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Digital Supply Chain Twins in Urban Logistics System – Conception of an Integrative Platform

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Abstract: Current trends in urban areas pose several challenges to city logistics stakeholders while also offering opportunities for optimization. With its analytics, modelling and simulation capabilities, the Digital Supply Chain Twin (DSCT) technology provides a possibility to optimize urban logistics processes. However, a number of barriers have limited the implementation of holistic DSCTs so far. An integrative, collaborative platform could decrease these barriers. By applying design science research methodology and expert interviews, this paper develops an architecture for a high-level cross-institutional platform for the generation of DSCTs. This framework includes a modular design of the platform through eight functional modules. The platform can facilitate the implementation of DSCTs for urban stakeholders and thus optimize urban logistics processes.

Keywords: cross-institutional platform; design science research; digital supply chain twin; digital twin; urban logistics

1 INTRODUCTION

The 21st century is the century of cities. For the first time ever, more people worldwide lived in cities than in rural areas in 2008. And the trend is clear: cities are the living space of the future. The United Nations (UN) predict a global population share of almost 70 % in urban areas by 2050 [1]. Cities are places of transformation and innovation, but at the same time this development condenses challenges. Congestion, air pollution, and growing demand for goods in urban areas are difficult to balance with an increased awareness of environmental and economic sustainability.

Several trends can be identified that influence urban logistics. Consumer behaviour in many relevant markets has shifted, and purchasing transactions are increasingly taking place online. The growing e-commerce has additionally been strongly influenced in the recent past by the COVID-19 pandemic [2]. Deliveries are getting more and more small-scale, the number of parcel deliveries is increasing, and customers have increasing demands for fast and efficient deliveries [2]. Goods can hardly be bundled due to a small-scale delivery quantities and distributed delivery points. These drivers cause that the so-called last mile is regarded as an important part of the supply chain, but is often linked with enormous costs and inefficiency [3].

Innovative measures must be developed to fulfil the increasing requirements for sustainable city logistics and planning in the inner-city areas. The UN Sustainable Development Goal 11 is a commitment to making cities safe, resilient and sustainable, and simulations can play an important role in the implementation [1]. Simulations are frequently used to analyse new logistics and supply chain concepts, providing a reliable method of assessing logistical challenges with a diverse range of applications [4]. However, current simulation models and associated optimizations have so far primarily been used for strategic planning [5]. These models are often constrained to single-use scenarios, failing to leverage the complete process optimization potential within a continually evolving urban landscape. To generate models and decision-making also for operational processes, timely access to up-to-date data is crucial [5]. The long-term, bidirectional exchange between a digital simulation model and a real logistics system with timely data enables a new approach called digital supply chain twin (DSCT) [6]. DSCTs are virtual replicas of logistics systems and can mirror everything from real supply chains – assets, inventories, logistics flows, transactions and relationships, to name a few [7]. The technology makes it possible to create continuous improvement and adaptation of the entire value chain, as well as end to end visibility and thus improving resilience [8].

However, urban players still face the challenge of how to integrate DSCTs into their existing processes to reap the benefits. The technology increases complexity within enterprises, as specific expertise is required for integration and security standards [9]. In addition to implementation costs, economic factors for underlying technologies are major hurdles [10]. To exploit the potential of DSCT and facilitate its implementation, close collaboration among stakeholders is needed. Urban actors need a technical platform to collect and analyse data in one place and to introduce DSCT technology [11]. These requirements pave the way for the development of an integrative, collaborative platform that can reduce the challenges for generating DSCTs. The objective of this study is to conceptualize such an integrative platform for the generation of DSCTs that reduce the growing challenges in urban logistics.

