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Identification of socio-technical changes caused by Industry 4.0

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Purpose: Industry 4.0 provides significant potentials for companies. Despite the promising opportunities, companies, especially SME, are still hesitant to implement new technologies. The main reasons are far-reaching changes with respect to the socio-technical dimensions causing risks that are difficult to assess. This research provides a methodology to identify these socio-technical changes for Industry 4.0 use cases.
Methodology: Based on the three Design Science Research Cycles, a procedure and the corresponding methods for identifying socio-technical changes and risks during the introduction of Industry 4.0 will be designed.
Findings: The developed tool enables the derivation of use-case specific changes and risks in the socio-technical dimensions of human, technology and organization. These interactions have to be considered when introducing Industry 4.0 use cases in order to ensure a promising usage. In addition, the need for further research in the field of socio-technical risk management is identified.
Originality: Classical approaches do not address socio-technical interdependencies during the implementation of Industry 4.0 solutions. To bridge this gap, this methodological approach combines risk management and the concept of socio-technical system design.

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1 Introduction

Progressive technological development in the form of information and communication technologies induces fundamental change in a wide range of sectors (Dowling 2016, p. 3). Digital transformation, digitization and Industry 4.0 are the frequently named catchwords by which this change is understood.

Industry 4.0 stands primarily for the digital networking of people, machines and companies through innovative information and communication technologies (Dowling 2016, p. 3). Intelligent networking and automation in particular are characteristic features of the current advancing change. Existing and proven technologies and processes are continuously being expanded or replaced by new ones (Forstner and Duemmler 2014, p. 200; Obermaier 2017, p. 31).

New technologies enable faster communication for companies, especially in the working environment, thereby creating shorter product development cycles and a more efficient use of resources (Forstner and Duemmler 2014, p. 199). Real-time capability, decentralized control and automation in production play a major role in this context and contribute to increased efficiency (Forstner and Duemmler 2014, p. 199; Appelfeller and Feldmann 2018, p. 8). Industry 4.0 also has an impact on interdisciplinary cooperation, for example by facilitating data exchange (Obermaier 2017, p. 293). It therefore stands to reason that companies want to recognise and exploit the opportunities of Industry 4.0 for themselves. New business areas, partners and customers can be acquired and the entrepreneurial competitive position can be improved. (Bitkom Research 2019, p. 9) Due to the rapid development, companies are challenged to identify suitable Industry 4.0 solutions and to implement them to their benefit. However, many companies are currently hesitant to take a comprehensive approach to Industry 4.0 (Staufen AG 2019, p. 9). This affects especially small and medium-sized enterprises. The reasons for this are manifold. For example, the low level of automation and the historically grown expertise of individual employees are often seen as obstacles to the adaptation of previously formulated Industry 4.0 concepts. (Ludwig et al. 2016, p. 73) Thus, Industry 4.0 has an equally impact on the employees, technology and the organization (Kauffeld and Maier 2020, p. 1).

The listed obstacles are reflected in risks which make companies shy away from the introduction of Industry 4.0. In order to be able to define measures to prevent or reduce these "socio-technical" risks, a better understanding about the reasons for the occurrence of these risks is essential. For this purpose, the changes which are associated with Industry 4.0 have to be identified. These are the triggers for the emergence of risks. Identifying the triggers is one of the most important steps in the risk management process (Romeike 2008, p. 39). Previous methods for identifying these socio-technical risks focus on individual instruments which are used separately for each area of expertise (compare e.g. Romeike 2003, p. 157). Moreover, they often do not address the triad of human, technology and organisation equally (Hobscheidt, Kühn and Dumitrescu 2019, p. 2). Against this background, the question is how socio-technical changes and risks can be identified holistically. In order to answer this question, the aim of this paper is to develop a process model that systematically leads companies through

the process of identification. This will facilitate the introduction of Industry 4.0.
The following chapter first gives an insight into the basics necessary for the construction of a process model that is suitable with regard to the research question. At the end of each subchapter, requirements for the development will be defined. These requirements are part of the research design which is presented in chapter 3. On this basis, a process model for the derivation of socio-technical changes and risks is designed and applied as an example in chapter 4. The paper concludes with a summary of the results and further steps in the field of socio-technical risk management for the introduction of Industry 4.0.

2 Theoretical background

The aim of this chapter is an explanation of the relevant theoretical principles in the conext of socio-technical risk management and the derivation of requirements for the development of a process model. Due to the large number of different definitions of Industry 4.0, companies do not have an overview of which use cases are suitable for them to introduce (Greschke and Greschke-Begemann 2017, pp. 28-29). In order to build a suitable understanding and define the application framework of the model, the term "Industry 4.0 use case" is explained in more detail in chapter 2.1. Afterwards, chapter 2.2 focuses on the challenges of introducing Industry 4.0 in detail. This substantiates the need for an instrument that supports the introduction process. Chapter 2.3 then discusses the principles of risk management. These are used as the basis for deriving the process model. Finally, the significance of the concept of socio-technical system design is postulated in chapter 2.4.

