle services for microgrid operation, Section 5 discusses e-vehicle services for energy trading, and Section 6 presents vehicle sharing based e-vehicle services. Section 7 provides an overview of hybrid services involving more than one class, and Section 8 concludes the paper and gives recommendations for policymakers.

2. E-vehicle service

In this section we use the concepts of service science for defining e-vehicle service. In particular we adopt service-dominant logic (Vargo and Lusch, 2004, 2016), where service means *applying specialized competences (knowledge and skills) for the benefit of another actor or the actor itself.*

Service-dominant (S-D) logic considers specialized competences as the *resources* an actor can draw on for support (Lusch and Nambisan, 2015), and distinguishes between *operand resources* (often tangible; those that an act is performed on) and *operant resources* (often intangible; those that act on other resources to produce an effect). Skills, knowledge, and the technology knowledge fosters are the most fundamental operant resources, and *value* is the result of beneficial application of operant resources, which are sometimes transmitted through operand resources. In S-D logic an actor is defined in terms of an arrangement of resources. Such an arrangement is also referred to as *service system* in the service science literature (Vargo et al., 2008), and the function of a service system is to make use of its own resources and the resources of others to improve its circumstances and that of others. Against this background, we distinguish between two types of service systems:

- **E-vehicle provider** (EVP) is a system that is mainly characterized by the fact that it operates one or more electric vehicles for the primary purpose of transportation. Both companies with a commercial e-vehicle fleet and private households with a smaller number of e-vehicles are examples of EVPs. The main resources an EVP consists of are electric vehicles, drivers, as well as information about the vehicles' present and future states, such as battery charge levels, geographical locations and idle times.
- **Skills and technology provider** (STP) is a system that is mainly characterized by skills and competences to manage electric vehicles in a specific context, and by the technology allowing for e-vehicles to become operands of these skills and competences. In the following sections we distinguish between skills and competences in the contexts of (1) microgrid operation, (2) energy trading, and (3) vehicle sharing. The main resources an STP consists of are his management skills and competences as well as the technology required to act on e-vehicles, such as software or smart meters. Note that the management skills and competences of an STP typically boil down to decision models and rules that allow for good operational decisions.

S-D logic does not distinguish between producing service systems and consuming service systems, but implies that value is always created collaboratively through resource integration, i.e., through reciprocal application of specialized competences. For example, integration of an EVP's resources (such as driving profiles) with an STP's energy trading skills and technology may result in specific (dis-)charge operations with vehicle batteries that directly create economic benefits for both service systems (e.g., revenues and fees). Both service systems are similarly resource-integrating, service-providing actors that have the common purpose of *value co-creation*. Note that in the special case of EVP and STP being the same system (e.g., a utility trading energy with its own e-vehicles) resource integration occurs within this system and for the benefit of the system itself.

In order to capture the value of e-vehicles beyond their primary use as means of transportation, we apply S-D logic and define e-vehicle service as *value co-creation among EVP and STP*. With this definition, we are able to distinguish between different e-vehicle service types in terms of involved resources. In particular, we distinguish between e-vehicle service types in terms of the STP's core management skills and competences. This distinction highlights the strong dependency of the co-created value on the STP's ability to derive sound operational decisions about, e.g., timing and amount of (dis-)charge for each vehicle. Highlighting this dependency is informative in two main ways. First, it offers a new, STP-centered perspective for policy makers, whose focus has often been more on policy measures for directly supporting EVPs, rather than on policy measures for supporting the development of core STP management competences. Second, it provides a new perspective on the scientific e-vehicle literature.

In the following Sections 4–7 we provide a thorough review of the e-vehicle literature from this perspective. We categorize the works from the literature according to classes of STP core management skills and competences, and introduce these classes as e-vehicle service types. Table 1 gives an overview of the services types that we derive from the literature, and shows that the types fall into three broad contexts:

- In **microgrid operation**, e-vehicles are considered as elements of self-sufficient energy systems.
- In **energy trading**, e-vehicles are considered as buffers for interacting with energy markets.
- In **vehicle sharing**, e-vehicles are considered as mobility enablers for community members.