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Implementing Data-Based Services: A Socio-Technical Model

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ABSTRACT

Organizational readiness is an important prerequisite for the successful implementation of data-based services. To support this, our interdisciplinary team of reserachers and practitioners has developed a structured approach to creating organizational readiness. This is guided by a socio-technical model, which provides evaluation criteria supporting process analysis, knowledge modeling, as well as organizational implementation. The paper describes the model in detail with examples of the evaluation criteria and the approach for its application.

Keywords: Co-production, Data-based services, Socio-technical system design, Human factor, Services implementation

INTRODUCTION

The trend towards digitalization requires equipment manufacturers to complement their products with data-based services. However, the successful co-production of smart services demands for a combination of novel methodological skills, such as data analytics, with in-depth domain expertise needed to identify the right indicators and interpret the analysis results in a way that adds value for customers. The skills and knowledge required for this is usually distributed throughout the organization. This is because, industrial companies optimize their organizational processes and structures over the years regarding the production, commissioning, and maintenance of their traditional products. Therefore, experiences and knowledge are gained by different organizational units. Combining this distributed expertise to create synergies in the analysis and interpretation of data can be a major challenge. It becomes even more difficult, when part of the expertise is new, tacit, or when its relevance is not obvious but requires linking seemingly unimportant information.

Baines at al. (2020) identified organizational readiness as one key factor for successful implementation of data-based services. Organizational processes and structures must therefore be found that enable co-production and thus the knowledge synergies required for data-based services. If a company still predominantly manufactures its traditional products it might be not ready to radically reorganize. In this case, new organizational structures must be established in parallel with the existing structures to enable the boundary-spanning co-production of the new services.

In our applied research project, based on an extended literature review and two in-depth case studies together with Swiss industrial companies, we developed a socio-technical model for designing and evaluating corresponding organizational processes and structures. The model is onion-like structured with different spheres. The data-based services to be implemented builds the core of the model. It is surrounded by the spheres "machine", "information technology (IT)", "knowledge", "human", and "organization". For each sphere as well as for the interface between service providers (supplier) and service users (customer) operationalized criteria are provided, which represent preconditions of successful service co-production. Following, the model and its application are described in more detail.

DESCRIPTION OF THE MODEL

Smart services are based on the data evaluation of intelligent and networked machines, whereby individually configurable and customer-oriented services can be offered and combined (Bullinger et al., 2017). According to Gebauer et al. (2017) collecting, merging, and evaluating data can make the use of equipment more efficient. However, companies face various challenges when implementing data-based services as new processes and capabilities are required (Kowalkowski et al., 2017). The implementation of these and the associated organizational change can be extensive (Martinez et al., 2017). Furthermore, data-based services are dependent on new technologies such as data analytics, which is composed of multiple algorithms. The use of data analytics in an era of big data means that collaboration between humans and technology is becoming increasingly complex (Varshney, 2016). In order to support a system-level understanding (de Weck et al., 2011 cited in Varshney, 2016, p. 2) and thus a comprehensive solution approach for an optimal implementation of data-based services we developed the socio-technical model. The socio-technical model with its operationalized criteria enables the design and evaluation of the service delivery with respect to the organizational processes and structures.

Core "Data-Based Service"

The core of the model represents the data-based services to be implemented. Predictive maintenance is an example of such a service. It is based on machine data and process data to be analyzed and interpreted. This also requires the explicit and tacit knowledge of experienced machine operators who know and understand their machines. Therefore, the model's spheres surrounding the core represent "machine" (i.e. the technology providing data) and "IT" (i.e. the technology analyzing data).

Sphere "Machine"

The sphere "machine" is concerned with a company's existing technology, for which new data-based services are provided. However, so that human operators can build up expertise and tacit knowledge, it is important that the technology and the processes are transparent and that the automated decision-making is understandable. Therefore, criteria that refer to "machine-understandability" are needed in this sphere.

"Machine-understandability": In order to guarantee a machine's process transparency and thus make the automated decision-making understandable, it is necessary that humans have the opportunity to explore the process (Waefler et al., 1999). Humans are only able to develop an accurate mental model when they are in direct interaction with the technical system and the process. To enable this, the criteria referring to "machine-understandability" focus on ensuring that human operators have a direct insight into the processes and access to process information.

Sphere "Information Technology (IT)"

According to Jain (2017) the implementation of data-based services requires IT to enable the systematic transmission, storage, and processing of data. This aspiring IT is used by humans to manage data in new ways. Therefore, the focus of this sphere is particularly on criteria, which refer to the human-IT collaboration and the human-IT function allocation. Two types of criteria can be distinguished:

"Flexible human-technology coupling": It is important for humans to have the opportunity to flexibly adapt their collaboration with the IT depending on the situation. This in turn means that humans can decide when, where, how, and with what degree of attention they engage with the data. For that purpose, humans need to have control over information channels (Waefler et al., 1999).