2.1 Industry 4.0 use case

There are different interpretations of the term "use case" in the context of Industry 4.0 (VDE/DKE 2018, p. 87). One reason for this can be found in the various definitions of Industry 4.0 itself. For example, while some authors focus on the technical aspects, others extend this understanding to the function of Industry 4.0 and its effects on the entire value chain (Obermaier 2017, pp. 7-8; Roth 2016, pp. 5-6).

Against this background, the German Institute for Standardization (2018) differentiates between three interpretations of the term use case, which are compared to each other in Figure 1.

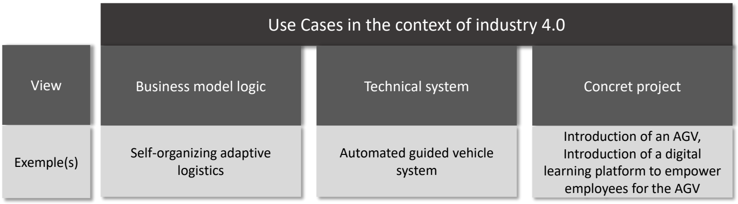

Figure 1: Different interpretations of Industry 4.0 use cases according to (VDE/DKE 2018, pp. 87–88)

The similarity is that different stakeholders, in particular users and operators, will gain a better understanding of Industry 4.0 through the use cases. In this way, company-specific potentials, needs for action, challenges and solution approaches can be identified. Accordingly, a use case is a practical or research example in the context of Industry 4.0. (VDE/DKE 2018, pp. 87-88; Fay, Gausemeier and ten Hompel 2018, p. 6; Kohl et al. 2019, p. 2) The business model logic maps use cases in the form of scenarios at a high level of abstraction, which act as idea generators. By contrast, use cases in the form of a technical system can be used to derive specific requirements for functionality, architecture and interoperability. On the other hand, the concrete projects provide information about the greatest need for action from a market perspective. In addition to the hardware, supporting processes such as the introduction of a digital learning platform are also included. (VDE/DKE 2018, pp. 87-88) As concrete projects are particularly suitable for the derivation of risks, this perspective will be taken as a basis in the following.

Use cases in the form of concrete projects are recorded in application collections. For example, the platform Industry 4.0 from the Federal Ministry for Economic Affairs and Energy lists over 350 concrete application examples in the so-called Industry 4.0-Map. This enables users and operators to select and adapt the appropriate use cases for their specific needs. (Platform Industry 4.0 2020; Platform Industrie 4.0 2016, pp. 6-7) Application collections form the basis for the identification and characterization of relevant use cases.

Requirement 1: Enabling companies to select suitable Industry 4.0 Use Cases.

In the course of the implementation of these Industry 4.0 Use Cases, a number of challenges arise, which will be explained in more detail subsequently.

2.2 Challenges during the implementation of Industry 4.0

According to a 2019 study by STAUFEN AG, 48 percent of the surveyed companies are already implementing individual Industry 4.0 initiatives. However, only eight percent of the companies manage the step from individual initiatives to comprehensive transformation. This applies in particular to mechanical and plant engineering (Staufen AG 2019, p. 10). This is due to the challenges that companies are facing in course of introducing Industry 4.0. Therefore, prerequisites must be created for Industry 4.0. For example, a suitable infrastructure is required to be able to implement innovative technologies (Forstner and Duemmler 2014, p. 199). However, the implementation of innovative Industry 4.0 solutions does not only have a technological impact on companies. Rather, information and communication technologies are changing structures, business processes and value chains (Lipsmeier et al. 2019, p. 3; Krause and Pellens 2018, p. 194; Kreutzer, Neugebauer and Pattloch 2017, p. 122). Especially because these changes are not fully visible in advance, it often seems too costly for companies introducing comprehensive technological solutions (Andelfinger and Haenisch 2017, p. 69). These technology-induced changes can give rise to a variety of risks that can hinder successful implementation and subsequent profitable operation (Schuh et al. 2020, pp. 33-34). On the one hand, these changes affect the technical infrastructure. With each new technological solution, the requirements to be ensured, e.g. for IT security and interfaces in the company increase. Many companies are not yet sufficiently equipped to comply with the new security standards (Bitkom Research 2019, p. 12; Andelfinger and Haenisch 2017, p. 100).

On the other hand, there are changes for the employees, who are also significantly involved in the successful introduction of new solutions. New types of human-machine interactions create new ways of working, for which the employees have to be prepared. If new technologies are not used due to a lack of acceptance by the employees, the introduction has failed (Staufen AG 2019, p. 22). This type of changes will be found along the entire value chain. From the initial development by means of novel programs up to production, in which, for example, assistance systems are supposed to support the employees, problems of acceptance may occur (Kauffeld and Maier 2020, p. 1; Obermaier 2017, p. 297).