2 DIGITAL SUPPLY CHAIN TWINS

To meet the ecological and economic requirements of sustainable urban logistics, it is necessary to optimize and redesign existing logistics and transport systems [12]. Innovative measures are needed to implement these changes. Simulation models are already widely used in logistics and supply chain management (LSCM) as well as in urban planning. These simulations are a reliable method for evaluating LSCM problems with their dynamic and complex interrelationships, as they can be used to create a database with various indicators, show implementation scenarios and alternative actions as well as support the stakeholders in decision making [4]. Furthermore, simulations in a LSCM context offer particular diversity regarding their use. Individual assets up to entire supply chains and transport networks can be simulated, and the models can also be applied in various ways to the problems of urban logistics [13]. However, data-driven simulation models and related optimizations have been used mainly for strategic planning so far [5]. They are often limited to a one-time application and do not exploit the full potential of supply chain optimization in a constantly changing urban environment. To enable models and decision making also for operational processes and in long-term, it is crucial that data is available in a timely manner [5]. To address these challenges of logistic simulations, digital supply chain twin technology has gained importance in various business areas and industries in recent years. Based on existing literature, three essential characteristics of DSCTs can be identified: a bidirectional data exchange between the twin and the logistics system is necessary, the model and the real system are in timely synchronization, and it is a long-term approach [6]. In the context of this research, a DSCT is therefore defined as “a digital simulation model of a real logistics system, which features a long-term, bidirectional, and timely datalink to that system. Through observing the digital model, it is possible to acquire information about the real logistics system to conclude, make decisions and carry out actions in the real world [6]. DSCTs have become a critical component of Industry 4.0, that emphasizes the integration of advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), and automation to create smarter, more connected factories and supply chains. Following [6], the digital twin technology in LSCM can be categorized into three levels. The so-called asset level does not represent a DSCT, it is a digital twin of logistics assets. The site level describes a DSCT of a logistics site (e.g., warehouse, production hall, etc.), while the network level represents a DSCT of a multi stakeholder value network. In the context of the research, mainly the network level is considered.

Urban stakeholders are faced with the challenge of finding the most effective way to integrate DSCT technology into their processes to fully exploit the benefits. The technology is associated with high costs and security requirements while also increasing the complexity within an organization. Specific expertise is required to ensure successful integration and data protection [9]. Additionally, the costs for the underlying technologies such as application programming interfaces (APIs), open standards, AI, IoT, or cloud computing are considered obstacles for the integration [10]. Consequently, it has rarely been feasible to introduce network-level DSCTs in urban areas. To make DSCT implementation feasible for companies, close cooperation among stakeholders in the urban environment is necessary. Actors need a centralized platform for data aggregation and analyses to fully exploit the technology’s potential [11]. These challenges presented that the use of an integrative and collaborative platform could alleviate the difficulties associated with generating DSCT.

Current research shows that both DSCT technology and corresponding platform approaches have gained importance. For instance, ref. [14] proposed the potential of DSCT for policymaking and planning in urban freight, taking a multi-stakeholder approach and urban focus. However, this study did not provide any conceptual architecture or implementation details. Ref. [15] proposed a framework for designing and assessing urban logistics policies, involving all relevant actors and adopting a multi-stakeholder approach. [16] presented an architecture following a platform approach and conceptualised a freight parking management use case for last-mile delivery. Considering the increasing use of automated vehicles, ref. [17] proposed a reference architecture as an intelligent transportation system, following a network view, thereby analysing aspects of transport mobility, safety and environmental applications. Ref. [18] conducted relevant application scenarios of a whole digital twin city. In regards to urban management, ref. [19] propose requirements and a basic structure of a city digital twin to improve urban planning and optimize asset management. Additionally, ref. [20] focused on an urban digital twin for urban planning and the development of smart cities. The authors analysed a variety of applications and considered a platform approach to be a promising concept for the implementation of an urban digital twin. However, no logistics focus was given in their research. The analysed literature has shown that DSCT with an urban focus are gaining relevance, and single applications areas were already analysed. However, current research lacks an approach, in which a holistic, multi-stakeholder view of urban logistics is combined with a DSCT implementation approach. This paper addresses this research gap by providing an architecture for a cross-institutional platform approach that can support stakeholders in the implementation of a DSCT.

3 RESEARCH DESIGN

For this work, design science research (DSR) methodology was chosen as a suitable research method. DSR is intended to develop new research results, so-called artefact, through a practice-oriented approach [21]. It is less about contribution to knowledge in the sense of classical science and more about a result contribution [22]. Through the integration of research and practice, intense and short feedback cycles are generated, which lead to an early research output and enable a fast integration into the problem areas. All in all, it can be stated that DSR is useful as a method, if a practical result is targeted [22]. In engineering disciplines, DSR is accepted as a valid and valuable research method because the research culture values incrementally applicable, effective solutions to problems [21]. The aim of this work is to obtain the framework of such an applicable solution to address urban logistics and supply chain management problems. Therefore, DSR is an appropriate research methodology for this work.

Authors in ref. [21] have created a generally accepted, common and comprehensible framework for presenting and conducting DSR. It consists of six iterative activities: the first step is problem identification and motivation, whereupon requirements/objectives for a solution are defined within the second step. From this, in the third step a solution approach (artefact) is designed and developed, which is afterwards demonstrated. Finally, step five includes the evaluation of the artefact. The last step communication is realized by this paper. The following figure visualizes the procedure.

