A Taxonomy of Barriers to Digital Transformation

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Abstract. Companies expect significant long-term gains in efficiency and productivity through digital transformation (DT). New ways of combining products, processes, and data-driven services, as well as new business models emerge. However, the rapid development of the DT leads to constraints regarding its realization. Barriers hinder companies to realize possible advantages out of DT. If firms promptly recognize potential barriers, they can reflect upon these challenges and can take well-coordinated countermeasures. Social, technical and socio-technical problems address different stakeholder and ask for specific solutions. Therefore, our study aims at developing a taxonomy for barriers to DT to enable researchers and practitioners to identify and classify existing barriers. For deriving the dimensions and characteristics, we collected data by conducting 46 semi-structured interviews with experts and enriched these by looking at the literature on DT barriers.

Keywords: Barriers, Digital Transformation, Taxonomy, Qualitative Research

1 Introduction

The increasing digitalization affects the industry and industrial processes [1]. A second machine age is announced to describe significant impacts of technology on the way of working [2]. Digital transformation (DT) is understood 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)." [3] It is regarded as a major change in business and society [4] and is often described as an ongoing process [5]. One implication of digital transformation (DT) is the overall digitalization and cross-linking of the value creation process [6] as information and communication technologies merge with production processes. Digital transformation marks the whole business and must be taken up by the enterprises' strategy [7]. As DT affects people, processes, and products on all levels [2], it implies more than just an application of technology. Because of these overall implications, enterprises expect significant long-term gains in

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efficiency and productivity by applying DT [4]. New ways of combining products and services [6] as well as new business models such as digital platforms emerge [8, 9].

Even though significant benefits are expected, many firms still struggle to realize transformation potential due to different barriers [10]. Only every sixth company in Germany has a high willingness for digital transformation [11]. So, the adoption of digital innovations is very faltering. Understanding present obstacles to planning countermeasures is critical. The rapid development of the digital transformation in companies leads to problems regarding the realization because of the development, diffusion, and implementation of new digitalized processes face many difficulties [12]. These difficulties or barriers (terms are used synonymously here) are understood as something that stands in the way of the realization of a project or the like and cannot be mastered without further ado.

The barriers to innovation approach [13] is often used to identify barriers and group these. Regarding DT, lists of barriers in specific technological contexts and different industries already exist [14, 15]. However, comparing and analyzing these to come to an overall view is still difficult. Taxonomies, which show dimensions and their characteristics, enable researchers and practitioners to understand, communicate and apply research findings in a more comprehensive way than lists. They help to "[…] structure or organize the body of knowledge" [16]. Describing taxonomies of barriers to DT are still missing. Thus, the goal of our study is to derive a taxonomy of DT barriers to contribute to the barriers literature. Different dimensions which can explain and classify these barriers are identified and analyzed. Categorizations help to generalize and lead to a better understanding. Therefore, the research question is: How can barriers to digital transformation be categorized into a taxonomy?

As the domain lacks theoretical foundation [17], we expect a qualitative approach to be useful to gain insights on barriers. On a broad database of 46 semi-structured interviews, we empirically derive the taxonomy in accordance with the procedure from Nickerson [18]. We use the collected material to develop a theoretical frame [19] which assists with overcoming the barriers. Results from the literature on DT barriers is also used to enrich the understanding.

For our study, we follow a holistic view. Digital transformation is said to transform whole value chains [6] which leads to a paradigm shift in business and focuses on the organization, rather than technological challenges [20]. Many researchers concentrate on distinct technologies or departments to describe the changes. As DT is still ongoing and many enterprises are at the beginning of the digital change, holistic approaches that regard the whole process of value creation are rare.

In the next chapter, we will define the term digital transformation and give an overview of existing classifications as well as barriers to DT literature. The methodology is presented in the third chapter. Afterward, the taxonomy is deduced from the interviews. Results from an evaluation and an outlook are shown. Finally, this paper highlights the contribution and describes limitations.

