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Identifying Digital Supply Chain Capabilities

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Abstract

In the global manufacturing sector, the ever-increasing digital transformation of Supply Chains (SCs) has become imperative, leading to building new digital and analytical capabilities to achieve SC competitiveness. However, building these new capabilities to integrate end-to-end Digital Supply Chains (DSCs) is a major challenge. There is a need to develop a SCM holistic view that facilitates the understanding of the fundamentals behind successful strategic alignment, information sharing, and collaborative decision-making across supply chains and networks. This paper examines key enabling digital and smart technologies transforming supply chains and networks through an explorative review of the scientific literature, identifying emerging DSC capabilities and technology adoption challenges that supply chains and networks face to achieve their digital transformation. Furthermore, this paper concludes that digital strategic alignment must be practised among DSC partners. The findings contribute to understanding how digital and analytical capabilities are built for DSC competitiveness – with implications for SCM theory and practice.

Keywords: Digital Supply Chain; Digital Integration; Digital Capabilities; Digital Technologies; Digital Transformation.

1. Introduction

In the global manufacturing sector, the need for a rapid *digital transformation* of manufacturing systems and supply chains, brought by the Fourth Industrial Revolution – or Industry 4.0, has become an imperative for *Supply Chain (SC) competitiveness,* leading to a *SC evolution* that involves redefining manufacturing and logistics processes, business models, and ways of working. At the same time, the rise in the adoption of *digital and smart technologies*

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has also progressed rapidly, resulting in the emergence of *advanced digital and analytical capabilities* that are driving the development of more competitive *digital supply chains and networks.* Furthermore, this adoption has significantly affected manufacturing industries' work dynamics, quickly revolutionising their *supply chain operations* by enhancing automation, data-driven decision-making, real-time visibility, and seamless integration across their value chains [1] [2].

However, building advanced digital and analytical capabilities to integrate *End-to-End Digital Supply Chains (DSCs)* is a significant organisational and technological challenge. All *SC stakeholders* must understand at least the fundamentals behind a *SC digitalisation initiative* to align their strategic individual and coordinated efforts, share information, and make collaborative decisions for the common good. In addition, the manufacturing sector's evolution towards sustainable value creation requires new intelligent systems, advanced technologies, and highly skilled SC actors agreeing to a common vision and strategy to reach agile, flexible, and sustainable collaborative processes, promoting enhanced efficiency and increasing productivity within a DSC [3]. Introducing new Information and Communication Technologies (ICTs) as well as Operational Technologies (OTs) for smart factory activities inspires *SC actors* to collaboratively redesign their processes and adopt the Industry 4.0 paradigm.

To effectively embrace the strategic digital transformation of supply chains and networks, SC stakeholders must undergo a technological transformation and invest in comprehensive training. Moreover, this training must equip *SC actors* with the necessary *digital skills and knowledge* to use the new tools and technologies brought by the Fourth Industrial Revolution. By doing so, *focal companies* can ensure that their SC actors are positively impacted, both directly and indirectly, and can take full advantage of the momentum of this new DSC revolution. Therefore, the strategic alignment of *SC digitalisation initiatives* can significantly enhance organisational performance, drive innovation, and achieve competitive advantages for all SC actors.

The advent of digital and smart technologies adoption, as a fundamental practice in modern SCs, is challenging *SC managers* to build new and specific *DSC capabilities* to address the complexities and demands of the emerging digital supply chains and networks effectively. This trend calls for the design of new *Digital SC Management (DSCM) practices* that prioritise real-time data exchange, interoperability, and collaborative decision-making – which opens research gaps for academics and managerial gaps for practitioners in the *DSCM domain.*

The vision of the digital transformation of SCs is to create more efficient, connected, and responsive supply chain networks, enabling SC actors to develop digital and analytical capabilities to leverage emerging smart technologies for effective SC competitiveness. Consequently, in the Industry 4.0 era, a strong SC actor is characterised by its proficiency in technology integration, data-driven decision-making, and collaborative relationships to create responsive and competitive SCs.

