



TECHNOLOGICAL TOOLS AND THE IMPACT OF DIGITALISATION ON THE SUPPLY CHAIN

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Abstract:

The supply chain has undergone a significant and innovative transformation in recent years with the introduction of new intelligent and digital technologies aimed at streamlining various supply chain activities from demand forecasting, manufacturing of goods, inventory management, and transport planning to delivery to customers. The digitisation of the transport and shipping industry incorporates advanced technologies such as cloud computing, the Internet of Things (IoT), artificial intelligence (AI), blockchain, and big data. These digital innovations are streamlining routes, forecasting demand, tracking shipments, and above all reacting quickly to changes, resulting in overall supply chain efficiency. This paper provides a comprehensive review of the issues that highlight the birth and construction of this transformation, as well as identifying the technological tools impacting the supply chain, in order to analyse the real impact of digitalisation on the development of relative supply chain strategies

JEL: L91, O33, L23, C88, M11, L81

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1. Introduction

The supply chain is an essential element of all modern economic activity, playing a critical role in the success of companies and aiming to coordinate and manage the fluid and efficient movement of products, raw materials, and information throughout the

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production and distribution process. Over the decades, it has undergone significant transformations in response to growing market demands and technological advances. One of the most significant revolutions is the digitalisation of the supply chain, which is seen as a major driving force in the transformation of logistics management. This includes the use of sophisticated software and intelligent sensors in the supply chain, from stock planning to final product delivery. Digital transformation involves the adoption of digital technologies such as cloud computing, 3D printing, the Internet of Things, data analysis, and many others, to transform traditional processes into automated, interconnected, and intelligent systems. The ultimate aim of this digital transformation is to enable better demand forecasting and more accurate supply planning, thereby reducing the risk of overstocking or stock shortages. Secondly, it facilitates product traceability, enhancing product safety and quality.

In this paper, we explore the different dimensions of supply chain digitalisation. First, we present the theoretical approaches and the general framework of digital transformation. We will then look at the key technologies fuelling this revolution, such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, and advanced data analytics tools. We will highlight their role in supply chain management. Finally, we will look at the impact of digital logistics on improving and managing stocks, reducing delivery failures, and optimising the use of resources. However, the digitalisation of the supply chain is not without its challenges. We will discuss the obstacles that can hinder the widespread adoption of these new technologies, such as additional costs, data security issues, and cultural barriers to change.

2. Conceptual Framework

In contemporary scholarly discourse, the topic of digital transformation and its subsequent ramifications has garnered pronounced attention. As postulated by Liere-Netheler et al. (2018), the realm of digital transformation can be demarcated by the strategic adoption of emergent digital paradigms, chiefly encompassing platforms like social media and mobile technologies, with an objective to drive economic accretion. Such endeavours can materialise in multifarious manners, including but not limited to the augmentation of user interactivity or the genesis of innovative business frameworks. Providing a supplementary perspective, Horlach et al. (2017) accentuate the purview of digital transformation, suggesting that it incorporates the digitisation of transactional paradigms, communicative interfaces, and business propositions, with the potential to either supplant or supplement pre-existing tangible offerings. In a lexico-centric discourse, Brillet et al. (2019) posited that the nomenclature "digital" predominantly resonates with facets intimately linked to technological deployment. On a parallel trajectory, the theoretical construct of a supply chain has been subjected to rigorous analytical critique and elucidation. Lee et al. (1993) posit that the supply chain paradigm epitomises an intricate matrix of infrastructural entities, entrusted with the paramount duty of ensuring an uninterrupted continuum of raw material procurement, its subsequent metamorphosis into constituent parts, and their eventual transformation into

saleable commodities, followed by their diligent dissemination to the consumer diaspora. In a nuanced exposition, Mentzer et al. (2001) propounds a divergent viewpoint, characterising the supply chain as an orchestrated symphony of operations, intrinsically tethered to the distribution and delivery conduits of tangible products, intangible services, and relevant informational assets, commencing from their genesis and converging at the terminal consumer interface.

