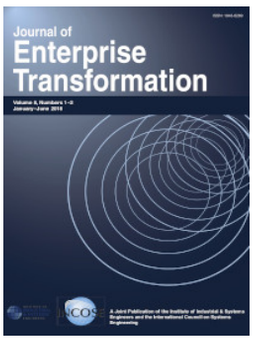

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Success factors for fostering a digital transformation in manufacturing companies

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ABSTRACT

Digital Transformation (DT) is an essential trend for manufacturing companies as digitalization of the value chain affects the entire company. Strategic management functions should consider DT technologies and their impact on assets and resources. The knowledge of the possible factors that influence DT positively may ease a realization of gains due to DT. In 20 qualitative interviews, we examined critical factors for DT's success in manufacturing companies. Based on the IS success model of DeLone and McLean, we have derived success factors that can trigger DT success. The success factors describe the three major dimensions in which DT takes place: technology, organization, and environment. The results show that DT can only be successful if companies collaborate with customers, suppliers and also other firms from the branch. A cultural change is necessary to enable an agile working environment as well as more interdisciplinary activities. It becomes evident that the choice of technology is essential. However, driving only technology forward is not enough to gain benefits from DT.

KEYWORDS

IS success; DeLone and McLean success model; Digital Transformation; qualitative analysis

1. Introduction

In recent years a development, called Digital Transformation (DT), has captured the business world (Kagermann, 2014). A second machine age is announced to describe significant impacts of technology on the way of how manufacturing is done (Brynjolfsson & McAfee, 2014). DT is a worldwide topic. In Germany, for example, the digitalization of manufacturing companies is called "Industrie 4.0" (Kagermann et al., 2014, p. 2) while in the US the term "industrial internet" (Evans and Annuziata, 2012) is common. DT is understood in a broad sense as "the use of new digital technologies (social media, mobile, analytics or embedded devices) to enable major business improvements (such as enhancing customer experience, streamlining operations or creating new business models)" (Fitzgerald, Kruschwitz, Bonnet, and

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Welch, 2014, p. 2). DT embraces more than technology use and includes the alignment to the organization and the environment (Matt, Hess, and Benlian, 2015). To manage this complex, cross-functional change, it is necessary to formulate a DT strategy to achieve a planned transformation (Kane, Palmer, Nguyen Phillips, Kiron, and Buckley, 2015). In research, authors claim a clear integration and alignment of the DT strategy to the enterprisès business strategy which is still a challenging process (Bharadwaj, El Sawy, Pavlou, and Venkatraman, 2013; Hess, Matt, Benlian, and Wiesböck, 2016; Schwab, 2017).

Even though DT is gaining more and more attention in research and practice, many firms still struggle to realize its transformation potential (Hess et al., 2016). The rapid technical development of the digital transformation in manufacturing companies leads to problems regarding its realization (Hirsch-Kreinsen, 2016). Especially firms from industrial branches struggle with new technologies compared to more agile sectors like entertainment or information technology (IT) (Dremel, 2017). New possibilities for the production process, like Business2Machine via the Industrial Internet of Things, Cyber-Physical Systems, or Human-Computer Interaction remain a wasted opportunity (Heng, 2014). To transform the business towards DT, it is necessary to understand the value of the technical impact on resources, courses of action and objectives, which form a strategy (Chandler, 1962).

It is important for companies to understand what is crucial for the successful realization of DT to be able to aim at a strategical transformation. These crucial factors are defined as "those few things that must go well to ensure success for a manager or an organization" (Boyton and Zmud, 1984, p. 17). Our study aims at the identification and analysis of these factors for DT to answer the research question: *Which success factors foster the perceived benefit of the Digital Transformation in manufacturing companies?*

For the identification of the success factors, we conducted 20 qualitative semi-structured interviews. The selected interviewees were experts and users of digital technologies. To assure a rich quality of data, the interviewees had different positions and provided knowledge from diverse enterprises. This proceeding leads to a broader perspective that primarily aims at a holistic view of DT (Devaraj & Kohli, 2003; Laudien, 2016; Mishra, Konana, and Barua, 2007). We expect this approach to be of more general value than a focused view on single technologies. Our research is influenced by the IS success model from DeLone and McLean (1992) which was introduced during the 1990ies and proven to be valid (Iivari, 2005; Urbach, Smolnik, and Riempp, 2009). Success factor models are critically discussed in literature (Hurrle and Kieser, 2005; Nicolai and Kieser, 2002). Part of the discussion addresses critiques of quantitative methods which is why we proceed following a qualitative design while choosing the IS model as a starting point for the coding procedure. This is in accordance with an abductive

research design which aims at exploring an adjacent field of a well-known domain by using theories from the latter (Timmermans and Tavory, 2012) to gain in-depth information (Walsham, 2006). As the model is originally focused on information systems, we expect a need to further develop and adapt the model to the domain of DT. The approach follows the call for more qualitative research from the streams of IS (Hirschheim, 2007).