The paper is structured into five sections. Section 1 presents the impact of SC digitalisation before honing the research gap. Furthermore, Section 2 offers a scoping literature review of the key terminology and ongoing discussion around synchronised systems in the DSC context. Section 3 introduces the main challenges for successfully digitalising SCs. Furthermore, Section 4 looks at the future steps and provides an outlook on how this new DSC integration effort will shape the global manufacturing sector. Finally, Section 5 concludes the paper and addresses the limitations of this work.

2. Research Methodology

A *scoping literature review* seeks to present an overview of a large body of knowledge about a broad topic [4]; in this review regarding: "DSC Capabilities". A *scoping review* was attempted to collect empirical evidence from the most significant studies in the scientific literature on the *advanced digital and analytical capabilities* that characterise a DSC. The *scoping review* conducted followed six stages [4]: (i) *Research Question* – What digital and analytical capabilities characterise a DSC?, (ii) *Relevant Literature* – Scopus and Web of Sciences databases were consulted as the two world-leading academic databases, (iii) *Selected Studies* – Using the keywords: "Digital Supply Chain" AND "Digital Capabilities", and the inclusion/exclusion criteria of only studies focusing on the adoption of *digital and smart technologies* for the development of *advanced digital and analytical capabilities* in *digital supply chains and networks,* 17 documents were identified and analysed, (iv) *Results Mapping* – Two tables were created identifying the key *digital and analytical capabilities* that characterise a DSC (see Table 1), and the *digital and smart technologies* that enable their development (see Table 2), (v) *Summary* – Sections 3 of this paper discusses the results of this scoping review, and (vi) *Opinion* – Sections 4 of this paper address research gaps and future developments.

3. Scoping Literature Review Results

3.1 Supply Chain Digitalisation

In the current global manufacturing landscape, supply chains and networks face numerous challenges and changes driven by rapid *digitalisation*. This process involves building sophisticated and smart technological capabilities to enhance connectivity, collaboration, and efficiency within a supply chain, giving rise to the concept of a *Digital Supply Chain (DSC).* Although the concept is still evolving, there are various definitions in the scientific literature for this term, which all share common terminology.

The most used definition in scientific publications for a DSC is the one proposed by [5], who define a DSC *as "an intelligent best-fit technological system based on the capability of massive data disposal and excellent cooperation and communication to support and synchronise interactions between organisations by making their services more valuable, accessible, and affordable with consistent, agile, and effective outcomes".* Hence, DSCs represent a new generation of supply chains where emerging digital and smart technologies become promising components to improve SC processes such as purchasing, logistics, planning, and scheduling.

Complementarily, [6] describe a DSC as *"interconnected systems that can integrate different processes, customers, and suppliers internally and externally via enhancing communications, data collection, and information transfer"*. Therefore, DSC's challenges to becoming more intelligent seek to develop competencies of sensing, monitoring, and interacting within the focal company and among SC partners.

Various advantages of *digitalising SC operations* have motivated manufacturing organisations and industries of many countries to act and engage in activities aimed at digitalising their supply chain processes [7]: (i) *Sustainable Operations* – By integrating digital practices, SC partners can establish data-driven decision-making environments that facilitate the adoption of sustainable SC operations. This approach brings several benefits, including cost savings, regulatory compliance, and competitive advantages, leading to more sustainable manufacturing systems; (ii) *System Integration* – DSCs facilitate synchronising systems and technologies across their value chains. SC partners can achieve seamless coordination by connecting with other partners, processes, and platforms; (iii) *Productivity Enhancement* – Digital and smart technologies streamline SC processes, resulting in increased productivity and efficiency, creating an environment where workers can focus on higher-value tasks; (iv) *Foster Innovation* – The availability of advanced digital and smart technologies fosters innovative ways of gaining valuable insights, identifying improvement opportunities, and developing solutions to meet evolving customer demands; and (v) *Resilient Processes* – Data Analytics in DSCs enables quick and effective responses to disruptions. In this sense, real-time data acquisition and analytics provide insights for proactive anomaly detection, alternative sourcing options, and adaptable strategies to mitigate the impact of disruptions.

The digitalisation of supply chains increases their level of management complexity. In this sense, emerging *digital SCM practices* are impacting the way supply chains and networks are developing their processes and operations. While the benefits of *digitalisation* seem evident, to achieve these advantages, SCs must build advanced digital and analytical capabilities that can support the adoption of such digital practices to improve efficiency and data-driven decision-making and compete in an increasingly digital business environment.

