Investigating the impact of digital transformation on relationship and collaboration dynamics in supply chains and manufacturing networks – A multi-case study

Jacob Hamann-Lohmer *, Miriam Bendig, Rainer Lasch

Chair of Business Management, esp. Logistics, Technische Universität Dresden, Münchner Platz 3, 01187, Dresden, Germany

ARTICLE INFO

Keywords:
Digital transformation
Supply chain
Case study
Collaboration
Organisational information processing theory
Manufacturing networks
Digital technologies

ABSTRACT

The digital transformation (DT) is reshaping the economy and society. In supply chains (SCs), DT involves adopting digital technologies to collaborate. DT opportunities are particularly diverse in globally distributed manufacturing networks (GDMN) and SCs. Here, DT influences both internal and external collaboration activities, i.e., configuration and coordination of the intra-firm network and network relationships, structure, and governance in the inter-firm network. This study investigates if and how DT changes relationship dynamics and collaboration efficiency in SCs and distributed manufacturing networks through information sharing and jointly used digital technologies. While existing studies have mainly focused on individual digital technologies and their potential for SCs and manufacturing networks, this study contributes to a better understanding of the adoption process and the change in relationship dynamics through DT and joint use of digital technologies. The methodology follows a qualitative approach in a multi-case study setting with six multi-national manufacturing companies operating extensive intra-firm and inter-firm networks. A theoretical framework based on organisational information processing theory guides the study. Data is collected in semi-structured interviews and enriched by secondary data from internal company documents and publicly available sources. The results indicate that digital tools are triggering a centralisation trend in intra-firm networks that leverages efficiencies but is met with stakeholder scepticism. SC collaboration is becoming increasingly dynamic through digital tools, which the SC partners often promote. Non-adopters are not being dropped yet, but the pressure of digital transformation is increasing and becoming more of a threat to small businesses.

1. Introduction

The digital transformation (DT) is currently reshaping the economy and society in many ways (Preindl et al., 2020). In supply chain management (SCM), companies are exposed to volatile, uncertain, complex and ambiguous (VUCA) environments (Bennett and Lemoine, 2014; Blackburn et al., 2015; Lechler et al., 2019) and now try to counter these effects through DT, e.g. by adopting Industry 4.0 technologies (Büyükozkan and Göçer, 2018; Demeter et al., 2021; Lohmer et al., 2020). DT, defined as “combinations of information, computing, communication, and connectivity technologies” (Vial, 2019, p. 118), can improve the performance of supply chains (SC) and facilitate seamless collaborations among different stakeholders. Increased transparency of processes and transactions enables companies to focus more precisely on their customer needs and provide efficient, individually tailored solutions (Stank et al., 2019).

The opportunities for DT are particularly diverse in globally distributed manufacturing networks (GDMN) and supply chains, where intra-firm networks are distributed and comprise multiple plants (Chen et al., 2014; Demeter et al., 2017a; Lanza et al., 2019). Here, DT influences both internal and external collaboration. Internally, in the intra-firm networks of plants, DT touches upon the configuration and coordination of networks, with shifts in autonomy and centralisation (Brennan et al., 2015; Lohmer et al., 2021). However, DT also changes the way firms operate in markets and influences how firms collaborate and foster business relationships with upstream or downstream partners (Demeter et al., 2021; Pagani and Pardo, 2017). From a governance perspective, relational mechanisms that control actors on an informal basis rather than through contracts (Pilbeam et al., 2012) will change as firms shift from human interaction to digital technologies. Efficient
relational governance relies on trust that is often built by personal contact and human interaction, which is likely to change drastically through DT (Büyüközkzan and Göcer, 2018; Keller et al., 2021) and needs to be investigated.

Research on DT in OM and SCM is progressing fast (Vial, 2019), yet with a special focus on specific technologies, their implications and potentials (Dubey et al., 2019; Lohmer and Lasch, 2020; Queiroz et al., 2020). These studies are important to provide the industry with a roadmap to DT (Hartley and Sawaya, 2019). Research on the impact of DT on network structures, relationships and collaboration is needed, while particular insights from empirical research and case studies are rare. The impact of these transformations and the shared use of digital tools on relationships within firms (intra-firm networks) and network actors (inter-firm networks) has hardly been studied. Therefore, this study aims to address the following research questions:

RQ1. How does digital transformation evolve in distributed manufacturing networks (internally) and supply chains (externally) and how does it affect information processing needs and capabilities of the firms?

RQ2. How may digital transformation reshape relationship and collaboration dynamics in distributed manufacturing networks and supply chains?

A multi-case study was conducted with six multi-plant manufacturing companies on their DT journey, using a framework based on organisational information processing theory (OIPT) (Galbraith, 1973). We investigate which changes DT initiatives and the adoption and utilisation of digital tools bring to intra-firm and inter-firm networks. Thus, this study contributes to the literature on DT in OM and SCM by providing empirical insights into the ways networks and SCs evolve in the era of digitalisation. We showcase and explain the changes DT brings to the configuration, coordination, and autonomy of intra-firm networks, which is a research area that has not been addressed adequately (Lohmer et al., 2021; Rong et al., 2019). Besides, our study enables to make initial statements about the dynamics of inter-firm SC collaboration facilitated by DT and highlights that non-adopters and smaller businesses need to adapt to the DT trend sooner than later to avoid the risk of being left behind.

The remainder of our study is organised as follows. The next section discusses the literature regarding DT, opportunities of DT for SCs and networks and our adopted theoretical lens. The third section presents our qualitative methodology. Then, the empirical results are analysed in the fourth section and discussed along the related theory and literature in the fifth section. The study is concluded with a summary, implications for research and practice and an outlook on future research opportunities.