2 Related Work

As the field of DT is still rather new and many areas, that are touched by this, do exist, there is a certain need to classify and sort correlated phenomena. Several approaches exist, that set up classifications in distinct fields of DT research such as technologies (like cloud computing and big data) [21], digital strategies [17, 22, 23] as well as product and service enhancements [24–26]. Other researchers concentrate on the technology focus such as system architectures [27]. Furthermore, there is research on correlated topics like legal and regulatory frameworks [28] and DT research (methods) [29]. Taxonomies for certain industries also exist [30, 31]. These taxonomies help to structure the field of research on DT which is necessary because this is still a growing topic missing theorization [17]. Researchers already examined the positive aspects of DT success and developed a taxonomy of benefits [32]. We consider a systematic reappraisal of the opposite side of DT, which are the barriers that hinder a successful transformation, as a further valuable approach to understand DT. Thus, we regard the structured development of a taxonomy from a hindering point of view as important to identify, structure and overcome existing barriers to DT. Recently the research area of barriers is still dominated by unstructured lists which are hard to compare.

One of the first approaches to identify barriers is a study by Piatier from which the barriers to innovation approach has arisen [13]. Different classifications of barriers came up in literature since the approach was formulated. Often, these are differentiated in internal and external which are further subdivided. Internal barriers include resource-related, management-, time-, culture- and systems-related as well as human-related challenges. External barriers are subdivided into supply-related, demand-related and environmental-related [33]. The classification between internal and external has been proven as useful in many studies in different contexts [34, 35]. D'Este et al. [36] differ between revealed barriers describing the process of innovation and deterred barriers meaning the obstacles from adopting an innovation. In a study of Coad et al. from 2016 [37] items for four different barrier factors were used in a questionnaire: cost, knowledge, market, and regulation. Another differentiation has been pointed out in firm-related, project-related, product-related, and market-related factors [38]. This study also highlights the second side of the coin regarding barriers – success. Often success factors are described as the opposite from barriers. Success is more often in the center of research compared to the negative side of barriers [39]. Critical success factors are defined as "those few things that must go well to ensure success" [40]. The approaches are closely related to the adoption theory which deals with either adopting (success) or rejecting (failure) IT [41]. Although there is a long-lasting tradition of barrier research, a homogenous classification or guideline to describe barriers is still missing.

Especially in the dynamic field of digital transformation, classifications need to be developed. First studies identifying barriers in this context recently arise. The closely related "challenges" of DT are discussed in different approaches. These are, for example, strategic, organizational and cultural as well as implementation related [42]. Technical and market relevant challenges like time to market also exist [43]. Bilgeri and Wortmann [14] identified 16 barriers to innovation in an IoT context. They could

highlight that DT also leads to new barriers referring to the knowledge of the people. The topic regarding business models is analyzed by different authors [14, 44]. Dremel [15] found six barriers to big data analytics for the automotive industry. In the context of the development of digital services through innovation contests, specific barriers like difficulties in finding competent team members are discussed [45]. So far, actual findings were valuable but they are generated in specific contexts. The results remain at a very detailed level and hardly allow systematic guidelines for action to be developed. They are heterogeneous and hard to compare, because they are often randomly compiled lists focusing on distinct aspects. Holistic approaches dealing with DT in a broader sense [46] are rather rare. We emphasize a certain need to characterize, describe and compare barriers to DT to be able to overcome these. A taxonomy is the first step to do so.

3 Method

As "fast-changing phenomena are difficult to investigate solely through the use of traditionally privileged methods" [47], it seems appropriate to conduct qualitative research in the context of DT. 46 interviews build the base for our study. In a first round, data from 30 participants were gathered. To check theoretical saturation [48], we gathered data from 16 more participants. Because no further impulses could be collected from the new data, we assessed the data set as useful for our purposes. We preceded the interviews in 31 different enterprises in varying industries. We aimed for a broad sample to be able to capture common base between different industries [49]. The taxonomy will be useful for a broad range of situations. Therefore, a purposeful sampling method was applied [50]. The selection criteria included a necessary affiliation of the interviewees to projects or departments explicitly dedicated to digital transformation in their company. All of the enterprises already implemented digital technologies successfully or/and were involved in digitalizing their processes and products. The dominant industries were automotive (7 companies) with mostly original equipment manufacturers (OEM) and agriculture (8 companies) with mostly agricultural machinery manufacturers (AMM). The length of the interviews ranges from 15 to 91 minutes with an average of 43 minutes. The interviewees are between 26 and 58 years old. Two interviewees are female and the rest male. All have German as mother tongue. Therefore, the interviews were conducted in German and mostly at the interviewee's offices. Table 1 gives an overview of the participating interviewees. Industries, an identifier for case companies (to be able to associate the statements from interviews with the companies) and their role in the supply chain are shown. Many interviewees provided knowledge from the perspective of a user, producer and customer of digital products or services. The interviewees from the agricultural sector, for example, use digitalized production processes, sell machines with digital abilities and digital interfaces, and they buy digital services for big data applications which they use for their products and production processes.

