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Digital interoperability and transformation in logistics and supply chain management: editorial

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Digital interoperability and transformation in logistics and supply chain management: editorial

Abstract: This editorial introduces this Special Issue on advances in research on digital interoperability and transformation in logistics and supply chain management. Eleven high-quality and original research works from both researchers and practitioners in the area have been selected to compose this Special Issue. This editorial first introduces the scientific context relevant to the Special Issue, then presents each of the eleven papers. From these papers, this editorial identifies several interesting prospective works, which are finally presented.

Keywords: Digital interoperability, Digital transformation, Logistics, Supply Chain Management, Editorial, Special issue.

1. Context

To surf on the wave of digitalization, companies are urging to improve digital interoperability through the digital transformation process. Digital interoperability is *the ability to achieve quick, seamless, secure, and reliable data and information exchange between companies* (Pan et al., 2021). The ability is of particular importance in the area of logistics and supply chain management (LSCM) which stresses the importance of cross-organizational and cross-functional collaboration for strategic planning and operation management. Although digital transformation is well underway in this area, companies are still struggling to find efficient and effective solutions and approaches to enhance the digital interoperability, especially at large-scale level (Leal et al., 2019).

The practical need for enhancing digital interoperability in LSCM has been particularly witnessed in the COVID-19 pandemic. A large number of issues regarding resilience and viability of the contemporary supply chain have been highlighted, most of which are pointedly related to the problem of digital interoperability, such as supplier's information viability and sharing, logistics service provider's operational information availability, end-to-end supply chain mapping and monitoring. At the beginning of the outbreak in early 2020, these issues were even more obvious to the companies (or those having suppliers) located in the quarantined areas. This can be attributed to the presence of information silos, i.e., the isolated information and data owned by individual companies or systems. Due to the lack of fast and reliable communication among the silos, information sharing is very limited. One of the goals of digital interoperability is to interconnect these information silos such that information can be exchanged in efficient and effective way with privacy preservation.

On the other hand, recent research has suggested the need to consider not just supply chains but supply networks. New relevant paradigms include intertwined supply networks (Ivanov and Dolgui, 2020) and Physical Internet (Montreuil, 2011; Ballot et al., 2014), which advocate horizontal and vertical collaborations based on the interconnection of the existing logistics networks for sharing the logistics resources and services involved. Likewise, in accordance with the Industry 4.0 principles such as *plug-and-play* and *the systems of systems*, recent approaches used in digital logistics systems modeling also put emphasis on the interconnectivity of systems (including objects, information entities, etc.). Among them, for example, Cyber-physical systems, semantics and ontology, and digital twins are the most investigated recently (Derigent et al., 2020). For all these new approaches and paradigms, digital interoperability is a key to success that makes company-to-company, network-to-network, or system-to-system communication possible and reliable.

It is in this context that digital interoperability has gained increasing attention in LSCM, from both researchers and practitioners in the area. Considering the recent challenges placed on today's logistics systems, as well as the new opportunities empowered by the disruptive technologies, new research questions and issues that merit more attention are put forward.

2. The current research focus

This Special Issue aims to advance the research on digital interoperability in LSCM, by collecting the high-quality and original research works from both researchers and practitioners in the area, and by raising new research questions. The scope is wide enough to incorporate the most relevant contributions including development and application of concepts and solutions, disruptive technologies and techniques investigation, state-of-the-art or survey studies, etc.

The Special Issue particularly encourages the cutting-edge solutions that foster logistics and supply chain collaboration at large-scale level. The solutions and the related issues that are investigated by the papers included in this Special Issues are summarized in Table 1. The solutions can be grouped in four main categories that are hereinafter discussed, as displayed in Figure 1.