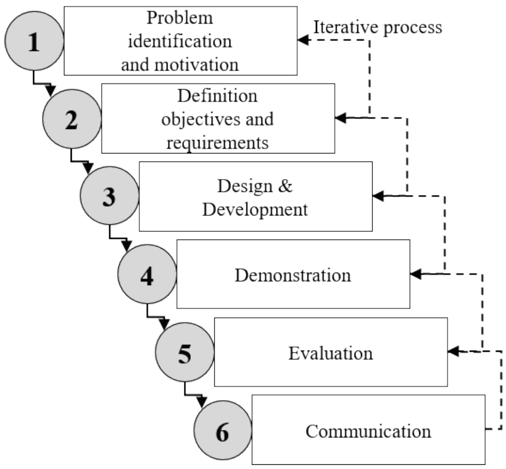

Figure 1 Design Science Research Methodology Process Model [21]

3.1 Problem Identification and Motivation

In this initial phase of DSR, specific research problems are defined, and the value of a solution is justified. In this case, the focus is on identifying problems in a urban LSCM context. The problem definition is the foundation for developing an artefact in the subsequent process, which will represent a solution to the identified problems [22]. According to [23] urban LSCM problems can broadly be categorized into four major areas: urban logistics systems and management, infrastructure, technology and economic factors.

The field of *urban logistics systems and management* faces significant challenges, primarily arising from the high degree of uncertainty and dynamic properties inherent in urban systems [24]. While technology trends such as Industry 4.0 have facilitated increased connectivity among customers, partners, and suppliers [25], companies still struggle with the coordination and optimization of networks and collaborations involving various actors [25]. Additionally, the lack of information and transparency within supply chains hinder an optimal control in complex urban systems, especially with the increasing social, ecological and economic awareness of customers. Not all companies are able to meet these demands, as creating transparency and changing to more sustainable processes may require additional effort and costs [23].

Relating to the second area of *infrastructure*, companies face congestion and high carbon footprints arising from increasing traffic volumes. Addressing LSCM problems and last-mile steps in urban systems requires a consideration of both logistical and urban planning challenges [23]. Logistics performance in cities is influenced by three key dimensions of urban planning: the built environment (with attributes such as population density), planning control (a system that addresses issues of parking, loading, and unloading) and transportation control (a system that addresses speed limits, traffic signals, bus lanes, railroad crossings, etc.) [23]. This interdependence of LSCM processes and urban planning highlights the complexity of urban systems. While emerging technologies and alternative fulfilment concepts may help reduce these problems, they also require new transportation and facility infrastructure.

The ongoing *technological transformation* is leading to the emergence of novel technologies, such as autonomous delivery vehicles or drones, which may replace or significantly transform existing urban logistics systems [26]. Such developments pose significant challenges to companies due to the associated uncertainty factors, especially when considering the integration into existing structures. Furthermore, the trend towards e-commerce is associated with large losses for many businesses operating in urban areas due to inadequate goods delivery planning and fulfilment [27]. This is further compounded by the fragmentation of orders leading to a high number of small orders, as well as narrow delivery windows, which add to the complexity of urban logistics systems [23].

Finally, the *economic problems* that can arise for companies in urban logistics systems are considered. In general, the last mile and urban LSCM are associated with high costs, with freight last mile logistics contributing on average to 28 % of the total delivery costs along the entire value chain [28]. In particular, the growing online and omni-channel grocery business involves high costs and complex fulfilment processes [29]. The fulfilment costs depend on various factors such as service time, service area, distance from distribution centre, driver costs and investment costs [23]. Not only the cost of delivery, but also the cost estimation and planning for goods delivery is challenging in urban areas. It is associated with many constraints related to traffic, driver working hours, refuelling intervals, battery charging processes and capacity (for electric transportation) and more [30].

Several tools are available to face the problems, including online freight exchange platforms, enterprise resource planning (ERP) systems, advanced planning and scheduling (APS) systems, transportation management systems (TMS) and supply chain management (SCM) systems [31]. Online exchange platforms connect transportation, logistics, and freight forwarding companies to market transportation capacities and search for specific freight. However, these platforms do not offer holistic optimization possibilities or sufficient details about freight and order information. Meanwhile, ERP, APS, TMS, and SCM systems are used to plan, control, and manage supply chains. Modern systems are user-oriented and offer tools of process optimization as well as an interface to external partners. Compared to DSCTs, these applications have major disadvantages that hinder problem-solving: timely data updates, insufficient applied analytical capabilities and lack of simulation capabilities for holistic supply chains [31]. As described in the previous chapter, DSCTs have the ability to improve these dimensions.

