Analysis and Discussion of Critical Success Factors of E-mobility Interconnected IS Infrastructure

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Abstract

Information systems (IS) and information and communication technologies (ICT) play a key role in the applicability of E(lectro)-mobility for everyday use. Although there already exist various studies about single IS/ICT aspects of E-mobility, literature lacks of a holistic view. Our analysis and discussion sets up critical success factors (CSF) of interconnected IS infrastructure (IISI) for E-mobility. IISI represents a comprehensive IS approach for E-Mobility. We define IISI as the connection of the needed sub IS whereby each subsystem is dedicated to special purpose. With an adapted DeLone and McLean IS Success Model we identify, analyze and discuss certain CSF in line with the special characteristics of IS in E-mobility. We recommend these CSF as a basis for further research using qualitative and quantitative methods to support the evolution of E-mobility.

1 Introduction

Mobility is an essential part of today's life, representing an urgent and necessary element for the modern society [16]. Due to reasons like increasing urbanization or flexibility for job activities the need for mobility is constantly growing. This need for more mobility is confronted with barriers like limited natural resources and environmental standards and requires new sustainable mobility concepts [15]. E-Mobility plays a central role when coping with these problems, manifesting in the form of increasing fuel prices or low-carbon policy.

Introducing E-mobility represents an extensive change in existing systems. While creating a basis for new services and possibilities new challenges induce a considerable impact on the value chain. As shown in Figure 1 new parties enter the value chain causing increased complexity, creating new interdependences and thus the requirement of new ways to process and exchange information.

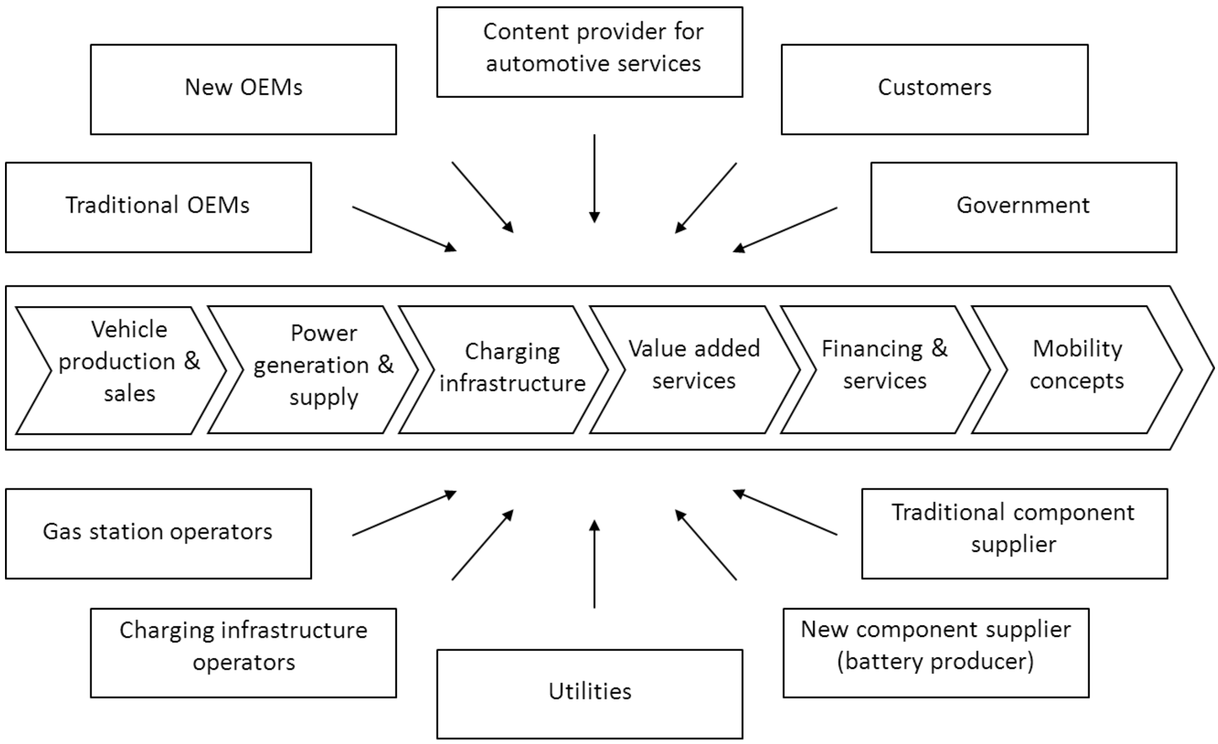

Figure 1: Value chain of E-mobility (own illustration; adopted from [13])

