The Role of Digital Connectivity in Supply Chain and Logistics Systems: A Proposed SIMPLE Framework

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Abstract. Industry 4.0 and its related-cutting edge technologies are generating unprecedented changes and bringing complex challenges in practically all types of business. In this context, new concepts such as digital connectivity, interconnection, and interoperability emerged as highly disruptive approaches for logistics systems and supply chain management (SCM). To shed more light on these complexities and see how companies organized in a SCM model can adopt, implement and operate in a digital connectivity model, this study proposes a framework, namely SIMPLE. To develop the framework, we employed a literature review approach, focusing on recent studies published in journals. After the literature analysis, six dimensions related to digital connectivity in supply chains and logistics emerged, namely Smart, Innovative, Measurable, Profitable, Lean, and Excellence (SIMPLE). This framework brings opportunities for future studies, while providing important insights into the dynamics of digital connectivity in logistics and supply chains. Therefore, these SIMPLE framework dimensions should enable the actors involved in organizations' operations to interact adequately and harmoniously so as to maximize the value generated in the network.

Keywords: Digital connectivity · Hyperconnected · Interoperability · Interconnection

1 Introduction

The digital age has imposed several challenges to the organization's logistics systems and their supply chain management (SCM) [1, 2]. In this new context, digital supply chains [1] are fundamental to organizations that seek to achieve efficient processes, create business value, and gain a competitive advantage in a sustainable approach. This environment has given rise to new methods such as digital connectivity, interconnection, and interoperability [3], which have emerged as paradigms to be fully grasped by SCM stakeholders, which have to develop new strategies to implement critical technologies and integrate them with the SCM field [4]. The concepts of interconnection and interoperability clearly define the level of digital connectivity [3] of an

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organization, and consequently, of the way it manages its supply chains. Interconnection in SCM refers to the connection enabled by different technologies in which supply chain partners can obtain information (mainly in real-time) from customers and SCM members and share such data while maximizing value by taking into account the personalization requirements [5].

In this study, we consider the logistics systems as a subset of SCM, according to Council of Supply Chain Management Professionals (CSCMP) "*Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies*" [6]. Thus, in logistics, interoperability refers to the interaction between SCM members that is rendered possible by the use of several technologies and that fosters information sharing and the utilization of exchanged information in a set of processes [3].

However, the existing literature on digital connectivity [1, 3, 7–9] is scarce, especially in developing frameworks applicable in the logistics and SCM contexts [1]. That is, the unprecedented move in digital connectivity in the fields of logistics and SCM is yet to lure the interest of a significant number of scholars, as the related literature is still at its infancy stage, coupled with the inexistence of a framework that could help to better understand this technology, especially in the aforementioned specialized areas. This study is an attempt to enable an understanding of the various aspects of the digital connectivity at different levels (e.g., operational, tactical and strategic), and to attain this goal, it proposes a framework, namely SIMPLE.

2 Background

2.1 Industry 4.0 and Cutting-Edge Technologies that Leverage Connectivity

Industry 4.0, also known as the 4th Industrial Revolution or Advanced Manufacturing [10], and its leading technologies are provoking significant disruptions on the firm's business model. This term (Industry 4.0) was coined at the 2011 Hannover Fair, from a German Government project aimed to revitalize the country's industry [11]. With almost ten years of age, Industry 4.0 has not yet gained consensus among scholars and practitioners when it comes to a unified and acceptable definition of the concept [12]. In this study, Industry 4.0 refers to a set of cutting-edge technologies that provide connectivity, interconnection, and interoperability of humans, machines, devices, and organizations.

To support the development of the SIMPLE framework, this study highlights the following Industry 4.0 technologies (Table 1):

Table 1. Example of Industry 4.0 related technologies.

