Authors' pre-published version (2022)

Overcoming Barriers to Digital Transformation – Development of a Decision Matrix

Henning Brink[1][0000-0003-4426-1790], Sven Packmohr[2][0000-0002-3488-708X], and Fynn-Hendrik Paul[1][0000-0002-9944-5717]

[1] BOW, Osnabrück University, Osnabrück, Germany
{henning.brink, fynn-hendrik.paul}@uos.de
[2] DVMT, Malmö University, Malmö, Sweden
sven.packmohr@mau.se

Abstract. Digital Transformation (DT) impacts industries, non-profit sectors, higher education, and even societies. As connectivity technologies blend with physical assets, modifications in value creation processes are provoked. These modifications may have positive impacts such as higher effectivity, enhanced business models, and improved customer connection. However, realizing a DT is a complex endeavor. Specific properties, so-called barriers, hinder the DT journey. Thus, it is essential to grasp the barriers and indicate ways to overcome them. We develop a decision matrix for overcoming barriers using qualitative data from participants working in different sectors. This work builds upon a pre-study developing a barrier classification and enhances it with specific recommendations such as "define clear DT responsibilities". Thus, our work takes the development of plain barrier classifications further. From a theoretical perspective, this work contributes to developing hypothetical models of the effects of recommendations to overcome barriers in the future. From a practical perspective, companies can use the recommendations to plan actions to take.

Keywords: Digital Transformation, Barrier, Countermeasures.

1 Introduction

The advances in overall digitalization and the association between digitalization and value creation are at the heart of digital transformation (DT). DT alters processes and workflows through the integration of information and communication technologies. Thus, transformation is described as a phenomenon bringing significant changes in "traditional ways of doing business by redefining processes and relationships" [1]. Following this viewpoint, DT includes a wide variety of research fields ranging from technology and software products to strategy and business models. In the discipline of Information Systems (IS), these fields intersect [2].

DT opens up for a combination of smart products and services, leading to servitization [3]. With the emergence of digital platforms and possibilities to capture real-time data, new business models that optimize the processes occur [4]. In corporations, expectations about DT are high as it indicates improvements in efficiency, productivity,

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

customer contact, and competition [5]. DT changes workplace settings and by this affects employee functions and competencies [3]. Thus, DT lays the foundation for gaining competitive advantages. Digital pioneers grow faster and are more profitable [6].

However, expectations are not realized easily. Companies experience difficulties in grasping DT potential [7]. Actually, an adoption, a diffusion, and a development of revised and digitalized processes face several barriers [8]. Thus, less innovative corporations are susceptible to underestimating the efforts required to drive innovations [9]. If companies do not consider and tackle these barriers, they would fail in the accomplishment of DT potentials [10].

Studies reporting failure factors are less prevalent than those that report success factors [9]. Thus, we address this research gap by focusing on the failure factors which could slow down, halt, or deform a DT. We address these failures as barriers [11]. A recognition of the nature of barriers, their causes, and related stakeholders is vital for the identification of countermeasures and reduction of the negative effects. In IS literature, structured approaches to connect barriers and countermeasures are lacking. Looking at the most frequent models for digital readiness and maturity, only a minor part provides suggestions for overcoming [12]. Thus, the research question was determined as follows: How can companies overcome barriers to digital transformation?

Within this research, we matched barriers with proposals for overcoming them. Our sector-independent research contributed to a wider discussion of barriers within the IS community. As our study connected barriers with their countermeasures in a structured way and culminated in a decision matrix (DM), it lies the groundwork for hypothetical models to model causal relationships. The most common reaction to a barrier in companies is trying to avoid them or implementing ad-hoc countermeasures [9]. Our findings could be employed by industrial practitioners to map the DT barriers and to produce well-aligned countermeasures for a successful DT. Also, our results contribute to the development of readiness and maturity models. If the DM is converted from a two-dimensional into a sequential approach, it could be a base for step-wise models.

We followed the succeeding structure to resolve the research problems: The introduction section was followed by a brief theoretical background. In the third section, we described our research design, including the coding approach. The fourth section discussed the connection between the barriers and the countermeasures. A DM was presented to identify countermeasures. The paper ended with discussion and conclusion sections that included the study's limitations.

2 Theoretical Background

Interest in DT has increased in research and practice. Aggregated definitions [10, 13] aim at generic descriptions of the impact of digital technologies on corporate enhancements. Specifically, these enhancements are associated with value creation, organizational structure, and distribution of finances [7], leading to a complex DT due to the requirement for adequate management [14]. DT is different compared to IT-enabled organizational transformation (ITOT). DT redefines value propositions, while ITOT supports these [15]. ITOT is similar to DT as a concept to use digital resources to set-

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

up a differentiated value creation [16]. As the redefinition of the value propositions gets complex, barriers to DT increase more than with an ITOT.

DT alters socio-technical constructs that were previously negotiated by using non-digital artifacts or relationships. Today, these constructs are negotiated by digitized artifacts and relationships [17]. Barriers originate from changes in socio-technical structures that prevent, slow down, or deform the DT process [18].

As DT is a universal occurrence, c-suite and middle managers need to overcome the barriers affecting DT. If managers understand how to better interweave physical and digital elements, barriers will decrease. As barriers are complex constructs, managers should adopt a holistic approach to DT to re-combine socio-technical elements. Often, barriers evolve from a leadership level or through environmental factors [9].

To determine the findings of previous studies on barriers to DT, we performed a systematic literature review [19]. The review was conducted using services such as Scopus, EBSCO, and AIS Electronic Library and a search string containing the words digital transformation and barriers as well as synonyms. It generated 562 articles (excluding duplicates). After a first screening, 148 articles were found applicable for our field of study. After several in-depth qualitative checks, we finally identified 99 applicable studies [20]. The number of studies demonstrated the importance of the field.