IISI represents a key factor to realize a large scale introduction of E-mobility. Through connecting relevant systems and parties to one comprehensive system reliable utilization of E-mobility can be ensured. The purpose of our analysis is to create an understanding of such a comprehensive IS and to set up CSF of IISI for E-mobility. By adopting the updated DeLone and McLean IS Success Model we identify, analyze and discuss certain CSF in line with the characteristics of IS in E-mobility. Due to the novelty and complexity of the topic we stay on a high level of abstraction.

Section 2 provides basic knowledge on how a comprehensive IS can be seen in this context and presents the IS Success Model of DeLone and McLean which will serve as the theoretical foundation for our analysis and discussion. In section 3 the DeLone and Mclean model is adapted to fit into the context of this paper. CSF are derived and discussed. Finally the results are concluded and further evaluation using qualitative and quantitative methods to support the evolution of E-mobility is recommended.

2 Theoretical Background

2.1 IISI for E-mobility

When considering E-mobility from a holistic point of view the sheer amount of involved parties, sectors and systems and their interdependences creates a complex structure which demands for a comprehensive system to process and deliver information. Most of these parties acted independent of each other in the past making the networking even more complex and challenging. As E-mobility is still at an early stage of development it lacks of research literature on a holistic level. Present literature mainly provides specialized investigations and pilot projects, e.g. for the charging processes. There is no unified understanding or definition of a comprehensive information system that considers all parts relevant to the provision of E-mobility. The demand for a comprehensive approach is present on a commercial level. This can be recognized through the consideration of several solutions that are currently presented by different IT companies [5] [6] [13]. Table 1 provides an overview of relevant IT technologies and IT services in the context of E-mobility.

Charger and energy	**Electric vehicle**	**User**
Authentication Billing Communication Content display Fraud prevention Energy management Demand side management Smart grid integration Meter data management	Onboard-units Dashboard driver interfaces PDA & mobile phone interfaces Telecommunication links Content display Car2X-communication	Self-care portal Booking & reservation Content ordering Charging interaction
Customer care	**Back office**	**Mobility and commerce**
Call center Breakdown & emergency handling	Billing CRM Reservation Inventory management Content distribution B2B-portals Security	Managed driving Telematics Content management Plug-in platform B2C / B2B solutions Business simulator

Table 1: Overview of relevant IT technologies and IT services for E-mobility (own illustration; adopted from [13])

In order to comply with these circumstances we propose a construct (IISI for E-mobility) which can be seen as a connection of several sub information systems whereby each of these subsystems is dedicated to a special purpose. As result one comprehensive system can be drawn. It processes the information of the tasks that are required to provide the utilization of E-mobility to the end-user [13].

Figure 2 represents one approach of IISI components playing a role in the E-mobility context in its currently arising form. While showing the interdependencies of the different IS among each other, it reflects the need of interaction between the different players along the E-mobility value chain and with this the need of new industrial and B2B standards. It is not necessarily apparent how IS parts and responsibilities will be divided between the different players. The approach shows which part of the system can be accomplished by standard software elements and where new components have to be developed and established.

