Barriers to the development of data-driven services: An ISM approach for SMEs

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Abstract

Data is nowadays considered as a key resource and represents the most valuable asset of our technology-driven world. However, the ability to use this resource in a value-adding way requires a holistic perspective. Small- and medium-sized enterprises in particular face major challenges in the innovation and development process. Despite preliminary research in the area of data-driven services (DDS), there is a lack of methodological analysis of the key barriers for SMEs in the context of DDS development. To address this shortcoming, we have developed an interpretive structural model based on a two-stage mixed-method approach by combining a structured literature review with practice-oriented focus group interviews to identify key barriers and their interdependencies and interactions. Our paper strengthens the knowledge of DDS development through a methodological barrier analysis and provides a guide for practitioners to eliminate the most relevant barriers to DDS development.

1. Introduction

Digital transformation is changing not only individual businesses but also entire markets based on new data-driven technologies such as the Internet of Things, cloud computing, or artificial intelligence, enabling companies to create original, novel, and meaningful value propositions based on large amounts of data (Hunke & Kiefer, 2020; Legner et al., 2017). These services utilize data as a key resource to provide sound, insights founded on the adoption of analytical methods to address complex problems, support customers' decision-making, and achieve goals more effectively (Azkan et al., 2020; Hunke & Kiefer, 2020; Schüritz et al., 2019). Predictive maintenance is a typical example of services of this type in the manufacturing industry, which enables businesses to accurately predict equipment failures, avoid downtime, reduce maintenance costs, and increase production efficiency (Azkan et al., 2020). German manufacturers, such as Trumpf and Kaeser Compressors, have successfully introduced these services to the market, leading to benefits, such as enabling deeper customer relationships (Ostrom et al., 2015), extending existing products and services (Goduscheit & Faullant, 2018), or generating competitive advantages (Davenport, 2013). Nevertheless, industrial product-centric companies still face significant challenges in the development of data-driven services (DDS), where data is the core resource for service delivery. (Kampker, Husmann, Harland, et al., 2018). This becomes particularly evident when considering the company size, where large firms are more likely to rely on new digital technologies. While small- and medium-sized enterprises often lack a comprehensive strategy for the implementation of DDS offerings or have concerns about data security (Schröder, 2016).

Apart from the practical implications, initial contributions can also be found in the literature on both barriers and challenges in the area of service innovations in manufacturing (Kowalkowski et al., 2015; Kindström & Kowalkowski, 2014) and on the development of DDS, the so-called smart services in general (Schüritz et al., 2017; Klein et al., 2018), as well as in the Industry 4.0 SME context (Orzes et al., 2020). However, both in practice and in academia, there is a lack of up-to-date methodological analysis of the correlation of the main barriers to the development of DDS for SMEs. This is supported by the aspect that SMEs often do not know which challenges to tackle first. Therefore, we pose this **research question (RQ)**: *What is the relationship and influence between existing barriers in the development of DDS for SME?*

To address the research question, we use a two-stage mixed-method approach based on a systematic literature review to identify core barriers, combined with an interpretive structural modeling (ISM)

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approach to analyze relations and interdependencies in the development process. The analysis is based on qualitative assessments from industry experts in the field of DDS development (Gholami et al., 2020). The objective is to reduce the complexity in the innovation and development process based on a systematic model of the core barriers, as well as their relations and dependencies that support practitioners in the implementation of DDS.

The remainder of the of this paper is organized as follows. In the literature review (Section 2), we provide the background information and identify the main barriers to implementing DDS. In Section 3, we describe the ISM analysis and summarize the outcomes. Building on that, we present the results and the discussion. Finally, we outline the limitations and an outlook.

2. Barriers to the Development of DDS

The starting point of the research process to identify the key barriers to the development of DDS was a structured literature review according to Webster and Watson (2002). The search was conducted in well-known databases (Scopus, AISeL, ScienceDirect), based on the search string "data-driven service" OR "smart service" AND "challenge" OR "barrier". To ensure the highest possible degree of quality, additional research criteria were included. Only publications that were peer-reviewed and published in English or German were considered. Based on these criteria, 342 relevant publications were identified. After excluding duplicates and based on the titles and the abstracts, 306 papers were excluded. To extract as broad a spectrum of barriers as possible from the literature, a forward and backward search was conducted, following Webster and Watson, and 35 relevant publications were identified. From this sample, 19 key barriers were identified and qualitatively categorized for a better overview based on a concept matrix approach (Table 1). The barriers are discussed in detail in the following section.