We expect the findings to be of value for practitioners and researchers. We generate a valuable overview of possible triggers of perceived benefits from experienced interview partners. Managers may use this compilation to identify actual gaps within their own DT to be able to derive actions for resources, courses, and objectives. By interpreting the success factors, we develop propositions which other researchers may find of value as a starting point for quantitative studies.

In the following, we will give a short overview of Digital Transformation as well as IS success in research. Afterward, we present our research approach and exposed success factors which lead to propositions for each group of the dimensions of DT success. Finally, an outlook is given and limitations are mentioned.

2. Conceptual background

As a conceptual background for our study, we regard it as necessary to introduce the DT in more detail. Involved technologies and implications of DT are described. Information systems form a necessary prerequisite for DT. Thus, we gain first insights on success factors from IS success research. A short overview of this research stream is given.

2.1. Digital transformation in manufacturing

Digital Transformation is about technologies that enable cross-functional value generation and shape the way of doing business massively. Fundamental innovations such as Cyber-Physical Production Systems (CPPS) (Roth, 2016), the Internet of Things (IoT) (Haller, Karnouskos, and Schroth, 2009; Mattern, 2005), Cloud Computing (CC) (Gubbi, Buyya, Marusic, and Palaniswami, 2013), and Human-Computer-Interaction (HCI) make up the underlying technologies of Digital Transformation in manufacturing, leading to so-called smart factories or intelligent production processes. The mentioned core technologies are the requirements for an intelligent linkage of systems. Based on these technologies and provided with specific data-interfaces, machines or assembly tools can be embedded in processes and influence the functions of products and services. Digital Transformation presents a new way of linking and using digital

technologies which makes the borders of enterprises blur (Lucke, Constantinescu, and Westkämper, 2008).

Innovative technologies are expected to disrupt markets, transform whole branches and impact its players (Bharadwaj et al., 2013), because new possibilities lead to a change (Matt et al., 2015) which alters "organizational structure, strategy, context, and use" (Nagy, Schuessler, and Dubinsky, 2016, p. 3). During the 21st century, the role of digital strategy shifted from a decentralized hierarchical functional structure to an IT-enabled global network structure (Bharadwaj et al., 2013; Nolan, 2012). Higher competitive environment (Mithas, Tafti, and Mitchell, 2013) and technologies like big data (Constantiou and Kallinikos, 2015) change the requirements for firms and thus their digital strategies (Fitzgerald et al., 2014). Moreover, the new role of customers also influences the way of developing a strategy and the strategy itself (Woodard, Ramasubbu, Tschang, and Sambamurthy, 2013).

Due to the deep integration of DT into the value creation processes, the strategy is more in focus than the technology (Kane et al., 2015). According to Chandler (1962, p. 13) strategy is the „the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals". This definition means that three levels together form a strategy: the objectives, the actions and the allocation of resources with regard to the objectives. All three levels are relevant for DT because it impacts the enterprise's long-term goals. As objectives companies expect major gains in efficiency and productivity by applying DT (Schwab, 2017). Furthermore, the objective's focus changes, as suppliers and customers are deeply integrated into the value creation process (Baird and Raghu, 2015). The interaction is strongly supported and enabled by digital platforms which are based on IS (Banker, Mitra, and Sambamurthy, 2011; Benlian, Hilkert, and Hess, 2015; Ondrus, Gannamaneni, and Lyytinen, 2015; Selander, Henfridsson, and Svahn, 2013; Woodard et al., 2013). This leads to new and different courses of actions. New ways of combining products and services are implemented (Kagermann, Wahlster, and Helbig, 2013). Besides the integration of DT in the business strategy, a growing interest lies on the formulation of a specific digital strategy which needs to be integrated in the strategy of the whole enterprise (Hess et al., 2016; Kane et al., 2015; Matt et al., 2015) and help to determine resource allocations (Devece, Palacios-Marqués, Galindo-Martín, and Llopis-Albert, 2017).

To sum up, DT is "a disruptive or incremental change process. It starts with the adoption and use of digital technologies, then evolving into an implicit holistic transformation of an organization, or deliberate to pursue value creation" (Henriette, Feki, and Boughzala, 2016, p. 3). DT implies radical internal and external changes (Schweer and Sahl, 2017). The base

for all these changes is the transformation within the resource application. Resources have to be allocated in the sense of DT, as DT innovation is about "combinations of information, computing, communication, and connectivity technologies" (Bharadwaj et al., 2013, p. 471).