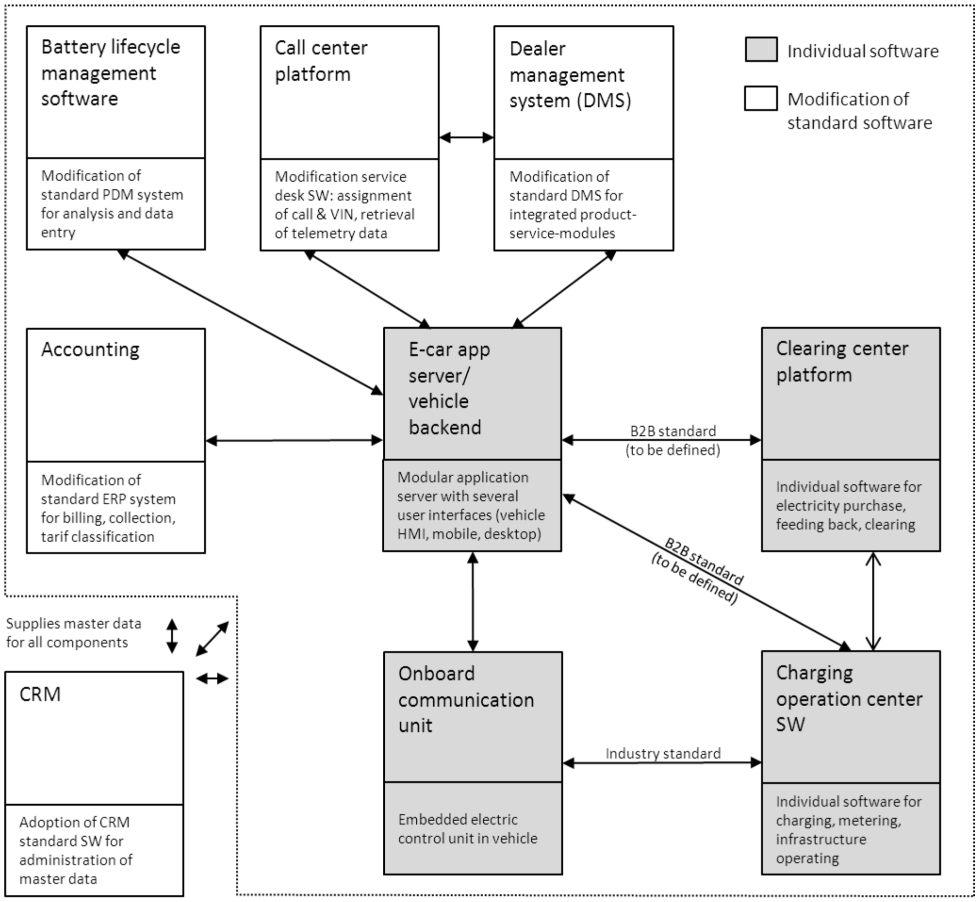

Figure 2: Example of an IISI architecture for E-Mobility (own illustration; adopted from [13])

2.2 The DeLone and McLean Information System Success Model

In 1992 DeLone and Mclean developed a model to measure the success of information systems which provided a comprehensive framework to measure the success on the basis of relevant factors [2]. The model was based on the communications theory research of Shannon and Weaver [12] as well as in advance on the research of Mason [10]. Empirical management information systems (MIS) research studies were applied and "a comprehensive, multidimensional model of IS success was postulated" [3]. Originally the factors of the model were divided into six success dimensions by which it was possible to indirectly measure the success of an information system.

In 2003 DeLone and McLean presented an updated version of their model [3]. Based on the research findings of other authors the dimensions of the IS success model were adjusted [2][3][4]. Originally the model consisted of 6 dimensions: system quality, information quality, use, user satisfaction, individual impact and organizational impact. Further research validated the correlation of these success dimensions [3]. Despite of this validation an additional dimension was added, the service quality. This adjustment was based on the findings of Pitt, Watson and Kavon [11] and other researchers [8][9][14]. Their findings criticized that information success could be measured incorrectly if no factors for service quality were included. This concern was based on a possible product focused rather than service focused view when looking at the IS function. The two independent variables individual impact and organizational impact were aggregated to a more comprehensive construct, the net benefits. Through this adjustment the inclusion of the increasing number of possible influences such as individual, organizational or industrial impacts could be ensured. In this context DeLone and McLean relinquished the further use of the term impacts and replaced it with benefits. As the target variable was not always completely positive or negative a "net" was added prior to benefits. Based on this specifications DeLone and McLean request researchers to decisively determine the specific context the model is applied to. It has to be clarified what is defined as net benefits and for whom (e.g. designer, user) these benefits are valid. The level of analysis has to be addressed, concerning the point of view benefits are measure from (e.g. individual, organizational, industrial). Figure 3 shows the graphical conclusion of the updated DeLone and McLean model.

