Preconditions and Challenges in the Digital Transformation of Supply Chains: Findings from Academia and Practice

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Abstract. Digital technologies are omnipresent in today's world, and successful involvement in the digital transformation becomes increasingly important to companies from all industries. To stay competitive, companies are pressured to rethink their supply chains and adapt. However, the topic of digital supply chains is still in its infancy. The goal of this paper is to shed light on the preconditions and challenges regarding the transformation. The different areas of the digital transformation of supply chains, namely the strategic, organizational, process & method, and technological area are considered. Preconditions and challenges for companies in the digital transformation of their supply chain are extracted from literature with literature reviews and followingly discussed with practitioners to capture the magnitude of the transformation process. Furthermore, differences between academia and practice are revealed, and future research opportunities are identified.

1 Introduction

The digital transformation of supply chains is driven by the latest advancements in technology. Companies are being pressured to adopt emerging technologies to stay competitive and to satisfy changing customer requirements (Agrawal and Narain 2018; Bienhaus and Haddud 2018). Furthermore, companies start such transformation initiatives to capitalize on the gains of improving supply chain processes, increasing their resilience, and minimizing risks, while also improving operational excellence and revenues (Ivanov et al. 2019). Besides the evolutionary side, new business models emerge, partly having the potential to disrupt.

While digital transformation is expected to mitigate some challenges in today's supply chain management and bring many benefits and opportunities, it can also be seen as a complex and expensive undertaking (Agrawal and Narain 2018). Supply chains involve several functional areas on an intra-organizational level as well as interconnections between multiple actors on an inter-organizational level, thus requiring several preconditions to be successfully transformed. However, the adoption of digital technologies in supply chains is not very advanced, hinting towards obstacles and barriers

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associated with this process (Lammers et al. 2019). Supply chain disruptions are identified as one of the most severe risks and challenges in 2020 (Greg Dobie et al. 2020). The resulting loss of revenue can threaten the existence of both small and large enterprises.

The understanding of what a Digital Supply Chain (DSC) is (Büyüközkan and Göçer 2018) is still in its beginning, and the potentials are not fully explored. Previous research mainly focuses on single technological drivers or concepts like Industry 4.0, underlining the complexity and novelty of this topic. The process of digital transformation involves various challenges and must be well thought out. It can be daunting not having an overview and understanding of possible challenges and not knowing which ones to focus on. This can hinder the process of innovation and prevent companies from accessing the promising opportunities of new technologies.

Thus, in this paper, all areas of the digital transformation are considered: from strategic to organizational, process & method, and technological aspects. This paper aims to identify the preconditions and challenges for companies in the digital transformation of their supply chain. Literature but also practitioner's knowledge is taken into account to shed light on the following research questions discussed:

- Which preconditions and challenges regarding the digital transformation of supply chains can be identified in the literature regarding the different transformation areas?
- What are the insights from discussing the literature results with practitioners and their experience in expert interviews?

The remainder of this paper is structured as follows: In Sect. 2, the theoretical background is briefly outlined. In Sect. 3, the methodologies of literature reviews and semi-structured interviews are introduced. Afterward, the results of the conducted literature reviews are presented (Sect. 4) and reviewed with experts (Sect. 5). Finally, the findings are discussed in Sect. 6, and the paper concludes with a brief recap, limitations, and further research opportunities in Sect. 7.

2 Theoretical Background

To create a common understanding of terms and concepts referred to, the theoretical background of this paper is outlined in the following.

While digitization can be defined as "the action to convert analog information into digital information" (Verhoef et al. 2019: 3), digitalization is about changing tasks and processes in an organization, as its objective is a "reconfiguration of assets to develop new business models" (Verhoef et al. 2019: 3 f.). Digital transformation goes one step further. It can be seen as a process that is "concerned with the adoption and use of emerging technologies" (Morakanyane et al., 2017: 438). The emphasis is on major changes to an entire enterprise (Cichosz et al. 2020).

In this paper, Büyüközkan and Göçers' frequently cited definition of a DSC is used (Büyüközkan and Göçer 2018). They define the concept as an agile, customer-driven, productive way to develop different forms of returns for companies and to leverage efficient approaches with emerging technologies. Researchers emphasize that it is crucial to take advantage of new technologies in traditional supply chains to be successful in

global markets (Agrawal et al. 2019). Frequently mentioned emerging technologies of a DSC in academia are, for example, big data analytics, internet of things, cloud computing, cyber-physical systems, or blockchain (Ivanov et al. 2019; Queiroz et al. 2019). However, besides the technological aspects, also other areas have to be taken into account to succeed in the digital transformation (Kane et al. 2015; Kohnke 2017).