3.2 Relevant Digital Capabilities for Digital Supply Chains

An efficient supply chain can significantly acquire competitive advantages through its capacity to meet customer demands and serve emerging markets. [8] define *Supply Chain Capability* as the ability to have the right equipment, attain quality, make proper deliveries, maintain excellent relations with customers and solve problems for them, achieve standardisation of products and service processes, and meet market requirements in new product developments in times of collaboration. These abilities include using internal and external resources/information to facilitate supply chain activities. In addition, these abilities can be used to gain a competitive advantage by understanding the market requirements and working with SC partners to create order-winning products and services [9]. In the supply chain literature, these "capabilities" are also known as *ilities* (in systems engineering literature), which aim to define the attributes that a supply chain (system) should possess to succeed. *Ilities*, conversely, are *"properties of engineering systems that often manifest and determine value after a system is put into initial use"* [10]. The central aspect of *ilities* is that they are constituted by a set of attributes that jointly construct the characteristics of a system.

Several researchers have previously developed frameworks that provide a broader understanding of *DSC attributes.* For example, [5] presented a comprehensive list of characteristics, technologies, and challenges frequently associated with DSCs. Furthermore, [11] in their exploration of supply chain openness, describe attributes as the characteristics that underpin the relationships between SC partners. As such, measuring and tracking traits in the supply chain help to identify process deficiencies, enabling SC partners to make data-driven decisions to improve efficiency and reduce costs. However, to navigate the digital landscape, supply chains must develop and acquire new skills that enable them to use available digital and smart technologies efficiently.

A refined list of *digital capabilities* built on this *scoping literature review* is presented in Table 1, which intentionally collects the main characteristics/attributes from previous works applied to the DSC context.

Table 1. Identifying Digital Supply Chain Capabilities (Ilities)

Capability	Description	Reference(s)
Agility	The ability to quickly adapt and react to dynamic conditions in the market, customer requirements, and disruptions within the SC.	[12] [13]
Connectivity	The ability to connect, interact, and exchange information with different entities to enable coordination across the SC.	[5] [14]
Flexibility	The ability to adjust SC processes, resources, and operations to meet changing customer demands and market conditions.	[5] [14]
Interoperability	The ability to integrate and exchange data seamlessly across different systems.	[15]
Proactivity	The ability to anticipate and address SC requirements, challenges, and opportunities to mitigate potential risks.	[5]
Scalability	The ability to adapt the scale and scope of SC operations quickly and effectively without experiencing significant disruptions in performance and efficiency.	[5]
Sustainability	The ability to integrate environmentally and socially responsible practices and considerations throughout the SC.	[13]
Traceability	The ability to track and trace the movement and origin of products, components, and materials throughout the SC.	[16]
Transparency	The ability to access accurate and real-time information across the SC.	[5]
Visibility	The ability to view SC activities, processes, and performance metrics at different levels from overall network to individual transactions.	[13] [14] [16]

3.3 Enabling Technologies for Digital Supply Chains and Their Adoption Challenges

Previous studies have examined the challenges of adopting digital and smart technologies in supply chains and networks, highlighting their importance in achieving digital objectives and contributing to operational strategies' preparedness, response, recovery, and mitigation. In this way, digital and smart technologies facilitate transparency, flexibility, and collaboration between SC actors in supply chain operations [6] [17]. However, even though the digital landscape has expanded, adopting digital and smart technologies does not automatically bring value to the SC actors unless they carefully consider the context into which these are being introduced and how these will become beneficial [18].

Table 2 provides an overview of the main challenges when adopting digital and smart technologies to build new digital and analytical capabilities in supply chains and networks [5] [19] [20]. Addressing these challenges requires a strategic and comprehensive approach encompassing organisational and technological considerations to increase the chances of successful digital transformation in supply chains. This way, the discussion drives to analyse and comprehend what is the role of adopting certain enabling technologies. In other words, "Which digital and analytical capabilities contribute to the digital transformation of supply chains?".