2. Literature review and theoretical framework

2.1. The concept of digital transformation

The digital transformation is an increasingly researched topic, for which various definitions have been developed (Vial, 2019). For a recent review and research agenda, the reader is referred to (Plekhanov et al., 2022). Following Vial (2019, p. 118), DT goes beyond adopting and utilising digital technologies as “a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies”. DT involves organisations but also their surrounding entities, e.g. society or SCs. DT initiatives and actions aim to improve operational performance by leveraging digital technologies that often focus on information sharing and increased collaboration (Stank et al., 2019). Other related concepts (or synonyms) are smart manufacturing or digital manufacturing, involving the term Industry 4.0 and digital technologies like the Internet of Things (IoT), big data analytics, cloud computing and more (Demeter et al., 2021). Early research on digital technology adoption and DT paths, e.g. examined the adoption of Enterprise Resource Planning (ERP) systems on SC performance and collaborations (Gatikker, 2005; Koh et al., 2008). Studies with a focus on operations management and manufacturing investigated the impact of digital technologies on concepts like lean manufacturing (Buer et al., 2021; Cifone et al., 2021). However, recent literature on DT in SCM mainly focused on the implications and potentials of specific technologies such as blockchain technology, IoT, big data analytics or artificial intelligence applications (Büyüközkzan et al., 2021; Dubey et al., 2019; Hartley and Sawaya, 2019; Lohmer et al., 2020). Theory-driven studies on the general deployment of digital technologies and their relation to SC collaboration and performance are scarce. As noteworthy exceptions, Ye et al. (2022) identified a positive relationship between the depth and breadth of digital technology deployment and SC visibility, which was vital for the performance in the Covid-19 crisis. Kessler et al. (2022) recently studied the relationship between Industry 4.0 technologies and SC risk management, where digital technologies are often adopted by SCs to address SC risks but lead to other risks in the process.

As DT is ideally strategy-driven (Matt et al., 2015), these studies are important to provide the industry with guidance and best practices, serving as a roadmap on the way to DT (Hartley and Sawaya, 2019). The adoption and utilisation of these digital technologies in organisations and along with partners in SCs and networks often emerge in response to uncertain market environments, global competition, and general VUCA environments (Bennett and Lemoine, 2014; Büyüközkzan and Göcer, 2018; Lechler et al., 2019). A recent example is the Covid-19 pandemic that led to increased adoption of digital technologies, according to industry surveys (McKinsey, 2020; SoftwareAG, 2021). The resulting advantages for SCs and networks can be increased quality, flexibility, and productivity (Lanza et al., 2019), as DT leads to structural changes and value creation changes (Matt et al., 2015).

While the implementation and deployment of digital technologies in the context of Industry 4.0 have been reasonably well investigated (Kessler et al., 2022), research on the impact of DT initiatives on collaboration processes in organisations and across boundaries (SCs or inter-firm networks) are scarce. Research on DT has so far mainly focused on ways to successfully integrate digital tools and establish new business models (Ates and Acur, 2022; Favorotto et al., 2022; Ferreira and Lind, 2022; Hausberg et al., 2019; Saarikko et al., 2020). Relationships and network structures are subject to potentially profound change. This lack of clarity of the underlying changes may explain the large number of failing DT initiatives (Bucy et al., 2016). Essential elements here are identifying the drivers of the transformation, considering the specific tools, and their impact on the networks (e.g. degree of integration).

2.2. Paths and impacts of digital transformation in SCs and manufacturing networks

The opportunities and implications of DT are diverse and relevant, especially in today’s often highly DGMN and SCs. In these structures, intra-firm (internal) and inter-firm (external) networks exist. The former is distributed and often comprises multiple plants (Demeter et al., 2017a, 2017b; Lanza et al., 2019), while the latter consists of various independent actors collaborating temporarily or permanently (Chen et al., 2017). Thus, DT impacts both internal and external collaboration and relationships (Pagani and Pardo, 2017). In the intra-firm networks of organisations, DT initiatives and enhanced internal collaboration affect the networks manufacturing strategy, which is mainly determined by the configuration and coordination of the network, with prospective changes in autonomy and centralisation of decision-making (Brennan et al., 2015; Lohmer et al., 2021; Millsenburg, 2005; Porter, 1986). The configuration element focuses on multi-plant strategies and plant roles, i.e. how products are manufactured in the intra-firm network and how the plants are specialised (Cheng and Farooq, 2018; Gillani et al., 2020; Mejboom and Vos, 1997; Shi and Gregory, 1998). Coordination centres
on decision-making authorities in networks, organisational structures, lateral relations, and communication (Colotla et al., 2003; Martinez and Jarillo, 1989). Autonomy relates to the plants in a network being able to make their own decisions, following Cheng and Farooq (2018) in strategic autonomy being measured as “the degree of a plant’s autonomy in defining its own competitive strategy” and operational autonomy as a range of decisions in three main categories: planning, production and control decisions (Cheng and Farooq, 2018; Golini et al., 2016). Recent literature on multi-plant and intra-firm networks focused on the configuration aspect (Arellano et al., 2019; Blomqvist and Turkulainen, 2019; Cheng and Farooq, 2018; Demeter et al., 2017b; Scherrer and Deflorin, 2017), coordination (Golini et al., 2016; Olhager and Feldmann, 2018) or autonomy (Demeter and Szász, 2016; Golini et al., 2016; Lohmer et al., 2021; Olhager and Feldmann, 2018, 2021) but did not consider the explicit impact of DT on these collaboration mechanisms. Therefore, to contribute to the ongoing literature stream on manufacturing strategy, we specifically target this impact in our empirical study.

Progressing DT can also facilitate a change of external collaboration in manufacturing systems and SCs and needs to be assessed along with the changes of inter-firm relationships and their respective management (Demeter et al., 2021; Lohmer et al., 2021). This includes SC integration with the strategic collaboration of partners through information sharing and collaborative decision-making to ensure SC performance (Flynn et al., 2010; Um and Kim, 2019). As collaboration with external actors is an interorganizational topic, interorganizational governance is another vital concept as it refers to the extent to which firms manage and oversee inter-firm relationships (Heide, 1994; Williamson, 1979). Here, the governance of SCs and networks mainly relies on formal and relational (or informal) mechanisms, based on binding rules and agreements for formal and shared norms, values and built trust as examples for relational mechanisms (Martinez and Jarillo, 1989; Pilbeam et al., 2012).