Different authors have proposed structures and frameworks of DSC to obtain a deeper understanding of the concept (Büyüközkan and Göçer 2018; Farahani et al. 2017). Merging the frameworks and further digital transformation-related literature, we suggest a working definition of a DSC framework with four areas, namely Strategic Digitalization, Organizational Digitalization, Process & Method Digitalization, and Technological Digitalization. The areas are briefly presented and examined separately to create a structured overview. However, strong interrelations exist. The area of business digitalization has an external steering focus and covers aspects like strategy, governance, value offering, and more. The second area, organizational digitalization, focuses on the internal digitalization of the supply chain, covering aspects like employees, culture, and structure. The third area, process & methods, concerns itself with aspects such as the digital transformation of business and supply chain-related processes, as well as supply chain collaboration and networks. Lastly, the area of technological digitalization relates to the implementation of smart objects and autonomous systems, the integration of data, information-related processes, technological infrastructure, architecture, as well as IT security aspects. The two areas, strategic and organizational digitalization, are closely related, and therefore the identified preconditions stem from the same stream of literature. The same holds for the technological and process & method areas examined regarding the challenges (cf. Fig. 1). We acknowledge that it would be beneficial to include all four areas in the review with preconditions and challenges, which we propose for future research.

Digitalization Areas / Subject of Study	Strategic	Organizational	Process & Method	Technological
Preconditions	Considered in this study	Considered in this study	Future research	Future research
Challenges	Future research	Future research	Considered in this study	Considered in this study

Fig. 1. Transformation areas in digital supply chains and scope of study

3 Methodology

In this chapter, the methodologies are briefly described to ensure a transparent and clear structure of the research process. First, for information gathering, literature reviews are conducted to answer the first research question. Second, the results from the literature are discussed with and evaluated by experts from the industry. The methodology of semi-structured expert interviews is applied to answer the second research question.

3.1 Structured Literature Review

The applied procedure for the literature reviews is based on the recommendations of Vom Brocke et al. (2009). A conceptualization of the topic follows the definition of the scope of the search. This conceptualization corresponds to the four areas of the digital transformation presented in Sect. 2. The database Scopus is selected as the primary source, as it is one of the most extensive abstracts and citation databases of peer-reviewed literature regarding science and technology, and widely used. Further, Web of Science is used (in snowball search) as a complementary source due to its reputation and multidisciplinary nature. The literature reviews took place in November and December 2020. The applied search strings are separated and results are depicted in Table 1. Firstly, for the preconditions, a more general string is applied to identify relevant literature because literature pointing out only preconditions is absent. "TITLE-ABS-KEY (supply AND chain AND digital AND transformation)". Secondly, regarding the challenges, the following term is applied: "TITLE-ABS-KEY ("Supply Chain" AND ("Digital Transformation" OR "Digitization") AND ("Challenges OR "Challenging" OR "Obstacles" OR "Barriers"))".

The inclusion and exclusion criteria in the first review ("preconditions") focus on papers naming or discussing preconditions for a successful digital transformation of supply chains in the strategical and organizational area. The criteria of exclusion are mainly related to the content, many papers only focus on technological aspects. A number of case studies specifically describe the implementation of single technologies, failing to analyze the required preconditions. In the second review ("challenges"), the focus lies on barriers of digital transformation in supply chains related to the areas of processes & methods, and technology. Insights regarding digital supply chains, industry 4.0, as well as digitization and digitalization in supply chains are considered as relevant. A high number of papers is rejected because they focus on challenges regarding other areas (e.g., organizational digitalization, only considered in the preconditions part) or on obstacles of companies in general and not especially on the supply chain. Papers and identified preconditions/challenges are sorted following a concept-centric approach by Webster and Watson (2002). Therefore, if a precondition or challenge is identified, the corresponding authors are added. The data analysis is an iterative process during which the concepts are re-structured and re-grouped. In this paper, we only present the final allocation of preconditions and challenges. Collection of identified preconditions/challenges and analysis, are presented next.

3.2 Semi-Structured Interviews

To gain further insights into the preconditions and challenges and their perceived importance in industry, the results of the literature analysis are discussed in semi-structured interviews with industry experts. This type of interview is chosen as it promotes a sociable and informal atmosphere, in which the interviewee can be more forthright and rather respond in his or her own words (Longhurst 2003). The interviewees should be able to raise their own ideas, thoughts, and questions in an open conversation, while certain guiding questions and issues must still be addressed for the objective of the work.

Table 1. Details of conducted literature reviews

Literature review	Preconditions	Challenges
Number of results with search string (Scopus)	332	108
Remaining number of results after title, abstract and keyword analysis	21	27
Remaining number of results after full-text	12	9
Additionally considered papers (e.g. snowball)	31	11
Total number of papers included	43	20

Guiding questions are prepared beforehand, which are used for orientation for the interviewer. The interview guidelines developed by Myers and Newman (2007) are taken into consideration.