Industry 4.0 technology	Example of application	Adapted from
Blockchain	Traceability of products in SCM	[13]
Artificial intelligence	Fraud detection in payment card	[14]
Big data analytics	Firm performance improvement	[15]
Physical Internet (PI)	The interplay of physical, operational, and digital interconnectivity of logistics systems	[9]
Internet of Things (IoT)	A framework for the analysis of the industrial internet of things	[16]
Cyber-physical systems	Production systems design based on cyber-physical systems knowledge tool	[17]
Digital platform	Platform openness in the SCM	[18]
Digital twin	Application for additive manufacturing in the aircraft context	[19]
Sensors	Application supported by big data and IoT to sustainable smart cities	[20]
Virtual reality	Virtual reality diffusion	[21]
Augmented reality	Adoption of smart glasses	[22]
Cloud chain	Connection of supply chain members to monitoring product lifecycle	[23]
Autonomous robots	Application in manufacturing processes	[24]
RFID	To support digital supply chains	[1]
M2M	Applied to support smart transactions in the electricity market	[25]

3 Proposing the SIMPLE Framework

To develop and propose the SIMPLE framework, this study employed a literature review approach, focusing on recent studies published in journals. We applied an unstructured searching approach [26] using different sources, such as ScienceDirect, Emerald Insight and Taylor & Francis database, as also the reference list of the papers selected. Firstly, we used as keywords the variations of "digital Connectivity," "hyperconnected," "Interoperability," "Interconnection," and "digital supply chain." After, we used the reference list of the articles to identify other papers. After the literature analysis, six dimensions related to digital connectivity in supply chains and logistics emerged, namely Smart, Innovative, Measurable, Profitable, Lean, and Excellence (SIMPLE).

3.1 Smart

This dimension refers to smart applications that are used not only in internal logistics systems but also in supply chains. An example of smart applications could be explained by the use of blockchain technologies [27] to support the organization's transactions efficiently, which in turn improves the collaboration and cooperation between the members of the SCM by a tamper-proof system [28]. The "Smart" dimension has the following main sub-dimensions:

- *Develop smart logistics/SCM capabilities by using cutting-edge technologies in the operations:* it means that organizations need to develop and integrate cutting-edge technologies into their operational processes. This involves internal and external digital supply chain efforts [1].
- *Provide integration and real-time interaction with key SCM members:* for an organization to achieve effective connectivity integration through its SCM operations, it should resort to cutting-edge technologies like blockchain to enhance real-time interaction and visibility [29, 30].
- *Create integration and leverage interplay between robots and humans:* smart concepts are built on SCM activities only when robots and humans work in symbiosis [31]. To this effect, humans should develop their own education and skills to maximize operations with robots [32].

3.2 Innovative

Innovation should be a mandatory competency for any organization. In the context of digital connection and interoperability, innovative solutions represent a significant opportunity for making several improvements [3]. For instance, innovation in the digital age has been supported by several ICT approaches, as smart cities [33] applications (e.g., the possibility of a transportation system more connected [33]). Also, with physical internet concepts, the interconnection and interconnectivity of the organization's logistics systems and their supply chain will be more innovative [34]. This dimension has the following elements:

- *Implementation of cutting-edge technologies in logistics and supply chain activities:* The innovation processes required for implementing a particular cutting-edge technology is not trivial [4]. That is, different efforts and several partners, as also human skills are necessary [4] to achieve success or minimize the failures.
- *Improve the logistics and SCM processes by key technologies and spread in the network:* critical technologies need to support improvements not only in internal processes [35], but also throughout the whole SCM channels [36].
- *Create new products/services as a result of the connectivity's interaction in the SCM:* the interaction that is brought about by connectivity should contribute to creating innovative products and services by means of SCM. For instance, the interplay between IoT-wearable operations, an example of connectivity, is crucial to provide smarter worker care services [37].

3.3 Measurable

The level of interoperability [3] is an essential aspect of the digital supply chain efforts and results. It indicates the efficiency generated by cutting-edge technologies in a smart approach, as well as the results achieved in the SCM. For instance, big data applications can enable measurable information to support transportation operations [38]. The following aspects are required:

- *Design indicators for intra-organizational and operational performance in logistics by means of digital connectivity strategies:* considering the challenging landscape imposed by the digital connectivity, organizations need to develop reliable key performance indicators [39] in all business perspectives, especially within the SCM.
- *Apply indicators to measure SCM operational performance using digital connectivity strategies:* after the design of key indicators, the next challenge is to implement them [40]. This implies that traditional measures are not sufficient [41] to face the digital connection age.
- *Manage a set of key indicators about the improved processes across the supply chain networks:* to follow the digital connectivity results and improve the decision-making process, a performance measurement system (PMS) [40] is fundamental.