2.2. IS success in research

Even though DT is a complex phenomenon, triggering different dimensions, IS technologies are the base to drive the topic forward. Thus, we take a closer look at research on IS success for the foundation of our study. The successful use of any IS solution is an immanent condition for today's work. From an organizational view, the linkage between IS and any other departments became stronger in recent time. Although the importance of success is indisputable, there is an only limited consensus about how to describe the success of digital technologies. Similar concepts and understandings of success are available in the literature (Markus and Lee, 2000). Research streams on productivity, efficiency or use exist which all have in common that they describe the phenomenon of success in detail. Thus, success is a multidimensional construct.

Many researchers tried to give applicable scales to measure IS success. Seddon et al. tried to name effectiveness measures (Seddon, Staples, Patnayakuni, and Bowtell, 1999) due to the type of system and the stakeholders involved. Beside the stakeholder, the time of success measure plays a significant role. IS success can be measured ex-post, ex-ante or constantly (Soh and Markus, 1995). Furthermore, the perspective from which the evaluation is made must be assessed (Grover, Jeong, and Segars, 1996). Different views on success from users, IS personnel, management, and internal audit exist (Hamilton and Chervany, 1981). Results in this area of success research are more like indicators which can be interpreted as the benefits resulting from IS use (Steinhueser, Richter, and Smolnik, 2015).

While indicators have the goal to measure the success, critical success factors are defined as "those few things that must go well to ensure success for a manager or an organization" (Boyton and Zmud, 1984, p. 17). For studies on IS success, it is essential to be aware of possible characteristics of dimensions of success and their interconnections. For example, from the perspective of the management, it is also important to consider individual workplace improvements (Grover et al., 1996). Many studies on IS success triggering the different possible dimensions were conducted. These studies provide valuable deep insights into the nature of success factors and give detailed descriptions (Liere-Netheler, Vogelsang, Packmohr, and Hoppe, 2018). Interrelations and mutual influences are presented. Some models also show valid and proven statistical models (Urbach et al., 2009).

Within IS success studies one model is very famous – the IS success model by DeLone and McLean (DeLone and McLean, 2003). This model implies antecedents of IS success from different dimensions. Aspects of the individual level of IS use are combined with economic advantages and characteristics of the technology. The IS success model consists of three levels: "systems quality" measures technical success; "information quality" measures semantic success; and "use, user satisfaction, individual impacts" and "organizational impacts" measure effectiveness success. This impacts the individual and finally the whole organization (DeLone and McLean, 1992). Already, this model aimed at strategic benefits. In a 10 year update, the determinant service quality was added to the dimensions of the model (DeLone and McLean, 2003). DeLone and McLean identified success factors for e-commerce as an example of IS. These are assigned to the three dimensions – system quality, information quality and service quality. These dimensions are fixed. However, the assigned success factors vary for different IS. The factors are said to influence intention to use and user satisfaction which are closely related to net benefits. The model has been used widely but has also been criticized for the combination of a process perspective and defining causal relationships (Ballantine, Bonner, Levy, Martin, Munro, & Powell, 1996; Seddon, 1997). Thus, new models like the IS-impact measurement model by Gable et al. (Gable, Sedera, & Chan, 2008) were developed.

The existence of success factors, in general, is a fragile construct. There is an ongoing debate about the relationship between success factors and business success (Boyton and Zmud, 1984; Hurrle and Kieser, 2005; Nicolai and Kieser, 2002). Critics cannot see a proof for the relationship between action and outcome. Furthermore, the significance of the chosen dependent variable was questioned. More methodical findings spur the debate, like the key-informant bias, simultaneity or the "regression to the mean" problem (Hurrle and Kieser, 2005; Nicolai and Kieser, 2002).

Despite the critical voices regarding success factors, we esteem (IS) success as a very prominent topic in IS research because companies implement systems to receive some kind of net benefit. To comprehend the nature of IS success is important for a broad understanding of the IS management activities (DeLone and McLean, 2003). On the one hand, it is interesting to know which factors lead to successful implementations and use. On the other hand, it is motivating to identify the desired and received benefits. Success factor models provide information about what may determine success and how the success can be measured.

3. Method

As "fast-changing phenomena are difficult to investigate solely through the use of traditionally privileged methods" (Sarker, Xiao, and Beaulieu, 2013,

p. iii), it seems appropriate to conduct qualitative research in the field of digital transformation. Qualitative methods are expected to be able to explore complex interactions between technologies, organizations and individuals involved (Dubé and Paré, 2003; Palvia et al., 2004; Walsham, 2006). Especially for the dynamic environment such as the success of DT, we regard a qualitative approach as useful. Theorization of success factors has been proven as complex without a clear theoretical foundation (Nicolai and Kieser, 2002). Therefore, our study aims at the description and in-depth understanding of success factors by capturing experiences from the field and interpreting these (Graebner, Martin, and Roundy, 2012).