Table 1. Overview of barriers identified from literature

ID	Category	Barriers	Sources
B01	Strategy	Unclear data-driven service strategy	Fritsch & Krotova, 2020; Grubic & Peppard, 2016; Klein et al., 2018
B02	Strategy	Lack of top management support	Brax & Jonsson, 2009; Dreyer et al., 2018; Klein et al., 2018
B03	Strategy	Insufficient financial resources	Fritsch & Krotova, 2020; Klein et al., 2018; Orzes et al., 2020; Rauch et al., 2020
B04	Market	Insufficient market knowledge	Klein et al., 2018; Parida et al., 2014; Schüritz et al., 2017
B05	Market	Low market maturity	Coreynen et al., 2017; Schüritz et al., 2017
B06	Market	New competition through other service providers	Mathieu, 2001; Schüritz et al., 2017
B07	Culture & Structure	Lack of service culture	Klein et al., 2018; Orzes et al., 2020; Rauch et al., 2020; Schüritz et al., 2017
B08	Culture & Structure	Unsuited organizational structure	Klein et al., 2018; Orzes et al., 2020; Porter & Heppelmann, 2015; Schüritz et al., 2017
B09	Customer	Customers' unwillingness to exchange data	Kampker, Husmann, Harland, et al., 2018; Klein et al., 2018; Porter & Heppelmann, 2015; Schüritz et al., 2017
B10	Customer	Data security and protection	Fedkenhauer et al., 2017; Fritsch & Krotova, 2020; Klein et al., 2018; Rauch et al., 2020
B11	Customer	Unclear legal status of data ownership	Klein et al., 2018; Marquardt, 2017; Töytäri et al., 2017
B12	Customer	Ineffective communication of the value of data-driven service offerings	Fritsch & Krotova, 2020; Kampker, Husmann, Jussen, & Schwerdt, 2018; Klein et al., 2018; Kuester et al., 2018
B13	Customer	Insufficient knowledge of customers' needs	Grubic & Peppard, 2016; Klein et al., 2018; Ulaga & Reinartz, 2011
B14	Processes & Technology	Insufficient service development process	Klein et al., 2018; Schüritz et al., 2017
B15	Processes & Technology	Lack of skills	Fritsch & Krotova, 2020; Kampker, Husmann, Harland, et al., 2018; Orzes et al., 2020
B16	Processes & Technology	Insufficient infrastructure	Kampker, Husmann, Harland, et al., 2018; Klein et al., 2018; Orzes et al., 2020
B17	Processes & Technology	Insufficient data quality and availability	Fritsch & Krotova, 2020; Pikkarainen et al., 2020; Richter & Slowinski, 2019
B18	Monetization	Inability of billing data-driven services	Anke, 2019; Enders et al., 2019; Klein et al., 2018
B19	Monetization	Customers' unwillingness to pay	Coreynen et al., 2017; Enders et al., 2019; Fritsch & Krotova, 2020; Schüritz et al., 2017

Strategy: First, designing a service plan that is compatible with their overall strategy is a difficulty for product-oriented companies (Schüritz et al., 2017). Due to an imprecise service strategy, some firms are unsure of what they aim to achieve with their data-driven businesses (Klein et al., 2018). These firms are therefore challenged to make a clear decision about the role of data analytics in their service endeavors and need to develop a clear data strategy (Schüritz et al., 2017). Especially, SMEs lag behind in developing strategies to implement new solutions and adapt new technologies (Glass et al., 2018).

In this sense, the lack of top management support is crucial as well. The management in product-centric companies in particular often overlooks service opportunities as it favors and rewards short-term achievements of product-based offerings (Töytäri et al., 2017). In SMEs, their ability to innovate often depends on the managing director who emphasizes the importance of acknowledging DDS at the top management level.

Since a strategic path toward DDS is missing in many SMEs, financial resources can be insufficient (Rauch et al., 2020). This makes it difficult to implement necessary changes, such as in the organization, in the processes or in human resources. If companies expect their DDS business to grow organically, the high upfront costs of developing an adequate infrastructure, implementing algorithms, and training or hiring employees can therefore be prohibitive for a successful start in the market (Klein, 2017; Klein et al., 2018).