3.4 Profitable

The connectivity in the SCM context can have a substantial impact on the organization's [42], and consequently, affecting their profitability performance. Recent literature had highlights that connectivity supports the creation of internet services [43] and, consequently, could impact an organization's profitability [44]. To understand and manage these effects, the SCM members need to develop the following activities:

- *Minimize logistics costs supported by interconnection and interoperability across the SCM:* Interconnection and interoperability can minimize the costs through the entire SCM, and this may involve, for instance, PI to deliver solutions [9].
- *Leverage the operational performance gains enabled by relationships in supply chain networks and generated by interconnection and interoperability:* Interconnection and interoperability are fundamental for creating value in the SCM. For instance, cooperation between SCM members can rely on interoperability to achieve business success [45].
- *Increase profit performance with interconnection and interoperability within the supply chain networks:* Interconnection and interoperability can impact positively on the organization's profitability. In other words, the more interactions between supply chain members are performed, the more profit performance could be achieved [46].

3.5 Lean

Lean initiatives in the logistics and supply chain connectivity should be achieved by the implementation of a vast of cutting-edge technologies to support sustainability achievement [35]. Hence, the "lean" dimension has the following elements:

- *Promote connectivity and develop a lean relationship with cleaner stakeholders:* the lean relationship in this study refers to the collaboration between SCM members that is rendered possible by cutting-edge technologies, with a high level of responsiveness to support strategic partnerships. For instance, with IoT, lean processes in the SCM could be facilitated [46].
- *Implement different types of technologies that will be used to support lean operations:* lean technologies in the SCM can minimize waste of resources and inventories through the network while improving efficiency through the reuse of resources [47]. It is therefore clear that different types of technologies could have a good effect on production systems sustainability, and they include IoT and platforms to resource management, AI, and M2M, among others [35].
- *Implement sustainable connectivity strategies that improve the society's well-being:* sustainable connectivity strategies are related to the technologies implementation that leverage connectivity without bringing (or at least minimizing) the side effects to organizations and society. That is, the implementation of cutting-edge technologies could bring some negative impacts to society [48]. A case in point has to do with the risks of cyber-attacks associated with any technology and their side effects for the society.

3.6 Excellence

There is not a proper definition of connectivity excellence in the literature. In our context, connectivity excellence refers to the best practices associated with technology adoption and implementation that support real-time interactions and enable hyperconnected members in different layers of the SCM to maximize multiple values simultaneously. The connectivity excellence was considered in the framework due to its influence on the other dimensions as also be simultaneously influenced by these dimensions.

- *Leverage efficient and effective processes through the SCM:* with innovative technologies, the traditional SCM is shifting to digital supply chains [1], thereby transforming and remodeling practically all processes to gain efficiency in the network. For instance, the connectivity can lead to improved flexibility, optimized interactions with suppliers around the globe, and real-time inventories, among others [1].
- *Optimize the level of services, interconnection and interoperability in the SCM using suitable technologies:* cutting-edge connectivity is expected to significantly improve the level of services. For example, product embedding sensors would enable real-time analysis of operations and thus help optimize transaction efficiency and speed in process delivery, among others [1].
- *Improve/generate competitive advantage supported by interconnection and interoperability:* if all the dimensions of the SIMPLE framework interact harmoniously, the organization will be able to improve or generate competitive advantage. Otherwise, digital connectivity will not be operating in an optimized way. For example, by using interoperability approaches, organizations could operate efficiently in collaborative networks, reflecting on capturing value and business opportunities [3]. Figure 1 highlights the SIMPLE framework.