Extending this discourse, Tsay et al. (1999) conceptualise a supply chain as a nexus of corporate entities, interlinked by the perpetual exchange of information, commodities, and fiscal transactions. In the intricate tapestry of merging digital transformation tenets with supply chain operationalisms, the nomenclature "Digital Supply Chain" has crystallised. Within this ambit, Ehie and Ferreira (2019) advocate for a bifurcated *modus operandi*. The foundational stratum orbits around the infusion of avant-garde digital modalities into supply chain protocols, acting as catalysts for forging commercial synergies with vested stakeholders. Simultaneously, the auxiliary stratum underscores the pivotal role these digital instruments wield in reshaping enterprise activities and accentuating operational efficacy. Offering an alternative schema, Bhargava et al. (2013) delineate the digital supply chain as a harmonious confluence of systems, encapsulating communicative matrices, software interfaces, and hardware infrastructures. Such systems serve as pivotal linchpins, enabling cross-border corporate engagements and orchestrating the supply chain continuum, from production to warehousing, distribution, and consummation.

Advocating a more prescient stance, Aliche et al. (2016) underscore the imperativeness of assimilating digital technological apparatuses, exemplified by the Internet of Things (IoT), data-driven analytical methodologies, and advanced automations, into the supply chain architectural framework. Such strategic incorporations pave avenues for mechanised pathways and circulatory systems, consequently bolstering performance indices and elevating consumer contentment metrics.

3. Analysis of the Literature Review

Generally speaking, the digitalisation of the supply chain has been seen as a major and necessary development for companies, in order to improve their operational efficiency, their agility, and their ability to respond to customer needs. The impact of supply chain digitalisation has therefore been the subject of numerous studies in recent years. The following paragraphs provide an overview of research on this subject. One of the studies on the digitalisation of the supply chain and its impact on the environment was carried out by Ait-Daoud (2012). The purpose of this study is to show that digitisation makes a positive contribution to environmental protection, through the use of technological systems such as blockchain and the Internet of Things, which enable real-time traceability of agri-food products while guaranteeing compliance with quality rules. Information technologies are also enabling the dematerialisation and digitalisation of work processes, and providing new services such as e-administration and e-payment, which can reduce

paper consumption and facilitate inter-organisational communication, as well as replacing travel and transport, which generate CO₂ emissions. In another study by (Bhat and Jōudu, 2019), selecting the most suitable technologies such as digital sensors, robotics can not only design and produce sustainable materials, but also achieve higher yields while ensuring better food safety. These revolutionary changes are helping companies to develop environmentally friendly processes and products. For example, the use of Industry 4.0 has led to improvements in energy consumption and a reduction in losses and waste.

Kayikci (2018) and Saberi et al. (2019) have studied the impact of supply chain digitalisation on the economy, thanks to digitalisation, companies have great visibility, and traceability of goods flows, information, and distribution channels, this helps to anticipate potential problems and identify opportunities for optimisation. Digitisation therefore helps to improve the effectiveness and efficiency of supply chain processes, and the application of technologies leads to significant reductions in operational costs, thanks to the automation of many manual tasks, and better use of company resources (materials, labour). In addition, the ability to collect and analyse data in real-time enables companies to make more informed decisions, which helps to minimise commercial losses, and react quickly to unforeseen changes. Concerning the social impact of the digitalisation of the supply chain and according to (Kayikci, 2018) and (Rogetzer et al., 2019), digitalisation allows consumers to access detailed information on the origin, and know the quality of the products they buy. Digitalisation is also changing consumer behaviour, making it easier to buy online, innovating product customisation, and this is having an impact on increasing customer confidence and purchasing volume.