Market: When offering novel DDS, companies enter new markets, which is accompanied by challenges such as insufficient market knowledge because of the existing product-oriented business (Schüritz et al., 2017). Here, product-centric industrial companies are often unable to identify and fully exploit business opportunities through data and analytics (Klein et al., 2018; Porter & Heppelmann, 2015). Another factor is that the market for data analytic offerings is still immature; therefore, some customers are reluctant to use such services (Coreynen et al., 2017). Additionally, many specialized start-ups or unexpected revivals are emerging and becoming new competitors (Schüritz et al., 2017).

Culture & Structure: Establishing a service-oriented culture in product-focused companies presents a huge challenge as it requires a shift of the corporate mindset to service orientation and customer centricity (Schüritz et al., 2017). A company's transformation can lead to strong internal resistance, as reluctance to change is an inherent characteristic of people and organizations (Mathieu, 2001). The lack of acceptance of new operational processes and technologies is highly relevant in SMEs, which hinders data-driven initiatives (Rauch et al., 2020).

The field of data exploitation in services is new to most industrial companies and brings a high degree of complexity to the development of new offerings, as various internal departments (e.g., IT, R&D, production, sales) must be involved in the process in addition to expanded external stakeholders (Kampker, Husmann, Harland, et al., 2018). Fostering knowledge transfer among the different functional areas within a servicing organization, as well as among the network partners, is an essential task and a complex challenge (Schüritz et al., 2017). Therefore, DDS do not only redefine roles and responsibilities but also create new ones, which often strain existing organizational structures (Klein et al., 2018). However, SMEs are characterized by flat and flexible structures, offering the opportunity to adapt to changing requirements in DDS development (Smith & Smith, 2007).

Customer: Security risks and loss of control over data represent significant challenges and barriers to data sharing and thus to DDS (Fedkenhauer et al., 2017). Customers must accept the collection of their data, which can be a sensitive issue for some (Rust & Huang, 2014). Many companies fear that their data could be used by third parties without permission and that trade secrets could be disclosed (Miller, 2012). Close attention must therefore be paid to data security and data protection concerns so that unforeseen potential dangers could be mitigated or prevented altogether (Azkan et al., 2022). In addition to data security, there is also the legal question of data ownership as the data has an unclear status—whether it belongs to the provider or the customer (Marquardt, 2017; Töytäri et al., 2017).

Companies are often unsure of which value proposition for DDS appeals to their customers; accordingly, they have difficulties in developing appropriate value propositions (Töytäri et al., 2017). A major reason for this may be a general lack of knowledge about customer needs. Therefore, understanding customer needs is one of the most important tasks of service managers (Brax, 2005). Another essential aspect of the design of service offerings is the definition of a communication strategy that clearly describes the value proposition to the customers and convinces them of its benefits (Schüritz et al., 2017; Ulaga & Reinartz, 2011).

Processes & Technology: The service development process must define procedures for data acquisition, transmission, and processing, as well as for building the infrastructure to meet the new requirements, in contrast to product development and traditional services. However, many companies lack a systematic and established process of implementing data-driven innovations (Cronholm et al., 2017).

Additionally, a major challenge arises from the lack of expertise in data analysis and processing (Marquardt, 2017), which is prevalent high in SMEs (Rauch et al., 2020). In contrast to traditional industrial services, such as maintenance and repair tasks, DDS require new competencies, such as comprehensive knowledge of IT and advanced technologies (Kampker, Husmann, Harland, et al., 2018). Qualified employees are generally in high demand, such as those from the fields of software development, systems engineering, cloud technologies, and data analytics (Porter & Heppelmann, 2015).

In traditional industrial companies, IT systems and management systems are built over time and optimized for existing product-based businesses. Since the requirements for the provision of DDS strongly differ, the existing structures are usually unsuitable. Technical immaturity and outdated technologies are therefore major obstacles in this context (Töytäri et al., 2017). Investment in data-driven servers and new technologies can represent a significant upfront cost, which can deter SMEs especially (Klein et al., 2018; Smith & Smith, 2007).