In the most prominent stream of literature, authors listed barriers to a particular technology [21]. Some studies applied an interpretative approach and clustered barriers based on internal and external perspectives [22]. Whereas others take a timely perspective of short-term orientation, and strategy [23] or a certain type of companies such as micro, small and medium-sized enterprises into account [24]. Other works took a more structured approach by using interpretive structural analysis to model dependencies between barriers [25–27]. A minor research stream takes even recommendations on overcoming barriers into account. Recommendations are solutions or advice to take a certain action to overcome a barrier [28]. Often, these studies do not focus on the complex interdependencies of barriers and recommendations. Examples are that educational offers are helping to overcome the missing knowledge of employees [29] or that an IoT implementation with systemic complexity might require external technical experts [30]. Further exploration of complex causal relationships is missing.

From the review, we conclude that research is focusing on identifying barriers. Research on overcoming barriers would be a logical next step but is often still missing. Thus, our current study is contributing to closing this gap and is adding relevance [31] to the field of overcoming barriers. We employed comprehensive data to come to a structured DM for decision-makers. The review revealed that no such scientific research has been conducted before regarding DT barriers. Although structured approaches exist for barriers, there are rarely recommendations to overcome them.

Previous studies applied barriers in various research approaches focusing on technology-enhanced business models, better customer relations, or more well-organized operations [32]. Often, the focus was on specific technologies or stakeholders, which limited generalizability. Thus, we did not focus on specific technologies or industries to balance the view between social and technical implications. This allows a holistic analysis leading to higher generalizability [33].

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

3 Method

To answer our research question, we conducted the three phases of development of a barrier model [34], identification of recommendations to overcome barriers, and formulation of a DM with the relationships between barriers and recommendations. We present this research design in more detail below.

In the **first phase,** we adopted a triangulation approach to develop a DT barrier model by employing comprehensive data [35] to reach findings at the cross-section of different data sets [36]. In two data series, we asked participants about perceived DT barriers. For the first data set, we conducted 46 semi-structured interviews from March 2017 to October 2018 using a joint interview guideline. Participants were asked for an introduction, the status quo of DT in their company, and potential barriers. The interviewees were experts involved in DT projects or in charge of DT in their companies. To obtain a diversified sample, which allows deriving the most insights [35], interviewees from different sectors and positions were interrogated (cf. Table 1). The interviewees are based in Germany, Austria and Switzerland.

Table 1. Interview sample.

Industry	Position	N
Automotive	Head of R&D, Engineer, Digital Manager, Managing Director	14
Agriculture	Head of Quality Management, Managing Director, IT Manager, Operations Manager,	9
Plastics Industry	Head of Production, Head of R&D, Shift Supervisor, Engineer	5
Steel Industry	Managing Director, Head of Production Intelligence, Head of Production and Innovation	4
Services	Information Manager, IT Support, Managing Director	3
Consulting	Consultant	3
Manufacturing	Business Development Manager, Operations Manager, Chief Technology Officer, Head of Production	8

We analyzed the interview transcripts using an inductive coding approach [37]. The codes relating to barriers were iteratively aggregated and revised. While categorizing, we oriented towards a socio-technical perspective [33]. The result of this procedure was an initial model on DT barriers with several dimensions and characteristics.

To validate and enrich the initial model, we gathered additional qualitative data from 525 completed online questionnaire. The questionnaire participants were determined in the same way as the interviewees by calls in personal and professional social networks. Three hundred forty participants responded and completed the survey. Although non-random sampling could be employed to explore a domain, it could potentially lead to bias [38]. To overcome this disadvantage, additional participants in four companies, who replied to a social network call, were surveyed. This phase of data collection was conducted with the random sampling approach. Thus, additional 185 participants completed the same voluntary and anonymous online survey. A total of 525 participants determined with both random and non-random sampling methods participated in the survey between December 2019 and April 2021. Most of the respondents (60%) lived

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

in German-speaking countries. The sample includes responses from European nations and non-European nations such as Turkey and the U.S. resulting in cross-country data. Detailed information on the diverse sample is presented in Table 2.

Table 2. Questionnaire sample.

Criteria	Attribute [Relative share of participants]
Sector	Automotive [18%] | Construction [13%] | Finance & Insurance [14%] | Food [7%] | Information and communications technology [3%] | Mechanical & plant engineering [9%] | Wholesale [16%] | Other [17%] | Not stated [3%]
Position	Manager [6%] | With personnel responsibility [26%] | Without personnel responsibility [55%] | Intern [4%] | Other [6%] | Not stated [3%]
Company Size	>= 1,000 [35%] | 250-999 [17%] | 50-249 [33%] | 10-49 [9%] | <= 9 [3%] | Not stated [3%]

We coded the questionnaire data deductively by using the dimensions and characteristics of the initial model. Since we could not fit all 1,372 statements on barriers from the questionnaire data into the initial model, we refined and extended it [39]. To do so, each author individually open-coded the 466 left-over statements. After, we discussed and aggregated the codes within the team and with external colleagues to determine a set of revised dimensions and characteristics. Through these rounds of individual work and consensus, we ensured inter-coder reliability [40]. The result was a revised coding guideline. Subsequently, all 1,372 statements were deductively coded again using the revised coding guideline. The result of this approach is a valid triangulated model for barriers to DT with dimensions ranging from socio to technical to cover the broad domain of IS [8].

In the **second phase**, we used the same data collection of the 525 completed online questionnaires mentioned above (see table 2). In the questionnaire, the participants not only stated barriers, as described in phase 1, but also stated recommendations to overcome the perceived barriers in open-ended questions. The participants were required to link the recommendations to their stated barriers. Using this identical data collection allows us to keep track of the relation between each respective barrier and their respective recommendations. As in the case of the barriers, the recommendations were individually coded by each author with an open coding approach [39]. Again, the individually determined codes were discussed to achieve inter-coder agreement. The revised coding structure was used to code all 1,256 overcoming statements again. Thus, the interim result consists of 39 different recommendations to overcome barriers to DT.