In addition to the changes in the technological infrastructure and employees, the changes also affect the organisation of the companies. The organisation is not only confronted with the financial risks of new innovations. It is possible that new technologies require adaptations in existing processes and therefore cannot be easily implemented in existing company structures. As a result, complex restructuring may become necessary in order to use the new technologies to create value (Leyh and Bley 2016, p. 30; Obermaier 2019, p. 356).

The outlined changes represent a breeding ground for risks that could be decisive for the failure of Industry 4.0. An isolated consideration of the technological risks is not sufficient here, since the changes affect the employees and the organization of the company equally (Kauffeld and Maier 2020, p. 1).

Requirement 2: Identification and assessment of potential risks during the implementation of Industry 4.0.

In order to treat risks by developing measures as soon as the risks arise, their causes have to be identified first. Classical approaches of risk management alreadyprovide support in this process. The basic principles of risk management are explained in the following section.

2.3 Foundations of risk management

The term risk management is used to describe "coordinated activities to manage and control an organization with regard to risks" (DIN ISO 31000:2018, p. 7). The risk management norm ISO 31000 defines guidelines for dealing with risks. A risk is defined in the norm as "the effect of uncertainty on targets" (DIN ISO 31000:2018, p. 7). In this context, an effect is understood as a "deviation from the expected" (DIN ISO 31000:2018, p. 7), which can initially be either positive or negative. Whether risks arise depends on certain events that occur with a certain probability. The result of

an event is called an effect. Risks can be controlled by taking measures. (DIN ISO 31000:2018, pp. 8-9)
The use of risk management is often described by using the reference process shown in Figure 2. In practice, this process is carried out iteratively. The first step of the reference process is to define the scope of application and the setting. This includes the establishment of risk criteria, which have to be set in relation to the targets. The criteria define the type and scope of risk that is accepted by the organization. The second step is the risk assessment, which includes risk identification, risk analysis and risk evaluation. (DIN ISO 31000:2018, pp. 17-23) First of all, the step of risk identification requires the identification of changes that give rise to the risks. Only when these changes are recorded, risks can be identified holistically. (Ellebracht, Lenz, and Osterhold 2011, pp. 80-81). In the second step of the risk analysis, risks are to be described, for example, by means of the causes and effects, whereby the level of risk can be derived. In the risk evaluation, based on the risk analysis, a comparison to the previously defined risk criteria is done, in order to decide on additional actions, such as options for risk treatment or further analyses. The third step is the risk treatment. This includes the selection of measures to influence the probabilities and effects of risks (DIN ISO 31000:2018, pp. 17-23).

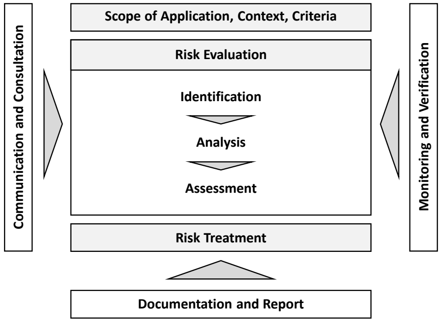

Figure 2: Reference process for risk management according to ISO 31000 (DIN ISO 31000:2018, p. 16)

These three steps are pursued through accompanying activities designed to ensure the success of risk management. Through the regular communication and consultation, opportunities are provided to involve relevant stakeholders and thereby to gather sufficient information, opinions and know-how at each step of the risk management process. The monitoring and verification process ensure the quality and effectiveness of the risk management process. The documentation and reporting aim to communicate the results of the risk management process across the organisation. This is intended to provide information for decision making and to improve risk management activities at the same time (DIN ISO 31000:2018, pp. 17-23).

Building on or extending on the guidelines of this risk management norm, there are numerous other works by various authors, which often focus on a specific risk management issue. Wolke (2008, p. 4) defines a reference process similar to the norm with the four steps risk identification, risk measurement and analysis, risk management and risk controlling. He divides operational risks into external and internal risks, which are divided into personal, process and system risks (Wolke 2008, pp. 201-202). Oehmen (2019, pp. 9-10) sees the ISO 31000 norm as the basis for value-added risk management. This should not be a burden for companies, but should contribute to value creation as a natural part of development. An essential part of this is the adaptation of the risk management process to specific requirements. As an example, a reference process for product development is presented based on the ISO 31000 norm (Oehmen 2016, p. 64).

Hopfener and Bier (2018, pp. 10-11) look at risk management in the context of digitization and see risk management as being moved into a new role in the future due to digitization. According to a survey it is expected that in risk management the advisory function as well as a control function coordinated with the corporate strategy will become increasingly important. This requires a close integration of corporate strategy and risk strategy. To control the corporate targets in a risk-oriented manner, a risk strategy derived from the corporate strategy is required. The knowledge gained from risk management can in turn be used to continuously review and adjust the corporate strategy. In addition to this new role, a change in risk management methods is also expected. An increasing use of standardized processes and quantitative mathematical models (e.g. big data analyses) in risk management is predicted. This allows a more reliable analysis of risks as well as a more transparent provision of information. It also enables risk management to be more closely integrated into strategic issues and to contribute to value creation (Hopfener and Beer 2018, pp. 10-16).