The availability of high-quality data is crucial for the success of DDS, as it ensures the usability of the novel services. With high quality, the reliability of the data and thus the analysis results can be ensured (Pikkarainen et al., 2020). However, in the course of data exchange, ensuring satisfactory data quality proves to be a major challenge (Richter & Slowinski, 2019). Here, a lack of standards leads to highly complex interoperability and compatibility among machines, companies, and infrastructures, which poses a special problem to SMEs (Orzes et al., 2020).

Monetization: Another aspect is the change in revenue models when offering DDS, for example, by moving from a traditional service purchase to a license or usage rate model (Enders et al., 2019). This raises the question of which revenue model is best suited to the specific service (Pikkarainen et al., 2020). Additionally, the companies offering new services often have little experience in pricing them. Furthermore, customers often expect traditional, product-centric services to be free (Allmendinger & Lombreglia, 2005). Customers are reluctant to pay extra for services and show an attitude that can be described as expecting "service for free" (Coreynen et al., 2017, p. 5), which is equally true for DDS.

3. Interpretive Structural Modeling Analysis

ISM is a qualitative and interpretive method that generates solutions to complex problems through discourse, based on the structural mapping of complex interrelations of system elements (Malone, 1975; Watson, 1978). The aim is to establish an interactive, computer-based learning process in which a series of heterogeneous, directly related elements are structured into a comprehensive systematic model (Dewangan et al., 2015). In this manner, the complex relations between system elements are identified and ordered so that their influence on each other can be analyzed (Pfohl et al., 2011).

The core idea behind ISM is the utilization of practical experience of experts and knowledge to transform complex articulated models into clear and evident models (Gholami et al., 2020; Sage, 1977), which is why this method was chosen to answer the research question. In the following, the most important steps of ISM are briefly described below according to Pfohl et al. (2011): First, the relevant barriers were identified based on the literature analysis [1]. In the next step, the influences of the barriers on each other are discussed [2]. Subsequently a pairwise comparison constructs the self-interaction matrix (SSIM, s. Table 2) [3]. Following, the final reachability matrix is created, and the transitivity is checked. Based on this, the level partitioning takes place. In doing so, it examines which of the barriers have the greatest impact and which play a downstream role. This forms the basis for creating the ISM model and graphically

Table 2. Structural self-interaction matrix (SSIM)

Barrier i	Barrier j																	
	B19	B18	B17	B16	B15	B14	B13	B12	B11	B10	B09	B08	B07	B06	B05	B04	B03	B02
B01	O	O	O	V	V	X	V	V	V	O	V	V	V	O	O	O	V	V
B02	O	O	O	V	V	V	O	O	O	O	O	X	V	O	O	V	V	
B03	O	O	O	V	V	V	O	V	O	V	O	V	O	O	O	O		
B04	V	O	O	O	V	V	V	O	V	V	V	O	O	X	X			
B05	X	O	O	O	O	A	V	O	X	O	A	O	O	O				
B06	V	O	O	O	O	O	O	O	O	O	O	O	O					
B07	V	O	O	O	X	V	O	V	O	O	V	X						
B08	O	O	O	O	V	X	O	O	O	O	O							
B09	X	V	O	O	O	X	X	A	X	X								
B10	V	O	X	X	A	A	O	O	X									
B11	O	O	V	O	A	A	O	O										
B12	X	V	O	O	A	X	X											
B13	V	O	O	O	A	X												
B14	V	V	V	O	X													
B15	V	O	O	V														
B16	V	V	X															
B17	O	V																
B18	X																	

depicting the dependencies (s. Figure 1) [4]. In the fifth step, a cross-impact matrix multiplication applied to classification (MICMAC) analysis is performed within this paper to analyze the driving and the dependence powers of enablers [5].

Finally, the ISM model and the MICMAC analysis are checked for inconsistencies [6].