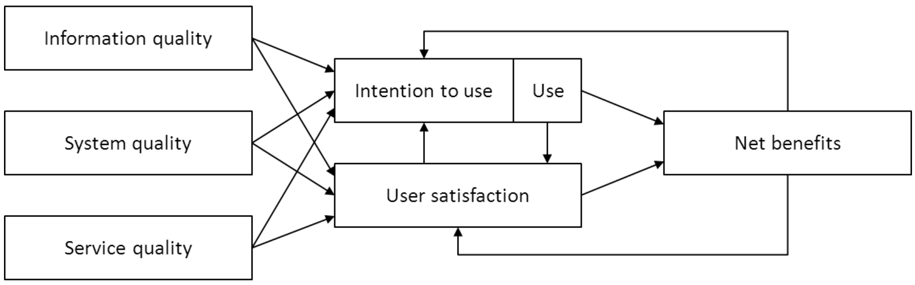

Figure 3: The updated D&M IS success model (own illustration; adopted from [3])

3 Model Adaption

3.1 IS Success Model for IISI for E-mobility

IISI for E-Mobility as a whole differs from other systems in its complexity and its comprehensive requirements over a new value chain. It integrates industries that did not work together yet and did not have the necessity to deal with IS in that complexity and intensity (e. g. regarding security aspects). We adapt the updated DeLone und McLean IS success model. The modulation of the CSF educes from the specifics of E-mobility and its IS. We see this as a theoretical starting point to be proofed empirically. Due to the novelty and complexity of the topic we stay on a high level of abstraction. According to that the six success dimensions are applied to IISI for E-mobility as follows:

- System quality reflects the desired characteristics of IISI for E-mobility on a technical level. Security, Systems Integration, Modularity and Reliability are examples that are supposed to be relevant measures for the quality of IISI for E-mobility.
- Information quality captures the content issue of IISI for E-mobility. Amongst others the content issues assume to contain transparence, privacy, traceability and security.
- Service quality represents the assessment of the overall support for the user of IISI. Measures of service quality in this case hypothesize to include end2end competence, availability, transparence, trust and troubleshooting.

- Use measures the nature and amount of system use in all forms. Due to the complexity of IISI and to increase the expressiveness of the measurements the use of services is measured instead plain overall system measures. Duration of services used, medium of services used, number of services used, regulatory of services used, type of services used are measures for the use of IISI.
- User satisfaction measures the attitude of the stakeholders towards IISI for E-mobility and should reflect the whole customer experience. User satisfaction thus supposes to include ubiquity, holistic perception of the system, satisfaction with the system/ information/service and fulfillment of expectations.
- Net benefits are still suggested to be the most significant CSF. They capture the positive and negative impacts on all stakeholders of IISI for E-mobility. We separate the net benefits into the different levels of individual, organizational, industrial and societal impact.

3.2 Metrics for IISI for E-mobility

We complete the analysis and discussion by choosing measures that match in the new IS context. Therefore we combined individual measures from the IS success categories. [2] The proposed compilation of CSF provides a first basis to measure the success of IISI for E-mobility. For an overview of the chosen measures see Table 2.

3.2.1 System Quality

The applied factors for system quality consist of some CSF which were already used in the DeLone and McLean model [2] but we add additional CSF according to our context. System reliability, system flexibility, response time and ease of use represent the most important CSF. As the system represents the basis for a whole infrastructure system reliability plays a central role. Impairments of a IISI would ultimately impair the whole E-mobility infrastructure and reduce the usability to a minimum level. Especially in the early stage of E-mobility with low availability of charging stations and without a system directing routes along available charging stations the driving range would be reduced. The system flexibility is required to allow the changing or adding of functions and services. This is critical because the distribution of roles along the value chain of E-mobility is not established yet. A module principle is required to allow adaption of the system and also offer mobility providers to adapt their processes afterwards. Response time mainly focuses on the time a customer has to wait until his billing is finished or driving routes and the related driving range are computed. The response time should be as low as possible. The ease of use represents the easy use of the system with high relevance for the customer. The customer should not be burdened with complex control mechanism while using the system for charging, billing or requesting additional information. Additionally to these CSF we add some CSF which in the context of E-mobility are of major relevance. These are system scalability, system integration and security. As the amount of customers an E-mobility provider has to service in most cases will not be a constant number the system scalability represents a CSF. With a increasing number of customers the system has to be able to handle increased load. System integration represents the system's ability to be integrated into foreign systems. For example the integration into an enterprise system to allow a connection to scheduling making electric vehicles available at the right time or rent one for a specific amount of time. Security in such a comprehensive system is an CSF as it contains a large amount of critical information like banking information and movement patterns as well as it offers many targets for attackers. Security becomes even more challenging as new parties are involved in the system which may have not focused on the topic security yet.