In the **third phase**, we use the results from the coded barriers and the coded recommendations to set up a DM consisting of two axes representing the barriers and the recommendations. Based on the first and second phase, 1,372 statements on DT barriers and 1,256 related statements on ways to overcome them were collected. By asking participants about a perceived barrier first and a recommendation then, we can indicate their relationship. We always preserved the linkage between those two in our data. Therefore, each cell of the DM indicates the relationship between a single barrier and a single recommendation.

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

4 Results

In a pre-study, we determined a wide range of socio-technical [8, 33] barriers to DT. The barriers are divided into seven different dimensions. In total, 29 barriers were isolated based on the perceptions of the questionnaire participants. These barriers form one axis of the following DM. Therefore, they are briefly presented in Table 3. A more detailed description of the barriers can be found in the pre-study publication [34].

Table 3. Barriers to digital transformation [34].

Dimension & Characteristics [Code for DM]
Missing skills: Missing organizational knowledge [MS1] | Missing DT potential knowledge [MS2] | Missing implementation knowledge [MS3] | Missing user technology knowledge [MS4] | Insufficient training & learning [MS5]
Technical barriers: Deficient IT infrastructure [TB1] | Isolated systems [TB2] | Security issues [TB3] | Missing technical support [TB4]
Organizational misalignment: Lacking DT roadmap [OM1] | Immature decision-making [OM2] | Lack of change management [OM3] | Lack of communication [OM4]
Corporate cultural barriers: Deficient innovative spirit [CC1] | Missing error culture [CC2] | Sticking to the status quo [CC3] | Diffuse fears & insecurities [CC4] | Silo thinking [CC5]
Structural mismatch: Bureaucracy [SM1] | Process complexity [SM2] | Lack of financial resources [SM3] | Lack of personnel resources [SM4] | Over-aged employee structure [SM5]
Regulatory restrictions: Restrictive laws [RS1] | Volatile & obscure legislation [RS2] | Lack of political engagement [RS3]
Market restrictions: Lacking customer pull [MR1] | Restrictive value network [MR2] | Volatile technology environment [MR3]

In the current study, we identified 39 different recommendations to overcome barriers derived from 1,256 statements. These recommendations form the second axis of the DM. To further cluster the recommendations, we sorted them into the different subsystems human, technology, organization, and the organizations' surrounding framework [41]. These subsystems need to be considered in a socio-technical system according to the authors Dregger et al. [41]. Using this systemization allows us to group related recommendations and it creates a common perspective within the results. Table 4 shows the coded recommendations, which will be presented in detail.

Starting with the **human subsystem**, our study provides recommendations in terms of leadership. Generally, participants recommend ensuring top management support. This includes to accelerate decision-making. Decisions need to be implemented faster in today's fast-paced digital competition. Reducing the level of hierarchy required to make decisions that trigger DT can enable faster action. Another important aspect is that short-term orientation needs to change to *thinking with foresight*. This process is lengthy and need to be supported by extrinsic motivational factors. In this respect, top management should derive and determine DT targets and *develop a clear DT roadmap*. The roadmap should be aligned with the company's strategy and guiding principles. It can be inspired by best practices in the business environment. By making use of all kinds of data available, the roadmap needs to be realistic to allow for project and capacity planning. The roadmap must be communicated to *provide transparency over the*

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

transformation process. If information is shared, barriers can be overcome according to the participants. It is imperative to inform employees about the targets and projects, for example in regular meetings, and keep them up to date with results. It is crucial to take employees' fears and concerns seriously. *Educating about the benefits and need of DT projects* helps to take away fears of uncertainty and change. It signals top management's serious offer to take care. "DT must not be seen as a threat, but as an opportunity not only for the company but for each individual" [Participant]. Thus, it is recommended to present the advantages and savings of new ways of working to the employees and actively support them in the changeover.

Table 4. Recommendations to overcome barriers.

Subsystem & Recommendations [Code for DM]
Human: Accelerate decision-making [H1] | Thinking with foresight [H2] | Develop a clear DT roadmap [H3] | Provide transparency over the transformation process [H4] | Educate about the benefits and need of DT projects [H5] | Promote open communication and creating transparency [H6] | Involve and motivate employees [H7] | Be open-minded to changes [H8] | Engage staff to realize their ideas and projects [H9] | Create capacity among employees [H10] | Conduct a competence gap analysis [H11] | Offer or intensify demand-oriented employee training [H12] | Use external expertise [H13] | Recruit or provide suitable staff [H14] | Rejuvenate the workforce [H15]
Technology: Extend or modernize IT-Systems [T1] | Harmonize IT infrastructure [T2] | Collect and analyze data [T3] | Ensure data security [T4] | Design simple and intuitive systems [T5]
Organization: Release or increase a separate budget for DT [O1] | Prioritize investments in DT [O2] | Conduct (long-term) cost-benefit analysis [O3] | Take advantage of financial support from the state [O4] | Streamline organizational processes [O5] | Flatten and simplify organizational structures [O6] | Increase scope for decision-making on lower levels [O7] | Implement IT support [O8] | Centrally coordinate DT efforts [O9] | Define clear DT responsibilities [O10] | Promote cross-functional collaboration [O11] | Implement agile project management and design methods [O12] | Provide improved working conditions [O13] | Move customers to the center of attention in the development of solutions [O14] | Simplify and expand customer touchpoints [O15]
Framework: Expand partnerships with external parties [F1] | Lobby [F2] | Encourage the broadband rollout [F3] | Comply with data protection laws [F4]

Promoting open communication and creating transparency should not be a guideline for top management only but for every single employee. An enhanced exchange and more information about success or failure stories within the company are recommended. The use of communication managers can be a helpful step. It is vital to intensify *involving and motivating employees*. It is the involvement of the workforce to partake in decision-making processes, e.g., by allowing them to provide feedback. When employees are given the space to act, a new mindset emerges. Being *open-minded to changes* is a basis for overcoming barriers to DT. It is connected to being open to continuous innovation. Such a mindset calls to *engage staff to realize their ideas and projects*. Participants recommend motivating employees to improve processes, which make their work easier. Allowing digital projects to be carried out without reservation, promotes motivation. "Doing and not just talking about it" [Participant] should be the

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

motto. Starting small, for example through pilot or research projects, build trust and awareness in the DT process.