3.2 Requirements Definition

According to [21], the second step of DSR involves the definition of requirements for a solution. For this purpose, several requirements were derived from the problem identification and expert interviews. The interviewees represented all players of a generic supply chain. In total, five semi-structured interviews were conducted as part of the research process. The requirements were then developed based on the insights and inputs gathered from these interviews and the mentioned problems.

The problem definition revealed that the supply chain actors suffer from inadequate information exchange due to insufficient data transfer, leading to a lack of comprehensive process insights for all players. As a result, none of the players has an overview of all processes that affect him, certainly not of all supply chain processes. To address this issue, a solution is required to strengthen the transparency and visibility of supply chain processes with available capacities, disruptions, process status information and all further status information [31]. Consequently, to address this issue, the artefact is required to enhance of data exchange capabilities between companies.

Data sharing is a critical aspect of urban logistics, not only due to the need for supply transparency and visibility but also for enhanced communication and coordination within urban systems. The benefits of data sharing extend beyond businesses and can involve other urban actors as well. Through extensive data exchange facilitated by platforms, communication and coordination among various urban stakeholders can be improved. Therefore, it is imperative that proposed solutions encourage data exchange between all relevant urban actors to ensure a holistic approach to urban logistics. Such data sharing can have a significant impact on enhancing the overall efficiency and sustainability of urban systems. Therefore, it is crucial to emphasize the importance of data sharing in the development of proposed solutions for urban logistics.

The existing solutions lack holistic optimization and are characterized by limited analytical and simulation capabilities. To address this limitation, the artifact is a DSCT that integrates modelling, analytics, and simulation capabilities with a high degree of accuracy. Achieving this requires the inclusion of both internal data from the stakeholders of an urban system and external data, such as weather, traffic, and strikes. The combination of data from various sources, including internal and external, is necessary to develop a comprehensive solution that can support holistic optimization in urban systems.

Data obtained from LSCM processes is often not provided in a timely manner. Although real-time data may not always be necessary for all use cases, it is crucial for time-critical tasks. However, it is important to ensure that data is regularly updated to create a DSCT that reflects the current real status of the system without significant uncertainty. Continuous data updates are required to maintain the integrity of the proposed solution.

LSCM processes are not always sustainable, reliable, and resilient. Factors contributing to this include challenges with warehousing and inventory, vehicle utilization, fleet management, vehicle routing, order management and fulfilment planning. To address these weaknesses, accurate models and analytics must be generated that leverage the high-quality data from previous requirements. A thorough modelling and analysis of the current state of the supply chain is required to identify areas of weakness and opportunities for improvement, with the aim of enhancing overall supply chain performance.

The previous chapter has highlighted a significant knowledge and experience gap in managing logistics processes within urban areas. One approach to prevent this is the use of models and simulations to increase stakeholders process understanding. However, there are currently few tools for simulating entire supply chain processes. Without the ability to simulate different scenarios, including what-if analyses, future impacts of possible decisions cannot be determined without affecting entities of the real supply chain. This limitation applies to both strategic and operational levels and results in decision-making being associated with high degrees of uncertainty. Adequate modelling and simulation of LSCM processes can minimize such risks by increasing the process understanding of the decision makers. Therefore, it is required that the artefact can model and simulate (with what-if-scenarios) the supply chain processes.

Digital transformation presents significant opportunities for modifying existing LSCM systems. However, numerous barriers exist that impede the implementation of new technologies and fulfilment concepts, including high costs, lack of knowledge, and established habits. As a result, the integration of new technologies and fulfilment concepts is obstructed. Accurate simulations considering new technologies and concepts minimize this problem as it creates a degree of certainty about how the new approach would operate in the existing system. To effectively reduce the barriers associated with integrating new technologies and concepts, the artefact is required to accurately simulate LSCM processes.

Existing process optimization tools have proven insufficient, causing problems related to cost estimation, goods delivery planning, warehousing and inventory, vehicle utilization, fleet management, vehicle routing and order management. To overcome these issues, comprehensive data-driven decision support can help urban players in their decision and thus optimize LSCM processes in these areas. Therefore, it is required that the solution should incorporate comprehensive data-driven decision support capabilities.