Table 2. Adoption Challenges for Enabling Technologies Supporting Digital Supply Chain Transformation and Digital Capabilities Building

Enabling Technology	SC Capability	SC Advantages	Technology Adoption Challenges	References
Additive Manufacturing (AM)	Agility	• Shorter manufacturing lead time. • Pull supply chain. • Quick response to customer demand. • Decentralised manufacturing.	• High technology costs. • Limited material selection. • Intellectual property and legal issues.	[21] [22] [30]

	Flexibility	• Easier management demand uncertainty. • Higher levels of customisation.	• Quality and safety concerns. • Lack of skilled AM talent.	
	Scalability	• SC disintermediation. • Less dependency on economies of scope. • Manufacturing closer to the point of use.		
	Sustainability	• Lesser transportation. • Reduced inventory.		
Artificial Intelligence (AI)	Agility Flexibility Proactivity Scalability Sustainability	• Improved demand planning and forecasting. • Better purchasing decisions. • Improved demand forecasting. • Predictive maintenance. • Enhanced transportation network design. • Better inventory control and planning.	• Data accessibility. • Data quality. • Lack of skilled AI talent.	[13] [19] [22] [30]
Augmented Reality (AR)	Agility Transparency Visibility	• Greater speed and accuracy in warehouse operations. • Real-time tracking in logistics and delivery processes. • Workflow optimisation.	• User acceptance and training. • Integration with existing systems. • Social acceptance. • High implementation costs.	[23] [24]
Big Data Analytics (BDA)	Agility Proactivity Scalability Transparency Visibility	• Efficient information handling. • Anticipation of SC trends. • Detection of atypical events through SC activities monitoring. • Assist order prediction. • Improved demand forecasting. • Improved quality control. • Optimised inventory management. • Effective risk management.	• Data quality issues. • Complex data analysis tools. • Data governance. • Privacy concerns.	[13] [21] [30]
Blockchain (BC)	Traceability Transparency Visibility	• Quality assurance. • Enhanced system resilience. • SC compliance. • SC process integration. • Increased information flow accuracy through the SC. • Proactive risk management.	• Lack of industry-wide standards. • Network capacity. • Achieve interoperability with existing SC systems. • Sustainable implementation. • Regulatory and legal challenges.	[23] [25] [26] [30]
Cloud Computing (CC)	Connectivity Flexibility Interoperability Sustainability Transparency	• Global and remote access to information. • Improved coordination across distributed locations. • Streamlined data exchange. • Enhanced collaboration among partners and systems. • Resource sharing across multiple SC actors. • Minimise infrastructure and maintenance costs. • Improved shared decision-making process.	• Data security and privacy. • Integration with existing systems. • Dependency on internet connectivity.	[13] [19] [22] [24] [30]

Digital Twins (DTs)	Agility Transparency Visibility	• Better coordination among SC partners. • Efficient situational demand-supply re-allocation. • Real-time tracking and monitoring.	• Compatibility across SC partners. • Lack of skilled DT talent.	[16] [19] [25]
Internet of Things (IoT)	Agility Connectivity Flexibility Sustainability Transparency Visibility	• Faster response to changing customer needs or supplier availability. • Efficient communication. • Enhanced collaboration in SC processes. • Shipment optimisation. • Predictive maintenance. • Efficient transportation planning. • Increase product quality. • Enhanced data-driven decision-making.	• High implementation costs. • Limited interconnectivity and interoperability among devices and platforms. • Privacy concerns.	[19] [21] [27] [28] [29] [30]
Radio Frequency Identification (RFID)	Connectivity Sustainability Traceability Transparency Visibility	• Real-time automated data collection to support decision-making. • Improved waste management. • Reliable inventory management. • Enhanced authentication. • Better demand and forecasting. • Increased inventory control and shipping.	• Data integration challenges among systems. • High implementation costs for operations, tracing, and tracking.	[13] [22] [30]
Robotics	Agility Scalability	• Process automation. • Improved order accuracy. • Shorter manufacturing lead times. • Higher production rates. • Improved order fulfilment.	• High implementation costs. • Integration complexity. • Lack of skilled talent. • Environmental impact.	[5] [21] [22]
Virtual Reality (VR)	Connectivity Transparency Visibility	• Enhanced remote collaboration among SC actors. • Product visualisation. • Improved monitoring.	• Elevated hardware costs. • Limited content availability.	[13] [19] [23]

The adoption of enabling technologies, digital and smart, impacts SCM. It contributes to supply chains' digital transformation by allowing them to build new digital and analytical capabilities. Furthermore, it is essential to recognise that these capabilities and technologies are also interdependent. For example, the effective use of Big Data Analytics relies on a well-designed and integrated system that supports seamless coordination between different SC processes. Moreover, focal companies and their SC partners must consider and address several technology adoption challenges to digitalise their supply chains.