The impact of DT on SC governance has recently been investigated by studies that focused on certain formal mechanisms or digital technologies (Lumineau et al., 2020; Manita et al., 2020). As an example, Keller et al. (2021) investigated how informal governance mechanisms are used to coordinate actors in SCs under DT and concluded that informal mechanisms are challenged by transparent, real-time communication and collaboration using digital technologies. A study that takes formal and informal governance mechanisms in the DT of SCs into account has not been conducted. Additionally, the effects of DT on the network structures (i.e. the type of behaviour, the interdependence, the intensity of coupling and the power of the actors in the network (Child et al., 2005; Galbraith, 1977)) and specific actors’ relationships are still uncertain and worth investigating in this context.

### 2.3. Theoretical lens

Several theories and frameworks have been and are being developed to understand and guide the diffusion and adoption of technologies in business environments. For instance, in the technology adoption model (Iacovou et al., 1995), the antecedents of technology adoption have been studied, including perceived benefits, organisational readiness, and external pressures. The technology-organisation-environment framework (TOE) focuses on the context of the three elements in an adoption decision (DePietro et al., 1990). Both theories are relevant as we aim to uncover environmental factors pushing or hindering DT and related organisational readiness aspects. Besides, the related contextual changes are of interest.

However, the main theory that guides this study is the organisational information processing theory (OIPT). According to Galbraith (1973), OIPT aims to cope with uncertainty in the environment, e.g. through information processing. The recent and ongoing Covid-19 pandemic can e.g. cause uncertainty. Firms and networks need to increase their information processing capabilities (IPC) to counterbalance the increased information processing needs (IPN) (Tushman and Nadler, 1978). OIPT has been recently applied successfully in SCM research, e.g., focusing on big data analytics adoption (Dubey et al., 2019; Rojmann et al., 2018). The theory assumes that organisational performance depends on the balance of IPN and IPC that can be influenced e.g., by adopting and utilising digital technologies to share and process information (Galbraith, 1973). Achieving this balance (or “fit”) can also be supported by reducing IPN through organisational means or by increasing IPC (Bensaou and Venkatraman, 1995; Galbraith, 1977). The dynamic VUCA business environment in OM and SCM further increases IPN (Lechler et al., 2019; Rojmann et al., 2018) and measures like slack resources to reduce IPN often lead to agility and efficiency losses (Galbraith, 1974). Therefore, firms tend to reduce IPN and increase IPC through DT activities, which impact operational performance, e.g. triggering improvements of operational efficiency, sustainability and innovation or SC collaboration (Galbraith, 1973). We focus on analysing the impact of DT on IPN and IPC and their balance on the different intra-firm collaboration elements of configuration, coordination and autonomy, while relevant inter-firm collaboration elements for this study include relationship management, governance and the structure of the network. Modern SCs are not linear anymore, but rather networks (and we refer to internal and external networks in this regard), with studies on network performance often focusing on return on investment, growth or competence development. We focus on operational performance in this paper, including efficiency (cost, lead time) and effectiveness (quality, delivery capability, flexibility), following studies like (Flynn et al., 2010; Golini et al., 2016; Szász et al., 2016; Vereecke et al., 2006). Fig. 1 illustrates the theoretical framing of the research questions that are grounded in OIPT. RQ1 is focused on the evolution of DT and how it affects information processing needs and capabilities, leading to the balance in OIPT. RQ2 on the other hand is focused on the performance part, where we aim to analyse the reshaping of internal and external collaboration through DT activities. The findings in Section 4 are organised along Fig. 1, with dedicated subsections for internal and external collaboration as well as challenges and best practices for DT approaches as a result of the observed evolution of DT in the cases. The results are complemented by the identification of future developments and DT trends of the cases.

**Fig. 1.** Underlying theoretical research framework.
3. Methodology

3.1. Research design

Synthesising the relevant literature addressing DT in supply chains and manufacturing networks, we see that studies on the impact of DT on relationships and internal and external collaboration are rare, and empirical studies that investigate the reasons and effects in detail are needed. We conducted a multi-case study to sufficiently address our research questions. Case study research is ideally suited to comprehensively examine a current phenomenon through empirical investigations embedded in its present context (Merriheth, 1998; Yin, 2018). The research design fits our goal of understanding how actual DT journeys are conducted in manufacturing networks and supply chains and how these transformations reshape relationship and collaboration dynamics along the way. Compared to a single case study, a multi-case study may be regarded as more robust and significant due to the examination and comparison of several cases. Generalizability is also better supported in the multi-case setting (Voss et al., 2002; Yin, 2015). We address the quality indicators for rigorous case study research by Yin (2018) to highlight both the relevance and rigour of this qualitative research approach. Therefore, the following sections describe the research conducted in detail. The appendix of this study includes the used interview guideline, the coding system with example quotes and concise, summarized case descriptions for all cases. Besides, detailed transcripts and notes taken during the interviews are available. For space reasons, we address only the cross-case analysis in the following section. The analysis and brief summary of each case is provided in Appendix C.

3.2. Sampling

Guidelines on case study research emphasise the significance of proper case selection (sampling) in multi-case research, as the cases define the entities from which theory-building is attempted (Eisenhardt, 1989; Voss et al., 2002). Only an appropriate and theoretical sampling of cases enables a potential generalizability of results, so cases are selected for replication rather than statistical factors (Eisenhardt, 1989). Therefore, this step played an essential role in our research process with cases selected according to the following criteria:

First, the targeted cases were limited to firms from the manufacturing industry that manage supply chains with physical production of goods. Unlike e.g., in e-commerce or retail firms, the complexity of internal networks plays a vital role in the manufacturing industry, as do management responsibilities such as selecting and pursuing an efficient manufacturing strategy, collaborating with suppliers, ensuring product quality, and reacting to dynamic customer needs (Lanza et al., 2019; Miltenburg, 2009). Second, as the goal of this study includes internal collaboration, we are specifically interested in firms with multiple production plants, as DT might be limited to internal collaboration and alignment first before moving towards external partners. Third, we restricted the sample to firms located in Europe to guarantee comparability regarding infrastructural and political circumstances. The EU consists of many industrialised countries, with Germany being particularly prominent and suitable in terms of DT. This suitability is driven by the mature experience in Industry 4.0 implementation of German firms (Veile et al., 2020). Therefore, we focused mainly on German firms. Fourth, it was required that all cases were involved in international activities with several suppliers and customers in global interlinked supply chains to capture DT influences fully. Therefore, we explicitly include the details of international locations. We comprehensively cover different industries and firm sizes in our sample to generate insights on differences in DT approaches, while the heterogeneity and different perspectives in the sample allows addressing sampling bias (Yin, 2018). We thus searched for small-, medium- and large-sized firms equally. The use of digital tools was a prerequisite to include firms and queried at the initial contact.