3.1 Construction of Structural Self-Interaction Matrix

The foundation for the development of the structural self-interaction matrix (SSIM) (see Table 2), following the ISM model, is formed by the experts' views and opinions on the definition of the contextual relation. To this end, we have collaborated with four companies originating from a consortium research project that has been ongoing for over 24 months and one external SME, dealing with the realization of industrial DDS in value networks. All involved industry experts (2x managing director; 1x head of production; 1x general manager; 1x head of sales) hold leading positions in product-centric SMEs, from head of production to managing director. Collectively, all experts had over 120 years of experience in the manufacturing sector, with SME company sizes ranging from 20 to 190 employees. Conducting focus group interviews (5 in total) has enabled us to identify the contextual correlation for each barrier, each relation between elements (i and j), and the associated direction of the relation ("will influence"). In accordance with the ISM model, we apply the method-specific four notations to represent the direction of the relations between two barriers (i and j):

- V: Barrier i will influence barrier j.
- A: Barrier j will influence barrier i.
- X: Barrier i and j will influence each other.
- O: Barriers i and j are unrelated.

The experts were asked to what extent they saw a connection between the individual barriers. The notations in Table 2 were set accordingly and jointly adjusted via the focus group workshops if there were any discrepancies.

3.2 Development of the Final Reachability Matrix

In the succeeding process step, the developed SSIM is transformed into an initial reachability matrix (binary matrix), based on the following substitution rules:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1, and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0, and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, then both the (i, j) and (j, i) entries of the reachability matrix become 1.
- If the (i, j) entry of the SSIM is 0, then both the (i, j) and (j, i) entries of the reachability matrix become 0.

Table 3. Final Reachability Matrix (1* denotes transitivity)

	B19	B18	B17	B16	B15	B14	B13	B12	B11	B10	B09	B08	B07	B06	B05	B04	B03	B02	B01	**Driving Power**
B01	1*	1*	1*	1	1	1	1*	1	1	1*	1	1	1	0	1*	0	1	1	1	**17**
B02	1*	1*	1*	1	1	1	1*	1*	1*	1*	1*	1	1	1*	1*	1	1	1	1*	**19**
B03	1*	1*	1*	1	1	1	1*	1	1*	1	1*	1	1*	0	1*	0	1	1*	1*	**17**
B04	1	1*	1*	1*	1	1	1	1*	1	1	1	1*	1*	1	1	1	0	0	1*	**17**
B05	1	1*	1*	0	1*	1*	1	1*	1	1*	1*	0	0	1*	1	1	0	0	0	**13**
B06	1	1*	0	0	1*	1*	1*	1*	1*	1*	1*	0	0	1	1*	1	0	0	0	**12**
B07	1	1*	1*	1*	1	1	1*	1	1*	1*	1	1	1	0	1*	0	0	1*	0	**15**
B08	1*	1*	1*	1*	1	1	1*	1*	1*	1*	1*	1	1	0	1*	0	1*	1	1*	**17**
B09	1	1	1*	1*	1*	1	1	1*	1	1	1	1*	0	0	1	1*	0	0	1*	**15**
B10	1	1*	1	1	0	1*	1*	1*	1	1	1	0	0	0	1*	0	0	0	0	**11**
B11	1*	1*	1	1*	0	1*	1*	0	1	1	1	0	0	0	1	1*	0	0	0	**11**
B12	1	1	1*	1*	1*	1	1	1	1*	1*	1	1*	0	0	1*	0	0	0	1*	**14**
B13	1	1*	1*	0	1*	1	1	1	1*	1*	1	1*	0	0	1*	0	0	0	1*	**13**
B14	1	1	1	1*	1	1	1	1	1*	1	1	1	1*	0	1	1*	0	1*	1	**17**
B15	1	1*	1*	1	1	1	1	1	1	1	1*	1*	1	0	1*	0	0	0	0	**14**
B16	1	1	1	1	0	0	0	1*	1*	1	1*	0	0	0	1*	0	0	0	0	**9**
B17	1*	1	1	1	0	0	0	0	1*	1	1*	0	0	0	0	0	0	0	0	**7**
B18	1	1	0	0	0	0	0	1*	0	0	1*	0	0	0	1*	0	0	0	0	**5**
B19	1	1	0	0	0	1*	1*	1	1*	1*	1	0	0	0	1	0	0	0	0	**9**
Dep. Power	**19**	**19**	**16**	**14**	**13**	**16**	**16**	**17**	**18**	**18**	**19**	**11**	**8**	**4**	**18**	**7**	**4**	**6**	**9**	

Transitivity is a basic assumption in ISM that leads to the final reachability matrix. It claims that if element A influences B and B influences C, it may be inferred that barrier A influences barrier C (Watson, 1978). The process of examining these relations has not been included in the initial reachability matrix. To fix this issue, a mathematical relation is advanced to form the final reachability matrix (see Table 3). The summation of each row shows the driving power of each element, which indicates how much each barrier can influence other barriers. The summation of each column also shows the dependence power on each element, specifying how much each barrier can be influenced by others (Gholami et al., 2020). Therefore, B1, with driving power 17 and dependence power 9, is discovered to be the dominant barrier.