The focus of this paper is primarily on the phase of risk identification, because risks cannot always be identified and assessed due to a lack of information (Gunkel 2010, p. 59). In this context, Romeike (2008, p. 39), for example, describes the gathering of information as the most difficult phase in the entire risk management process, but at the same time it has a key function for the subsequent phases. Therefore, this paper will take a closer look at this important part of the risk management. In addition, a first evaluation of these risks is made.

Requirement 3: Capturing changes in order to understand the background of the emergence of risks by using established structures from the field of risk management.

Through its involvement in strategic issues, especially in the context of Industry 4.0, risk management affects the company as a whole. There are various ways to structure this holistic approach. The socio-technical systems approach is used in many disciplines to structure the technology-induced changes. This will be discussed in the following chapter.

2.4 Socio-technical structuring framework

As already apparent in chapter 2.2, it is not sufficient to consider only technological factors when introducing Industry 4.0 solutions. For example, the use of autonomous guided vehicles in intralogistics requires optimally coordinated collaboration between human and machine, for example by stopping the transport robots when necessary and allowing employees to correct malfunctions. In addition, the use of robots requires an optimization of processes, which in turn requires the experience and knowledge of the employees. The introduction of new technological solutions must therefore be considered together with the organizational and personnel elements and especially with regard to their interfaces and interactions (Hirsch-Kreinsen et al. 2016, pp. 10-13).

A general connection between the technological, organisational and human elements is described by the concept of the socio-technical system. The socio-technical system is defined as follows by Hirsch-Kreinsen and Weyer (2014, p. 11) in reference to Rice (1963, pp. 181-185):

„A socio-technical system can be understood as a production unit consisting of interdependent technological, organisational and personnel subsystems. Although the technological subsystem limits the design possibilities of the other two subsystems, the latter have independent social and work psychology characteristics, which in turn have an impact on the functioning of the technological subsystem. Moreover, the overall system is always in close interaction with its environmental conditions." (Hirsch-Kreinsen and Weyer 2014, p. 11; Rice 1963, pp. 181-185).

With this definition, Ulich (2013, pp. 4-5) describes the three dimensions of human, technology and organisation in the context of socio-technical system design. These three dimensions always have to be considered in their interdependence and can only be optimised together. Ulich (2011, p. 111) captures as the human dimension the social system with aspects such as task characteristics or personal development. The dimension technology includes the technical system, such as production systems in the manufacturing process. The dimension organisation forms the framework for linking the social and technical systems and can be considered at different levels such as the entire company or other organisational units. (Ulich 2013, pp. 4-7) According to these definitions, a clear classification into the three dimensions human, technology and organisation is possible. However, there are many different illustrations in the literature that show differences in the assignment of aspects to the respective dimension.

Hobscheidt, Kühn and Dumitrescu (2019, pp. 2-3) have analysed these different aspects of the dimensions of the socio-technical system with regard to the frequency of their mention in each dimension in the current literature and have formed clusters. These are named components. For the dimension technology, the resulting components are automation, IT systems and data management. For the dimension organization the components culture, knowledge and processes and organization were created. In the dimension human the resulting components are collaboration, qualification, cooperation and work task. The three dimensions with their respective components are shown in Figure 3.

The need to take equal account of technological, organizational and human elements in risk management becomes already apparent in Wolke (2008, pp. 201-202). He classifies risks into personal, process and system risks, which corresponds to a similar classification to the three dimensions of human, technology and organization. But a holistic socio-technical consideration of risk management is not yet taking place. To bridge this gap, the procedure model has to combine the field of risk management with the concept of the socio-technical system design.

Requirement 4: Consideration of the dimensions human, technology and organization for a holistic collection of changes and risks.

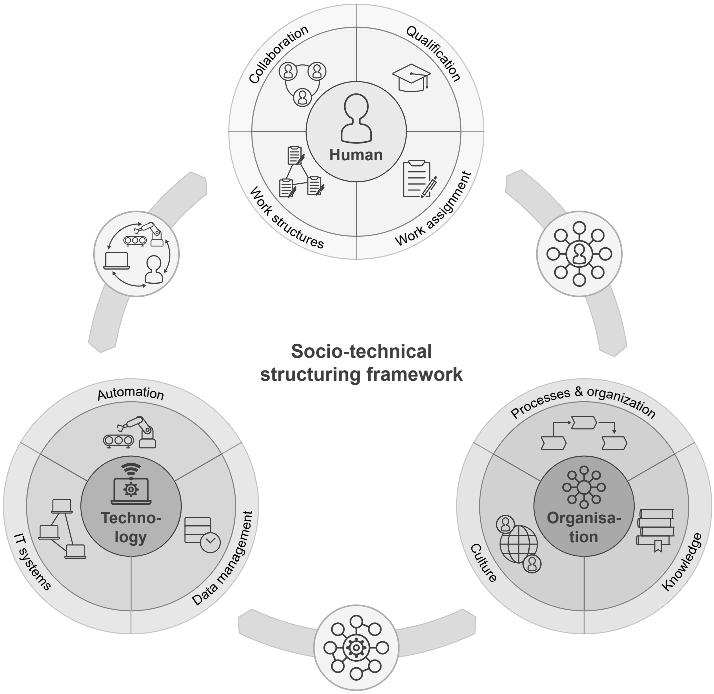

Figure 3: Socio-technical structuring framework (Hobscheidt, Kühn and Dumitrescu 2019, p. 2)