3.4 Digital Supply Chain Challenges and Enablers

The growing demand for building *digital and analytical capabilities* through enabling *digital and smart technologies* has become imperative to remain competitive in a DSC context. However, several challenges and barriers prevent large-scale technology adoption across supply chains and networks. First and foremost, there is a lack of awareness and understanding of the current *digital SCM trends* and the potential benefits of adopting digital and smart technologies [31]. Additionally, the high initial investment costs and complexities associated with integrating these technologies pose financial and operational challenges, especially for SMEs that often serve as suppliers in the SC.

The following subsection presents the main challenges and barriers to the development of digital supply networks, focusing on the most significant impacts to reflect the relevance of clear *digital transformation initiatives* (see Fig. 1).

Firstly, *strategic digital orientation*, which refers to the lack of alignment between SC partners' digital initiatives and its overall *digital SCM objectives,* is a significant barrier. This directly impacts the ability to envision the value-adding use of digital and smart technologies to enhance operational efficiency across digital supply chains and

networks. In this sense, failure to deliver impact is causing a significant delay in leveraging technologies for the successful digitalisation of supply chains and networks. To address this challenge, SC partners must focus on developing a clear vision by aligning individual digitalisation efforts with the overall SC strategy and fostering a culture of innovation based on feedback and performance metrics [32].

Secondly, the existing *digital infrastructure* incompatible with the latest digital advancements or requirements can be viewed as a major barrier to digital transformation. The reliance of many SCs and their partners on outdated legacy systems and their mismatch with current digital and smart technologies poses a hindrance to leveraging their full potential. Furthermore, they are acquiring cloud services to mitigate infrastructure costs related to acquiring operating systems and technologies. However, the dependence on those cloud systems may lead to challenges regarding cyber security and control over processes. To overcome this challenge, SC partners must develop standardised interfaces and open architectures to optimise their SC operations, reduce costs, and collaboratively work on different platforms [33] [34] [35].

Thirdly, *digital skills and talent*, referring to the limited strategic use of digital and smart technologies, require tailored qualifications to meet present and future market needs. This means that it is necessary to provide SC actors and their employees with the (digital) skills to cope with emerging digital challenges by acquiring new talent and retaining the knowledge and expertise of old employees [3] [35] [36].

Fourthly, *change management* refers to the absence of innovative practices driven by the organisational culture. Therefore, top management support is key to successfully adopting digital transformation and overcoming resistance to change in supply chains. Change management involves implementing strategies and practices to help SC actors transition to new processes and working methods. However, ensuring SC partners efficiently drive digital transformation requires capable SCM managers that set the vision and direction of digital transformation, communicate the strategic importance of digitalisation, and provide a clear roadmap for implementation to create a shared understanding and alignment throughout the supply chain or network [37]. This approach helps to address and mitigate pushback to change, ensuring a smoother transition and successful implementation of *digital transformation initiatives* across a DSC.

Fifthly, *context readiness* can be considered a significant challenge to achieve digital transformation. This refers to the preparedness and adaptability to effectively leverage technologies and tools in a given environment. It encompasses technological infrastructure, organisational culture, skillsets, and regulatory frameworks. For example, the openness of SC partners to adopt digital practices allows them to recognise the potential benefits. As a result, SC partners are often more agile in adopting new technologies and implementing changes in their processes and operations. Moreover, the willingness and environment with outstanding technological infrastructures, favourable policies and regulations, and technological access create new challenges for digital adoption. In this sense, focal companies are more likely to embark on the *digital transformation journey* of their supply chain in contexts where advanced technologies are readily available and affordable.