The structure of the interviews is briefly presented: First, general questions are asked about the interviewee, the company, and the importance of digital transformation. Second, the categories of preconditions/challenges identified in the literature are presented and explained by the interviewer without the number of occurrences in the literature. Next, the interviewees rank the preconditions/challenges regarding their perceived importance in practice. The interviewer inquires for detailed reasons and takes notes. Further questions conclude the interview. Subsequently, a protocol is created shortly after the interview.

The interviews are conducted as a virtual meeting due to contact restrictions given by the current pandemic. Furthermore, the interviews are conducted in German, the interviewees' native language, to foster an open and informal conversation. At the start of the meeting, the participant is asked for permission to record the meeting to create a transcript. Only the position and name of the company will be included to ensure anonymity but underline credibility. Each interview lasted about 60–90 min. The transcripts are sent to the interviewees to ensure appropriate representation. The first company chosen for the interview is an agricultural machinery manufacturer situated in Germany. Two supply chain managers attended the interview, providing extensive knowledge and project experiences in digital supply chains transformation projects. The second company is an outsourcing service provider with more than 15.000 employees, situated in Germany. The interviewee is head of a division in the digital solutions department.

4 Results of the Literature Review

The preconditions (Tables 2 and 3) and challenges (Tables 4 and 5) identified in the literature review are presented in the following. They can be ranked regarding their number of mentions in the literature and are presented in descending order.

4.1 Preconditions in the Area of Strategic Digitalization in DSC

One of the most elementary preconditions for the successful adoption of a DSC is the specific strategic orientation that guides a company as well as its associated business

objectives (Sabri et al. 2018). The strategy of a company supports the translation of innovative ideas regarding the DSC into a framework for the project of transformation (Agrawal et al. 2020), besides playing an important role in deciding on goals and a vision for the whole organization (Narver and Slater 1990). A digital transformation initiative of a supply chain requires orientations such as customer-, technological-, competitor-, supplier- as well as innovation orientation (Agrawal et al. 2020; Wang et al. 2015). The focus of a customer-centric oriented strategy should especially be speed, flexibility, and transparency, among other related features (Agrawal et al. 2020; Büyüközkan and Göçer 2018; Xu 2014). Speed regards the reduced delivery time for, e.g., suppliers (Büyüközkan and Göçer 2018). Flexibility portrays the operational agility of a supply chain in adaption to changing circumstances by using collected and modeled information (Büyüközkan and Göçer 2018; Xu 2014). Regarding a transparent supply chain, actors perform according to the behavior and needs of other actors, enabled by anticipation, modeling of the network, or what-if scenarios (Büyüközkan and Göçer 2018).

Some authors report on the importance of suitable innovation strategies for the efficient development of digital transformation processes, as weak innovation strategies can be considered as a barrier (Lammers et al. 2019; Molinillo and Japutra 2017; Peansupap and Walker 2005; Sabri et al. 2018). Peansupap and Walker (2005) elaborate on issues of such a strategy that are critical for the adoption of information and communication technology, and especially emphasize management and employee issues. First, sufficient training and development should help users to understand the basics of applications they should use (Peansupap and Walker 2005). Second, from a psychological perspective, supervisor and organizational support is necessary to address the willingness of adopting new applications by role models. Lastly, reward systems motivating users in the adoption of applications in their work processes are of importance (Peansupap and Walker 2005). The above mentioned aspects depict the high significance of employee-focus.

The availability of industry-specific guidelines is another important aspect for a successful transformation of a supply chain and to have a clear vision of the implementation (Agrawal et al. 2020; Lammers et al. 2019; Preindl et al. 2020; Wu et al. 2016). Following guidelines can be challenging since most studies on DSC were conducted focussing on benefits. Frameworks and roadmaps on the adaption and implementation of a DSC in academia for specific industrial sectors are not yet available, even though they could provide helpful blueprints (Agrawal et al. 2020; Preindl et al. 2020). In such cases, joint efforts of business and IT are needed to formulate strategic plans to realize the transformation (Agrawal et al. 2020).