To allow space for own ideas and projects, it is essential to *create capacity among employees* and to have suitable skill sets within the company. To identify which competences are lacking, participants recommend conducting *a competence gap analysis* through knowledge tests and documentation in digital personnel files. By knowing central competence gaps, the targeted development of necessary skills and knowledge can be started. One way is to *offer or intensify demand-oriented employee training*. "By providing the necessary training, the advantages of DT can be brought to the staff" [Participant]. Setting up an education portal and coaching systems enables efficient and demand-oriented training. Another way is to *use external expertise*. Involvement of external organizations with expertise and best practices is recommended if internal training does not pay off. Furthermore, participants recommend *recruiting or providing suitable staff* to overcome the skills gap. Specialized professionals with an educational background in the field of IT are required. Here, participants emphasize that companies should focus on *rejuvenating the workforce*. "A new generation of young people should be recruited, and existing employees should be given mentors" [Participant].

Participants mentioned multiple recommendations, which we classified into the **technology subsystem**. *Extending or modernizing IT-Systems* is imperative for fostering DT. On a rolling basis, companies should invest in new hardware to build and keep the critical IT infrastructure up to date. This includes expanding data storage capacities as well as customized software applications. Tracking technological trends supports them in being informed about innovations in the field of IT. *Harmonizing IT infrastructure* is according to the participants another recommendation. Consistent implementation of the IT architecture and software systems that are unified across departments are required to avoid isolated solutions. Furthermore, *collect and analyze data* provides the basis for targeted decision-making. "It must be possible to store and backup large amounts of data" [Participant] and to have it available at all levels, e.g., data to analyze user feedback. In addition, data integrity is required which means setting clear storing and archiving rules. When dealing with data, it is vital to *ensure data security*. There should be effective database protections in place. "Vulnerability tests should be carried out regularly, durability should be measured, and open areas should be determined, and necessary precautions should be taken" [Participant]. To improve the user-friendliness of software and hardware, *designing simple and intuitive systems* is recommended. An easy and simple graphical user interface for software applications together with comprehensible handbooks support user-friendliness.

The next element of the socio-technical system refers to the **organization subsystem**. It contains numerous recommendations related to the handling of resources in the company. *Releasing or increasing a separate budget for DT* is seen as necessary by many participants. "The company should accept to invest" [Participant]. Budgets need to be planned and created or increased to create more scope for digital innovations. "A larger share of the overall budget must go to digitalization" [Participant]. Thus, participants see *prioritizing investments in DT* as necessary. Critical consideration should be given to which investments should be made by *conducting (long-term) cost-benefit analysis*. Participants recommended analyzing DT efforts in detail regarding

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

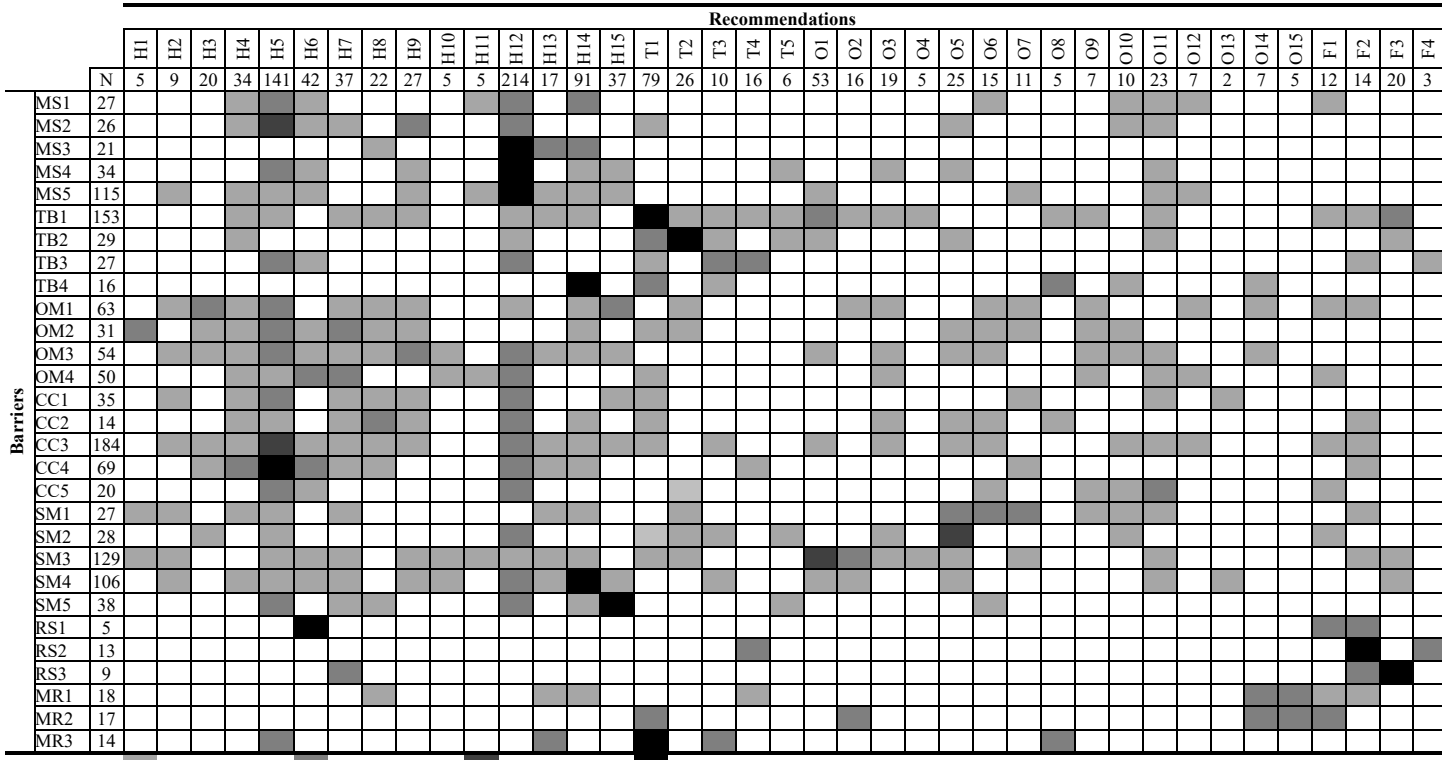
operational and strategic goals. However, "investments should also be made without expecting immediate profit maximization" [Participant]. Rather the "long-term effect needs to be analyzed" [Participant]. *Taking advantage of financial support from the state* can increase financial flexibility. Companies should therefore monitor grant programs.