Eisenhardt (1989) recommends four to ten cases as the ideal number of sampled cases, followed by most studies in the literature. Hedges (1985) also highlights four to twelve cases for applied qualitative research. This amount ensures the empirical credibility of findings while addressing and interpreting the specific case characteristics. We contacted suitable companies after an initial analysis using industry and project reports and company websites. We specifically targeted interviewees with knowledge of the infra- and inter-firm network, DT strategy and preferably close contact with other firms. The final sample of this study includes six firms, which are summarized in Table 1. The number of employees and the revenue per firm are displayed in ranges to ensure the anonymity of the firms involved. All of the interviewees have significant professional experience in their positions.

Each case in our study represents a unique firm, with different drivers and challenges on its path to digital transformation. In a targeted in-depth analysis, we analysed the path dependency of the cases and categorized them into three different DT levels: Beginner, Intermediate and Advanced (see Table 1). Cases at the Beginner level are without a broad and coordinated digital transformation strategy and are reacting to the needs of their supply chain partners. At the Intermediate level, the cases are already one step ahead and, in some cases, are themselves defining the digital transformation steps through their strategy, whereas the cases at the Advanced level are continuously researching new technologies and are constantly developing further.

3.3. Data collection and analysis

The data collection process combined several sources of evidence, with interviews with the industry experts as the main data source. Internal company documents and publicly available sources enriched the interview data and allowed for triangulation while ensuring increased construct validity. Besides, the authors were able to accompany two of the cases on their DT path in longitudinal case observations over several years, including (informal) discussions with various decision-makers and stakeholders and attending in-house workshops. The interview questionnaire (see Appendix A) was developed based on the literature review and discussions within the group of authors. It follows a semi-structured design with open questions that allow for flexibility without restricting the specifics and focus of each interview (Yin, 2018). The primary interviews were conducted between December 2020 and February 2021 through video meetings that were recorded with the permission of the interviewees. Interview duration lasted between 45 and 100 min, with an average of 59 min, resulting in 97 pages of interview transcripts after verbatim transcription. The qualitative content analysis software MAXQDA 2020 supported handling the large amount of data for the structured data analysis, as Yin (2018) recommended. During the interviews, one author took notes that were discussed afterwards, leading to initial memos used in the coding process. Each of the interviewees was sent the transcript afterwards to confirm its correctness and provide the opportunity to add further information (Yin, 2018). The coding procedure itself was conducted in a mixed inductive-deductive approach. First, we deductively developed the main categories for the coding system (see Appendix B) based on the literature analysis, the research questions and the interview guidelines. The whole interview data was then coded in a first run and assigned to the main categories. Next, we inductively created subcategories from the coded material that we aggregated in the main categories and iteratively coded the interview data again. Beyond the iterations, the coding process was performed independently by two of the authors, followed by discussions to resolve inconsistencies and discrepancies. This approach allows for rigorous data analysis, which contributes to higher reliability of the results (Eisenhardt, 1989; Yin, 2018).

Assessing the quality of case-study based research, we address the criteria of Yin (2018) in the following. The extensive literature analysis allows us to relate closely to previous research. Besides, internal validity is also enhanced by the detailed description of the context of our study.
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and the comparisons of findings with the literature in the subsequent sections. External validity is concerned with result generalisation. The sample of this study allows for greater relevance of the results, as the cases differ in key parameters and represent a certain heterogeneity (Patton, 2015). The research framework can also be used for subsequent quantitative studies. Next, construct validity is ensured by grounding our theoretical framework in existing theories, such as organisational information processing theory (Galbraith, 1974). Then, reliability focuses on the replicability degree. Through the detailed methodology description and the transparent research process, the verbatim transcription of interview data and including multiple investigators, we enhance the reliability of our results. Lastly, objectivity is assured by providing sufficient and detailed specifications of the collection and analysis approach, which is enhanced by providing the interview guidelines and the coding system in the appendix.

4. Findings

The findings of the study are organised along the guiding theoretical framework and detailed in the following. We derive several propositions for the influence of DT on the elements of the theoretical framework and the collaboration structures and efficiency in the cases.

The cases’ IPN are congruent with the literature (Roßmann et al., 2018). Epsilon notes that “projects are getting bigger, a global distribution is evolving, and as a result, digital transformation must also accommodate these aspects”. The interviewees particularly emphasise the increasing size of projects, the fast-changing business environment and more complex collaborations, which are essential for a strategic alignment of supply chains and networks. Digital transformation and shared digital tools were attributed to a reducing effect on IPN as less coordination, are facilitated by DT, lead to more autonomy of networks and multi-plant structures, which can work together more effectively. While digital tools facilitate enhanced collaboration in intra- and inter-firm networks, they are still rather the consequence of (re-)configuration of networks than the driving force.

DT influences on network configuration and coordination are also addressed. Fundamentally, digital tools facilitate and support collaboration in a global intra-firm network. However, a modification of the network configuration is not necessarily what follows. In the case of Epsilon, the interviewee emphasises that IPN and the dynamic environmental conditions determine the requirements for DT and the tool landscape: “So it’s rather the other way round, that the requirements arise due to the demands and challenges in the business environment and we then try to keep up with the digital transformation and adaptation.” In the case of Alpha and Beta, it also became evident that internal restructuring is increasingly taking place, supported by DT, but more radical changes driven by DT have not emerged. This finding may well be related to the firms’ consolidated and established business model and leads to our second proposition:

P2. While digital tools facilitate enhanced collaboration in intra- and inter-firm networks, they are still rather the consequence of (re-)configuration of networks than the driving force.