4.2 Preconditions in the Area of Organizational Digitalization in DSC

The organizational design of a company that is planning to transform its supply chain should be aligned according to Agrawal et al. (2020) for direct communication and sharing of data and information between different stakeholders. They argue that the DSC aims at enabling greater data transparency and synchronicity for the decision-making of stakeholders (Agrawal et al. 2020). Even though this can be considered as an important precondition within one organization, the same applies to inter-organizational collaboration within a supply chain, since accurate and timely sharing of such information

Table 2. Preconditions in the strategic digitalization area identified

Strategic precond.	Sources
Strategic orientation & business objectives	(Agrawal et al. 2020; Büyüközkan and Göçer 2018; Sabri et al. 2018; Wang et al. 2015; Xu 2014)
Innovation strategies	(Lammers et al. 2019; Molinillo and Japutra 2017; Peansupap and Walker 2005; Sabri et al. 2018)
Industry-specific guidelines	(Agrawal et al. 2020; Lammers et al. 2019; Preindl et al. 2020; Wu et al. 2016)

might enhance demand forecasting by suppliers or retailers in providing products and services on time (Rajaguru and Matanda 2019; Wu et al. 2016). Thus, Agrawal et al. (2020) identify the organizational structure for a digital transformation of a supply chain to be agile, integrated, innovative, and adaptive to allow a transparent flow of information serving the sharing of knowledge and learning, collaboration, and decision-making.

The development of a suitable organizational culture plays a significant role when addressing the changes needed for a digital transformation of a supply chain and highlights the human-related factors. One aspect is the innovation culture, which relates to the constant attention for improvement potential in products, strategies, and processes (Hjalmarsson et al. 2014). In case such an innovation culture is unsupportive, it is mentioned as an obstacle to introducing innovations (Hjalmarsson et al. 2014; Lammers et al. 2019). Additionally, this kind of culture requires an environment of open discussion, e.g., among employees, supporting new ideas and improvement suggestions. Other crucial aspects are time spent on planning (Lammers et al. 2019) or the readiness to take risks (Agrawal et al. 2020).

Another important precondition mentioned in the literature is knowledge management (Büyüközkan and Göçer 2018; Campos Martins and Simon 2018; Lammers et al. 2019). Employees need to possess a certain set of knowledge, skills, and attributes required to use digital applications in supply chains (Janssen et al. 2013). Companies require personnel to be able to implement the digital innovation beforehand, e.g., data scientists, who are often missing (Lammers et al. 2019).

Table 3. Preconditions in the organizational digitalization area identified

Organizational precond.	Sources
Organizational design	(Agrawal et al. 2020; Rajaguru and Matanda 2019; Wu et al. 2016)
Organizational culture	(Agrawal et al. 2020; Hjalmarsson et al. 2014; Kaner 2014; Lammers et al. 2019)
Knowledge management	(Büyüközkan and Göçer 2018; Campos Martins and Simon 2018; Janssen et al. 2013; Lammers et al. 2019)

4.3 Challenges in the Area of Process & Method Digitalization in DSC

The most prominent challenges in the area of processes & methods in the selected literature relate to a lack of standards, guidelines, and frameworks to support the digital transformation in supply chains. Having no guidance or best practices to refer to can complicate making the right decisions. Furthermore, not knowing what to transform first and where to start such an elaborate process is a barrier (Agrawal et al. 2020). It also makes the planning of such projects more complicated and prone to errors (Büyüközkan and Göçer 2018). This can cause mistakes and inefficiencies, which can consume many resources. Problems like this could be avoided when having industry-specific guidelines based on past experiences and studies to give directions and recommendations to facilitate the digital transformation. Further studies should therefore focus on creating standards, guidelines, and frameworks to overcome this challenge (Ghadge et al. 2020). At the same time, practitioners should also be aware of already available supporting measures and consider their benefits for their company (Zangiacomi et al. 2018).

Other obstacles are collaboration and coordination difficulties. Being an extensive and far-reaching process affecting many entities, the complexity of the coordination between the actors of the supply chain becomes more demanding. This is especially the case for cross-channel logistics (Ivanov et al. 2019). In addition, insufficient or too little collaboration between actors can lead to issues like inconsistencies or misalignments when implementing new technologies that have an influence on different systems and infrastructures. As a result, effective collaboration and coordination between those involved becomes imperative, and their capabilities should be leveraged for collective value creation (Lavikka et al. 2017).

Furthermore, the complexity of underlying processes, structures, and networks is also identified as a challenge. The digital transformation can require radical changes to the supply chain, its structures, and the processes of an organization (Ivanov et al. 2019). As this involves many business processes that can be extensive, involve many stakeholders, and might not always be well documented, their transformation can be hampered. This is further underlined by the multitude of actors in a supply chain and the underlying complex networks (Ghadge et al. 2020), as well as through the differences within an organization and its various projects (Anand and Krishna 2019). Due to this complexity, it becomes increasingly challenging to standardize different processes and synchronize the IT systems of those involved in the transformation (Cichosz et al. 2020). It emphasizes the need for efficient collaboration as well as structured guidelines to support the transformation.

The last challenge of process & methods relates to a lack of flexibility of processes, referring to the ability to adapt the processes to changes. When this is not the case, and the processes of an organization do not have the required agility, performing a digital transformation associated with a lot of change will be difficult (Büyüközkan and Göçer 2018). Business processes need to be adjustable and configurable to perform well (Agrawal et al. 2020).