Sixthly, *vision alignment* refers to the lack of an overarching perception of digital capabilities building among SC partners. This means that without a clear vision of the benefits of new capabilities building, DSC partners may encounter difficulties in aligning their digital initiatives with their strategic objectives and fail to prioritise investment in the right technologies. Moreover, a well-defined strategic vision can yield notable outcomes in the SC, including improved responsiveness to customer demands, cost reduction, enhanced competitiveness, and increased SC flexibility [38].

However, some SME SC partners may show resistance due to a lack of understanding of the advantages. In this context, where there is limited or outdated infrastructure, systems incompatibility, and high adoption complexity, SC partners may step back when trying to implement digital initiatives. This means that more significant efforts are required to raise awareness, educate and demonstrate the tangible benefits of digital transformation to overcome their reluctance [39] [40].

The standardisation of DSC concepts still needs to be included in the scientific literature, leading to inconsistencies in how researchers and practitioners classify these attributes and characteristics. Failure to properly communicate and compare *SC performance* is holding back the development of competitive integration of a DSC. Furthermore, the rapidly evolving technology challenges the DSC to keep up with the latest developments and categorise these terms.

To facilitate shared understanding when adopting digital practices, it is necessary to address how to orient the digitalisation of supply chains. In this sense, it is important to establish a common terminology to develop a shared language and understand key terms and concepts related to digitalisation. This ensures that all stakeholders in the supply chain can effectively communicate and align goals.

Furthermore, implementing frameworks that can be universally adapted to enable SC collaboration and integration can provide multiple benefits. These must clearly define and orient roles, relationships, and goals to acquire the capabilities that must be achieved, and how to develop them to facilitate collaboration. In this sense, defining the capability orientation required for successful digitalisation can serve as a guide for development and implementation.

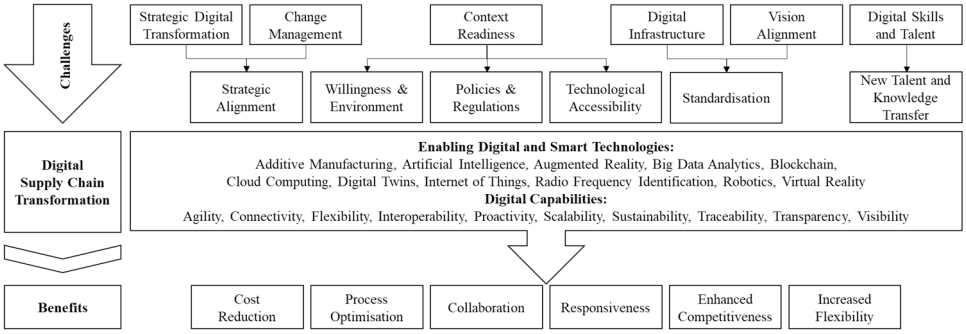

Figure 1. Digital Supply Chain Transformation: Challenges & Benefits, and Enabling Technologies & Capabilities

4. Research Gaps and Future Developments

The digital transformation of supply chains is still at an early stage, especially when developing *digital skills* to integrate *digital processes.* While there has been accelerated progress and significant efforts to achieve greater efficiency, there is still potential for using technology to enhance new digital skills in focal companies, which will be extended to all SC actors involved in a digital supply chain or network.

The need for robust SC partners within digital supply chains and networks has been recognised by researchers and practitioners. However, while collaboration is increasingly necessary, some, such as SMEs, need help to stay ahead in this new digital age. In this sense, exploring new ways to standardise digital skills development for SC partners is fundamental, which has been an under-researched topic.

New *DSC trends* should optimise the use of digital and smart technologies, focusing on developing integrated digital supply chains and networks. However, in digital transformation, a clear strategy is needed to develop the digital characteristics and skills that promote supply chain competitiveness in digital markets.

The need to digitally transform supply chains has also led to the emergence of reference models and frameworks for this purpose, such as the *Supply Chain Operations Reference (SCOR) model,* which is used to assess *SC maturity* and define strategic routes for digital transformation to result in enhanced performance [41]. However, the reference models available must be adapted to the specific needs and requirements of those SC actors that are still in their early stages of digital transformation. Therefore, a future approach could be to explore how these reference models and frameworks are used to integrate and digitalise the SC actors involved.