The theoretical foundation has already demonstrated that the DSCT technology offers promising solutions to many of the urban LSCM problems described before. However, the widespread adoption of this technology in businesses has been impeded by various challenges. Especially small and medium-sized enterprises require an affordable and accessible means of implementing DSCT technology into their operations. This can be achieved by integrating them into an appropriate platform and providing software development kits for DSCT generation. It is required that the artefact provides organizations with an IT fundament (platform).

The present section represents the culmination of the requirement gathering phase of the DSR process. While the requirements are able to address a majority of the multiple problems identified in chapter 3.1, it is important to note that certain challenges, such as high traffic volume and urban-specific impediments, may require further attention. Nonetheless, the requirements defined in this section serve as a robust foundation for the subsequent chapter, which will propose a solution approach for optimizing LSCM processes in urban areas.

3.3 Design and Development

The third step of the DSR methodology involves the design and development of an artefact using a systematic methodology [22]. Authors in ref. [21] describe these artefacts as "potentially constructs, models, methods, or instantiations (each defined broadly) or new properties of technical, social, and/or informational resources." Based on the requirements described in the previous chapter, we developed an artefact using ideation techniques with several iterations. At each iteration, we evaluated the extent to which the defined requirements were met, and continued to refine the artefact until they were fully satisfied. The solution was a high-level architecture of a platform approach for the generation of a DSCT in urban areas. This artefact served as the basis for the next step in the DSR process, in which we conducted five additional expert interviews to theoretically demonstrate the platform approach.

3.4 Demonstration

The subsequent stage of the DSR process is the demonstration phase, which seeks to validate the functionality of the developed artefact. The artefact can then be optimized and adapted by reverting back to the previous stage and repeating the development process. Various activities, such as experiments, simulations, case studies, or proofs, may serve as effective demonstrations. In the context of this work, further expert interviews were selected as an appropriate activity. This qualitative approach is chosen on the fact that DSCTs are a rather new and innovative concept. Generally, resources needed for the demonstration include deep knowledge of the application area as well as knowledge on how to use the artefact to solve the problems. The experts were chosen in order to meet these requirements as they have industry-specific expertise. The architecture and functionality of the platform were presented and demonstrated to the same five experts. During the interviews, the platform architecture and functionality were presented and demonstrated to the interviewees. Following each interview, the artefact was refined based on the feedback received, with the aim of optimizing the architecture. Finally, the last two expert interviews saw no potential for optimisation, leading us to conclude that the development and demonstration stages were completed. The final and adjusted artefact is the platform architecture, which is presented in chapter 4.

3.5 Evaluation

During the evaluation phase of the DSR methodology, the effectiveness of the developed artefact in addressing the problems identified in chapter 3.1 is assessed. The objective is to compare the intended outcomes of the artefact with the actual results obtained through its application. In general, this fifth process step of DSR can also be performed using quantitative methods or, as in this case, the expert interviews. By selecting the suitable interviewees, we were able to generate the necessary knowledge about the relevant industries, enabling us to assess the potential of the platform approach to address the current urban LSCM problems. To achieve this, the final platform architecture was presented to the experts, who were then tasked with evaluating and justifying how specific platform components could potentially solve the urban LSCM problems. The problems were further considered in four categories (see chapter 3.1). The results and justifications are presented in chapter 4.

4 RESULTS

This chapter introduces the platform architecture for generating DSCTs and evaluates its effectiveness in addressing urban LSCM problems.

4.1 Platform Architecture

Based on the requirements and expert interviews, a framework for a cross-institutional platform to generate DSCTs in urban areas is proposed, based on [31]. The platform consists of the integration of various stakeholders, a central instance for the provision of external data, and eight modules. The central instance integrates data from multiple external sources, including city data such as traffic, environmental monitoring, and weather data, which is then made available to all relevant actors. This approach streamlines data sharing and avoids redundant data collection. Specific (aggregated) data from individual urban actors form an information and communication network, whose data is integrated into the DSCTs. The final output is presented in figure 2. A detailed description of the individual modules is presented below.

The proposed solution is designed to transfer a large amount of data to a platform, utilizing technologies such as IoT, 5G, and cloud computing. Within this platform, the data is stored in the *Interface Module*, which is located alongside the SDK Module. The Interface Module plays a crucial role in the further process, fulfilling multiple tasks. On the one hand, all data are available in a wide variety of formats and does not always meet criteria for high data quality (e.g., consistency, completeness, uniqueness, timeliness, validity, accuracy). Interface Module filters the data from various sources and translates it into a suitable format for processing in subsequent steps [31]. Applications of AI can help to process the unstructured data with different quality. On the other hand, the Interface Module also processes the data regarding data privacy and confidentiality. As not all companies are willing to share their entire information, the Interface Module performs filtering and processes the data to comply with privacy protection requirements. All in all, the Interface Module is intended for the storage and processing of data.