4.4 Challenges in the Area of Technological Digitalization in DSC

Challenges relating to technology competence and the qualification of employees have a high occurrence in the selected literature. In general, the development of employee skills

Table 4. Challenges in the process & method digitalization area identified

Process & method chall.	Sources
Lack of standards, guidelines, and frameworks	(Agrawal and Narain 2018; Büyüközkan and Göçer 2018; Ghadge et al. 2020; Horváth and Szabó 2019; Lammers et al. 2019; Raj et al. 2020; Zangiacomi et al. 2019)
Collaboration and coordination difficulties	(Agrawal and Narain 2018; Büyüközkan and Göçer 2018; Ghadge et al. 2020; Ivanov et al. 2019; Lammers et al. 2019; Lavikka et al. 2017)
Complexity of underlying processes, structures, networks	(Agrawal and Narain 2018; Anand and Krishna 2019; Cichosz et al. 2020; Ghadge et al. 2020; Ivanov et al. 2019)
Lack of flexibility of processes	(Agrawal et al. 2020; Agrawal and Narain 2018; Büyüközkan and Göçer 2018)

is assigned to the organizational area of digital transformation. However, the employees' technical knowledge is crucial for providing a technical foundation and performing the transformation. Studies show that digital skills among employees are often scarce (Hoberg et al. 2017). A lack of necessary skills and qualifications is a major obstacle and can heavily stall the digital transformation (Agrawal et al. 2020). Enterprises should invest in staff training and acquire new personnel to address this vital challenge (Bienhaus and Haddud 2018). Nevertheless, this requires them to recognize the importance of developing the necessary technical competence, as well as to promote the sharing of knowledge and best practices among employees (Zangiacomi et al. 2018). In addition, it is challenging to determine how much staff and training in which specific areas is required (Schlaepfer and Koch 2015).

Obstacles addressing financial issues are frequently covered in the selected literature. The digital transformation requires large investments in new technologies, innovations, digital tools, and equipment (Lammers et al. 2019). Implementing and maintaining technologies is essential for the transformation but associated with high costs (Agrawal et al. 2020). Furthermore, it can be difficult to evaluate the financial merit of such investments (Raj et al. 2020). This can be seen as a barrier, but organizations should not disregard the long-term benefits. The selection of the right technologies and solutions in terms of their return on investments and the business needs of the respective enterprise is essential. For this purpose, a clear strategy for shaping investments should be developed (Zangiacomi et al. 2018).

IT security and data privacy issues are identified as one of the most critical challenges of technological digitalization in supply chains. As more devices become digitally connected and more information is shared between companies, cybersecurity risks will rise dramatically (Agrawal et al. 2020). Besides, as businesses become increasingly dependent on the various networked information systems, their smooth and proper functioning becomes more critical as well. Viruses and cyber-attacks can disrupt networked systems and cause downtime and enormous costs (Schlaepfer and Koch 2015). Incidents like

unauthorized access or data breaches can lead to lawsuits and losing customers (Cichosz et al. 2020).

Another category of challenges relates to building a proper IT infrastructure. The digital transformation requires a solid technological foundation to build on, e.g., broadband infrastructure. Furthermore, new systems need to be integrated, and existing systems need to be adjusted. Studies show that many companies are lacking behind regarding this aspect (Schlaepfer and Koch 2015). Establishing a software architecture and platforms that can collect and utilize data to manage and operate the supply chain can be challenging (Büyüközkan and Göçer 2018). Large volumes of storage capacity are necessary, and problems such as a lack of uniform communication protocols or back-end integration systems can further obstruct this process (Horváth and Szabó 2019). This also relates to some of the other challenges. Large investments are needed for the realization of a solid IT infrastructure, and digital skills, proper collaboration, and supporting guidelines are important.

Information and data management is also associated with obstacles. Underlined by the multitude of different actors and projects in a supply chain, a variety of valuable information accumulates. Yet, much of this information is lost and not stored for future reuse (Anand and Krishna 2019). At the same time, large amounts of data are generated through multiple interconnected information systems. Managing these volumes of data can be demanding (Schlaepfer and Koch 2015). It is accumulated from different sources, while its accuracy and quality has to be ensured (Büyüközkan and Göçer 2018; Raj et al. 2020). To address these challenges and problems, organizations should establish information and knowledge management systems, as well as data warehouses and database management systems.