3 Research Design

The approach for the development of a process model is based on the design science research cycles from Figure 4 by Hevner (2007). This method-

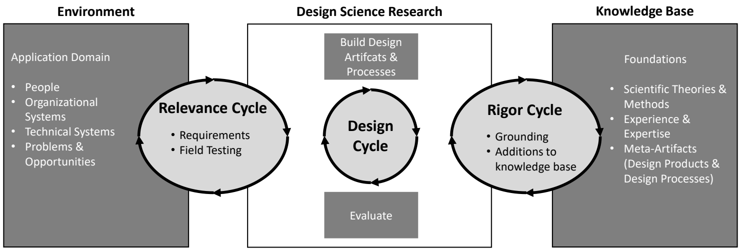

Figure 4: Design Science Research Cycles (Hevner 2007, p. 89)

ology is structured into three inherent research cycles. The relevance cycle bridges the design science activities with the contextual environment of the research project. Whereas the rigor cycle connects the knowledge base of scientific foundations, experience and expertise with the design science activities. The central design cycle uses the information from the rigor cycle and the relevance cycle to iteratively develop new design artifacts and processes. (Hevner 2007, p. 89) In this case, the goal is to develop a process model for the identification of risks, which is based on various methods.

In order to capture the theoretical foundations, the relevant basics for the development of a process model have already been presented in chapter 2. As these fundamentals have a strong practical relevance, requirements were derived which reflect the relevance of a process model for the identification of risks. Thus, in the context of the relevance cycle, not only requirements for the research are provided as input, but also acceptance criteria for the final evaluation of the research results are defined (Hevner 2007, p. 90). In the following, the defined requirements are summarized:

- Requirement 1: Enabling companies to select suitable Industry 4.0 Use Cases.
- Requirement 2: Identification and assessment of potential risks during the implementation of Industry 4.0.
- Requirement 3: Capturing changes in order to understand the background of the emergence of risks by using established structures from the field of risk management.
- Requirement 4: Consideration of the dimensions human, technology and organization for a holistic collection of changes and risks.

In order to fulfill these requirements, a process model was developed within the design cycle. This is presented in chapter 4. To exploit the potential of the developed approach, workshops were performed with four companies in the context of the field tests. Thereby real solutions in the form of use cases were used and evaluated by using the procedure model. 13 company experts took part in these workshops. The companies come from various sectors, with sizes varying from small and medium-sized enterprises to large companies. This resulted in a diversified picture for the identified risks.

4 Methodology for the derivation of use case specific changes

The introduction of Industry 4.0 involves a variety of changes, which in the worst case also entail risks (see section 2.2). These can prevent a successful implementation, especially for SMEs. In order to capture these risks holistically and to be able to derive adequate measures to avoid or reduce them, the changes that trigger the risks have to be identified first. In this context, it is not sufficient to capture only the technological changes. The organization and the human are also affected by the change. Against this background, a sequential process model was developed to identify socio-technical changes and risks during the introduction of Industry 4.0. As explained in chapter 3, the development is based on the design science research approach. The aim was to develop a process model that fulfills the identified requirements. The model is shown in Figure 5. In the following, the individual steps are described in more detail and exemplarily applied to a concrete Industry 4.0 use case of one of the involved companies.

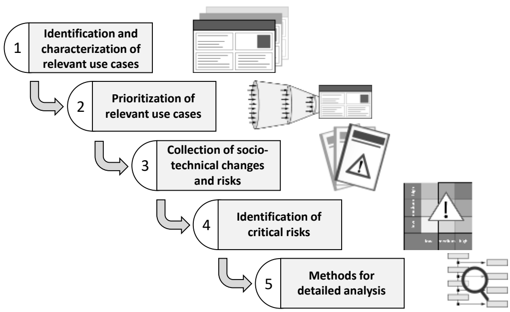

Figure 5: Process model for the identification of socio-technical changes during the introduction of Industry 4.0 use cases

4.1 Identification and characterization of relevant Industry 4.0 use cases

In order to support companies in the selection of Industry 4.0 Use Cases according to requirement 1, a knowledge base of the current possibilities in the context of Industry 4.0 has to be established first. Therefore, the first step of the process model aims at the collection of Industry 4.0 use cases, which offer potentials for the respective company. For this purpose, the range of use cases from the different fields of application has to be shown first, before a concrete selection can be made by internal experts. The application collections described in chapter 2.1 provide a basis for this, visually demonstrating companies the diverse possibilities of Industry 4.0. In addition, the targeted search for scientific publications or the exchange of experience with the surrounding business environment are also helpful sources of information. These external sources are supplemented by internal sources, such as the company's own employees, who can provide helpful impulses through their experiences (Wellensiek et al. 2011, pp. 140-169; Kohl et al. 2019, p. 6).