An additional aspect to consider amid this rapid digital change is that these new digital age capabilities and skills are not just about integrating technological tools but also about achieving digital infrastructures that can foster the integration of digital supply chains and networks. In this sense, collaborative digital environments can improve processes, digital skills, and interconnectivity for strategic decision-making.

Moreover, the continued demand for digital skills and capabilities will also require advanced mastery of digital technologies and concepts. Process automation will become more prevalent in the workplace, leading to shift-like work. In this sense, SC partners will prioritise a workforce that can achieve technical and critical skills, using digitalisation to drive innovation and competitiveness.

Finally, outdated digitalisation systems and practices hinder the incorporation of new *DSC trends.* Therefore, these strategies should generate digital capabilities considering social, environmental, and governance spheres geared towards sustainable growth in this new digital age.

5. Conclusions and Limitations

The digital transformation of supply chains is rapidly evolving in the global manufacturing sector. In addition, the interconnectivity brought by digital technologies also drives interest in developing services for the smooth functioning of emerging digital supply chains and networks. It represents an opportunity to integrate SC systems, improve SC

relationships, and gain valuable data-driven SC insights. However, as a relatively new concept, the use cases for these strategic characteristics (capabilities) still need to be clarified for the emerging *end-to-end digital supply chains.* As part of their development process, several *digital and analytical capabilities* were identified and described when adopting *digital SCM practices.* A summary of key challenges and enablers is presented to demonstrate the digitally transformed supply chains' value. These characteristics can be used to plan the strategy to address these challenges and to integrate the enabling technologies at the operational level.

One of the main challenges that focal companies and their SC partners face in their digital transformation process is the inconsistent categorisation between the main drivers and enabling technologies that contribute to the digital transformation of their supply chains and networks, which hinders strategic decision-making. Therefore, it is essential to establish a clear and comprehensive picture of the *digital supply chain transformation* that can guide their efforts to develop digital skills and build digital capabilities. In addition, further research is needed to align individual and coordinated supply chain efforts by exploring reference models and frameworks for developing DSCs at the operational level to understand the *digital maturity* of supply chains and their stakeholders.

On the other hand, for this *digital integration* to be effective, DSCs must align the actors involved in this process. Rapid technological advances have brought about significant changes in the business landscape, requiring all SC stakeholders to develop digital skills and build digital capabilities to remain competitive. Failure to do so could lead to an asymmetry in the new digital markets, leaving certain supply chains and networks at a disadvantage compared to their digitalised counterparts or even forcing them out of the market.

Given the rapid growth in the digital transformation trend, not all suppliers are adequately equipped to support the achievement of digital supply chain objectives. Hence, supplier management becomes an essential practice to build new suppliers' capabilities and improve their performance. In this sense, one of the most promising avenues for aligning and developing this strategic *digital vision* is through new *digital supplier development programmes,* which are strategic initiatives led by focal companies to improve suppliers' performance. This emerging approach remains largely unexplored in the context of the growing supply chains and networks digitalisation trend and offers a mechanism to foster alignment and build suppliers' digital capabilities. This area of research holds significant potential for future exploration due to its contribution to enhancing SC performance, driving innovation, and fostering competitive advantage.

The global manufacturing sector will continue to digitally transform in the coming years, with digital and smart technologies as essential enablers for developing/building new digital skills and capabilities in supply chains and networks. Furthermore, to develop competitive DSCs, new *digital capabilities* have the potential to elevate the sector's industries towards the use of advanced digital and smart technologies in which human skills are harnessed and complemented by advanced technologies. At the same time, applying these new digital skills will allow the optimisation of current SC functionalities.

While the discussion presented in this paper is a step forward in addressing this research and practice gap, several venues must be addressed going forward, including a typology that classifies the strategic drivers that address the emerging characteristics and capabilities to address efforts towards *Digital Supply Chains Integration.* In addition, based on the classification that can be built on the descriptions presented, a study can be developed at the operational level based on *digital maturity models* for supply chains, including their suppliers.

Finally, while the future looks bright for the digital transformation potential of supply chains and networks, it is important to keep in mind that existing strategic initiatives must also be considered from a practical perspective. Therefore, SC partners be challenged to take an agile and prominent approach to address a holistic and end-to-end approach to digitalise and integrate their operational processes and strategic initiatives.

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