Further recommendations to overcome barriers can be assigned to the structure and processes of a company. Accordingly, participants recommended *streamlining organizational processes* and reducing complexity. This contains optimizing and re-engineering processes. Higher process efficiency can free resources for DT. However, such an approach needs to be implemented in form of continuous improvement in the long term. Lean principles such as the 5S method were also mentioned in this context. In addition to the process view, statements also referred to *flattening and simplifying organizational structures*. Many participants recommended the dismantling of hierarchical levels, the restructuring of divisions, and new linkages between departments. Furthermore, an *increase in scope for decision-making on lower levels* is named. Companies should "give more responsibility to each individual" [Participant]. Like this, decision-making paths can be shortened and decentralized in independent divisions, departments, or teams. *Implementing IT Support* can help these subordinate levels. However, as DT encompasses the entire company, *centrally coordinating DT efforts* is mandatory. Innovation departments can support line departments, centralize communication, and set clear shared goals. Central coordination should also focus on ensuring that the measures of the digital strategy are carried out. Thus, *defining clear DT responsibilities* in the company and its departments is necessary. At the same time, silo thinking in the departments must be diminished and an exchange encouraged by *promoting cross-functional collaboration*. In the context of DT, this is particularly important regarding IT staff and line employees. A "stronger involvement of the business departments in the solution design of technical innovations" [Participant] is desired. This also allows "employees to learn from employees" [Participant]. The work in the team should be supported by *implementing agile project management and design methods*. A few statements issue *providing improved working conditions* to overcome some barriers, for example, the possibility of working from home was mentioned.

Participants also recommend *moving customers to the center of attention in the development of solutions*. The customer perspective must be considered when developing the digital strategy and "customer needs should be at the center of all new customer solutions" [Participant]. Companies should "conduct market research and produce products compatible with the market" [Participant]. In addition, customers must be included in the solution development process. Especially, when they are less willing to go digital. Therefore, *simplifying and expanding customer touchpoints* is essential for overcoming DT barriers. Touchpoints are online stores, call centers, and social media channels which are "advertising activities that will support digital sales channels can be focused" [Participant]. Here, customers are also accessing the technological subsystem. Thus, companies need to "create simple technical procedures so that older customers can be supplied without the need for technical support" [Participant].

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

Table 4. Decision Matrix.



The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

As companies are framed by "political regulations, functional context preconditions, networks, [and] value chains" [41], participants pointed out several recommendations to address these factors which we group into the **framework subsystem**. Several statements referred to *expanding partnerships with external parties*. These partnerships could be shaped in different ways, like getting consultancy, outsourcing processes, or even long-term cooperation by vertical integration of the supply chain. Companies can "align themselves with other digital players or lead by example to create market pressure" [Participant]. *Lobbying* is also mentioned by participants in this context. Companies should "work with legal & lobbying to change the rules of the market to digitize it" [Participant] as well as "improve collaboration and coordination on what and where infrastructure is needed" [Participant] such as *encouraging the broadband rollout.* Companies need access to fast and stable connection technology. Furthermore, participants recommend *complying with data protection laws*. "Always make sure that data protection is respected and submitted with the customer's consent" [Participant]. It is crucial to eliminate non-compliant software applications and to consider and evaluate new ones. External consultancy about laws serves as support here.

Combining the results of the current study with the findings of the pre-study allows us to obtain a DM (see table 4). The barriers are plotted on the x-axis and the recommendations on the y-axis. Depending on the direction of reading, the matrix shows for which barrier which recommendations are suggested by the participants (left to right) or which barriers could be addressed with the help of a specific recommendation (top to down). In addition, the DM shows the relative frequency of mentions of the recommendations for a given barrier. The relative frequency is divided into quartiles (QX): 0 < Q1 < 25%, 25% >= Q2 < 50%, 50% >= Q3 < 75%, and Q4 > 75%. For example, to overcome barrier MS1, less than 25% but greater than 0% of the statements referring to the barrier MS1 recommended action H4. A blank cell indicates no association between the barrier and the recommended action.

Some statements of the questionnaire participants were explicitly directed at other stakeholder groups, such as governments. Governments should promote broadband rollout, create incentives, and provide subsidies. Legislation is also expected to provide clarity and room for innovation. In the DM, these recommendations were not illustrated, as the DM captures the business perspective only.

5 Discussion

The combined data collection of barriers and recommendations allowed us to create a DM with in-depth insights. It provides an answer to which actions can be taken to overcome certain barriers or several barriers at once. Both the barriers identified, and the recommendations orient towards socio-technical dimensions. Our work fills aspects of change management with specific recommendations. In change management, guidelines lead the way to a successful transformation [42]. We also see guidelines in our data as developing a clear DT roadmap or promoting open communication and creating transparency that are related to the field of change management.