Barriers regarding the selection and adoption of the right technologies can be perceived as a hindrance as well. The digital transformation requires companies to implement new technologies (Bienhaus and Haddud 2018). However, recognizing, selecting, and adopting the best technology at the right time can be challenging (Cichosz et al. 2020). In addition, long-term ambiguities about legislative and regulatory requirements can further complicate matters (Hackius and Petersen 2020). Related to investment obstacles, selecting new technologies can also be difficult if their economic benefit cannot be accurately determined (Raj et al. 2020). Consequently, enterprises need to consider new technologies and identify which ones they should focus on based on their business needs (Zangiacomi et al. 2018).

The final challenge identified is related to the newness and immaturity of technologies. This concerns usability barriers due to selected technologies being novel and unsophisticated (Hackius and Petersen 2020). Resulting constraints in terms of security or interoperability can cause problems for the organization (Peraković et al. 2020). Such aspects should not be overlooked and taken into account when selecting and adopting new technologies.

5 Expert Interviews

In the following, two interviews are conducted to capture the expertise and opinion of the practitioners and depict them in a basic, measurable form. They are asked to allocate the

Table 5. Challenges in the technological digitalization area identified

Technological chall.	Sources
Technology competence and employee qualification	(Agrawal et al. 2020; Anand and Krishna 2019; Bienhaus and Haddud 2018; Büyüközkan and Göçer 2018; Cichosz et al. 2020; Dougados and Felgendreher 2016; Ghadge et al. 2020; Herceg et al. 2020; Horváth and Szabó 2019; Ivanov et al. 2019; Lammers et al. 2019; Pessot et al. 2021; Raj et al. 2020; Schlaepfer and Koch 2015; Sundaram et al. 2020; Zangiacomi et al. 2019)
Financial issues	(Agrawal et al. 2020; Anand and Krishna 2019; Cichosz et al. 2020; Ghadge et al. 2020; Herceg et al. 2020; Horváth and Szabó 2019; Ivanov et al. 2019; Lammers et al. 2019; Raj et al. 2020; Sundaram et al. 2020; Zangiacomi et al. 2018; Zangiacomi et al. 2019)
IT security and data privacy issues	(Agrawal et al. 2020; Bienhaus and Haddud 2018; Cichosz et al. 2020; Ghadge et al. 2020; Horváth and Szabó 2019; Ivanov et al. 2019; Lammers et al. 2019; Peraković et al. 2020; Raj et al. 2020; Schlaepfer and Koch 2015; Sundaram et al. 2020)
Establishing a proper IT infrastructure and foundation	(Büyüközkan and Göçer 2018; Ghadge et al. 2020; Horváth and Szabó 2019; Lammers et al. 2019; Raj et al. 2020; Schlaepfer and Koch 2015; Sundaram et al. 2020; Zangiacomi et al. 2019)
Difficulty and lack of information and data management	(Anand and Krishna 2019; Büyüközkan and Göçer 2018; Ghadge et al. 2020; Raj et al. 2020; Schlaepfer and Koch 2015; Sundaram et al. 2020)
Selecting and adopting the right technologies	(Bienhaus and Haddud 2018; Cichosz et al. 2020; Hackius and Petersen 2020; Raj et al. 2020; Zangiacomi et al. 2018; Zangiacomi et al. 2019)
Newness and immaturity of technologies	(Hackius and Petersen 2020; Peraković et al. 2020; Raj et al. 2020)

preconditions/challenges to two categories. Preconditions are divided into fundamental and supporting, and challenges into severe and moderate. Fundamental preconditions are argued to be indispensable to successfully transform the supply chain. Supporting conditions ease the transformation but can be counter-measured. This holds for challenges as well; severe challenges hinder the transformation process to a very high degree, while

moderate challenges can be counter-acted more easily. This basic rating allows first insights into the topic. At the same time, the experts get the opportunity to explain their ratings, elucidating the perceived importance in a small-scale and explorative setting (cf. Figs. 2 and 3).

5.1 Expert Interviews on the Preconditions

The interviewees were asked to sort the preconditions aggregated from the literature into two categories. Not all literature distinguishes preconditions into categories and thus implies all preconditions to be fundamentally necessary. The interviewees classified the organizational design, industry-specific guidelines as well as the knowledge management as supporting conditions (see Fig. 2). They reasoned that the organizational design is quite important concerning inter-organizational communication and reported on projects like a web-based Electronic Data Interchange. However, they did not elaborate on intra-organizational design. They also recognized the benefits of their industry-specific guidelines to enable digital transformation. Still, they stated that those often cannot be used for the companies' operations and supply chain, as they are very specific and often not comparable with other manufacturers, e.g., guidelines coming from the VDA (German association of the automotive industry). Knowledge management was also categorized as a supporting precondition, often the innovation initiatives are started within the company, but human resources, especially from IT, are lacking. This problem can be countermeasured, and in such a case consultancies are engaged to provide those resources. The strategic orientation & business objectives are categorized as fundamental. The digital transformation strategy is placed very high at the company, and the interviewees referred to the annual report showing that both of their projects are driven and approved by the general initiatives on digital transformation. Innovation strategies are also a fundamental precondition since many instances of lacking change management made projects quite challenging. The same applies to the organizational culture, which was identified as a barrier and showstopper for initiating digital transformation projects. The interviewees emphasized for all of those three preconditions that those might be fundamental not only for supply chain-specific digital transformations but for all similar initiatives in different functions and areas.