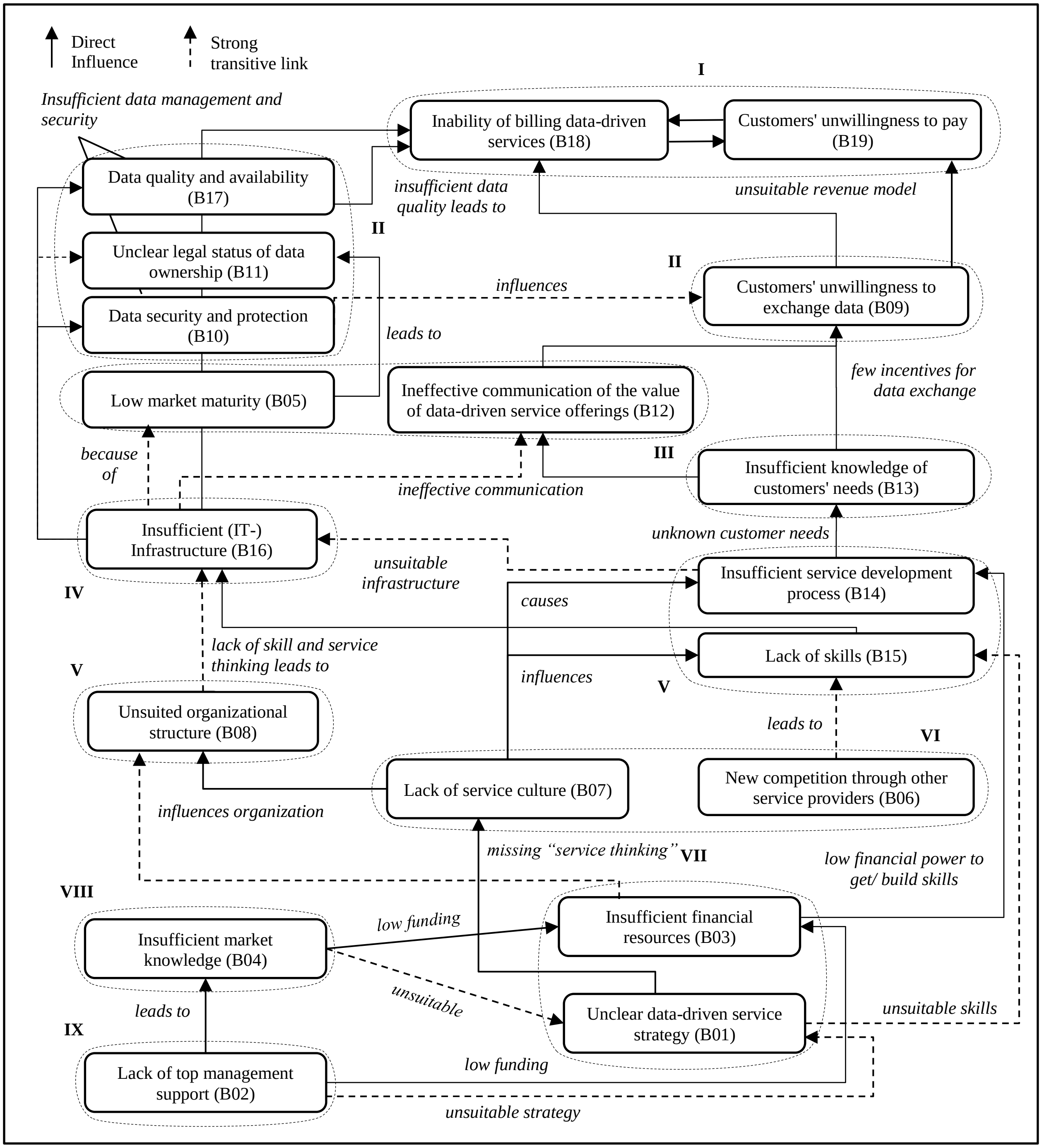

Figure 1. Interpretive structural modeling (ISM) approach for barriers (read from bottom to top)