As the use cases form the basis for deriving socio-technical changes and risks, a uniform understanding is essential. For this purpose, the selected use cases can be characterized by using fact sheets which have the property of presenting essential aspects in a shortened form and thus make information easy to transport. In addition, they are suitable for comparisons among themselves and serve as a basis for discussion (Wellensiek et al. 2011, pp. 138). Against this background and with respect to the following prioritization in chapter 4.2, the profile shown in Figure 6 was designed. In addition to a brief description, the fact sheets contain an assessment of the maturity using three levels based on Bischoff et al. (2015, pp. 25-26) and Schuh et al. (2011, pp. 43-44):

Basic-solution: This includes Industry 4.0 use cases, whose market potential has been greatly exploited. No exclusive knowledge is required for the application and therefore no unique selling point is achieved with this solution. However, its use is still a market standard and the abandonment of this application would have negative competitive consequences. Since the solution is already established, there is no uncertainty about its performance.

Key-solution: This level covers Industry 4.0 solutions with a large economic potential that are already established on the market. However, since they are not available to all competitors, their use can create significant competitive advantages. Since the application is reserved for only a few experts, there is a medium uncertainty with regard to the performance. As the application is reserved for only a few experts, there is a medium uncertainty with regard to performance.

Pacemaker-solution: Pacemaker solutions are expected to have a high economic potential. Since they are still in the development phase, there is a high degree of uncertainty whether the solution will become established in industry.

In addition to the maturity level, those areas of the value chain which are directly affected by the introduction of the use case have to be marked. This, as well as the assessment of the maturity level, provides the first indications for the derivation of desired potentials and challenges, which are then also recorded in the fact sheets. These four elements serve as a basis for the company specific pre-selection of the Industry 4.0 use cases, as they

show first findings about the consequences of the introduction and the associated risks.
In figure 6 the fact sheet of the use case "Data acquisition and analysis in the system for generating smart services" is presented as an example. This has been shortlisted, in addition to the introduction of agile development teams and the introduction of a customer-integrated development team. In essence, this involves the collection of machine data, which is to be used for new services, such as predictive remote maintenance of machines. In order to achieve a consistent understanding of the process model, the next steps are explained by using this use case as an example.

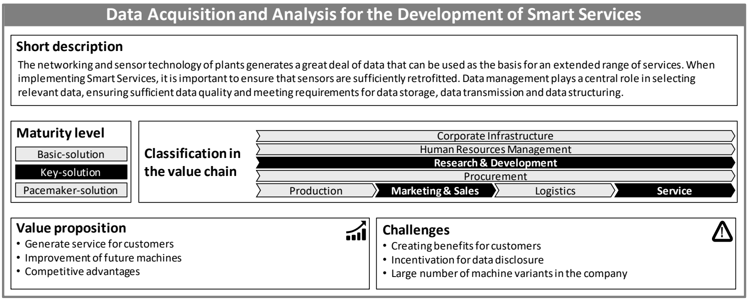

Figure 6: Exemplary fact sheet for the description of an Industry 4.0 use case

4.2 Prioritization of relevant use cases

In order to select a promising use case and to fulfill requirement 1, a ranking of the pre-selected use cases needs to be generated. The use case with the highest priority offers the potentially highest added value for the company. From the field of methods for investment decisions, the instruments of ben-

efit analysis are particularly suitable for this application, since it is uncomplicated in its use and is bound to only a few preconditions (Buses von Colbe, Laßmann and Witte 2015, p. 311). With the benefit analysis, a methodology is selected that focuses primarily on the non-monetary aspects for the multidimensional evaluation of action alternatives (Busse von Colbe, Laßmann and Witte 2015, p. 312; Weber and Schäffer 2014, p. 313). In the literature, different forms of benefit analysis are discussed (Zangemeister 1976, p. 252-255.; Blohm et al. 2012, p. 161-163). This paper distinguishes four steps, based on Busse von Colbe, Laßmann and Witte (2015), which will be transferred to the application framework of this paper in the following.
At the beginning of the benefit analysis, evaluation criteria have to be defined. For this purpose, the five criteria according to Hobscheidt, Kühn and Dumitrescu (2019, p. 5) are used. These were identified as part of the development of risk-optimised implementation paths for Industry 4.0 based on socio-technical patterns:

- High strategy fit: devisional strategy, strengthening of core competence, competitive relevance
- High urgency: competitive pressure, customer pressure, internal preparations
- Low expenditure: personnel expenditure, cost expenditure, project scope
- Low risk: market risk/competitors, acceptance/motivation of employees
- High benefit: economic efficiency, satisfaction of employees/customer, further development of the company

In the second step, the evaluation criteria are related by weighting them according to their relevance for the user. The method of pairwise comparison can be used for this. The following third step consists in determining the partial utility values for each criterion and each use case (Busse von

Colbe, Laßmann and Witte 2015, pp. 315-316). A five-level Likert scale ("0 - does not apply at all" to "4 - fully applies") can be used for the assessment (Blasius 2014, pp. 1051-1062). The partial utility values are then obtained by multiplying the weight factor by the estimate from the Likert scale. In the last step, the individual partial utility values per use case are added together to calculate the total utility value. The highest total utility value represents the use case with the highest potential for the company (Busse von Colbe, Laßmann and Witte 2015, pp. 318-321).