We aim at a holistic view to generate valuable results within this broad field (Karimi and Walter, 2015). The technological realization of Digital Transformation has many different usage scenarios, and therefore technical solutions are examined in specific context situations. Recent research offers many articles that discuss – from an engineering perspective – context-specific usage scenarios. However, the Digital Transformation includes more than just the implementation of new technologies. DT implies multiple possibilities of combining different technologies (resources) in use (Stock and Seliger, 2016). Therefore, it is helpful for our research to understand the term broadly. Our view is not limited to single technologies or goals. Furthermore, there is a need for research regarding the socio-technical implications and perceptions of Digital Transformation. These implications can be enormous and have also been discussed in similar approaches like computer integrated manufacturing which is described as a holistic approach to the activities of the enterprise (Chang and Wysk, 1997; Radhakrishnan, Subramanyan, and Raju, 2008). Our exploratory focus is beyond specific strategies, the shape of organizations and single technologies. Such a perspective merges the individual and the organizational needs on a higher level (Orlikowski, 2000) to support the development of a common corporate strategy.

As a basis for our study, we conducted semi-structured interviews in a first step. Secondly, we independently coded the statements which describe success factors. The factors from DeLone and McLean were used as a starting point here for an abductive research design (Timmermans and Tavory, 2012) and complemented with newly deduced factors. When the list of factors from the interviews were complete, these were, in a final step, assigned

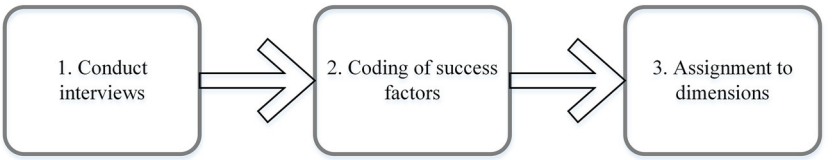

Figure 1. Research steps.

to dimensions, gained from the technology, organization and environment perspective which has been proven useful in research (Baker, 2012; Kuan and Chau, 2001; Pan and Jang, 2008; Tornatzky and Fleischer, 1990). The entire step-by-step research process is shown in Figure 1 and detailed information is provided in the following chapters.

3.1. Conducting interviews

Between December 2016 and April 2017, we conducted semi-structured interviews with experts from manufacturing companies which have already started their Digital Transformation process and are currently working on the topic. We carefully arranged the sample with a clear focus on the interviewee's experience, state of DT and role in the enterprise. The interviewees were identified mainly by calls in social network groups dealing with DT. Interested conversation partners contacted us directly and received the project information and interview questions. So, the potential participants could in the first step evaluate themselves as possible interview partners. Afterward, we received information about current projects in the companies. If the projects had a significant impact on the value creation process of the firm, the interviews were conducted. So, we intentionally selected the interview partners (Creswell, 2015). The technologies in use were described during the conduction of the interviews. This allowed getting deeper insights into the readiness of the companies to drive digitalization forward. According to Lerch et al. (Lerch, Jäger, and Maloca, 2017) many companies are still at the beginning of their transformation which is typical for the manufacturing industry. However, some participants already implemented many digital processes in their workplace and can thus be classified as pioneers of DT. This diverse sample opens up the opportunity to search for success factors at different stages of the digitalization process. We aimed to gain different perspectives on the subject. Therefore, we spoke to managers (decision maker), users of the technologies, and consultants. Even if user satisfaction plays a major role in the IS success model, we consider perspectives of decision makers and consultants of importance as they bring together experience from different projects with different degrees of success. Furthermore, most decision makers also act as users of digital technologies and sense the difficulties and possibilities of the technologies.

Due to the aimed widespread focus, we searched for interview partners from different manufacturing industries. The leading industries were automotive, engineering and agriculture (see Table 1 with interview numbers). We consider these industries as the primary target group for our area of interest, as these industries provide both: the application of smart assets as well as the production of smart and hybrid products. Other industries were

Table 1. Interviewees and their role.

Industry	Decision maker	User	Consultant	All
Automotive	01, 08, 14, 15	16, 19		**6**
Engineering	02, 05, 06, 07, 09	18		**6**
Agriculture machinery		04, 17	13	**3**
Chemical		11, 12		**2**
Metal industry	10			**1**
Consulting			03, 20	**2**
All	**10**	**7**	**3**	**20**

added in order to gain a wider focus and to work on a broader context. In total, we conducted 20 interviews with 11 companies. The interviews had an average duration of 37 min.