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

A large proportion of the recommendations made by the questionnaire participants were associated with the human subsystem, followed by the organizational, technical, and framework subsystem. This order is also consistent with findings from other studies, according to which humans and organizations are more decisive than the technology itself regarding barriers to DT [10, 15, 43]. Although many barrier models strongly relate to some form of technical perspective [12], our recommendations suggest a more socio-focused approach to overcoming barriers. Thus, our findings related more to the social side of the socio-technical continuum [33].

Our results reveal that different recommendations are appropriate for different barriers. The findings show that a single recommendation could address multiple barriers, which makes some recommendations more impactful than others. Already, barriers show inter-dependencies [25]. For instance, the barrier lack of knowledge triggers other barriers such as staff resistance to change, difficulties in finding qualified personnel, and lack of information and communication technology adoption. The more impactful recommendations influence barriers with higher inter-dependencies. Most mentioned by questionnaire respondents is to offer intensifying demand-oriented employee training. The DM shows that this could overcome or mitigate several barriers.

The DM does not indicate whether a single recommended action is sufficient to completely overcome the respective barriers or whether all actions recommended for the respective barrier must be undertaken. As barriers are complex, it is more likely that the interaction of several recommendations is needed for a complete resolution [12]. Nevertheless, it can be assumed that some recommendations have a more significant share in overcoming barriers, such as the most mentioned recommendation training. This is consistent with findings by Hadjimanolis [9]. According to these findings, increasing human capital through training and motivation systems should have a top priority. Multiple other authors in the literature refer to training as a top recommendation [25, 44–46]. Therefore, the relative frequencies in the DM might also indicate which recommendations to prioritize. Since resources are scarce, the simultaneous implementation of all recommendations could lead to further challenges.

However, some recommendations were mentioned only a few times in our data collection, such as taking advantage of financial support from the state, providing improved working conditions, or simplifying and expanding customer touchpoints. Thus, these recommendations only show links to a few barriers. In contrast, the literature shows that these actions could potentially overcome other barriers. However, government subsidies, for example, could be of greater importance in enabling financial freedom in innovation, especially for SMEs [47]. Other studies point out the importance of the interplay of the usage of digital technologies and the readiness of a business model for digital operation [48]. A first step to addressing this interplay is the development of a clear roadmap followed by setting up a dedicated budget. As a small starting point might have a high impact, companies need to critically review their status quo and check the recommendations for their company-specific suitability and importance.

Our findings specify the results pointed out by Kane [43]: "Only by fundamentally changing the way the organization works – through flattening hierarchies, speeding up decision-making, helping employees develop needed skills, and successfully understanding both opportunities and threats in the environment – can an organization truly

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

adapt to a digital world." Taking a sector-independent perspective, our study provides specific results applicable in different IS contexts, industries, and types of organizations. Our holistic approach gives the impulse to represent first the sum of barriers and recommendations as well as secondly validate and compare barriers and recommendations across sectors in future research projects. Various findings of a larger and more diverse data set allowing different sectors and companies to be able to learn from each other [49]. The DM provides a systematic guide to succeed in transforming digitally. As the authors de Jesus Pacheco et al. [50] have pointed out, the matrix opens up numerous different utilization strategies. First, companies can identify a set of recommendations for perceived barriers. Second, companies can evaluate actions taken in the past by comparing them to the suggested recommendations in the DM. Third, companies can proactively implement recommendations to prevent the occurrence of barriers in the future and may be able to generate a competitive advantage.

6 Conclusions and Implications

By using a qualitative data collection of different sectors and positions, we identified different barriers to DT in a pre-study and coded suitable recommendations to overcome them in the current study. Combining the result of both studies led to a DM that relates 29 barriers and 39 recommended actions.

The developed barrier model of the pre-study helped practitioners to identify potential barriers [34]. With the DM, practitioners receive an even more valuable tool to drive forward the DT in the company. The versatility of barriers and recommendations affirms that a successful DT requires an interplay and intersection of software, information systems, business processes, and people. For this reason, the DM addresses IS practitioners from multiple sectors and positions. Scientists can base future work on a solid model which indicates different kinds of barriers and recommendations.

Despite all thoroughness in the research process, this study is not without limitations. Great care was taken in coding and aggregating the statements. We ensured external validity through a large amount of data, continuous checking for inter-coder agreement [40], and orientation towards socio-technical dimensions [33]. Still, another group of researchers might have come to different coding labels. The matrix is based on data from different people with different expertise and leadership responsibilities. As Yin noted, a diversified sample helps to get the most impressions out of data [35]. However, the matrix should be reviewed in more depth by experts, for example, by conducting a Delphi study, workshops, or modeling DMs for comparison. Subsequent qualitative research could also tailor the model to specific sectors or develop targeted, individual, more in-depth recommendations. The matrix shows which recommendations are mentioned particularly often, which is the first basic indicator for effectivity in overcoming a specific barrier. Future quantitative studies could measure the relationships between recommendations and barriers. Thus, more reliable information about the relationships and effect sizes can be researched.