We identified an implicit influence of DT on the coordination of networks and multi-plant structures, which can work together more productively through DT. Redundancies in storing and handling data and information are eliminated and know-how transfers enabled. Various decision-making categories of the manufacturing strategy (Mittenburg, 2009), such as the selection and integration of suppliers, the selection and utilisation of quality methods and standards, and capacity coordination, are facilitated by DT, lead to more autonomy of manufacturing plants and may be conducted in a more integrated manner, i.e. due to “absolute transparency and clear allocation across all country organisations”, as in the Delta case. Thus, competitive
advantages like flexibility and delivery capability can be realized, also enhancing the operational performance of the SC. The increased transparency also positively impacts both IPN and IPC of the organisation. Besides, central management has the opportunity to establish appropriate network control mechanisms by selecting suitable DT approaches and technologies (Zeta). A standardised quality framework can e.g., be established, but internal competition can also be initiated. This leads to our third proposition:

P3. DT initiatives lead to more integrated manufacturing strategy decision-making, increasing plant autonomy while enhancing flexibility and delivery capabilities of intra-firm networks.

Solid integration of the tools and an alignment with the general DT strategy are crucial. This alignment and a dynamic corporate philosophy geared toward innovativeness lead to greater acceptance by employees. Indeed, conservative and traditional structures can jeopardise the success of DT initiatives (Alpha, Gamma). As the interviewee of Gamma mentions: "There is also a bit of an inhibition threshold and this again shows this conservative behaviour, in part certainly also from the staff. We always did it that way - that’s the best answer." The level of tool integration was rated as either good or very good in four of the six cases. If digital tools are harmonised with each other, employee acceptance increases. In the case of Alpha, the interviewee mentions that "the more different technologies and tools are introduced, the faster you lose acceptance for them. I think this is the first step to bring some consistency into it." So, it was evident that digital tools may fall short of their potential if there is no corresponding training of employees and they are not involved in the changeover at an early stage. "The biggest challenge we have is to give our staff the necessary detailed knowledge of the possibilities, so what can the systems actually do and what don’t you use because you’re just not properly trained …", as Delta notes. Training specialist experts to distribute this knowledge across the plants can be useful. In this way, multi-national and multi-plant firms achieve more global manufacturing distribution and efficient cooperation structures through DT.

P4. Embedding the tool selection and introduction in the overall DT strategy is just as essential for its success as harmonising the different layers and engaging the employees on this change journey.

4.2. Collaboration, governance and business relationships

Turning to DT initiatives to connect with SC partners (external collaboration), it is evident that DT can optimise existing activities and improve collaboration. This is reflected in a more efficient and simpler design of collaboration activities. Greater transparency through the shared use of digital tools can increase the flexibility of the SC and enhance efficiency, e.g., by reducing inventories, as Alpha notes: "Sharing data in real time and providing better forecasts allows us and our suppliers to reduce expenditures and, by consolidating deliveries, our inventories as well." In terms of governance mechanisms, there are differences in the cases examined. While DT does not influence Zeta’s governance mechanisms, Alpha and Beta notice changes and a stronger bond between the collaborating partners: "If the whole supply chain is managed well and all partners benefit individually from collaborating, then the incentives to participate in this collaboration are high enough and I think that certain things of such a collaboration are only made possible by digital transformation" (Beta). Interestingly, relational governance mechanisms are strengthened at the beginning of DT initiatives to gain the most significant benefit from the projects and technology adoptions. Subsequently, however, a greater emphasis on formal mechanisms that protect process automation and shared data is evident. Through alignment and joint tool utilisation, existing relationships can be strengthened. We thus postulate the following proposition:

P5. Although relational governance mechanisms become less relevant as a result of DT, they are essential to the initiation and success of DT initiatives in global manufacturing networks.

Several interviewees stated that their firms, as central and focal actors in the SCs, often trigger DT initiatives. However, non-focal actors such as suppliers or customers also increasingly participate in the projects with great initiative or initiate them themselves to improve digital capabilities and perform more efficiently as SCs. Alpha highlights in this context that "many of them approach us, which shows that the suppliers themselves are interested in such digitalisation projects". For Gamma, an expansion of its network and project-related collaborations are only made possible by digital tools in the first place. The business environment creates strong IPN, which in turn must be countered by DT. Regulatory measures that influence SC collaboration through IPN are also highlighted in other cases. Delta indicated SC traceability in the context of the emerging “Supply Chain Due Diligence Act” in Germany and the European Union: "There are increasing legal requirements, especially in our sector, that you can only deal with through digital transformation.” This leads to our sixth proposition:

P6. SC actors like suppliers or customers are now increasingly aware of the need for digital solutions and are even taking over the driving force towards DT initiatives in distributed networks.

Other changes to the networks and their structure are apparent as DT leads to more restrictive tender criteria, e.g., mandating specific capabilities or tools. In terms of the influence on existing networks, Beta perceived more significant pressure to act and experienced power plays by certain SC partners, resulting from the increased transparency and stronger system linkages. Besides, more targeted offers can be made to partners and customers due to the increased amount of data available. As part of Delta’s digital transformation, the company could significantly strengthen its position along the SC. By taking over SC tracking and tracing, Delta was also able to take over SC coordination to a certain extent, driven by the conversion of its tools. These activities reduced efforts for the SC partners and increased their integration with Delta, as the interviewee stated: ‘That is exactly the kind of expenditure that you can eliminate easily and that is an efficiency and effectiveness potential that is very underestimated in my point of view. So that’s huge resources you can raise here’.

In this context, for the companies that did not experience changes in the network structures (like Alpha or Zeta), it becomes apparent that many partners are neither already sufficiently digitised or not all SC partners have to be integrated with the same priority. Excluding non-cooperative or reluctant SC partners is possible but was not yet carried out in the cases studied. The significance of trusting partnerships is emphasised in all cases and the interviewees highlight collaboration and joint development of skills as significant here. However, Gamma’s case underlines that many firms can no longer avoid DT trends and investing in this area, especially for public contracts or complex projects. “In the end, the customer is the king and tells us what digital technologies and tools have to be used, and yes, we then try to employ them basically”, as Gamma mentions. Moreover, Delta initially lost some of its SC partners in the DT course, which it was able to make up for over time by gaining other competitors: “It is this shift in thinking and solving things in a more digital and streamlined way that has made it possible for us to now have a larger number of network partners.” This highlights the gravitational force of increased efficiency through DT, leading to new business relationships. We thus develop a seventh proposition:

P7. Moving fast in their DT journeys enables firms to intensify collaboration with existing and new partners and increase integration levels, enabling further efficiency gains.