3.3 Formation of ISM Model

From the final reachability matrix, reachability $R(s_i)$ and antecedent sets $A(s_j)$ for each barrier are obtained. The reachability set comprises the particular barrier itself and other barriers that it may influence, whereas the antecedent set consists of the barrier itself and the other barriers that may influence it. Subsequently, the intersection ($R(s_i) \cap A(s_j)$), of these sets is determined for all barriers so that the levels (number of iterations) of different barriers can be verified. The barrier for which the reachability and the intersection sets are the same is assigned the top level in the ISM hierarchy and then discarded from the other remaining barriers.

This process continues until the level of each barrier is derived. The 19 barriers are categorized along with their reachability sets, antecedent sets, intersection sets, and finally, their derived levels, which have been completed in seven iterations. Level I represent the top of the ISM model and consists of "inability of billing data-driven services" (B18) and "customers' unwillingness to pay" (B19). After the level of each barrier is recognized, the ISM model can be created. Figure 1 illustrates the final structural model that is developed from the final reachability matrix (Table 3) and based on the level partitions.

To analyze the driving and the dependence powers of enablers (i.e., barriers in the context of this study), a cross-impact matrix multiplication applied to classification (MICMAC) analysis is performed. The driving power and the dependence power of each barrier are calculated in Table 3, referring to the summation of each row and each column, respectively. The aim of the analysis is to classify the key barriers, depending on their driving and dependence powers.

4. Results and Discussion

During the development of the ISM, we have gathered further insights about the barriers and their interactions in the context of implementing DDS. In this way, based on the driving force (19) and the dependency performance (6), we have shown that the central barrier is the "*lack of support from top management*" (B02). Furthermore, we have divided the barriers into four clusters and have conducted further analysis based on each cluster (Figure 2).

Autonomous barriers do not have much influence on the model. Barriers located in this area will be virtually isolated since they are relatively disconnected from the model (Gholami et al., 2020). The analyses have shown that none of the examined barriers can be considered autonomous. Thus, they have no low impact in terms of driver and dependency on the development of DDS.

Dependent barriers have low driving power and high dependence. These are insufficient infrastructure (B16), insufficient data quality and availability (B17), inability of billing data-driven services (B18), and customers' unwillingness to pay (B19), which are derived from the top of the ISM hierarchy (levels I–IV). Therefore, SMEs should take special care in handling these barriers. To this end, a full understanding of the dependence of these barriers on other-level barriers in ISM should be considered by service managers.

Linkage barriers, namely low market maturity (B05), unsuited organizational structure (B08), customers' unwillingness to exchange data (B09), data security and protection (B10), unclear legal status of data ownership (B11), ineffective communication of the value (B12), insufficient knowledge of customers'