All interviews were recorded, transcribed and translated for research purposes. An interview manual was used including (1) an introduction regarding digital

transformation in general (including the understanding of the topic from the interviewee's perspective), (2) questions on the actual situation of DT and related barriers (including situations of success, frustration, emphasized support, and barriers), and (3) a subsumed report of three major barriers to DT.

Table 1. Overview of Interviewees

Industry	*Case*	*Role*
Automotive	Au1- Au7	OEM; supplier; service provider
Agriculture	AC1-AC8	AMM; food producer; farmer
Plastics Industry	P1-P3	processing chain; manufacturer
Steel Industry	SI1-SI3	processing chain
Other Manufacturing	OM1-OM4	engineering; cosmetics
Services	S1-S3	service provider; facility mgmt.; software solutions
Consulting	C1-C3	consultant

For the development of the taxonomy, we combined the approach according to Nickerson [18] with a qualitative content analysis [51]. We specified "meta-characteristics" by reading relevant literature regarding the field of barrier research. They serve as a guideline for the deduction of objects (Steps 4e – 6e) from the empirical material gained from the interviews. We used empirical data as the main source to develop the taxonomy. However, results from the literature were used to complement the understanding. The steps from Nickerson as well as our application for this study is shown in Table 2.

As an approach, we mainly used the empirical-to-conceptual procedure to gain insights on the characteristics (C) first. Afterward, we clustered the obtained characteristics according to dimensions (D). We openly coded the interviews [52] to iteratively develop a well-prepared database. We used the online-tool QCAmap for coding the material. Statements about barriers to DT and similarities regarding the structure and possible characteristics of the barriers were searched for. We sequentially adjusted the research for a simultaneous collection of data and analysis. All authors were permanently involved in the research process of data generation and analysis. Thus, making it necessary to discuss the coding in which the coders disagreed to come to an inter-coder agreement [51]. This led to a repetitive induction and discussion of concepts [53]. The cross-fertilized relationship between analysis and data generation as well as the development of the taxonomy led to a complex process of iterative revisions [54]. The research process was characterized by a comparative method [52] to deduce logical and consistent categories of barriers to digital transformation. Besides the data from the interviews, we included corresponding research streams for the development of the taxonomy. These also implied a conceptual-to-empirical iteration which complements the procedure.

Table 2. Development of the Taxonomy

Step by Nickerson	*Application of Steps*
Step 1: Determine meta-characteristic	(1) who is affected by the barrier; (2) major implications; (3) next steps for barrier
Step 2: Determine ending conditions	Going in iterations; no new, merged or split D or C in the last iteration; at least two Cs under every D
Step 3: Choose approach	Mostly empirical-to-conceptual
Step 4e: Identify (new) subset of objects	Coding of barriers and/or identification of barriers from literature
Step 5e: Identify common characteristics and group objects	Check context of barriers in interviews and/or look for characteristics in literature
Step 6e: Group characteristics into dimensions to create (revise) characteristics	Name dimensions independently and discuss within researcher group
Step 7: Ending conditions met?	Check independently by all authors; only if all agree, the process ends

Nickerson does not intend the last step of our research approach. Finally, we evaluated the taxonomy on the base of a qualitative interview. We chose a sample of ten interviewees and asked the interview-partners to apply the taxonomy with the help of a self-chosen case example. Afterward, we asked for an assessment and explored additional dimensions. The sample consisted of practical users (mainly IT consultants) and researchers in the field of DT. None of the participants was involved in the constructive analysis of the model or the creation of the taxonomy. As the sample of ten is rather small, we regard the evaluation as ongoing.