3.2.2 Information Quality

This dimension encompasses the quality of information in the context of IISI for E-mobility. Beneath the content of the information the handling of the information is relevant. The CSF are considered from the customer's point of view as well as from the back-end user's point of view. From a customer's point of view as well as for back-end users the relevance, usefulness, reliability of information are crucial. Due to the complexity of the system it is important to only deliver relevant and useful information. This prevents the customer from being confused through irrelevant information which generates no gain for him. Back-end users are reliant on receiving relevant and useful information to not diminish their work efficiency. For a customer charging his vehicle at a charging station as well as for a backend user working on billing services, information on load balancing would not generate any value. The reliability of information is especially important for the customers as they rely information like pricing, routing or traveling time. If the system provides information that is not reliable, customers will stop trusting the information which could lead to the rejection of the whole system. Equally back-end users rely on the information the system provides while working on their jobs. This is especially important for the service employees as they are in direct contact with the customers. The correctness and accuracy of information has to be assured to provide system reliability. The information provided by the system has to be correct in terms of alteration and absence of errors. On the one hand to let the customers trust in the information and on the other hand to prevent negative aftereffects. Wrong charging point measurement data could let the customer feel deceived as well as it would lead to distorted billing processes and energy demand predictions for the provider. Accuracy plays a crucial role as information may be converted due to different systems of measurement in an international context. The information has to be accurate in terms of precision. As for most IT systems, privacy and the associated transparency are CSF for IISI for E-mobility. Privacy is required so that critical information is treated confidential and only authorized persons can access it. For example this would apply to banking information, movement or behavior patterns. A lack in privacy could lead to mistrust by the customers. Through the complexity of the system many different parties with different interests are involved creating a high potential for committing fraud [7]. In order to deal with this transparency is crucial especially for the back-end users. It has to be comprehensible where information goes to, how it is altered and who is responsible for actions concerning the information.

3.2.3 Service Quality

The Service Quality measures proposed by DeLone and McLean 2003 are predicated on the SERVQUAL instrument. The SERVQUAL measures such as competence, trust and transparency suppose also to be valid for IISI for E-mobility. Of major importance in this context is the CSF competence. Because of the comprehensive and novel interaction of IISI coming into operation for E-mobility, it will be of high relevance if it will succeed to offer support for the customer along the process chain as a whole. Regarding the customer's experience it is important to get the required support for the product in terms of the "One face to the customer" principle. Answering questions along different levels from technical, process-related and regulatory driven ones to questions concerning the IS system as well as the charging infrastructure or the electric vehicle itself presents a serious challenge. For this reason only a well-organized support level concept, that involves systematically all relevant parties in the background, will be able to fulfill the requirements of a competent support. To distinguish the holistic approach of the service concept we call this CSF end2end competence. The availability also represents a CSF of service success, because in case of problems or malfunction the customer has to keep the feeling of continuous usability of IISI and therewith the E-mobility itself. Particularly in the initial run of E-mobility it is supposed that the appearance of malfunctions could merely be avoided regarding the complexity and novelty of the product and the underlying system, processes and techniques. Therefore especially in those situations it is important to supply a highly available support to not compromise the success of the system as a whole through negative customer experience. As the use of the product is not limited in its temporal disposability, the same expectation will be adverted to the availability of the support, at least regarding critical malfunctions. Trust is another CSF form the SERVQUAL instrument, because the user has to know that he can rely on the support in case of a problem [1]. As in certain circumstances the usability of the product itself can be limited in case of malfunctions. An efficient and fast troubleshooting also represents a CSF for the service quality.

3.2.4 Use

Due to the chosen point of view that comprehends IISI for E-mobility as a whole follows the need to adequately abstract the use indicators. Measuring the use in terms of a single system access would not approve any relevant conclusion for the overall system. For this reason the use of the system is measured, compared and evaluated with the help of the services that are provided to the user. The number of the overall used services can give information about the use of the system as a whole. To accomplish comparability between different systems a distinction of the used types is important. Regarding the number and type of used services an inference to the impact of a single service to the overall system is drawn. The regularity of use provides an indication of the service relevance along time duration. It gives an additional hint to the constant importance of the regarded service. A decreasing frequency could for example be explained with initial curiousness but little impact for the entire use, thus possibly no or little additional value. Further relevance is assumed to be represented through the duration of service uses as well as the used frontend.