We structured the interviews into three major parts:

1. Introduction of the topic and a short presentation of the interviewee including DT projects (in order to create a trustful atmosphere),
2. interviewee's definition of major characteristics of Digital Transformation (in order to develop a common understanding),
3. narrative description of Digital Transformation success (including the major issues: What is DT success for you? How do you measure success? How do you make sure that you receive benefits from your investments? What are the success factors for your transformation process?).

All interviews were recorded and transcribed. The interviews were conducted in German and afterward translated by the research group for further presentation.

3.2. Coding of success factors

Following the concept of the qualitative content analysis by Mayring (2014), we were able to identify major success factors. This technique has been proven as a useful method to receive well-based explanations of a complex phenomenon (Vogelsang, Steinhüser, and Hoppe, 2013). We used QCAmap which is an online tool specifically designed to carry out the qualitative content analysis by Mayring. According to the content analysis, it is important to derive the coding based on existing theories and to follow coding rules (Mayring, 2014). Thus, in a first step, we oriented towards the IS success model by DeLone and McLean who identified 13 success factors in their study regarding e-commerce systems (see Table 2). These factors were nevertheless used as a starting point for the coding. We see the thematic restriction, but the model was also successfully proven in different scenarios (Iivari, 2005; Urbach et al., 2009). Thus, we regard the model to be of value in the field of DT, as IS technologies are one part of the DT.

Table 2. Success factors from the IS success model (DeLone & McLean, 2003).

Dimension from D&L model	Success factors for e-commerce
System quality	adaptability, availability, reliability, response time, usability
Information quality	completeness, ease of understanding, personalization, relevance, security
Service quality	assurance, empathy, responsiveness

We will not give scales or measures to rate success factors. It is the aim of this study to provide detailed information about the nature of DT success, the areas DT is affecting and the perceived impacts. Thus, we anticipated the need for further success factors regarding Digital Transformation. The statements which could not be allocated to one of the factors from the success model were independently named by the authors and afterward discussed. Thus, making it necessary to discuss the coding in which the coders disagreed to come to an inter-coder agreement (Mayring, 2014). The coding had to be carried out iteratively so that, as a result of the discussions, new factors were formed. With the help of the new formulated factors, the coding started again (iterative steps) until all statements could be allocated to one success factor.

3.3. Assignment to dimensions

After the identification of success factors, we assigned these to the dimensions from the TOE (technology, organization, and environment) framework (Tornatzky and Fleischer, 1990) which we assess as useful because DT does not only impact the technology but also organizations and processes. Moreover, company borders become blurred (Lucke et al., 2008), so that the environment needs to be considered regarding DT. The dimensions help to show (1) if the factors are technology related and (2) who is responsible for the factor. Thereby, firms can implement appropriate courses of action. The model was developed, improved and refined in iterative loops. All authors were involved in the consensus loop which leads to a permanent involvement within the research process of data generation and analysis and an enduring deduction and discussion of factors and dimensions (Corbin and Strauss, 1990).

4. Results

In the following, we present the results of the qualitative study. We describe the identified success factors. All success factors could be aligned with one of the three dimensions: technology, environment, and organization. These three dimensions are prepositions for DT's success. The success factors describe the dimensions over their entire bandwidth. All success factors from one-dimension influence this in the same direction. Since we

Table 3. Success Factors of Digital Transformation.

D	Success factor	Description	No.
Organization	Pilot projects	… are needed to learn from success and failures. Successive rollouts make it possible to quickly identify sources of error and correct them "on a small scale" before the entire company is affected.	64
	Prepare for future	… includes the ability to set up roadmaps and strategic as well as operational goals.	50
	Customer needs	… must be considered in two ways: with a focus on the product and a sense for the mutual trust to build reliable cooperation with the customer.	49
	Autonomy	… includes the decentral machine-controlled organization of production processes.	41
	Employee qualification	… changes due to knowledge intense work. Employees and organizations need to keep up with new knowledge. Ideas from employees can be used to be more innovative.	39
	Culture	… means to allow failures and sense opportunities. It is part of the change that it has to be established.	36
	(Big) Data use	… enables new ways of value creation but is also risky as enterprises also distribute their information.	23
	Management support	… includes the provision of projects with the resources, knowledge, and time needed.	23
	Usability	… ensures the fit between technologies and tasks.	16
	Interdisciplinarity	… affects the team structure. Employees from different disciplines and with different knowledge work together due to knowledge intense work.	15
	Total counts for organizational success factors		**356**
Environment	Connectivity	… includes the seamless data exchange within the/ a network.	57
	Transparency	… requires trust into the data exchange.	41
	Collaboration	… is necessary because tasks are not solvable alone due to complexity.	39
	Hybrid value creation	… is cooperatively proceeded along the value chain.	26
	Standards	… need to be established by international bodies.	15
	Total counts for environmental success factors		**178**
Technology	Infrastructure	… must provide open interfaces for the free scalable use of machines which enable operating sequences in short set-up times.	15
	Reliability	… of the system guarantees the right data.	14
	Relevance	… of data delivers the right data for the right user.	13
	Adaptability	… means a flexible system which can adjust to new information needs and the company using the system.	12
	Security	… is the base for the exchange of information. At the same time roles of users and allowance to access information needs a stricter control.	8
	Completeness	… of information needs to cover different aspects and alternatives.	7
	Availability	… secures the access to the system.	7
	Real-Time Data	… have to be available without delay.	4
	Total counts for technology success factors		**80**