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

References

1. Dehning, B., Richardson, V.J., Zmud, R.W.: The value relevance of announcements of transformational information technology investments. Management Information Systems Quarterly. 27, 637–656 (2003). https://doi.org/10.2307/30036551.
2. Laudon, K.C., Laudon, J.P.: Management information systems: managing the digital firm. Pearson, New York, NY (2020).
3. Kagermann, H., Wahlster, W., Helbig, J.: Recommendations for implementing the strategic initiative Industrie 4.0. acatech – National Academy of Science and Engineering (2013).
4. Benlian, A., Hilkert, D., Hess, T.: How open is this platform? The meaning and measurement of platform openness from the complementors' perspective. Journal of Information Technology. 30, 209–228 (2015). https://doi.org/10.1057/jit.2015.6.
5. Schwab, K.: The fourth industrial revolution. Crown Business, New York (2017).
6. Gnamm, J., Kalmbach, R., Schertler, M.: Digitalization must be given top priority, https://www.bain.com/insights/digitalisierung-ist-chefsache-2018/, (2018).
7. Hess, T., Matt, C., Benlian, A., Wiesböck, F.: Options for formulating a digital transformation strategy. MIS Quarterly Executive. 15, 123–139 (2016).
8. Hirsch-Kreinsen, H.: Digitization of industrial work: development paths and prospects. Journal for Labour Market Research. 49, 1–14 (2016).
9. Hadjimanolis, A.: The Barriers Approach to Innovation. In: Shavinina, L.V. (ed.) The International Handbook on Innovation. pp. 559–573. Pergamon, Oxford (2003). https://doi.org/10.1016/B978-008044198-6/50038-3.
10. Vial, G.: Understanding digital transformation: A review and a research agenda. The Journal of Strategic Information Systems. 28, 118–144 (2019). https://doi.org/10.1016/j.jsis.2019.01.003.
11. Vogelsang, K., Liere-Netheler, K., Packmohr, S., Hoppe, U.: Barriers to Digital Transformation in Manufacturing: Development of a Research Agenda. In: Proceedings of the 52nd Hawaii International Conference on System Sciences. pp. 4937–4946 (2019).
12. Jones, M.D., Hutcheson, S., Camba, J.D.: Past, present, and future barriers to digital transformation in manufacturing: A review. Journal of Manufacturing Systems. 60, 936–948 (2021). https://doi.org/10.1016/j.jmsy.2021.03.006.
13. Reis, J., Amorim, M., Melão, N., Matos, P.: Digital Transformation: A Literature Review and Guidelines for Future Research. In: Rocha, Á., Adeli, H., Reis, L.P., and Costanzo, S. (eds.) Trends and Advances in Information Systems and Technologies. pp. 411–421. Springer International Publishing, Cham (2018). https://doi.org/10.1007/978-3-319-77703-0_41.
14. Pabst von Ohain, B.: Leader Attributes for Successful Digital Transformation. ICIS 2019 Proceedings. (2019).
15. Wessel, L., Baiyere, A., Ologeanu-Taddei, R., Cha, J., Blegind Jensen, T., Cha, J., University of Westminster, UK, Blegind Jensen, T., Copenhagen Business School, Denmark, Copenhagen Business School, Denmark: Unpacking the Difference Between Digital Transformation and IT-Enabled Organizational Transformation. JAIS. 22, 102–129 (2021). https://doi.org/10.17705/1jais.00655.
16. Bharadwaj, A., El Sawy, O., Pavlou, P., Venkatraman, N.: Digital business strategy: toward a next generation of insights. Management Information Systems Quarterly. 37, 471–482 (2013).
17. Yoo, Y., Lyytinen, K.J., Boland, R.J., Berente, N.: The Next Wave of Digital Innovation: Opportunities and Challenges: A Report on the Research Workshop "Digital Challenges in Innovation Research." SSRN Journal. (2010). https://doi.org/10.2139/ssrn.1622170.

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

18. Klötzer, C., Pflaum, A.: Toward the development of a maturity model for digitalization within the manufacturing industry's supply chain. In: Proceedings of the 50th Hawaii International Conference on System Sciences. pp. 4210–4219 (2017). https://doi.org/10.24251/HICSS.2017.509.
19. Webster, J., Watson, R.T.: Analyzing the past to prepare for the future: Writing a literature review. MIS Quarterly. 26, xiii–xxiii (2002).
20. Varwig, T., Brink, H., Packmohr, S.: A Systematic Literature Review on Barriers to Digital Transformation: Insights and Implications for Overcoming. Presented at the 37th EBES Conference , Berlin (2021).
21. Bilgeri, D., Wortmann, F.: Barriers to IoT Business Model Innovation. Proceedings of the 13th International Conference on Wirtschaftsinformatik. 987–990 (2017).
22. Henriette, E., Feki, M., Boughzala, I., others: Digital Transformation Challenges. In: Mediterranean Conference on Information Systems (MICS). pp. 1–7 (2016).
23. Kumar, P., Singh, R.K., Kumar, V.: Managing supply chains for sustainable operations in the era of industry 4.0 and circular economy: Analysis of barriers. Resources, Conservation and Recycling. 164, 105–115 (2021). https://doi.org/10.1016/j.resconrec.2020.105215.
24. Khanzode, A.G., Sarma, P.R.S., Mangla, S.K., Yuan, H.: Modeling the Industry 4.0 adoption for sustainable production in Micro, Small & Medium Enterprises. Journal of Cleaner Production. 279, 123489 (2021). https://doi.org/10.1016/j.jclepro.2020.123489.
25. Karadayi-Usta, S.: An Interpretive Structural Analysis for Industry 4.0 Adoption Challenges. IEEE Trans. Eng. Manage. 67, 973–978 (2020). https://doi.org/10.1109/TEM.2018.2890443.
26. Abdul-Hamid, A.-Q., Ali, M.H., Tseng, M.-L., Lan, S., Kumar, M.: Impeding challenges on industry 4.0 in circular economy: Palm oil industry in Malaysia. Computers & Operations Research. 123, 105052 (2020). https://doi.org/10.1016/j.cor.2020.105052.
27. Agrawal, P., Narain, R., Ullah, I.: Analysis of barriers in implementation of digital transformation of supply chain using interpretive structural modelling approach. Journal of Modelling in Management. (2019). https://doi.org/10.1108/JM2-03-2019-0066.
28. Dudenredaktion: Handlungsempfehlung, https://www.du-den.de/node/63055/revision/63091.
29. Westerman, G., Calméjane, C., Bonnet, D., Ferraris, P., McAfee, A.: Digital Transformation: A roadmap for billion-dollar organizations. MIT Center for Digital Business and Capgemini Consulting. 1, 1–68 (2011).
30. Zaychenko, I., Smirnova, A., Shytova, Y., Mutalieva, B., Pimenov, N.: Digital Logistics Transformation: Implementing the Internet of Things (IoT). In: Schaumburg, H., Korablev, V., and Ungvari, L. (eds.) Technological Transformation: A New Role For Human, Machines And Management. pp. 189–200. Springer International Publishing, Cham (2021). https://doi.org/10.1007/978-3-030-64430-7_16.
31. Mentzer, J.T.: RIGOR VERSUS RELEVANCE: WHY WOULD WE CHOOSE ONLY ONE? J Supply Chain Management. 44, 72–77 (2008). https://doi.org/10.1111/j.1745-493X.2008.00058.x.
32. Dremel, C.: Barriers to the adoption of big data analytics in the automotive sector. In: Proceedings of the 23rd American Conference on Information Systems (AMCIS). pp. 1–10. , Boston (2017).
33. Sarker, S., Chatterjee, S., Xiao, X., Elbanna, A.: The Sociotechnical Axis of Cohesion for the IS Discipline: Its Historical Legacy and its Continued Relevance. MISQ. 43, 695–719 (2019). https://doi.org/10.25300/MISQ/2019/13747.
34. Brink, H., Packmohr, S., Paul, F.-H.: Extending a Socio-Technical Model of the Barriers to Digital Transformation through Data Triangulation. In: 2022 8th International Conference