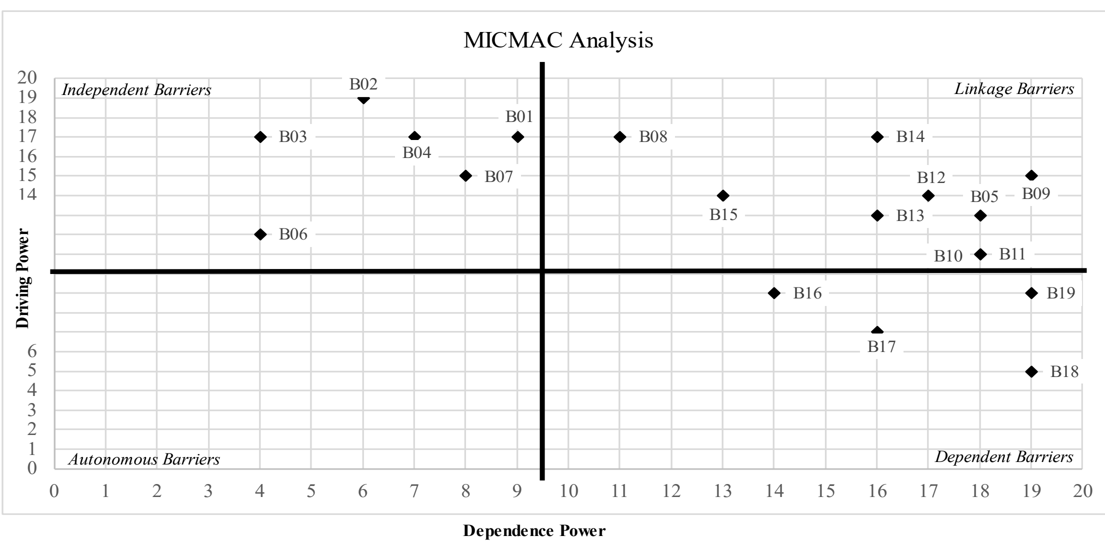

Figure 2. Driving Power and Dependence Power Diagram

needs (B13), insufficient service development process (B14), and lack of skills (B15), have both strong driving power and high dependencies. They are also considered unstable, which means that any action on them will have an impact on other barriers, as well as on themselves (Gholami et al., 2016). For this reason, SMEs should consistently pay attention to these barriers.

Independent barriers have strong driving power but weak dependence power. Besides the aforementioned barrier (B01), there are lack of top management support (B02), insufficient financial resources (B03), insufficient market knowledge (B04), new competition through other service providers (B06), and lack of service culture (B07) shows the study. They are the dominant barriers and are accordingly located on the lower levels of the ISM. Thus, to implement DDS, SMEs need to focus on these barriers, which represent strategic and resource issues, and should formulate approaches to reduce or overcome them in order to successfully develop DDS.

In summary, the biggest challenge in developing DDS for SMEs is getting support from the top management. This is required by all other factors, such as the development of the service strategy or the provision of sufficient financial resources in general. Aspects such as data quality or even data security initially play rather less of a role. This is probably due to the fact that most of the SMEs still have a different level of maturity compared to larger companies and initially still rank the relevance of DDS for their own business model higher internally. A further key aspect is that SMEs in the manufacturing sector are, for example, strong in producing special machines or performing services. However, the costs of developing and establishing DDS would be very high compared to the expected return on investment. This seems to be one of the main reasons why SMEs find it so difficult to develop DDS, according to feedback from the consortial research project.

5. Conclusions, Limitations, and Outlook

Developing DDS is a key challenge for most SMEs in our technology-oriented world. In particular, identifying the key barriers in the innovation and development process is a key challenge for companies. To address this issue, we have identified 19 core barriers, as well as their driving and dependence powers, based on a combination of a systematic literature review and focus group interviews. Furthermore, we have transformed these into an ISM and have created a tactical and strategic decision support for SMEs' DDS development.

Our study contributes theoretical and practical knowledge to the development of DDS through a barrier analysis. Specifically, we have analyzed the interactions between these barriers that face SMEs by developing the contextual relations between the identified key barriers.

Furthermore, our study provides practitioners and managers with a guide for developing DDS by focusing on reducing or eliminating the most relevant barriers. As illustrated in Figure 1, SMEs must solicit top management support first, as well as analyze the market for DDS and supply sufficient financial resources. This indicates that DDS should not be developed without appropriate pre-planning; rather, it should follow a structured process and strategy aligned with the business model. Thus, the model can help practitioners prioritize and focus on those barriers to increase the likelihood of success with DDS.

Regardless of the academic and the practical implications, this paper is not free of limitations. For example, the literature selection process—in which the key barriers have been identified and on which the ISM that we have developed has been based—is always prone to a certain degree of subjectivity. To provide the highest possible degree of objectivity at this point, the selection and the barrier development were done cooperatively by several researchers. Furthermore, the ISM approach has its own limitations, such as the dependence on expert judgments. To counteract these, we conducted various rounds of interviews with different experts from diverse companies over a 24-month period. Furthermore, it would be valuable to check the results with other companies from the industry in order to increase the validity.

The developed ISM provides a methodologically sound starting point for future research. From our perspective, the central points here are expansion and adaptation of the barriers based on further development of the topic area, on one hand, and further evaluation of the model based on structural equation modeling, on the other hand. In conclusion, this study's developed model provides a supportive framework for the development of DDS and establishes a conceptual foundation for future research.

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