The *SDK Module* is an essential component of the platform. It represents a software development kit (SDK) that enables the creation of DSCTs [32]. The platform is accessible to various urban stakeholders who can load the content onto their machines as executable program files, also known as machine code, that are then loaded into the computer's memory for execution. The primary purpose of this module is to provide urban stakeholders with a suitable system for running a DSCT on their devices [32]. Together with the Interface Module, the SDK Module forms the foundation necessary for companies to generate their DSCT. As illustrated in Fig. 2, the DSCT comprises six additional modules: the Supply Chain Modelling, Simulation, Analytics, Reporting, API and ULC Module.

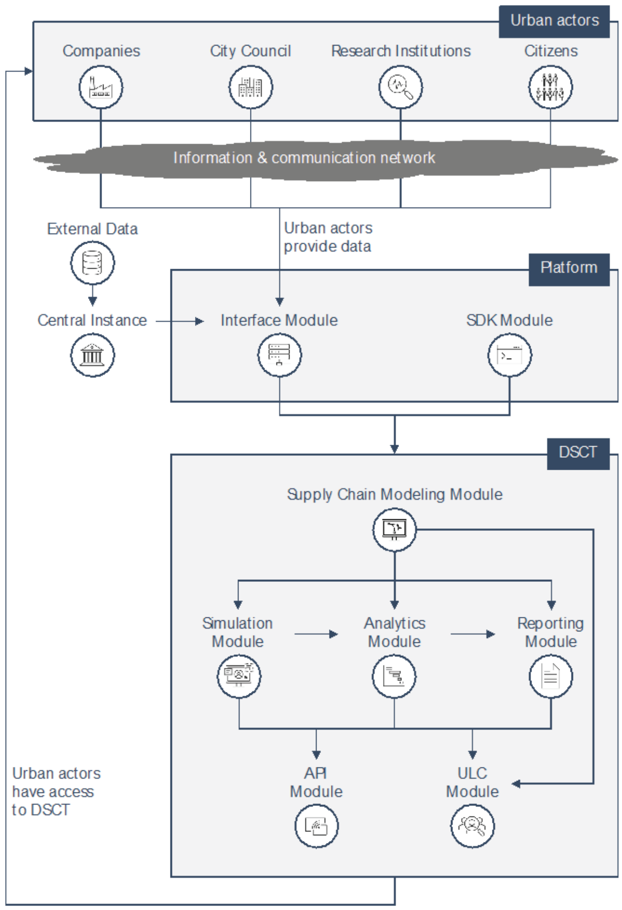

Figure 2 Proposed Architecture and Environment of DSCT Platform [31]

Data and SDK from the platform merge in the DSCT, where they form the *Supply Chain Modelling Module*. It enables to model a real, physical supply chain. The module provides the ability to represent all aspects, interdependencies, and relationships of the intricate urban LSCM systems, thereby offering a better understanding of the underlying processes [31]. By synchronizing real-world data, the current status of the physical supply chain can be monitored (e.g., inventory monitoring, delivery tracking). Classical algorithms or AI techniques can help in achieving this goal.

The *Simulation Module* can determine potential (future) states of the physical supply chain by applying different alternative parameters on the Supply Chain Modelling Module. It provides the ability to determine the impacts and outcomes of decisions and influences without affecting the real supply chain by conducting what-if scenarios. The simulation can be applied to both operational supply chain processes as well as to strategic planning processes. The use of this module optimizes the decision-making process of stakeholders. In addition, the introduction of new technologies and concepts can be simulated, the potential consequences become apparent, allowing stakeholders to anticipate and mitigate any barriers that may arise [31].

The *Analytics Module*, which is based on the Supply Chain Modelling Module, aims both to analyse and provide optimization opportunities of the physical supply chain. This module provides the ability to recognize, interpret, and communicate patterns within the data. The LSCM optimization opportunities made possible by this module can include for instance inventory optimization, maximization of vehicle utilization, efficient fleet management and route planning. These optimization opportunities can be realized with the use of algorithms or AI techniques [31].