3.2.5 User Satisfaction

The user satisfaction concludes the attitude of the users towards the system. For this purpose a comprehensive image of the users' opinions is created. To measure the satisfaction several CSF from the dimensions system quality, information quality and service quality are chosen. These chosen CSF are combined with directly measurable factors to describe the comprehensive user satisfaction. In the dimension information quality this is measured by the difference between the expected information and the received information. In the dimension of service quality this is measured by the intensity a received service differs from the expected service. Through this comparison of expected and received values the fulfillment of expectations is derived. As additional CSF the perception of the system and the individual attitude are measured. To determine the perception of the system users are questioned if they perceive the system as comprehensive solution or just as single parts and how this affects their use. Through the individual attitude it is determined if the users changed their attitude towards the system after using it. This attitude may be positive or negative.

3.2.6 Net Benefits

The net benefits depict to be the most important category for the CSF. Regarding IISI for E-mobility we adopt the differentiation between the levels of individual, organizational, industrial and societal impact. The following specific items are named below for IISI for E-mobility. On the individual level the IS-supported use of the product E-mobility enables mobility enhancement. Examples for this are distance optimization through pre journey remote climate control or the comprehension of charging stations when estimating remaining distances. Besides with these effects the user achieves time savings. Without IS-support invested time in daily routines would be higher. The IS support provides relevant information for the user acceptance of the product such as the accounting of electricity billing. With the possibilities of smart grid costs can be saved and at the same time sustainable behavior can be stimulated. One example for this is the so called vehicle-to-grid system that not only lets electricity flow from the car to the power lines but also back to the car for example to balance load peaks. IISI for E-mobility is an important part of the value chain. On the organizational level participation in the arising E-mobility value chain can be ensured through conceptualize, develop and operate IISI for E-mobility. We hypothesize a successful IISI might impact the market share and so imply financial aspects. Successfully IS supported E-mobility could have an important influence on the acceptance of E-mobility itself and therefore make a contribution to the market growth of the developing industry. From the social level IISI as an enabler of E-mobility helps to fulfill the necessary mobility change and therefore makes a contribution to more sustainability.

System quality	**Information quality**	**Service quality**
Ease of use Flexibility Reliability Response time Scalability Security Standardization Systems integration	Accuracy Correctness Privacy Relevance Reliability Transparence Usefulness	Availability End2end competence Responsiveness Troubleshooting Trust
Use	**User Satisfaction**	**Net Benefits**
Duration of services used Medium of services used Number of services used Regulatory of services used Type of services used	Individual attitude Perception of the system User satisfaction regarding - System - Information - Service	Individual impact: - Financial advantage - Extended mobility - High availability of information - Time saving Organizational impact: - Assurance of market share - Assurance of supply chain quota - Profit Industrial impact: - Market Growth Societal impact: - Enabling more sustainability

Table 2: Metrics for IISI for E-mobility

4 Conclusion and Outlook

This paper discusses and analyses critical success factors (CSF) of interconnected information system infrastructure (IISI) for E-mobility. We introduced the construct of IISI which represents a comprehensive IS approach for E-Mobility connecting all parts required for the provision of E-mobility to the end-user. This construct consists of several subsystems each dedicated to a special purpose. By using this construct we intend to meet the challenges arising from the emerging E-mobility value chain. Adapting the updated DeLone and McLean IS Success Model we identified, analyzed and discussed CSF in the context of IISI for E-mobility. For this purpose established factors from the original model as well as from the SERVQUAL instrument were analyzed and discussed. New factors with relevance to our context were added as well. The results were consolidated in an overview and represent a theoretical starting point to fill the lack of scientific studies regarding IISI for E-mobility as a whole.

For further research in this context we propose conducting expert interviews to complement, adjust and validate the CSF in a qualitative way. Second quantitative cause and effect models must be derived with quantitative data collection and analysis. Structural equation modeling is, e.g., an adequate methodology. Special attention should be paid to the fact that the success model itself is inherently complex, even without the addition of further measures to the dimensions. As a consequence the high empirical effort has to be taken into account in the planning phase of the success measurement. Getting deeper into the discussed topics there are connecting factors leading to further IS research topics. Regarding user satisfaction and use there can be referred to technology acceptance models. From the point of organizational and industrial benefits could be linked to integrated business models. Security spects for IISI of E-mobility are a comprehensive field of research on its own.

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