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Digital Supply Chain Twins in Practice: Outlining the Technological and Organizational Requirements for Successful Implementation

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Extended Abstract

Summary. Digital supply chain twins (DSCT) are often considered as one of the most promising technologies to efficiently and proactively manage increasingly complex international logistics networks in the future. Despite the recognition of the potential, the concrete development of digital twins of logistics networks is still in earlier stages in practice. Most twins focus on mapping digital twins of logistics assets or sites rather than elevating the technology to a network level. Building on the Nominal Group Technique among 18 logistics managers this study seeks to investigate the requirements of successful DSCT implementation at a network level. The study shows that while there are various technological requirements that need to be created for the development, it is also DSCT-specific intra- and inter-organizational requirements that influence the successful implementation and use of DSCTs.

Keywords. digital supply chain twins, network level, data connectivity and interoperability, organizational barriers, governance

1. Background and Motivation

The dynamics of managing international logistics networks is increasing at a rapid pace. Disruptions and volatility pose ever new challenges for international logistics (Alexander et al. 2022). Although the COVID pandemic has highlighted the limits of globally distributed value creation systems, recent studies suggest that the globalization of international logistics networks is not reversing. Rather, companies will rely on new approaches to resilience and flexibility in the future through more diversified logistics networks, among other realized through a broader supplier base (Nitsche and Straube 2021). It can therefore be assumed that logistics networks will tend to increase in complexity. In order to be better able to deal with increasing dynamics and complexity of international logistics networks in the future, innovative approaches to

digitalization are necessary in order to master the complexity and to be able to proactively plan and design logistics networks.

In this context, digital supply chain twins (DSCT) are one of the most promising technological approaches for generating nearly real-time transparency of complex logistics networks and enabling predictive logistics planning and control (Bhandal et al. 2022). In the past, the establishment of digital twins primarily focused on the digital mapping of individual assets, such as machines, and in some cases, specific locations such as warehouses or production sites. However, recent technological advancements have enabled the digital mapping of entire logistics networks and equipped them with advanced simulation capabilities (Tao et al. 2019). Therefore, the DSCT received increasing attention by research and practice alike in recent years (Wagner et al. 2019). Formally, DSCT are defined as "a digital dynamic simulation model of a real-world logistics system, which features a long-term, bidirectional and timely data-link to that system" (cf. Gerlach et al. 2021, p. 5). Current research in this field often focuses on the theoretical testing of DSCTs in various scenarios to prove the feasibility. Even though this technological perspective is necessary to develop implementable solutions, other technological innovations have also shown that not only the technological factors, but also organizational and maybe other factors are decisive for the successful implementation of a technology (Nitsche, Straube, and Wirth 2021).

Recent literature divides DSCT into twins at site level (warehouses and manufacturing sites) and network level involving multiple stakeholders (Gerlach et al. 2021). Especially in the case of a DSCT of an international logistics network, various stakeholders must be integrated into the solution to ensure holistic optimization. Achieving this is not only dependent on technological maturity but requires a holistic approach. This study therefore sets itself the goal of investigating the requirements for the successful implementation of DSCTs at the network level. More specifically the study aims at solving the following research questions (RQ):

Which requirements must be met to successfully implement and use DSCT at the network level?

2. Methodology

In order to contribute to the aforementioned RQ, an inductive qualitative research approach is adopted, which aims to extract the knowledge of logistics experts in a methodologically rigorous and systematic manner. While focus groups in such discussions can lead to less confident participants being suppressed in their opinions and not participating equally, the Delphi technique in turn has the disadvantage that here the panel participants do not meet at all and thus no valuable interaction is possible (Goodman 1987; Van de Ven and Delbecq 1971). In this study, the Nominal Group Technique (NGT) is applied, which lies between the two aforementioned methods of group work and aims to eliminate the disadvantages of the first two approaches (Delbecq and Van de Ven 1971).