4 Taxonomy of Digital Transformation Barriers

During our research procedure, we deduced nine different dimensions (Table 3) that help to describe and explain the barriers to DT. The dimensions provide none or just parsimonious overlapping.Some dimensions are slightly connected (e.g., effect and duration). Characteristics describe dimensions. They explain the quality of the barriers. Some dimensions seem obvious to describe barriers to DT (e.g., stakeholder, impact and IT integration). Others needed a careful analysis and interpretation of the context (such as visibility, nature, solvability, duration, effect, recipient). Any dimension alone can be used to cluster or group existing barriers. However, the interplay of dimensions delivers a multi-focal view of the problem. The taxonomy helps to find out who is actually affected by the barrier (stakeholder, impact), what are the major implications (IT-integration, visibility, nature, solvability, integration) and what is the possible future of the problem (duration, recipient). Furthermore, we try to align the dimensions to related research streams.

Table 3. Taxonomy of DT Barriers

Dimension	*Characteristics*		
Stakeholder Who emphasizes the barrier?	individual	organiza-tional	environ-mental
Impact Which level does the barrier impact?	internal	external	
IT-Influence How strong is the influence of IT?	social	socio-technical	technical
Visibility How obvious is the barrier?	hidden	visible	
Nature What does the stakeholder sense?	standing by	fear of	lack of
Solvability What is the actual status of the problem?	low	high	
Effect How huge is the effect on development?	no	slow	stop
Duration How long will the barrier last?	short-term	long-term	permanent
Recipient Who may solve the problem?	inner circle	outer circle	

Stakeholder. The dimension stakeholder shows who emphasizes the barrier. The differentiation between the stakeholder groups is inspired by Coad et al. [37] who concentrated more on the level of who/what is affected. The stakeholder is not necessarily the person who expresses the barrier. Barriers often result from a lack of adoption. Adoption proceeds on different levels [55]. The level of impact is therefore related to the individual [56], the organization [57, 58] or the surrounding environment [59]. “Especially the internal employees. They are left alone. They do not know how they can handle this on their own.” (AC8) The characteristic organizational implies the core-enterprise as well as corporate networks for development and knowledge transfer. “It is all about cooperation. If data are not shared, the [digital transformation] won’t be a success.” (Au2) Customers [43] and suppliers (“The more change, the more risk to fail. That is, what the customer realizes” (Au3)), but also governmental or other third party organizations are subsumed with the term environmental.

Impact. Barriers to digital transformation do not only affect the stakeholders themselves but their surroundings as well [13, 34]. It is a question of where the barrier occurs. Therefore, we identified two contrasting forms of impact. The internal view, including employees, departments or the whole company, can hinder the pervasion. Internal change resistance [60], fear of high investments [36, 45] or lack of skills [61] proceed here. "We have a change in skills needed.” (Au5) However, digital transformation also implies the blur of borders and forces cooperation on a business

level. “Network integration will be the biggest problem.” (AC1) Therefore, often external partners, customers, suppliers or others are also affected [8]. “Soon the digital transformation will change the market from buying things to using data. This will affect the suppliers.” (C2) Still, enterprises complain about the non-existence of legal standards. Using their market power, companies can develop quasi-standards in the new markets of DT. “Currently, in the software development, enterprises define the interfaces. […] I expect problems of norming occurring in the future." (OM2) Due to blurring borders, “internal” might mean more than just one company, e.g. in the evolvement of innovation networks [62].

IT-Influence. Digital transformation is to some extent a process of IT adoption [15] to achieve success [63]. Hence, barriers to DT can affect different stages of human-computer interaction caught between technical, socio-technical and social barriers. The pure technical barriers often result from a lack of technical standards [64], security aspects [65], and integration to the existing system environment [66]. “That is the problem. Digital transformation means: to work in a big general store with hundreds of different technologies and solutions.” (Au2) Furthermore, the access to network technologies slows down the DT. “One problem is the lack of network speed at specific locations.” (Ac1) The socio-technical implications refer to the knowledge of the workers and the way the technology is used [67]. “They left the people on the shop floor alone. That reduces the quality. There was no one left, who cared for the problems because they were all in front of their computers.” Moreover, the clear social implications are triggered by the DT but relate more to social effects like the fear of unemployment [2]. “Yes, I guess, many workers are afraid, that digitalization of works implies the loss of the workplace.” (AC8)