4.3. Challenges and best practices for DT approaches in SCs and networks

We now focus on the challenges of DT perceived and best practices derived from the studied cases (see Table 2). It is important to note that DT with a migration to new digital technologies and tools can also negatively impact SC collaboration in the short term (e.g. in the cases of
4.4. Future developments and DT trends

In all studied cases, the DT journey is ongoing and more digital technologies will be added to the networks in the future. Beta and Delta highlight that advanced digital technologies are researched and evaluated centrally to develop proofs-of-concept that can then be deployed broadly in the intra- and inter-firm networks. “That’s what’s cool about the digital transformation, the possibilities can also push you in a certain direction” (Delta). Evaluated technologies include IoT, blockchain and artificial intelligence. Further developments are envisioned in enhancing inter-firm data transparency and the analysis and evaluation of intra-firm and SC-related data through business intelligence systems. The next stage includes intelligent automation of business processes, where two of the cases are testing Robotic Process Automation solutions. It is also necessary to balance pushing the DT imperative and globally distributing capabilities without neglecting the social component in the DT course. Here, the interviewees see a weakening of relational governance as a challenge in the context of trust, which is often formed implicitly: “I would say that this is less a question of trust and more a contractual question. Trust certainly still plays a role, but in the future, it will be a subordinate one” (Gamma).

5. Discussion

The findings of the study and the developed propositions show that DT may increase the capabilities of organisations and networks to process information while reducing IPN at the same time. These IPN are driven by dynamics and uncertainties in the business environment. However, DT and the associated adoption and joint use of digital technologies also affect SC collaboration internally and externally. The study confirmed existing findings that DT initiatives and IT adoption can enhance collaboration among SC partners (Stank et al., 2019; Vial, 2019). The literature-based presumption that SC network structures could change fundamentally driven by DT could not be confirmed. In the cases considered, although enhanced collaboration activities and efficiencies are perceived, the use of digital technologies is somewhat following the reconfiguration of networks instead of leading to a reconfiguration through their adoption. In the intra-firm GDMN, DT triggers a trend to more integrated rather than more centralised decision-making structures. This coordination aspect is an interesting result, as it fundamentally contradicts the centralised engagement with new technologies observed in several cases. The empowerment and evolution of the manufacturing plants distribute decision-making power in the network. This can increase the networks’ flexibility and delivery capability (Lohmer et al., 2021). Supporting the findings of Vial (2019) and Demeter et al. (2021), our results confirm that an overall DT strategy should guide the adoption of technologies and their embedment.

The research questions posed can be answered as follows: DT influences the relationships between firms in SCs and networks in different ways. A stronger bond between existing collaborations was observed as well as an improvement in external SC collaboration due to the increased transparency and automation potentials. Formal mechanisms to govern relationships are gaining importance over relational governance mechanisms, which are still crucial, especially in early-stage DT activities. SC actors such as suppliers or customers are often involved in the initiatives and increasingly even initiate them themselves. DT leads to integrated decision-making and distribution of competencies within intra-firm networks, although general configuration adjustments have not yet been attributed to DT. For non-adopters of digital transformation, the pressure rises, as regulatory frameworks increasingly target digital capabilities and standards, making them a condition for decision-making structures. This coordination aspect is an interesting result, as it fundamentally contradicts the centralised engagement with new technologies observed in several cases. The experience gained through adoption and the capabilities built through the shared use of the tools facilitate a subsequent connection of additional (new) partners.

To conclude, this article set out to address the research gap perceived in the impact of DT initiatives on IPN and IPC of SCs and manufacturing networks and the evolution of relationships and collaboration efficiency in these networks. Driven by multi-case observations, the study results have several theoretical contributions and practical implications that are addressed in the following before providing future research opportunities while highlighting some limitations of this study. The theoretical contribution of this article is manifold. First, this research contributes to theory by shedding light on the impact of DT on existing relationships in SCs and structural changes through DT, adding on to findings of recent studies like Demeter et al. (2021) or Um and Kim (2019). The study focuses on intra-firm and inter-firm transformations...
and thus provides insights beyond the organisational boundaries. Second, the findings indicate that DT can indeed reduce an organisation’s IPN and increase its IPC. Through this, collaboration among SC partners can be enhanced although the case-study observations do not point towards radical network structure changes. DT initiatives tend to follow as a reaction to structural changes in the network. Third, adding to findings by Demeter and Szasz (2016), Golini et al. (2016), Lohmer et al. (2021) and Olhager and Feldmann (2018, 2021) on autonomy in GDMN, we observed that DT initiatives lead to more integrated manufacturing strategy decision-making in our case study, that increased plant autonomy as well as flexibility and delivery capabilities of the intra-firm networks. Fourth, we add to studies that considered the effects of DT initiatives on relationships in SC networks like Büyüköztürk and Göçer (2018) and Keller et al. (2021) and confirm the reduced need for relational governance mechanisms in business transactions induced by DT. However, further findings point towards relational mechanisms being and staying essential for the setup and success of DT initiatives in collaborative GDMN.

The results of this study also lead to practical implications: By highlighting challenges and best practices from the observed cases, managers are guided on efficient approaches to start DT initiatives in their organisations. For example, as noted in the Delta and Epsilon cases, pursuing DT initiatives can negatively impact SC collaboration in the short term and managers should be prepared for this issue. A good starting point is crucial as trusting partnerships are especially valid for enhanced collaboration and joint development of skills. On this foundation, managers can push their organisation to move fast in their DT journey and enable to increase integration levels as well as significant efficiency gains.