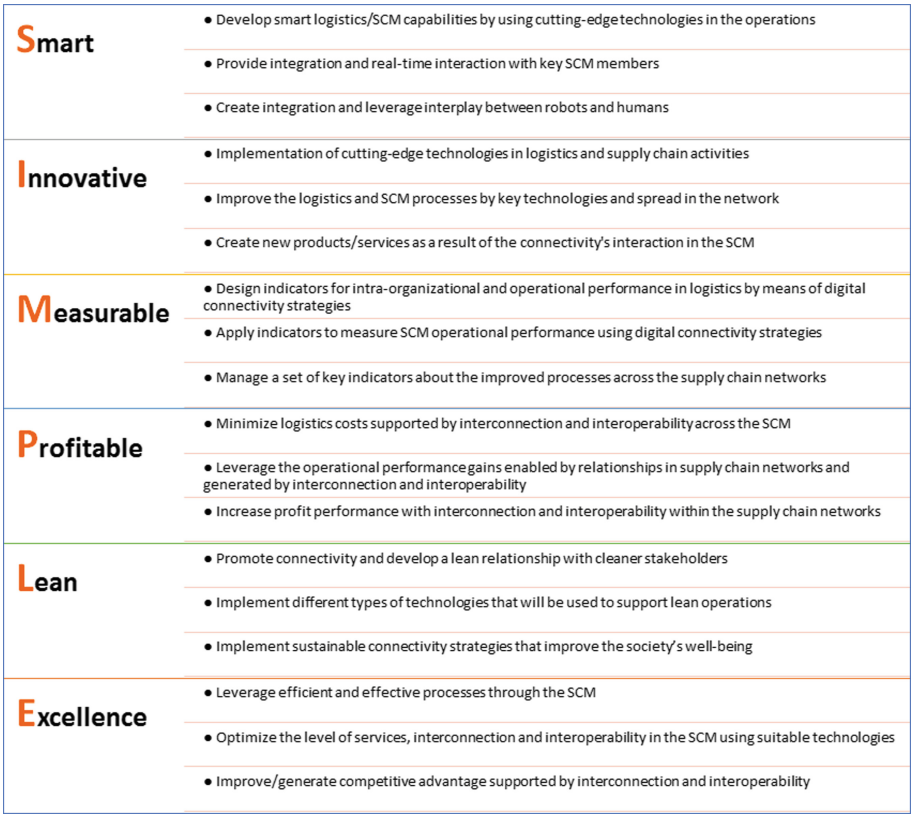

Fig. 1. SIMPLE framework.

Regarding the aforementioned characteristics of the SIMPLE framework, the following propositions emerge:

P1. The SIMPLE framework or part of its elements is positively associated with the organization's logistics and supply chain connectivity performance.

P2. The interconnection and interoperability maturity level of an SCM member is positively associated with the SIMPLE framework implementation quality or part of its elements.

P3. The adoption and diffusion of the SIMPLE framework or part of its elements are positively related to the competitive advantage of an SCM member.

Thus, taking account of the elements as mentioned earlier of the SIMPLE framework, it can be seen that it could help in information sharing and cost reduction. That is, with leveraging the information sharing [3] by the digital connectivity, the logistics systems and SCM should be more responsiveness, by operating with members in a more collaborative way [1]. The SIMPLE framework offers elements in terms of operational, tactical, and strategic levels to provide insights to organizations capture value considering the digital connectivity age.

4 Concluding Remarks, Implications, Limitations and Future Research

In this work, the SIMPLE framework was introduced in order to understand more profoundly the digital disruptions in logistics and SCM business models, in the digital connectivity era. The main contribution of this study resides in that it proposes an original framework to support and provide organizations with key insights into digital connectivity in the logistics and supply chain domain. The SIMPLE framework highlights that thanks to its six dimensions (smart, innovative, measurable, profitable, lean, and excellence), organizations can maximize their value in the network, provided that they manage such elements carefully while considering their internal and external capabilities. Therefore, these SIMPLE framework dimensions should enable the actors involved in organizations' operations to interact adequately and harmoniously to maximize the value generated in the network.

Furthermore, this work has implications from both the practitioners and theoretical perspectives. From a managerial perspective, the SIMPLE framework could be a starting point to managers and decision-makers who want to better understand the importance of an integrative tool for improved awareness and enhanced digital connectivity strategies. In terms of theory, the SIMPLE framework brings opportunities to scholars as they may want to develop empirical studies about this framework's adoption, implementation, and generalization across supply chains. Also, the three propositions that are being suggested herein could be used to develop a conceptual model to empirically test the framework. Due to the nascent status of the SIMPLE framework, the main limitation is concerned with its effectiveness in broader supply chain contexts. Therefore, opportunities for future studies may include analyzing the same framework in other industries, countries and social contexts worldwide.

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