Title	Authors	Solution
An approach and decision support tool for forming Industry 4.0 supply chain collaborations	Sonia Cisneros-Cabrera, Grigory Pishchulov, Pedro Sampaio, Nikolay Mehandjiev, Zixu Liu, Sophia Kununka	Digital platform
Digital connectivity in an innovative joint distribution system with real-time demand update	Yuan Shi, Meng Chen, Ting Qu, Wei Liu; Yiji Cai	Data-driven planning
Use of proximal policy optimization for the joint replenishment problem	Nathalie Vanvuchelen, Joren Gijsbrechts, Robert Boute	Machine Learning
Synchromodal transportation planning using travel time information	Hannah Yee, Joren Gijsbrechts, Robert Boute	Data-driven planning
Orchestrating product provenance story: When IOTA ecosystem meets electronics supply chain space	sabah suhail, Rasheed Hussain, Abid Khan, Choong Seon Hong	Blockchain
Blockchain-enabled circular supply chain management: A system architecture for fast fashion	Bill Wang, Wen Luo, Abraham Zhanga, Zonggui Tian, Zhi Li	Blockchain
An information architecture to enable track-and-trace capability in Physical Internet ports	Patrick Fahim, Yusong Pang, Jafar Rezaei, Lorant Tavasszy, Rowoon An, Benoit Montreuil	API
Peeking into the void: Digital twins for construction site logistics	Toni Greif, Nikolai Stein, Christoph Flath	Digital twin
Cyber physical system-enabled synchronization mechanism for pick-and-sort ecommerce order fulfilment	Xiangtianrui Kong, Xuan Yang, Kelin Peng, Clyde Zhengdao Li	CPS
An investigation into emerging industry 4.0 technologies as drivers of supply chain innovation in Australia	John L. Hopkins	Empirical study
Digital interoperability in logistics and supply chain management: state-of-the-art and research avenues towards Physical Internet	Shenle Pan, Damien Trentesaux, Duncan McFarlane, Benoit Montreuil, Eric Ballot, George Q. Huang	Landscape analysis

Table 1. Papers included in this Special Issue.

Figure 1. The four main categories of solutions presented in the Special Issue.

Digital platform: Digital platform can be seen an online platform that consists of information systems, interfaces and engines for the users to collect, exchange and search information. It could be web-based or mobile application-based marketplaces for *BtoB*, *BtoC* or *CtoC* markets (B for business, C for consumer). As per its advantages especially for ecosystem development, digital platform has been considered as a powerful tool of digital transformation, which also assists the interoperability among companies connected to the ecosystem. However, several issues must be dealt with in order to ensure the effectiveness and efficiency, for example, data format and integration, privacy preservation, information system architecture, searching and matching engine and algorithms design. These issues are particularly crucial for large-scale multi-party supply chain and logistic collaboration, as demonstrated by (Cisneros-Cabrera et al., 2021). From a practical point of view, the authors design a digital platform as a decision making tool for matching demands and supplies from companies in manufacturing. On the demand side, companies post Call for Tenders with specific requirements; on the supply side, suppliers publish their capabilities available. As the platform is ontology based, the devised matching algorithm is able to efficiently and effectively match the demands and supplies. The interoperability is therefore enhanced for multi-party at large-scale.

Data-driven solution design, planning, modeling and control: The decision-making processes in LSCM has been conventionally and primarily supported by Operations Management & Operations Research (OM/OR) fields. Moreover, purely data-driven approaches have also shown the great potential to assist in the processes, such as using real-time information for dynamic planning, exploiting historical data for forecasting, etc. This can be considered as a reorientation of some of the traditionally mathematical approaches to OM/OR. For example, Yee et al. (2021) suggest to use cargos' real-time travel information in synchromodal transportation planning. The results denote that real-time information may help optimize modal choice by minimizing the total transportation and overtime delivery costs. Likewise, Shi et al. (2020) investigate the importance of real-time demand update in joint distribution systems, i.e., horizontal collaboration among shippers. They propose an architecture of digital connectivity for the dynamic joint distribution system, in order to collect and communicate synchronously and continuously data from customers, shippers, logistics platforms, etc., for the purpose of route optimization. More recently, the application of Machine Learning technique in logistics industry has further fundamentally altered the conventional approaches, enabling more efficient and visionary decision-making process. In the work of (Vanvuchelen et al., 2020), the authors experiment proximal policy optimization (PPO) algorithms in joint replenishment schemes, which is an optimization method in the domain of deep reinforcement learning. The results of their experiments show that, whatever at small- or large-scale, the suggested PPO algorithm outperforms the conventional heuristic methods for joint replenishment decision making. It means the algorithm can eventually facilitate the coordination in cooperative logistics schemes, especially at large-scale. This first work should encourage more research on the applications of AI in the area of LSCM.