This study has certain limitations: The sample is numerically and regionally limited and built on a specific theoretical framework that may affect the theoretical findings. Future research should be conducted to replicate the findings in other geographical regions and with diverse samples. Besides, we propose to conduct large-scale quantitative studies to test and extend the developed propositions to increase the significance of this research. Further research is needed on the in-depth and longitudinal analysis of relationships between actors in the DT process as well as specific case studies on the impact of DT in GDMN of different industries to shed light on industry-specific influencing factors. Furthermore, governance mechanisms in times of DT and their development should be the focus of further research.

Funding source
None.

Declaration of competing interest
None.

Data availability
Data will be made available on request.

Appendix A. Interview guidelines

1. Organisational details
   • Please briefly describe the following elements:
     o your company,
     o your work experience and current position,
     o your intra-firm and inter-firm network,
     o your product range.

2. Intra-firm network (internal collaboration)
   • Please explain the structure of your intra-firm network in detail. How are decisions made within the network of plants? (Follow-up questions e.g. on plant structure and manufacturing strategy, if needed)?
   • How do DT and digital tools influence network coordination?
   • Have there been any changes in recent years due to DT?

3. Inter-firm network (external collaboration)
   • Please explain the type and characteristics of your inter-firm network in detail.
   • How do DT and digital tools influence network coordination?
   • How did the need for DT and the digital tools arise, and who pushed for the introduction?
   • Have you noticed changes in the networks lately? If so, in what way?

4. Changes in the network dynamics
   • Have you observed any changes in the dynamics of the networks in relation to DT? What further kind of changes do you expect?
   • Are changes perceptible in the interaction between partners since the use of digital tools?
   • Do you see further changes due to the introduction of sophisticated digital tools like cloud manufacturing, additive manufacturing, artificial intelligence or blockchain?

5. Integration degree of digital tools and future tool introductions
   • How do you rate the completeness of the integration of tools used so far?
   • What are the challenges in integrating these digital tools?
   • Are there specific plans to introduce further digital tools in order to collaborate more effectively within the network? If yes, which ones and why?
   • If not, why not?

6. Current challenges of digital transformation
   • Where do you see current challenges within the digital transformation? Are there specific challenges for external collaboration?
   • Which requirements must be met for successful implementation and use of the tools?

7. Trends for future development of the networks and supply chains
   • What future digital development do you see within your internal and external network?
   • How can increased use of digital tools and digital transformation along the supply chain contribute to the development of the network?
Appendix B. Coding system with examples

Table 3
Coding system with example quotes for each 2nd level subcategory

<table>
<thead>
<tr>
<th>Category</th>
<th>1st sub-category</th>
<th>2nd sub-category</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-firm network</td>
<td></td>
<td></td>
<td>Characteristics of the intra-firm network in the specific case</td>
<td>“We have plants in Europe, North America and Asia, and supply chain management, for example, is centralised in general.” (Beta)</td>
</tr>
<tr>
<td>Inter-firm network</td>
<td></td>
<td></td>
<td>Characteristics of the inter-firm network in the specific case</td>
<td>“We distinguish between globally released and locally released suppliers who can only supply one specific plant and are handled by this plant.” (Zeta)</td>
</tr>
<tr>
<td>Level of digital transformation in the intra-firm network</td>
<td>Specific tools</td>
<td></td>
<td>Digital tools, which are used in the intra-firm network</td>
<td>“This is a central requirements tool with which you can maintain such data worldwide. There is a web interface where you can log in from anywhere and make changes in documents that are then visible to others at the same time.” (Epsilon)</td>
</tr>
<tr>
<td>Influence of the digital transformation on networks</td>
<td>Intra-firm network</td>
<td></td>
<td>Influence of the digital transformation on the intra-firm network</td>
<td>“This leads to a huge cost advantage and absolute transparency and clear allocation across all country organizations.” (Delta)</td>
</tr>
<tr>
<td>General challenges of the digital transformation</td>
<td>Internal challenges</td>
<td>Selection and use of digital tools</td>
<td>Challenges that the managers perceive in selecting and using the digital tools</td>
<td>“I think that this also results in a new market model - that the partners can be developed further, as it is simply much faster.” (Epsilon)</td>
</tr>
<tr>
<td>Change management in DT</td>
<td></td>
<td></td>
<td>Challenges related to measures for the successful management of change</td>
<td>“The biggest challenge we have is to give our staff the necessary detailed knowledge of the possibilities, so what can the systems actually do and what don’t you use because you’re just not properly trained…” (Delta)</td>
</tr>
<tr>
<td>External challenges</td>
<td></td>
<td></td>
<td>Challenges in the introduction and use of digital tools in the inter-firm network</td>
<td>“The main focus has to be on working out the advantages, i.e. where do the partners also have an advantage?” (Alpha)</td>
</tr>
<tr>
<td>Level of integration of digital tools</td>
<td>Internal integration</td>
<td>Perception on how well digital tools are integrated and adopted in the intra-firm network</td>
<td>“I am happy with the tools we have because they actually make my everyday life easier. But it always takes some convincing and there is a start-up phase until the tools are really used properly by everyone.” (Gamma)</td>
<td></td>
</tr>
<tr>
<td>External integration</td>
<td></td>
<td></td>
<td>Perception on how well digital tools are integrated and adopted in the inter-firm network</td>
<td>“They are completely integrated into our infrastructure, on which the entire network and the entire distribution process is based.” (Delta)</td>
</tr>
<tr>
<td>Future developments and trends</td>
<td>Progression of DT - further tools</td>
<td></td>
<td>Specific plans for additional digital tools in the future</td>
<td>“There is also an RPA solution that we are testing for dummying with suppliers.” (Zeta)</td>
</tr>
<tr>
<td></td>
<td>New digital technologies</td>
<td></td>
<td>Perception of further Industry 4.0 technologies in the cases</td>
<td>“There are units that deal with this, and a lot is being attributed to blockchain in particular for the future.” (Zeta)</td>
</tr>
</tbody>
</table>