In the selected application example from the research project, the use case from figure 6 was rated highest. An excerpt from the benefit analysis is shown in figure 7.

Evaluation Criteria 4 = Agree completely . . . 0 = Disagree completely	Weighting [%]	Industry 4.0 Use Cases				
		Data Acquisition and Analysis for the Development of Smart Services		Introduction of Agile Development Teams		
		Rating (1-3)	Partial Utility Rating x Weight.	Rating (1-3)	Partial Utility Rating x Weight.	
High Strategy Fit	40,00	3	120,00	2	80,00	
High Urgency	0,00	3	0,00	2	0,00	
Low Effort	10,00	2	20,00	2	20,00	
High Benefit	30,00	3	90,00	1	30,00	
Low Risk	20,00	2	40,00	2	40,00	
Total Utility			270,00		170,00	

Figure 7: Excerpt from the benefit analysis of a company

4.3 Collection of socio-technical changes and risks

After the selection of Industry 4.0 use cases has been prioritized, the third step involves the identification of the changes accompanying with the introduction and the resulting risks. For this purpose, a canvas was designed based on the Business Model Canvas by Osterwalder and Pigneur (2010) against the background of socio-technical risk management for each of the three dimensions of human, technology and organization. The canvas for the dimension organization is shown exemplarily in figure 8. The canvas shows results that were developed in cooperation with an industrial company. For this reason, the results have been made anonymous and slightly modified. The contents are recorded individually for the three dimensions and for each Industry 4.0 use case. Depending on the components of the socio-technical structuring framework of Hobscheidt, Kühn and Dumitrescu (2019, p. 2) of chapter 2.4, the changes are first identified. These form the basis for the derivation of risks. Thereby, the identified risks could address several dimensions. The components serve as an aid for the derivation of concrete changes and risks. In order to generalize these use case-specific risks, risk categories are finally defined and evaluated hierarchically.

With the help of the presented canvas, changes as well as risks can be derived for each of the socio-technical dimensions, whereby requirements 2, 3 and 4 are fulfilled.

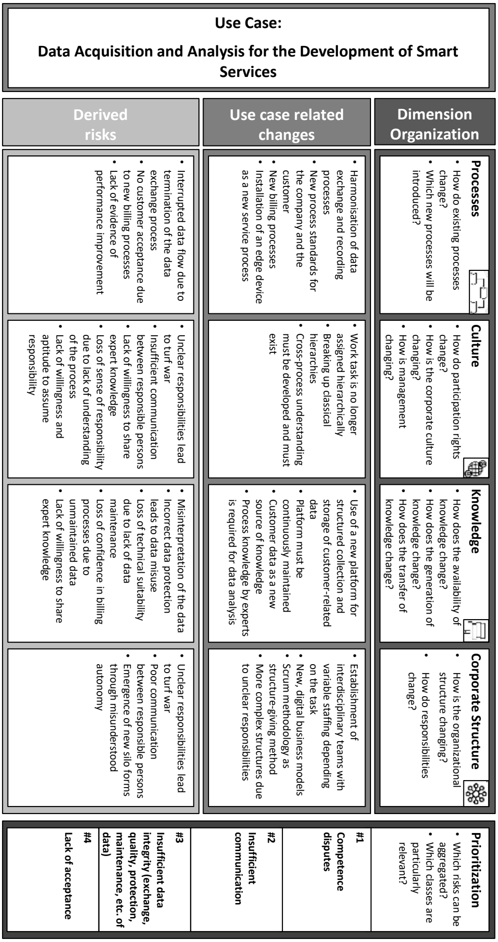

Figure 8: Canvas for the identification of changes and risks in the dimension organization using the example of Smart Services

4.4 Identification of critical risks

As the resources especially of SMEs are often limited (Müller 2016, p. 8), measures cannot be derived for all risks. Therefore, and with regard to requirement 2, which requires an initial assessment of the risks, the fourth step of the process model is to identify the particularly critical risks. For this, following Brauweiler (2018, pp. 8-11), the assessment of the dimensions of probability of occurrence and damage potential per risk is suitable. The assessment is made by company experts. To facilitate the assessment of damage potential, the criteria from chapter 4.2 of Hobscheidt, Kühn and Dumitrescu (2019, p. 5) can be used as a guide. The assessment of the probability of occurrence reveals itself to be much more difficult. In order to get hints for this evaluation as well, the Quick Check Industry 4.0 from the research project INLUMIA can be used (Pierenkemper et al. 2019, p. 31). By determining the actual state of the dimension's technology, business and human, conclusions can be drawn about the potential probability of occurrence of the risks. Thus, for example, the assessment of the company's decision-making structure in "central" or "collective" (Inlumia 2020), can lead to findings about the probability of the risk cause "unclear responsibilities". The assessment of the damage potential and the probability of occurrence in low, medium and high is shown in a risk matrix. The coloring of the individual areas additionally symbolizes the significance of the individual risks. The risk with the highest probability and the highest extent of damage should be examined more closely in the next step.
Figure 9 shows an example of a possible classification of critical risks. Here, as an example, the risks in the component culture of the dimension organization from the application example were evaluated. In this case, the risks "loss of sense of responsibility due to lack of understanding of the process"