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.

on Information Management (ICIM). pp. 68–74. IEEE, Cambridge, United Kingdom (2022). https://doi.org/10.1109/ICIM56520.2022.00020.
35. Yin, R.K.: Case study research: design and methods. SAGE, Los Angeles (2014).
36. Fetters, M.D., Molina-Azorin, J.F.: The Journal of Mixed Methods Research Starts a New Decade: Principles for Bringing in the New and Divesting of the Old Language of the Field. Journal of Mixed Methods Research. 11, 3–10 (2017). https://doi.org/10.1177/1558689816682092.
37. Mayring, P.: Qualitative content analysis: theoretical foundation, basic procedures and software solution. Beltz Verlag, Klagenfurt (2014).
38. Stern, M.J., Bilgen, I., McClain, C., Hunscher, B.: Effective Sampling from Social Media Sites and Search Engines for Web Surveys: Demographic and Data Quality Differences in Surveys of Google and Facebook Users. Social Science Computer Review. 35, 713–732 (2017). https://doi.org/10.1177/0894439316683344.
39. Azungah, T.: Qualitative research: deductive and inductive approaches to data analysis. QRJ. 18, 383–400 (2018). https://doi.org/10.1108/QRJ-D-18-00035.
40. Konradsen, H., Kirkevold, M., Olson, K.: Recognizability: A Strategy for Assessing External Validity and for Facilitating Knowledge Transfer in Qualitative Research. Advances in Nursing Science. 36, E66–E76 (2013). https://doi.org/10.1097/ANS.0b013e318290209d.
41. Dregger, J., Niehaus, J., Ittermann, P., Hirsch-Kreinsen, H., ten Hompel, M.: The digitization of manufacturing and its societal challenges: a framework for the future of industrial labor. In: 2016 IEEE International Symposium on Ethics in Engineering, Science and Technology (ETHICS). pp. 1–3. IEEE, Vancouver, BC, Canada (2016).
42. Kotter, J.P.: Leading Change: Why Transformation Efforts Fail. Harvard Business Review. 60–67 (2016).
43. Kane, G.: The Technology Fallacy. Research-Technology Management. 62, 44–49 (2019). https://doi.org/10.1080/08956308.2019.1661079.
44. Ajmera, P., Jain, V.: Modelling the barriers of Health 4.0–the fourth healthcare industrial revolution in India by TISM. Oper Manag Res. 12, 129–145 (2019). https://doi.org/10.1007/s12063-019-00143-x.
45. Müller, J.M.: Assessing the barriers to Industry 4.0 implementation from a workers' perspective. IFAC-PapersOnLine. 52, 2189–2194 (2019). https://doi.org/10.1016/j.ifacol.2019.11.530.
46. Cichosz, M., Wallenburg, C.M., Knemeyer, A.M.: Digital transformation at logistics service providers: barriers, success factors and leading practices. The International Journal of Logistics Management. 31, 209–238 (2020). https://doi.org/10.1108/IJLM-08-2019-0229.
47. Chen, C.-L., Lin, Y.-C., Chen, W.-H., Chao, C.-F., Pandia, H.: Role of Government to Enhance Digital Transformation in Small Service Business. Sustainability. 13, 1028 (2021). https://doi.org/10.3390/su13031028.
48. Tekic, Z., Koroteev, D.: From disruptively digital to proudly analog: A holistic typology of digital transformation strategies. Business Horizons. 62, 683–693 (2019). https://doi.org/10.1016/j.bushor.2019.07.002.
49. Vogelsang, K., Packmohr, S., Brink, H.: Challenges of the Digital Transformation – Comparing Nonprofit and Industry Organizations. In: Ahlemann, F., Schütte, R., and Stieglitz, S. (eds.) Innovation Through Information Systems. pp. 297–312. Springer International Publishing, Cham (2021). https://doi.org/10.1007/978-3-030-86790-4_21.
50. de Jesus Pacheco, D.A., ten Caten, C.S., Jung, C.F., Sassanelli, C., Terzi, S.: Overcoming barriers towards Sustainable Product-Service Systems in Small and Medium-sized enterprises: State of the art and a novel Decision Matrix. Journal of Cleaner Production. 222, 903–921 (2019). https://doi.org/10.1016/j.jclepro.2019.01.152.

The final authenticated version is available online at https://doi.org/10.1007/978-3-031-20706-8_5.