"Reliable human-IT decisions": Data processing by IT and hence results produced are mostly not traceable for humans. Therefore, the transparency of the system suffers, and it increasingly becomes a black-box for humans. Especially in critical situations, it is irresponsible to trust the results of a black-box system, so it is crucial that a human experts can validate them. For this, explainable and interpretable data processing and decision models are a prerequisite (Samek et al., 2017).

Sphere "Knowledge"

This sphere is about identifying the knowledge and information needed to deliver the service. As data-based services are knowledge-intensive (Chu and Lin, 2011), a continuous knowledge and information exchange between all those with relevant expertise is a requirement for the provision as well as the continuous adaptation and optimization of data-based services (Dreyer et al., 2019). In order to ensure transmission, the specific knowledge and information must be made explicit. While information refers to the current situation, knowledge rather concerns permanent system states (Nonaka and Takeuchi, 1995 cited in Stenmark, 2002, p.3). In addition, it is important to distinguish between the degree of knowledge awareness (explicit vs. tacit knowledge) and the entity that holds the knowledge (individuals vs. collectives) (Waefler et al., 2018).

Sphere "Human"

The necessary knowledge and information identified in the sphere just described is normally distributed among many people inside and outside the service provider. A main focus of this sphere is therefore the individual ability to share knowledge. Humans gain knowledge and competencies from concrete experiences and by continuous learning (Zirkler and Werkmann-Karcher, 2020). However, there are a variety of challenges when people should share their knowledge (Al-Busaidi and Olfam, 2017). Such challenges are addressed for a targeted design in the sphere "human". Furthermore, organizations are increasingly focusing on team collaboration (Seelheim and Witte, 2007). Therefore, the sphere "human" refers also to individual abilities of collaboration. With regard to such individual capabilities, three types of criteria are distinguished:

"Personal openness": Openness to new experience leads to a better acceptance of knowledge transfer (Wang et al., 2014). Employees who are open to new knowledge transfer systems and processes are actively involved in them earlier (Waefler et al., 2018). Following Cabrera et al. (2006) this could be due the fact that humans with a high openness to experience are more curious. Therefore, the focus of corresponding design criteria is the support of the employees' personal openness to new systems and processes.

"Individual knowledge awareness and conviction": The congruence between one's own knowledge and the knowledge of others is usually overestimated. To create an individual awareness for inter-individual differences in knowledge, information about the knowledge of others is required (Engelmann et al., 2009). It is therefore essential to have design criteria that make employees aware of the importance of knowledge documentation and knowledge transfer. This ensures that information about the knowledge of others is made available.

"Individual preconditions for collaboration": Teams are understood as social systems in which individuals work together to achieve a joint objective (Zirkler and Werkmann-Karcher, 2020). According to Seelheim and Witte (2007) there are various individual-related influencing variables that can affect team performance. Thus, design criteria are needed that address the individual level and create the preconditions for successful collaboration.

Sphere "Organization"

The sphere "organization" covers social systems, which include individuals with different roles and tasks. All members of a social system share the same objectives, and formal structures help them to pursue these objectives (Nerdinger et al., 2014). Therefore, this sphere focuses on designing organizational structures allowing objective-oriented cooperative routines and knowledge exchange. The sphere "organization" represents the following two types of criteria:

"Knowledge culture": These criteria refer to the design of tasks, structures, and instruments with regard to knowledge transfer as well as to the facilitation of knowledge synergies. This requires a common understanding of knowledge transfer (Al-Busaidi, 2013). In addition, it is essential that

the organizational culture encourages learning from mistakes rather than punishing for them (Kronawitter, 2013). These are all preconditions for generating new knowledge. Therefore, according to Al-Busaidi (2013), support from superiors in knowledge exchange is critical. Hence, the design criteria referring to "knowledge culture" promote those conditions required for an optimal exchange of knowledge.

"Agile teams": In the case of customer-oriented data-based services, the organization must be flexible so that employees and organizational structures can adapt more quickly to the conditions (e.g., to changing customer needs). To this, it is helpful to reduce hierarchies and shorten decision-making processes (Hasebrook et al., 2020). Accordingly, criteria need to be included that aim at designing collaboration with as few interfaces as possible.

Interface "Service Provider – Service User"

For data-based services, increased interorganizational exchange of data is likely. Therefore, all spheres described above have an interface between service providers and service users. According to Gulati et al. (2012), this kind of collaboration can be very complex and risky. Hence, it is essential to focus on designing structures and relationships, which enable service providers and service users to successfully collaborate across boundaries (Gulati et al., 2005). Two types of criteria can be distinguished in the corresponding design criteria:

"Precondition for cooperation": These criteria refer to the preconditions necessary for inter-organizational collaboration. In particular, they focus on the quality of the relationship between service providers and users (Gulati et al., 2005). These includes design criteria related to creation and maintenance of sustainable relationships and on the ability to manage conflicts constructively.

"Perception of the cooperation partner": According to Ingram and Yue (2008), having a positive perception of each other seems to be an essential factor for successful cooperation. For example, similarities between the cooperation partners (e.g. similar structures) can positively influence mutual perception. Hence, corresponding design criteria are needed.