take a holistic view, we have not sorted or restricted the success factors according to specific technologies or application scenarios. Thus, it may be possible in individual cases that not all success factors emerge. Since qualitative research offers rich information about the different usage scenarios of the same kind. We regard the following presentation as a sorted collection of possible factors and their combinations. The division into dimensions facilitates the assignment and also the practical work with the results.

With our qualitative study, we strive for a better understanding of DT's success. Therefore, we offer suggestions to stimulate and guide further research.

4.1. Identification of success factors

We identified 614 statements concerning the factors that impact the success of Digital Transformation technologies. The codes and success factors provide a n:1 relationship. Each code was assigned to one distinct impact factor, but each factor is built up from numerous codes. Doing so, we were able to detect 24 independent success factors that describe the success dimensions of Digital Transformation. Table 3 gives an overview of the results. We identified 7 of the 13 tested impact factors from the basic DeLone and McLean model. Most of these could be allocated to the technology dimension because the basic model focuses on technical IT factors. Furthermore, we identified 17 factors that provide characteristics that are specific to the Digital Transformation.

These are essential success factors directly connected with Digital Transformation. Most success factors were associated with the dimension organization which reflects the challenge but also the chance for companies to drive their own DT. Furthermore, the environment plays a crucial role for DT as many projects cannot be executed without other companies from the network. The results confirm the definition given for DT above. Technology is important and a driver but other dimensions need more attention and should be considered from a research as well as the practical lens.

Our results show the broad picture of the factors that determine DT success. Although we used the IS Success Model as a base, we cannot – as expected – completely support the model. The technological focus of the model is useful but does not picture the nature of DT completely. Two additional dimensions also foster DT success. Furthermore, we were not able to detect any factor that could be aligned to the service quality in the meaning of the basic success model. This could mean, that the emphasis of the participants is not very strong concerning the service quality from the suppliers of IS due to their advanced position in the technology lifecycle. Instead, we were able to identify several categories that imply a special and different meaning of service such as the quality of collaboration with suppliers. These are indicators of a shift in how value is created in times of Digital Transformation: enterprise borders blur and cooperation gets essential.

4.1.1. Organizational success factors

Most of the identified success factors (in total 356 statements) were allocated to the organizational dimension. One major expected change by DT

is the control of the production processes which shifts from a centralized to the decentralized machine-controlled organization. This requires higher **autonomy** (41 counts) of machines. "We have robots that work connected to build car bodies. It is important to connect the units to steer them from outside to become more flexible." [08-16][1] The connected machines control themselves autonomously. Moreover, an important capability for firms will be the ability to use and "to collect lots of **data** and provide these." [11-08] "By using the data that potentially lie behind it, I can build up knowledge that other competitors cannot build up in the context and can use it to secure my competitive situation in the long term because hardware becomes more and more interchangeable in the long term and knowledge is the key capital." [02-14] This opens up opportunities to meet expectations of customers like better services and connected devices. "And then the data is collected in such a way that you [as a farmer] know exactly where and when I have the crop yield." [16-06] "It was one benefit to meet the expectations of the customer. If you cannot meet these, you will not get the order." [06-19] The focus on the customer is still growing in today's business environment. Companies are dependent on their ability to understand **customer needs**. "We know what the customer needs by using design thinking; we try to work out solutions at the customer's site, with the customer." [10-14] Thus, customer needs was mentioned 49 times in the interviews. However, also internal advantages have to be realized. As is already known from research and practice, the system cannot be successful, if it does not offer benefits. "This means we take a look at the **usability** […] for the users to optimize the web front-end and other things again." [10-16]

To achieve these goals, companies need to evaluate and rethink their culture. **Pilot projects** was mentioned in 64 codes which is the highest value of counts. It implies a stepwise introduction of digital integration instead of a complete rollout for whole sites. One interviewee summarizes: "Pilot projects are important to realize how the whole issue operates and to see the difficulties." [01-18] This also points towards a new way of working and handling mistakes because people are developing solutions more quickly and trying things out. The working environment is becoming more agile. "You have to try it out first; then you find faults, then you fix these faults." [14-25] This is closely related to **culture** which explains a new direction of company values. "The working methods, the thoughts have changed." [10-08] "The impact of culture is very important." [15-23] One special aspect is an increased **interdisciplinary** working environment. "I think this is one of the major topics. Finally, the merging of engineering and informatics." [20-27]