The DSCT is further equipped with a *Reporting Module*, which can be regarded as an essential component of the platform [31]. The results obtained from the Analytics Module, the Supply Chain Modelling Module, and the Simulation Module are processed and presented in a structured and clear format, thereby facilitating data-based decision-making by the stakeholders. Effective communication of information, opportunities, and recommendations is critical in enabling the stakeholders to make informed decisions based on the insights gained from the DSCT [31].

As component of the DSCT, the *ULC* (user level customization) *Module* ensures that the DSCT or its individual elements are adapted to the corresponding user. The ULC Module enables the modification of the complexity, information, and decision-making capabilities of the DSCT depending on the user's level of expertise. Authors in ref. [33] have designed a solution approach for user-level customized modelling and simulation in production facilities, which can be used as starting point for the implementation of the ULC Module. However, further research is necessary at the network level to determine the number of modelling levels that should exist and which actor utilizes each level.

Additionally, the *API Module* ensures that the information gained by the DSCT is transferred into appropriate format, enabling the integration of DSCT outputs into existing systems such as SCM software, ERP software, and APS systems. To enable integration with the DSCT platform, existing software must be appropriately interfaced. This, in turn, allows for the integration of the platform with existing LSCM planning operations, thereby supporting an incremental implementation process [31]. The API Module plays an essential role in ensuring interoperability and compatibility between the DSCT and existing systems, thereby enabling the seamless integration of data and information to facilitate process optimization.

4.2 Potential Solutions for Urban LSCM Problems

After presenting the platform architecture, this chapter examines the extent to which urban LSCM problems can be addressed through it. The origin of the described DSCT platform approach are the multifaced problems in urban areas, with a special focus on LSCM. The primary objective of the platform approach is to enhance the sustainability of LSCM operations in urban settings across the three dimensions of economics, social, and environmental impact. The possible solutions are again considered in the four areas *urban logistics systems* and *management*, *infrastructure*, *technology*, and *economic factors* (see chapter 3.1).

The interviewed experts have assessed that the DSCT platform approach can effectively tackle major problems in the field of urban logistics system and management. According to their consensus, enhanced communication among urban stakeholders can alleviate conflicting interests of different actors in urban systems. The Supply Chain Modelling and Simulation Module can significantly increase process understanding, thereby reducing the lack of know-how regarding last mile processes. In addition, the Modelling, Analytics and Reporting Modules can help to minimise LSCM-specific problems in areas such as warehousing and inventory, vehicle utilization, fleet management, vehicle routing, and order management. The interviewees have also confirmed that the problem of insufficient data acquisition and processing can be addressed with the increased data exchange facilitated by the central instance, Interface and Analytics Modules. The increased data exchange between partners also helps to increase supply chain transparency and visibility, thus enabling the identification of unsustainable and unreliable processes/suppliers, so that the challenges of increasing demands for sustainability and reliability can be addressed. However, there are some problems in the field of urban logistics systems and management that cannot be solved directly by the DSCT platform. These include the increasing complexity of logistics solutions as well as uncertain and dynamic conditions of urban logistics systems.

In the area of infrastructure, the experts also evaluated that some problems can be solved by the DSCT platform. One of the major problems is the adaptation of urban infrastructure to the increasing freight volume. Modelling and simulation can help in the decision-making process for new urban infrastructure, thus facilitating its introduction. The interviewees also stated that the problem of insufficient infrastructure for new fulfilment technologies and concepts can be reduced as the impacts can be simulated beforehand, which can reduce the barriers for the introduction of new technologies and infrastructures. The Modelling and Simulation Module can increase process understanding and replace real experience to a certain extent, which can mitigate the lack of experience in introducing new infrastructure concepts in urban systems. However, the interviewees also acknowledged that the platform approach cannot solve issues related to high traffic volume and challenges resulting from the complex and dynamic condition of urban areas.

In the area of technology, the results are mixed. The experts stated that by simulating the impact of emerging technologies and business models in advance, potential barriers to their integration can be identified.

The Analytics and Reporting Modules also improve the planning of goods delivery, planning and fulfilment. However, the potential of new technologies to replace existing urban systems cannot be addressed.

Finally, the economic issues are considered. The experts confirmed that the Analytics and Reporting Modules can help with data-based analyses, leading to a reduction in cost estimation and better planning for goods delivery. The upfront expenses associated with the implementation and operation of new technologies, as well as the high cost of new infrastructure, cannot be immediately lowered. The expenses associated with urban fulfilment operations are typically high, and the platform may not have a direct impact on reducing them. However, through the simulation of various scenarios, the most financially feasible options can be determined.