APPLICATION OF THE MODEL

In our research project, we applied the socio-technical model in two case studies with industry partners to enable novel data-based services, i.e. to design and sustainably implement corresponding organizational structures and processes. The procedure included modeling the data-based services (step 1), identifying services-relevant knowledge and information (step 2), designing suitable organizational structures (step 3), and ensuring that these structures are continuously developed (step 4). Following, these four steps are described in more detail. We started with the core of the model and worked our way through it from the inside out.

Step 1 – Content and process modeling: The core of the socio-technical model represents the data-based services. Therefore, we started with the development of the content and the modeling of the processes as a basis for the subsequent steps. It was important not to simply capture the process sequentially, but rather to identify relationships and interdependences between the different process steps. For this purpose, the Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012) was applied to model the process of the new services. The distinctive characteristic of this method is that the central functions (key tasks to achieve a result) of the process are modeled, aspects of the functions' interrelations are identified, and instantiations of the functions are specified in detail. Structured expert interviews with employees from the two industry partners built the basis for the modeling. In each case study, a FRAM model was developed, which provided a basis for the next steps.

Step 2 – Knowledge and information analysis: Knowledge and information are valuable resources for driving innovation and making decisions (Al-Busaidi and Olfam, 2017). Therefore, in the sphere "knowledge" of the socio-technical model it was essential to identify and interconnect all pieces of knowledge and information needed to successfully provide the data-based services. In order to collect and explicate all the necessary knowledge and information required, further structured expert interviews were conducted with representatives from the industry partners. The interviews included questions derived from the critical decision method for knowledge elicitation (Stanton et al., 2006; e.g., How do you know if someone is an expert in this function?) and from the storytelling method (Dalkir, 2005; e.g., Can you recall a situation where a new employee made a wrong decision in a similar function and was corrected?). Such questions allowed to capture the general knowledge, the specific information, and the experts' line of reasoning when providing the data-based services. In particular, the storytelling method helped to uncover the tacit knowledge. With the insights gained from the interviews, it was possible to model networks of knowledge and information. On the one hand, these provided insights into what knowledge and information is necessary for each function of the data-based services. On the other hand, the networks also made it transparent which knowledge and information transfer between the functions is required.

Step 3 – Design of agile organizational structures: For data-based services, the environment is becoming increasingly complex and dynamic. It is almost impossible for an organization to predict when and where which form of collaboration will be necessary. Inflexible organizational structures are overwhelmed by this. Hence, responsibilities, decisions, and cooperative relationships need to be adaptive to situational dynamics (Oestereich and Schroeder, 2019). To ensure this, in the sphere "organization", a step-by-step development of agile organizational structures was developed. In a series of workshops with the industry partners different forms of agile organizational structure were discussed and concretized. To do so, the functions required for providing the data-based services were clustered in circles (e.g., circle operational security). For each circle, a purpose was specified (e.g., ensuring the operational safety of the customer), which the circle should achieve as a contribution to a successful provision of the data-based services. Derived from this, roles required to realize a circle's purpose (e.g., technical specialist) including their interrelations were described. For each role profiles were developed, which included the typical operational activities as well as assigned responsibilities. Corresponding discussions among the persons involved promoted a common understanding of each role. In addition to the operative, services-related roles, basic roles were introduced for facilitating each circle's self-organization. Corresponding tasks and responsibilities (e.g., organizing operational meetings) were assigned to these basic roles.

Step 4 – Continuous optimization based on the criteria of the socio-technical model: The objective of step 4 was to ensure a continuous improvement of the organizations designed in step 3 by using the criteria of the socio-technical model. In several workshops the assigned role holders identified potential for improvement by assessing organizational structures and processes against the criteria of the spheres and the interface of the model. All participating employees were asked for their individual assessment. For this purpose, the criteria from the spheres and interface of the model were operationalized and compiled in a questionnaire. Following the surveys, holistic assessments of the organizations were available and thus the basis for developing measures to optimize prioritized areas of improvement. The prioritizations were made on the basis of influenceability (i.e. Do we have the means to implement the improvement?), benefit (i.e. Which improvements have the greatest benefits for the organization?), and time horizon (i.e. Is the benefit for the organization short-term or longer-term?). Following, concrete measures were developed for the selected areas of improvement. For this purpose, guiding questions of the following type were discussed in order to obtain a basis for deriving concrete and implementable measures: "Why has the criterion not been achieved so far?" and "How could the criterion be achieved in the future?"

CONCLUSION

The provision of data-based services requires co-production, i.e. cooperation of internal and external experts distributed throughout an organization and beyond. These people need to exchange and combine their expertise and their tacit knowledge in order to enable those synergies needed for identifying relevant indicators as well as for analyzing and interpreting corresponding data. The prerequisite to do so is organizational readiness. In order to achieve this, a structured approach is required. In this paper we have described the structure of the socio-technical model and given examples of the evaluation criteria. Furthermore, we have described the four steps of how the model is applied to support the implementation and the continuous improvement of data-based services. In the case studies with our industry partners the model proved to be very instrumental for creating organizational readiness to implement data-based services.

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