When using the NGT, problem identification is separated from problem solving and worked out separately in two individual discussion rounds. the individual groups are accompanied by neutral moderators who ensure that the methodology is adhered to (including interruption of discussions and sharing ideas in the round robin procedure) and thus ensure that all group participants contribute to the solution in the same manner. To approach the solution of the above RQs, a heterogeneous mixed-industry group of experienced logistics managers was assembled to gain broad insights into the barriers and requirements of DSCT implementation. Within the first NGT round, the barriers of DSCT implementation were discussed and transferred to a group

result (problem identification). In the second step, the requirements that should be met to ensure a successful DSCT implementation were discussed (problem solving). Following the NGT procedure, in a silent generation phase, participants were asked to write barriers and also requirements on individual cards and then share them with the group one by one in a round robin procedure. In total, this process was carried out in parallel in three groups. In order to bring the partial results together, the cards were subsequently merged by three scientists using Q-methodology in a bottom-up approach to obtain a holistic, synthesized picture of barriers and requirements of DSCT implementation.

3. Results

As previously explained, the barriers to DSCT implementation were first discussed before the requirements could be defined. Although the barriers are not the focus of this conference paper, it should be mentioned that, in addition to various technological barriers (including secure IT infrastructure, data quality, interoperability, trust in the technology, and lack of technology know-how), there are also company-specific internal barriers (including lack of will to be transparent and missing understanding of the need) as well as network-specific barriers (e.g. conflicting goals of network actors, unclear ownership of the solution, complexity of the logistics systems) that currently hinder DSCT implementation. While the technological and internal company barriers are also relevant for DSCT developments at the site level (e.g. of a warehouse), it is the network-specific barriers that make the development of DSCTs at the network level even more difficult and are certainly one of the reasons why hardly any network solutions for DSCTs have become established to date.

In Figure 1, the main results of the discussion and structured synthesis of results on the requirements of successful DSCT implementation and use are shown. In order to implement DSCT successfully at the network level, it is necessary to create a basic technological foundation that ensures the practical feasibility of the solution. However, many of the technological requirements identified by the experts are aspects that affect many of the technological solutions currently being discussed in the course of digitalizing the planning and control of logistics systems. For example, the availability of data and its connectivity and interoperability must be ensured, which is a core prerequisite for the use case. What sounds simple, however, often poses challenges in practice, especially at the network level, since different data formats are processed at different times and must be transferred to the DSCT in a timely manner. This also means that the issue of data transmission is gaining importance, both in terms of speed and the technological implementation of the transmission. Even though data standards are rarely available, network level considerations of DSCT quickly indicate that this would clearly advance transmission and processing. It also remains to be seen how data protection concerns can be addressed in internationally distributed value creation systems.

In addition to the technological requirements described above, however, it quickly became clear in the discussions among the expert groups that the implementation of a DSCT solution at the network level appears to be feasible from a purely technological point of view. The greater hurdles are seen more in organizational barriers that must be overcome to ensure successful implementation and use. On the one hand, there are intra-organizational requirements, which are also important for the implementation of DSCTs at the site level. Transparent communication about the expectations of the DSCT solution and its use is essential in order to pick up and involve future users. Concerns about potential job losses due to automated processes with the help of the DSCT must also be taken seriously and addressed. However, especially for DSCTs at

the network level, the creation of intra-organizational requirements is key to ensuring a successful solution. As described above, for use cases at the network level, there are sometimes a large number of stakeholders who need to be involved in the DSCT, some of whom have conflicting goals. Creating a win-win situation between the stakeholders is one of the core challenges in the conceptual design of DSCTs, for which there are currently no established solutions. If a benefit is not apparent for all the players involved in the network and a clear cost-benefit sharing is regulated via fair contracts, so that not only the initiator but also the logistics network as such benefits, many DSCTs will fail at network level. If the benefits of sharing data in near real time are not visible to all, stakeholders will neither create the technological prerequisites nor have the will to join the solution. It would be conceivable to set up sensible incentive mechanisms here, but from a scientific point of view this has hardly been investigated and has not yet been implemented in practice. Therefore, it is suggested that while technological requirements are indispensable to develop DSCT solutions, it is the DSCT governance of all involved stakeholders, consisting of the creation of inter- and intra-organizational requirements, that is the key to the success of DSCT solutions in practice.