Blockchain and API: To alleviate some critical issues related to data sharing, e.g., data tracking, traceability, trustability, and privacy preservation, Blockchain or API (Application programming interface) based disruptive solutions have been put forward. For example, the blockchain technology is being growingly investigated in LSCM for the traceability of material, responsibility or data, e.g., Wang et al. (2020) use it for tracing the reuse of materials for circular supply chain management in fast fashion, and Suhail et al. (2020) suggest IOAT blockchain to ensure trustworthy data for tracing product provenance from raw material to end of life. Further, the technology of Smart Contracts based on blockchain is also

receiving increasing attentions, especially for automating processes and exchanges, like services procurement and payment. APIs are also used to simplify and secure data exchange, as shown in the case of track-and-trace capability in Physical Internet ports done by (Fahim et al., 2021). Besides, API is also the key technology to provides blockchain with information from the outside world, in other words, to connect blockchain to other data bases. As the research on Blockchain in the area of LSCM is still in its infancy, a number of issues still need to be addressed, such as scalability, typology (open, private or consortium), time- and cost-effectiveness, and sustainability of the technology.

Digital twin and Cyber-physical systems: One outcome of the digital transformation in many industries is that physical object and its lifecycle can now be sharped in the digital world, thanks to the advancement of IoT and sensing technologies. The virtual counterpart, namely Digital twin, can then be used to handle the very complex problems, such as product design, real-time status monitoring, maintenance scheduling, new value creation, etc. In addition, cyber-physical systems (CPS) that integrate technologies of sensor, computing and communication are primarily used to intertwine physical and cyber worlds for the purpose of controlling the objects. Based on these technologies, digital interoperability can be achieved among objects (or systems, companies). In the literature, intralogistics is currently the main field of application. The authors in (Greif et al., 2020) apply digital twin concept on the silos in construction sites; and they prove that the developed digital silo twins can offer new business values as well as supports for silo dispatch and replenishment decisions. Another common application is related to logistics platform, since smart (or intelligent) objects are now being employed in intralogistics systems, for example, industrial wearables, AGVs (automated guided vehicles), AMRs (autonomous mobile robots), autonomous vehicles. Kong et al. demonstrate in their paper (Kong et al., 2020) that integrating smart objects and CPS modelling may become an efficient and effective solution for pick-and-sort operations in ecommerce fulfilment centers. These works showcase the capability of digital twin and Cyber-physical systems in LSCM, especially to handle the high complexity of decision-making and control.

It is worth mentioning that two papers in the Special Issue are putting focus on the digital interoperability research landscape rather than on specific solutions. Pan et al. (2021) provide a comprehensive bibliometric analysis on the stat-of-the-arts solutions for digital interoperability in LSCM. The research trends, as well as new challenges raised by recent paradigms such as Physical Internet are discussed. Some future research avenues are also pointed out in order to advance the research. In another paper (Hopkins, 2021), the author applies empirical methods to investigate how merging industry 4.0 technologies drive the SCM innovations, the digitalization and the inter-company connectivity.

3. Discussion

Since digital interoperability is an emerging research topic in the area of LSCM, this Special Issue with the included contributions should encourage more research on the topic. Several research questions can be discussed here.

First, the solutions discussed above could be further industrialized and deployed in real-life world, especially for large-scale multi-party logistics systems. It is foreseeable that some design issues must be addressed beforehand.

Second, this Special Issue also reveals the significance of interdisciplinary approaches to the research topic, involving operations research, data science, computer science, information

system management, software and hardware engineering, as well as systems and organizational theory. It is believed that this axis will attract more attention in the future.

Third, as shown by the studies above, data-driven and digital twin-driven approaches have the great potential to enhance system-to-system, object-to-object, or object-to-context interoperability. Data-driven approaches include Big data analytics, data mining, machine learning, graph database etc.; and digital twin-driven approaches are for example semantics and ontology, cyber-physical systems, holonic systems, etc. The research on the application of such approaches in LSCM has just begun.

Last, blockchain and especially smart contract technologies are being considered as an enabler of automated processes and autonomous (self-organizing) systems. But one main issue is the interconnection and dynamic interaction among such processes and systems so that real-time information could be considered and communicated. Recent concepts like Oracle (e.g., *Chainlink*) show the potential to deal with the issue, but more research on the proof of efficiency of applications in LSCM are still appealing.

With the development of the above-mentioned technologies, this emerging research field will also have to consider organizational questions related to adoption and the transformational potential of such technologies implemented at large-scale level by companies involved in supply networks in general.

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