Visibility. This dimension describes how obvious a barrier is for third parties. Reasons for the hiding of barriers differ. The fear of repercussions, avoiding conflicts and even anxiety of job loss and harassment play an important role [68]. Especially barriers that rely on personal problems and estimations are slightly invisible. “Often the people do not tell. However, they are afraid.” (S2) Talking about barriers increases visibility. Furthermore, technical problems can be hidden and only appear when they accumulate. However, visibility is dependent on the observer. What is obvious for one group may be hidden from the other. Visibility, as well as existing barriers, can be very dynamic. "You cannot predict when the feeling of employees regarding the project changes, but suddenly it does.” (C2) Visible and invisible barriers have also been observed in case studies in research [69].

Nature. To understand what the stakeholders perceive and what they sense eases the later solvation. We differentiate three manifestations: standing by, fear of and a perceived lack of. The transition between these characteristics is often seamless. At an early stage of change for innovation, people and organizations prevent from changing existing structures. This behavior can be named resistance to change or the desire to stand by and can also be found in innovation research [70, 71]. “Possessive thinking, traditional role administration, […] they hinder the process.” (Au5) Many barriers also result from deficiencies. “The lack of standards is one of the major barriers to network integration. Moreover, of course, the habit of interdisciplinary co-working.” (Au5) For many enterprises, the implied investment and the lack of free capital plays an important

role. “Initially it is expensive, and we do not save money at first glance.“ (Au1) Moreover, we detect a large group of unspecific fears that hinder the successful digital transformation. “There is much diffuse fear. Diffuse is important in this context.” (Au5)

Solvability. Solvability describes the actual status of the problem or barrier. Do the subjects of the obstacle consider the impediments as solvable or not from the current status? The classification of a barrier within this dimension might change over time as the status of its solvability might change. There are for example barriers that are (from the actual time of consideration) not solvable, such as standardization of interfaces and legal policies [72]. “From my point of view, we suffer from deficits of the technology. To name it: we have striking lack of standards.” (C1) Then again, other problems are more easily to solve, such as missing skills. “We need to […] train future skills.“ (SI1)

Effect. It is important whether the barrier has the potential to lead to massive interferences of an enterprises’ DT. We gradually distinguish the effects regarding how massive the barrier affects the DT process. Some implications seem to be negligible while others may stop the digital transformation process. A missing legal base for the use of data and the interconnection of firms can harm the DT of a company’s network [73]. “There is no improvement in sight. We realize that some things like works council, data protection statements massively brake the development.” (S2) Otherwise, barriers like a lack of technology acceptance from a few employees are threatening but not existential. “We worked with the employees. We went there and took a look at the situation. Why didn’t it work? Moreover, we included them in the development process.” (P3) There are also several research contributions dealing with the nature of technology acceptance [56, 71] and ways to handle [74].

Duration. The estimation of the duration of the barrier is also necessary to consider for the future planning of DT. The length of the barrier may influence strategic planning [10]. “What are we doing? We have to change as an organization. Moreover, this is difficult: to change the whole business model.“ (AC2) Many interviewees see the DT mainly as a long-term challenge: “There is still a lot to do to find the right solutions.” (Au4) Research about DT maturity may help to assess the duration of change processes [72]. We chose the dimension duration rather than a dimension that aims at the processual aspect including different states of adoption (suggested by Henriette et al. [42]). We consider the differentiation of adoption stages as less applicable, as the stages are often overlapping and they differ even within the enterprises as rollouts often proceed in several steps.