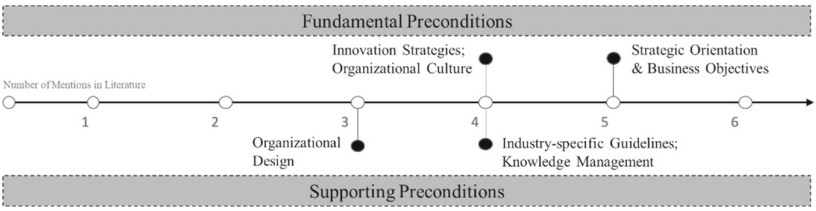

Fig. 2. Preconditions in literature and practitioner's assessment

5.2 Expert Interviews on the Challenges

Regarding the process & method challenges, five challenges are identified to be severe, while the remaining six challenges are perceived as moderate (Fig. 3). According to the interviewee, the complexity of underlying processes, structures, and networks is one of the most difficult challenges because processes are often not thoroughly understood and transformed without genuinely improving them. This indicates that the context of processes needs to be considered and understood to result in increased efficiency. A lack of flexibility of processes is also assessed as severe, while it is implied that the problem rather lies in people resisting change than in processes being inflexible. This strongly hints towards the connection to the organizational area of digitalization. Collaboration and coordination difficulties were ranked on the moderate level, as well as the lack of standards, guidelines, and frameworks. As an additional challenge, the difficulty of making change during ongoing operations is pointed out. This can hamper the digital transformation and associated efficiency gains, as old processes are often preserved in order to avoid risks such as business interruptions. Moreover, the problem of having multiple actors and interfaces in the supply chain and realizing the value of digitizing individual parts only when the entire process is digital is stressed by the interviewee. When asked for plans or strategies to approach the process & method challenges, the importance of proper change management and planning is brought forward. To recognize the inevitability of the digital transformation and to be open to change is key.

Moving to the technological challenges, financial issues are assessed as most challenging by the interviewee. The cause relates to the late amortization of added value of digitalization, the difficulty of estimating economic benefits of investments in advance and making the right assumptions. Also, this obstacle highly influences the other challenges. Technology competence and employee qualification are also evaluated as severe because of the overwhelming nature of new technologies when lacking the expertise to deal with them. The respective training is time-consuming and expensive, relating to financial issues again. The high pace of IT and the related continuous adoption to innovations were underlined as a crucial problem. IT security and data privacy issues are ranked as severe. The fast speed of new developments in IT leads to new legal requirements. The compliance of these can be laborious and hinder the optimization of processes. The establishment of a proper IT infrastructure is highly dependent on the previous challenges and is categorized as moderate, as well as the difficulty and lack of data management. It is pointed out that the company tries to introduce more AI-based technologies and that there is often a shortage of the proper mindset and strategy when it comes to data. Selecting and adopting the right technologies is considered moderate as well, besides the newness and immaturity of technologies. According to the expert, the company has always been able to solve obstacles associated with the immaturity of technologies as they have experienced software developers at their disposal.

6 Discussion of Results

In the literature, the occurrence of the different preconditions in the strategic as well as organizational area is relatively balanced. None of the identified sources in the literature include all preconditions. Most papers only refer to one of the preconditions identified