5 DISCUSSION

The results illustrate that the DSCT platform has the potential to address numerous urban LSCM problems. Especially in the field of urban logistics system and management, major problems can be addressed. However, certain obstacles cannot be resolved by the DSCT platform, including for instance the complexity of logistics solutions, dynamic conditions of urban systems, high traffic volume and city conditions. Hence, it should be emphasized that the platform is not a universal remedy, but rather a partial solution to urban challenges. Therefore, it is crucial to consider other strategies for the comprehensive optimization of urban LSCM systems. The implementation of the DSCT platform may lead to several issues that have not been considered in this study. These include for instance financial obstacles for both the software and hardware required for data generation and underlying technologies. Furthermore, a high level of technical and economic expertise is necessary to realize the concept, and employees must receive training to operate the platform competently.

From a management perspective, the findings suggest that companies in the LSCM industry should consider the potential benefits and challenges of implementing the DSCT platform. While the platform offers significant advantages such as timely data updates, analytical capabilities, and simulation capabilities for holistic supply chains, it also requires a high level of technical and economic expertise to realize the concept, and employees must receive training to operate the platform competently. Thus, companies need to invest in the necessary technical skills and training to ensure successful implementation and effective use of the platform. Furthermore, companies must also consider the financial obstacles associated with implementing the platform.

From a research perspective, further research is necessary to explore alternative approaches for addressing urban LSCM challenges that are not amenable to the platform. In particular, research should focus on strategies for the comprehensive optimization of urban LSCM systems, considering the complexity of logistics solutions, dynamic conditions of urban systems, high traffic volume, and city conditions. Further research is also needed to investigate the financial obstacles and technical expertise required to implement the DSCT platform effectively. Finally, research should explore the long-term cost-saving potential of the technology and its ability to improve urban systems in terms of financial and environmental sustainability. By addressing these issues, researchers can contribute to the ongoing development and optimization of the DSCT platform and other innovative solutions for urban logistics challenges.

Although the platform solution cannot solve all problems related to urban logistics and poses several challenges, a clear image emerges from the research: the opportunities associated with the technology integration can surpass the challenges. Compared to traditional solutions like ERP, SCM, or TMS systems, the platform approach offers significant advantages such as timely data updates, analytical capabilities, and simulation capabilities for holistic supply chains. Moreover, the platform has more data generation possibilities and increased connectivity of supply chain actors and urban stakeholders compared to a DSCT utilized by a single supply chain or organization. Additionally, the availability of software development kits simplifies implementation. By combining the advantages of DSCT technology and a platform, the modular architecture provides flexibility for constant adjustment and optimization of the solution. Although the initial financial outlay for implementation may appear very high, the technology offers considerable cost-saving potential in the long term. The technology offers opportunities to improve urban systems in terms of financial and environmental sustainability. All in all, at first glance, introducing the DSCT platform seems challenging. However, in the long term, the benefits can outweigh the challenges. This study has established an initial framework to resolve urban logistics issues.

6 SUMMARY AND CONLUSION

The 21st century is the century of cities. Urban spaces are transforming, and with-it urban logistics. This study explores how a digital platform for generating DSCTs can address urban logistics challenges. It uses DSR methodology to identify and categorize urban LSCM problems, elaborate requirements, design the platform, and evaluate its effectiveness. The final result is a high-level platform architecture and an assessment of its potential to solve urban logistics problems. It can be concluded that the DSCT platform offers a viable approach for addressing numerous urban LSCM problems. These problems include insufficient knowledge about last-mile procedures, inadequate data generation and processing, lack of supply transparency and visibility, inadequate communication among urban stakeholders, and challenges in adopting new technologies Nonetheless, it is important to acknowledge that the proposed platform and our research have limitations and cannot provide a comprehensive solution to all urban LSCM issues. To overcome these limitations, additional research and approaches, such as reducing urban traffic or minimizing the high costs of fulfilment operations, are needed. The limitations of this study include its theoretical and conceptual nature. The DSCT platform was not practically implemented, and the research relied solely on a qualitative approach with a relatively small number of five interviews. As a next step it is essential to practically implement and verify the platform in future research. All in all, based on current trends, it is expected that DSCT technology and platform approaches will become increasingly important for companies in the future, despite some challenges. The technologies provide numerous opportunities to address urban problems and promote sustainability in both cities and LSCM. The elaboration of the DSCT platform approach in this research aims to facilitate and encourage its implementation and address urban LSCM problems.

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