Appendix C. Case descriptions

Alpha

The Alpha case is operating in the travel and motorhome industry, has a manufacturing network of five plants and comprises two separate brands. These are produced at two different locations and their parts service is also located at two separate sites. However, the headquarter is responsible for strategic purchasing or product management and R&D. Due to the fact that Alpha belongs to a superordinate group, the internal network can be classified as significantly larger. As the intra-firm network is quite complex and different, heterogenous digital tools are used in the network, the DT journey can be classified as a “Beginner” level. The company’s current focus in the DT is on connecting suppliers in the inter-firm network via a centralised supplier portal. At the time of the interview, it was possible to transmit data to the supplier unilaterally via the B2B system. A two-way communication via the tool and the connection of further suppliers is planned for the future. The alignments of the partnerships were not fundamentally affected by the DT pathway in the first place, regardless of whether a supplier supports or opposes a digital connection. However, it is also evident that connecting all suppliers via the B2B system is not necessarily needed either. The interviewee sees this as having only a minimal impact on cooperation in a spirit of partnership. The suppliers also see the need for this, and many of them are helping to initiate the transformation themselves.
Internal challenges at Alpha were mentioned by the interviewee as a lack of acceptance of technical innovations, mainly caused by a lack of change management. Digital innovations are often tested at the headquarter and then rolled out to the plants if the need arises and the ROI is positive.

**Beta**

Beta is based in the electrical components industry, although it comprises a larger internal network with 47 locations and a workforce of nearly 50,000 people. Central functions are coordinated through the headquarter in Germany for all globally distributed sites. At Beta, customers are given the opportunity to transmit forecasts and orders to the company via corresponding tools, thus ensuring more planning reliability in a certain way. The depth of the digital transformation depends on the optimization potential, the “trust in technology” and must always be accompanied by adequate change management according to the interviewee. It became clear in the discussion that Beta does not necessarily see a connection between the use of the digital tools and the alignment of the partnerships or their existence, but that the behaviour within existing collaborations can certainly be influenced by this change. At Beta, trust is pivotal to the success of DT in the supply chain. However, SC partners, especially smaller suppliers, are careful not to become too dependent on Beta, e.g. by blindly following on their DT journey. The intelligence that can be achieved through DT helps with more tailored collaboration and e.g. contract design. Therefore, Beta is researching and testing the use of artificial intelligence, blockchain technology and more. We thus classify Beta at the “Advanced” level of digital transformation.

**Gamma**

At Gamma, a global player in the construction industry, 80 plants form the intra-firm manufacturing network. The organisation is divided into five regions, which primarily handle regional projects according to their location. Gamma is also part of a superordinate group, which also commissions a large part of the construction-related projects. The overarching DT strategy is set by the group’s headquarters, but smaller digital changes are also made at the corporate level. There are many distributed tools intended for specific uses, but the interviewee lacks regular review and consolidation. On the customer side, Gamma always tries to meet the requirements and follow the digital path in order to stay ahead of the competition. The company can, however, be described as conservative and classified at the “Intermediate” level of DT. First steps have been made and there is a strategy for the future, but there is still a long way to go to achieve actual changes in collaboration or even the business model. The interviewee sees the trend that digital transformation is also indispensable in the construction industry and can and will be useful for building collaboration.

**Delta**

Delta is operating in the field of medical technology with three subsidiaries. The headquarters are located in Europe, as well as another site, which is still a pure sales and marketing location. An additional manufacturing plant is located in North America. A special feature of the internal network is that Delta is operating in a total of 65 countries worldwide in addition to these three plants in Europe. This constellation is created by corresponding employees who are not assigned to a specific plant, but who represent, e.g. sales or marketing for a specific country. The corporate structure results in a particular requirement to bring teams together virtually across countries. During the interview, it became clear that Delta is mainly driven by a comprehensive cloud solution, which, in addition to the collaboration of employees in a virtual space, also offers network partners a direct connection through appropriate licenses. The resulting simplification of certain processes and more consistent connection of partners to the company’s own data technology enabled the company to retain and win back more partners than expected in the long term, following previous losses in the course of the DT changeover. Overall, the interviewee emphasised the importance of increasingly comprehensive digital tools and the company’s interest in focusing on them. The research on business intelligence tools enables to classify Delta on the “Advanced” level of DT.

**Epsilon**

The internal network of Epsilon, operating in the electrical components industry, comprises a total of six plants, four of which are located in Europe and the other two in Asia and North America. As a subsidiary of a superordinate group, the company employs around 800 people in its six plants. Due to Epsilon’s affiliation with the semiconductor industry, and in particular with the chip development sector, there is a high pressure to innovate, which can only be realized with appropriately well-coordinated cross-location teams. During the interview, it became clear that the DT is a fundamental prerequisite for this type of work in particular. According to the interviewee, the existing digital tools have less of an effect on the alignment in the network; rather, the demand for corresponding digital solutions would shape the development of certain tool landscapes. In the cooperation with its external development partners, Epsilon is rather pragmatic: previously existing connectivity difficulties are circumvented by integrating the partners directly into the digital internal network. The digital tools help to make collaboration with existing partners more efficient and strengthen the idea of collaboration. As Epsilon is not particularly pushing for new solutions or an intensified DT in the near future, we classify the case as on the “Intermediate” level of DT.

**Zeta**

The electrical engineering and energy technology firm Zeta operates with its globally oriented network at more than 70 company-owned plants worldwide and employs a total of around 90,000 people. Zeta is divided into corresponding business units, which in turn are subdivided into products-dependent segments. Communication and also the use of certain digital tools extends across all levels, whereby the direct internal network primarily relates to cooperation with plants in the same product spectrum. In this case, it becomes clear how far a digitally well aligned internal network can also influence cooperation and collaboration in the external network. Synergy effects can be exploited by connecting suppliers via cross-plant supplier portals. However, Zeta still perceives a rather short leverage in influencing suppliers to embark on the DT journey with them. There is also a certain peculiarity in the fact that, due to different factors, not all suppliers are connected via the same digital tools. Regardless of the extent of the use of digital tools, the interviewee assessed the influence of these on the alignment of the partnership as rather low. There are dedicated teams at Zeta for researching and testing new technologies such as artificial intelligence or blockchain technology, which leads to a “Advanced” level of DT.