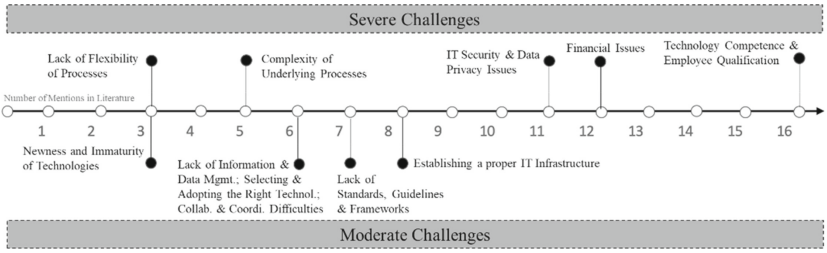

Fig. 3. Challenges in literature and practitioner's assessment

(Campos Martins and Simon 2018; Hjalmarsson et al. 2014; Janssen et al. 2013; Kaner 2014; Molinillo and Japutra 2017; Peansupap and Walker 2005; Preindl et al. 2020; Rajaguru and Matanda 2019; Wang et al. 2015; Xu 2014). For example, Janssen et al. (2013) conduct Delphi studies and define digital competence areas that are reflected in the knowledge management precondition. However, two sources include at least four of the six identified preconditions in their work, while only Agrawal et al. make an effort to rank them and analyze interrelations (Agrawal et al. 2020; Lammers et al. 2019). The expert interviews expand the seemingly relatively balanced importance of the preconditions and divide them into fundamental (three) and supporting (three) preconditions. This reveals an essential difference between academia and practice. The strategic orientation and business objectives as well as innovation strategies and organizational culture are ranked highest by the practitioners, which is in line with some transformation-related literature (Kane et al. 2015; Kohnke 2017). Yet, other authors argue that industry-specific guidelines are most important (Agrawal et al. 2020). By the experts in this study, this was only seen as supporting. To master the transformation, companies must include supply chain-related issues on the agenda and connect them to the overall strategy, even though strategies vary (Preindl et al. 2020).

Moving on to the challenges, the findings deviate regarding the two areas. In the process & methodological area, only one source includes all identified challenges but misses to thoroughly elaborate on the methodological aspects of the research conducted (Agrawal and Narain 2018). Other authors focused on barriers regarding Industry 4.0 and take into consideration other aspects, e.g., the influence of company size (Horváth and Szabó 2019). Discussion about the challenges of the process & methodological area with the practitioner shows that the assessment deviates from the findings in the literature. On the one hand, the lack of standards, guidelines, and frameworks is identified most frequently in the literature (c.f. Table 4). Authors like Raj et al. (2020) underline the high importance of standards. This challenge is followed by collaboration and coordination difficulties (c.f. Table 4). It is addressed by different authors focussing on digital technologies in supply chains and the ripple effect (Ivanov et al. 2019). On the other hand, the expert sorts both previously mentioned challenges in the moderate section. In contrast to the literature, he perceives the complexity of underlying processes, structures, and networks as most challenging. He describes one issue as follows: "*A common problem is that processes are not fully understood and then just digitized without improving them. If you simply digitize an inefficient process, you end up with an inefficient process that is digital*". In the technological area, it is striking that the evaluation of the practitioner

seems almost equal to the importance in the literature (c.f. Table 5). Only the financial issues are rated as slightly more critical by the interviewee. However, some authors specifically point out the high importance of investments (Zangiacomi et al. 2019).

Comparing the different areas, the interviewee states that the process & method area can be seen as more challenging than the technological area altogether. The reason is that technological constraints can be overcome as long as sufficient monetary and time resources are available, which is not always the case with the other area. Furthermore, the interviewee noted that the main challenge of digital transformation rather lies in people than technology, which is a claim supported frequently in literature (Kane et al. 2015; Kohnke 2017). This hints towards the importance of the organizational area, evaluated in the first interview, and strengthens the call that all areas of the digital transformation should be considered simultaneously.

Regarding the implications for academia, this study gives first insights into preconditions and challenges connected to the digital transformation of supply chains. We hope to start an academic discussion, highlighting further research in the conclusion. For practitioners, the identified preconditions and challenges are first reference points to consider when planning transformation projects.

7 Conclusion

Regarding the first research question, preconditions and challenges of the digital transformation are identified in the literature. Three to seven preconditions/challenges are determined (c.f. Tables 2, 3, 4 and 5). The preconditions all have similar numbers of occurrences in literature. In contrast, some challenges stand out, being more noticeably present in literature. Regarding the second research question, the results from the literature are discussed with experts from industry. The experts sort the preconditions and challenges regarding the perceived importance in practice. Deviations but also similarities are uncovered and discussed.

However, some limitations of this work need to be taken into account leading to future research. First, the structure of DSC into four areas is preliminary and the current analysis is limited to the preconditions in two areas and the challenges in the remaining two. This could be extended including all four areas with preconditions and challenges, leading to interesting connections between them, e.g., when examining the challenges, many sources consider organizational and human-related factors, not in the scope of this paper. Second, regarding the literature review methodology, including more sources is beneficial. Currently, the results from the literature only represent an approximation of the actual relevance of the preconditions/challenges. Third, the insights from practice are liable to the subjectivity of the interviewees. The small number of interviews leads to a certain bias, and context-based argumentation can be brought forward, e.g., that guidelines and frameworks of similar industries often cannot be used to enable transformations. It would be necessary to discuss this with more experts from different companies. The focus of this study is small-scale and exploratory, and only two categories are introduced to rank the preconditions/challenges. Further research could apply more elaborated measuring criteria, with a greater number of participants, to assess the perceived impact of the different preconditions/challenges more accurately. Prioritizing the various options can lead to a roadmap, highlighting what should be tackled first.

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