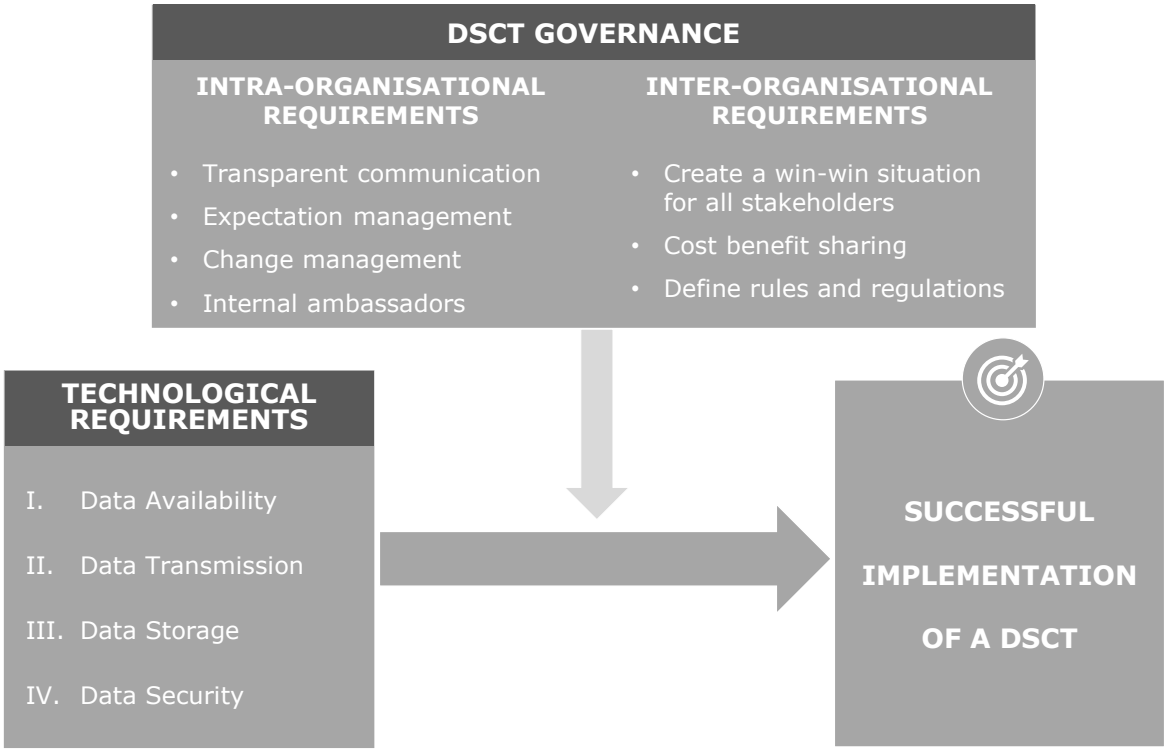

Figure 1. Requirements of successful DSCT implementation

4. Implications and Outlook

The presented findings shed light on the challenges that hinder the implementation of DSCTs at the network level. While technological requirements are important, it is the creation of intra- and inter-organizational requirements that are critical to the success of DSCT solutions. This means that the governance of DSCTs requires careful consideration of the interests and expectations of all stakeholders within the logistics system to ensure the technology concept is

holistically enhanced and beneficial to all. The study also underlines the importance of data connectivity and interoperability for a successful DSCT implementation. This is especially important at the network level, where different data formats are processed at different times, making data transmission and processing a crucial aspect to consider.

It is also evident that the benefits of sharing data in near real time need to be visible to all stakeholders. To achieve this, it is suggested that incentive mechanisms could be created to encourage stakeholders to participate in DSCT solutions. Further research is needed here to identify the most appropriate mechanisms that would work in practice. Looking ahead, the development of DSCTs will continue to be an important area of research and practice in logistics. The study notes that more research is needed on the governance of DSCTs, including the development of incentive mechanisms, and on the role of data security and data standards in data transmission and processing. There is also a need for more practical application-oriented research of DSCTs at the network level to identify and address the challenges that may arise in practice. Ultimately, the successful implementation of DSCTs requires a joint effort of all stakeholders involved in the logistics network, including companies, governments and technology providers.

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