and " lack of willingness and aptitude to assume responsibility" must be examined more closely.

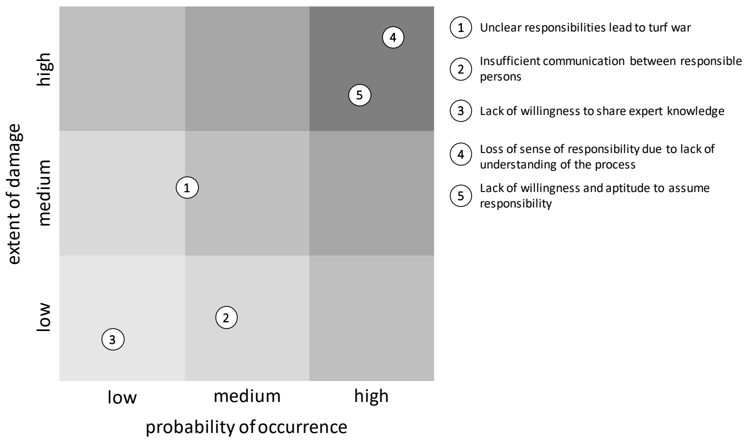

Figure 9: Risk matrix for identifying critical risks according to (Brauweiler 2018, p. 10)

4.5 Methods for detailed analyses

In order to obtain a better understanding of the risks and to fulfill requirement 2, the critical risks identified in chapter 4.4 have to be analysed in more detail. For this purpose, a toolbox has been developed, which explains different methods in the form of fact sheets for each socio-technical dimension. Thereby, in addition to the objective, the usage hints, the advantages and disadvantages as well as the concrete approach of the methodology, an evaluation is also presented. Here, the criteria difficulty factor, level of detail of the results, required employee capacities as well as the time required are roughly rated on a four-level scale. It should be noted that the actual effort can vary depending on the individual application. Nevertheless, the evaluation provides a first indication of the scope of the respective method, which should facilitate the selection.

The in-depth analysis of the critical risks forms the basis for deriving efficient measures to avoid or reduce the risk causes. The selection of a suitable method depends on the components of the dimension of the risks. Figure 10 shows a simplified version of the toolbox. An exemplary method from the dimension human is the stakeholder analysis. With it, for example, target groups can be identified which are particularly affected by a change. These groups are usually those with the highest risk potential.

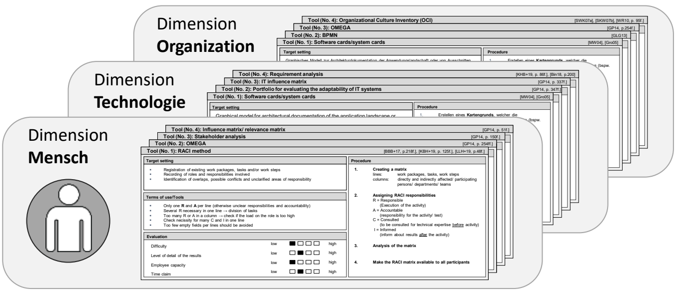

Figure 10: Toolbox for in-depth analysis of the critical risks

5 Conclusion and further research

This paper highlights the various changes during the introduction of Industry 4.0. These represent a breeding ground for risks, which makes particularly SMEs shy away from the implementation of Industry 4.0. The changes that occur during the implementation process relate not only to the technological aspects but also to the human and the organization. Against this background, classical risk management was linked with the sociotechnical systems approach. The focus was on the phase of risk identification. In order to derive suitable measures to avoid or reduce risks, the concrete changes that trigger these risks have to be identified and understood first. This phase of risk identification represents one of the most challenging tasks in the field of risk management. For this reason, a five-step process model was developed, based on the research cycles of design science by Hevner (2007). This process model enables companies to derive socio-technical changes and risks depending on their specific Industry 4.0 use case and the individual company requirements. Methods were developed for the individual stages of the process model, which were validated in practice in cooperation with companies. These methods allow a detailed analysis to understand the manifold reasons for risks.

Based on the identified socio-technical changes and risks, the next step involves the identification of interactions between risks among each other and between different socio-technical dimensions. These interactions also affect the selection of appropriate countermeasures to avoid or reduce risks. In addition, for a selection, risk strategies have to be defined first, which are in line with the corporate strategy.

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