Recipient. Considering there is a possible solution for the barrier, it is central to understand who may solve the problem. We differentiate the inner and outer circle [75]. While the inner circle reflects the changing organization, its parts, and partners, the outer circle comprises legal institutions and governments. It is often up to the people to foster the DT. “I like to join community meetings. […] We share knowledge, and we exchange views.” (AC2) We assume that there will often be a group of people and institutions who remove barriers [42]. The overcoming of barriers is seldom limited to individuals. Schools (“It is a major barrier: the skills. IT should start in school.” (AC8)), governments (“The biggest barrier is the whole legal thing.“ (Au2)), and the people have to work together. „And it is due to the people, the organizations, and institutions

beyond our organization like trade associations to become friends with the whole topic." (Au5)

5 Discussion and Future Research

The evaluation of the model confirms the usability of the taxonomy. None of the respondents had a problem naming a barrier for DT and describing the problem using dimensions and characteristics. Using a 4-point-Likert-scale (very useful, useful, not useful, annoying), most respondents rated the model as useful or very useful for identifying, describing and discussing the barriers. However, the taxonomy is considered only slightly useful to find solutions. The group of consultants requested more space for solutions (e.g., for the resources needed to solve the problems) and the way to communicate the barrier. The group of researchers suggested further gradations for the characteristics. All respondents confirmed the high usability for the discussion of barriers. It will be part of future research to find out how the taxonomy can be used to identify barriers within DT projects. The taxonomy can be enhanced with dimension regarding the salvation of problem. Since the evaluation is not yet complete, we aim for future research at questions like: Which industry-specific adjustments of the taxonomy have to be made? How can the identification of barriers promote the formulation of a DT strategy [10]?

By using this taxonomy, one can develop a profile of any barrier which can help to overcome these challenges. For example, a wide discussed barrier to DT is the fear of losing jobs [2] which is often emphasized internally by individuals. It is a social barrier which is in many cases not visible to others. This could also mean that the solvability is complicated. It could affect others and last permanently. The inner or outer circle could be responsible for salvation. These interpretations of the barrier are not fixed. They depend on the company and the specific barrier that hampers DT. So, the taxonomy is useful in practice, if it is applied by companies to identify characteristics of barriers and thus be able to find solutions. In this example, employees would need to be educated about further projects and their impacts.

Though we carefully conducted this research, there are still limitations to our work. Even though the holistic view implies advantages regarding the usefulness of the taxonomy, it is also a limitation because the object of analysis is broad. Moreover, the qualitative approach implies limitations by nature as results could be due to the sample and subjectivity of the researchers. We tried to minimize this by coding interview data independently and discussing results in iterative rounds. Furthermore, the sample was chosen broadly to cover many different opinions. Besides this qualitative approach, it could be very fertile to quantify the characteristics of the dimensions. Moreover, it could be of great value to combine the findings of this study with case studies focusing on the overcoming of barriers. The evaluation and quantitative verification of the taxonomy is a call for additional research in this area.

6 Conclusion and Contribution

Any barrier in the field of DT leads to a slow down or complete termination of the digital change in enterprises. It is of great importance for research and practice to understand barriers to digital transformation. Different lists of barriers already exist in research but it is hard to comprehend those. To understand the barriers from a broader perspective, we developed a taxonomy that implies dimensions and characteristics of these to describe and classify barriers. The taxonomy consists of nine dimensions. Each of them answers questions on barriers to DT. Potential barriers can be classified by using each dimension of the taxonomy. Then, the characteristics can be used to describe barriers more in detail. The taxonomy was the result of a research process that orients towards Nickerson`s approach [18]. The findings of this study rely on the base of a qualitative analysis of 46 semi-structured interviews. To ensure the quality and validity of our conclusions, we enriched the results by further research on barriers.

The first and still ongoing evaluation of model proves the usability of the model so far. The structured taxonomy helps to identify, describe and discuss barriers to DT in research and practice. The taxonomy can foster the creation of a knowledge base for the ongoing process of DT [4]. Practitioners can use the taxonomy to understand and detect obstacles of DT as well as deduce action plans for a successful transformation. If firms can reflect upon their challenges, countermeasures can be taken.

Our approach builds upon the barriers to innovation literature by integrating barrier types like internal and external barriers [33] but adding new dimensions like visibility and solvability to structure barriers. Researchers in the field of barriers to DT research [e.g., 14, 15] can use the taxonomy to classify the identified barriers. Future findings can easily be aligned with actual and further research and connections can be discovered. We hope to foster the discussion on the understanding and structuring barriers.

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