Employee qualification and **management support** are two factors which are essential to every socio-technical system. Together they were mentioned 62 times. "The staff must be trained and prepared" [12-09] and "in sum,

you need support from the management" [06-13] represent the interviewee's reflections about these factors. Both factors refer to the readiness to understand what possibilities lay ahead due to the DT. Changes are inevitable to **prepare for the future**. "Thus, if you do not change, in the end, you will be left behind." [04-25] The need to prepare for the future is strongly linked to the capabilities of an enterprise to seize the gains of DT and to anticipate future developments. The enterprises must develop competencies in sensing future trends and be able to transform their business according to their strategy. The capability to discover useful innovations and use them successfully is more important than ever (Karimi and Walter, 2015).

4.1.2. Environmental success factors

To be successful in Digital Transformation not only a more cooperative working environment inside the company is necessary but also **collaborations** (39 counts) across company borders. The thought of cooperation requires to rethink the individual position in the enterprise as well as within the net of customers and suppliers. Still, research and practice do not deliver reliable solutions to bridge resort borders. "But also integration I would say into business networks." [10-04] This step requires a readiness for higher **connectivity** between enterprises. The success factor was mentioned 57 times in the interviews and thus regarded as very important. "The customer has somewhere a big fabrication, has hundreds of our devices at different cabinets, and now can see that collected in the cloud connection." [07-17] This also goes with the supplier side. "Externally it is the case that our suppliers have to play along because without connectivity we cannot get any further there." [15-28] Much information is generated from the products, the processes and the integrated parties. The relevant data are meant to be **transparent**. This is especially useful for customers to trace information back. As one interviewee highlighted: "traceability: which batches, which material, and which components were installed." [09-01] "The success is of course that we have traceability." [12-12] "Finally, it is a high degree of transparency that is created there that can be both: negative and positive." [20-28] During the interviews, the need for **standards** to exchange data was expressed. "I think you have to make it a standard, so suppliers do not have to think about [name of possible purchasing company] or another solution for us, but there must be a standard for it." [20-20] "It is one major point, I think, to provide a standard. We have to push on standards for interfaces and other things." [20-25]

The role of the manufacturing enterprises shifts to a more service-oriented one (**hybrid production**). "Therefore, the priority of service for mechanical engineering will grow." [05-02] This also implies a shift of the customer role. The customer does not only receive the product and the

services but also provides data. This dimension implies a modification in the value generation strategy of the enterprises. Value creation is no longer bound to the real products but can also happen via additional services. This new dimension is strongly linked to the strategy of the enterprise (Matt et al., 2015; Nagy et al., 2016), as new products and additional services reshape the value creation. DT offers both: new innovative products (like data and smart assets) and new business models (Christensen, Baumann, Ruggles, and Sadtler, 2006; Markides, 2006). People are also worried about the possibilities that arise with new products and the collection of big data. This is why a new way of empathy must accompany the new way of value generation. "You have to tell the consumer about the advantages of more automated processes. […] The new products are not worse." [13-26]

4.1.3. Technical success factors

First of all, the systems have to provide**, reliability, adaptability**, and **availability**. Technologies have to be tailored for the companies. "Reliability, as I said before, is an important reason." [04-28] It was mentioned 14 times during the interviews. "You have to know that almost every technology that is used in our factory is particularly adapted for us." [08-06] "Highest availability, that is, of course, a very important issue." [08-08] Moreover, the data have to be of certain **relevance** and **complete**. "Do we have enough data about the farmland?" [15-25] "[We have a problem] if our database is not good enough if we do not do the preliminary work well enough." [05-20] "Yes, get your small data right. This is a catchword, which we often use here. First of all, to define the data source correctly: if the correct data is written away, the data is reliable, the data is correctly configured, parameterized." [14-32] These data can be used for **real-time** applications such as "in real-time, we can also see what is already where in the logistics chain on the way. We track data on quality and know what passed where through the RFID scanner. This is also intensively rolled out now." [14-36] As already mentioned, **security** is of special interest. One interviewee recapitulates: "This is associated with the description of the interfaces down till the last variable. This is associated with the cloud infrastructure that has to be there; it also has to be established that the involved companies trust in the structure, this is very important that the data handling and the data security be all right." [06-38] So, companies also need to provide a useful **infrastructure** (15 counts) for DT. Open interfaces are needed. Higher scalability of machines can improve set-up times. "When I can produce a larger variety of products […], this gives a good return. Fewer inventory costs, more flexibility, but the machines have to adjust themselves." [20-11] This goes hand in hand with the mentioned real-time data and also transparency of data which includes a kind of retraceability.

4.2. Propositions on DT success

DT affects people, processes, and products on all levels (Brynjolfsson and McAfee, 2011). We complemented an aggregated technology-related dimension with success factors from the IS success model by an organizational as well as an environmental dimension. The three dimensions are described by different success factors (see Table 3). The interplay and composition of success factors per dimension can vary regarding different scenarios in practice.

DT affects the whole organization in the way people work, the tools, and techniques they use. As DT is a fast-changing process, the education of employers is a current topic for enterprises. The change of work contents affects all departments. Organizational aspects need to transform. Open culture with agile working conditions and pilot projects is necessary. Employees need to get involved by bringing in ideas and teams should be set up more interdisciplinary. Companies also need to improve and train competencies like Big Data. The dimension organization provides the strongest strategic impact on the success of DT as this dimension contains the effect of DT on long-term goals, the market alignment and the improvement of the product and service portfolio. The factors that describe and trigger the organizational perspective of DT success are expected to act durable when they provide a strategic alignment.

Proposition 1: *A dynamic and flexible organization is necessary for digital transformation. The organization has to give room for improvement, technical capabilities and resources. The better the organization is aligned towards change, the more likely is the success of the DT.*

Especially for the topic of DT, the environment plays a crucial role because company borders are said to blur (Lucke et al., 2008). Firms have to interact in innovation networks (Galvagno and Dalli, 2014) and manage their competence exploration (Gersch, Goeke, and Freiling, 2009). More collaboration requires higher connectivity and also needs more transparency. The dimension environment comprises both ends of the value chain: the supplier as well as the customer. The high interconnectivity enables a larger exchange of ideas. At the same time, this opening is also risky, as companies make themselves vulnerable about their data and core processes. Therefore, it is important, that legal requirements are transparent and compulsory for all participants. The environment is the dimension that can be probably least influenced by the company. Companies that want to promote the success of DT must orient themselves towards the legal and relational level when dealing with third parties.

Proposition 2: *The environment of the company influences DT success. Enterprises need to work together to create stronger value chains for DT. The base for a good cooperation is set on a legal and on a relational level.*

The dimension technology can be described by the current infrastructure which needs to offer useful interfaces as well as real-time data processing. Moreover, systems in use need to be reliable, available and adaptable. Important aspects are system and data quality. As DT requires a high interchange of data, security is also one major success factors for DT. Our findings motivate the following propositions regarding the dimension technology as a predictor of DT success.

Proposition 3: *Technology is a prerequisite for DT. Without (secure and reliable) technological innovations, DT is not possible. However, driving only technology forward is not enough to gain benefits from DT.*

5. Implications and outlook

By following an abductive research design with a qualitative approach, we were able to identify and describe significant success factors of Digital Transformation. We allocated the factors to three major dimensions: technology, organization, and environment. As a starting point, mostly technology related factors from the IS success model by DeLone and McLean (2003) were identified, for example, reliability, adaptability, availability, completeness, relevance, and security. However, the given factors do not explain the whole complex phenomenon of DT. While DeLone and McLean developed the model to explain IS success, the perspective of DT is much broader and includes not only software system related factors. Hence, 17 new factors were identified. These mostly describe the organizational as well as environmental dimensions of DT.

The impact of success factor research has been criticized because of samples, general validity, and procedure. No clear impact on the performance of companies can be found. Thus, there seems no usefulness of results for practice (Nicolai and Kieser, 2002). However, there is still a desire and need to understand the success of technologies (DeLone and McLean, 2003). Decisions can ex-ante be supported and ex-post be evaluated. As statistical approaches try to prove significant relationships, we regard our qualitative approach as useful for success factor studies. This enables us to describe dimensions of success factors and give in-depth insights from practical experiences (Graebner et al., 2012). We see our study as a base for enhancing success factor research. Due to the number of cases and interviews, we cannot claim overall generality but give an insight. We observed the success factors of Digital Transformation from a holistic view to capture the whole issue of transformation. To validate the factors in further research, we suggest examining the dimensions identified for single technologies in a Digital Transformation context. This would show how stable the results of this holistic view are, compared to a specific view.

Additionally, we expect to gain further insights based on applying the results in other branches like the service industry. Furthermore, researchers should focus on how success in Digital Transformation can be measured. The deduction of key performance indicators should consequently follow in further research. This article can only give brief examples based on our data. We would appreciate research applying the success factors for a further understanding of the strategic benefits.

Nevertheless, the results of this study may help practitioners to detect potential success factors for their DT. The aggregated merger of success factors from different perspectives can be used to classify the own situation and may help to deduce further operations to emphasize DT success.

Note

1. [<*Number of Interview*> - <*Number of statement*>]

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