4. Digital Technologies

Digital technologies have profoundly reshaped our world, transforming the way we communicate, work, and interact with our environment. These technologies encompass a wide range of tools such as:

4.1 Big Data

Big Data (BD) is characterized by its voluminous and intricate nature, which undergoes constant evolution, rendering traditional analytical techniques inadequate for its examination. This term not only encapsulates the sheer scale and complexity of the data but also signifies an assortment of technological innovations and analytical methodologies that have emerged in recent times to facilitate the gathering and rigorous assessment of such expansive and intricate data sets (Wang et al., 2016). In the domain of supply chain management, Big Data plays an instrumental role, empowering organizations to amass and scrutinize extensive data sets from disparate sources, thereby enhancing operational efficiency (Othman et al., 2016). For instance, the utilization of Big Data analytics enables enterprises to undertake more precise demand forecasting, thereby fine-tuning inventory levels and mitigating waste. Concurrently, Big Data analytics serves as an invaluable tool for supply chain managers in scrutinizing supplier

adherence to compliance standards, overseeing the transportation of goods, and proactively identifying potential hindrances prior to their manifestation.

4.2 Cloud Computing

Cloud computing functions as both a service model and a computational framework that delivers data on an as-needed basis to end-users, irrespective of their geographical location or the devices they are using (Blair et al., 2016). This technology has radically transformed the landscape of supply chain management by enabling instantaneous collaboration and the seamless exchange of information among various stakeholders in the supply chain, such as manufacturers, retailers, distributors, and suppliers (Liu et al., 2014). Moreover, cloud computing equips companies with real-time insights into fluctuating market conditions, thereby allowing them to adapt promptly and effectively to such variations. Consequently, a supply chain that leverages cloud-based solutions benefits from heightened transparency and enhanced governance over inventories, purchase orders, and the transit of goods.

4.3 The Internet of Things

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4.4 Artificial Intelligence

Artificial Intelligence (AI) encompasses a suite of theories and methodologies aimed at constructing and refining machines endowed with capabilities that traditionally necessitate human intelligence, such as learning, problem-solving, perception, and decision-making processes (Haenlein and Kaplan, 2019). Employing algorithms and statistical frameworks, AI systems are adept at analyzing and manipulating voluminous data sets (Ben-Daya et al., 2017). Within the context of supply chain management, AI serves as a catalyst for agility, allowing organizations to adapt swiftly to fluctuating consumer demands and mitigate the risks associated with overstocking or inventory shortages, all while achieving elevated levels of visibility (Tao et al., 2014). Furthermore, AI is leveraged to enhance logistical operations, such as determining the most cost- and time-efficient shipping routes, thereby leading to reductions in delivery durations and transportation expenditures. This, in turn, contributes to superior optimization in terms of energy consumption, waste management, and carbon emissions.

4.5 Blockchain

Blockchain technology is characterized as a digital ledger that maintains data across a distributed network of participants. This ledger is structured as a series of interconnected blocks, each housing a collection of transactions (Swan, 2015). This architecture produces a comprehensive and publicly accessible log of all transactions executed on the blockchain, subject to verification by any interested party. In the realm of supply chain management, blockchain has the capacity to instigate transformative changes, principally by amplifying transparency, fortifying secure data exchange, and bolstering mutual trust among stakeholders (Wang, 2019). Consequently, blockchain's inherent features contribute to heightened traceability and accountability, thereby mitigating risks associated with fraudulent activities, deceit, and other supply chain-related malfeasances. Additionally, blockchain technology can automate specific functions, such as financial transactions, obviating the necessity for intermediary agents and thereby streamlining operations. This results in cost reductions and elevations in operational efficiency (Queiroz et al., 2019).

5. Research Methodology

Every scholarly endeavor necessitates the employment of a methodological framework that enables researchers to scrutinize and interpret the amassed data. In the present study, we leverage the Statistical Package for the Social Sciences (SPSS) software as well as the Chi-square statistical test for the analysis of data derived from questionnaires.

5.1 Description of Methods

5.1.1 SPSS Programme

The acronym SPSS refers to the "Statistical Package for the Social Sciences," a software application designed for the Windows operating system. Originally conceived in the 1960s by Norman H. Nie, C. Hadlai (Tex) Hull, and Dale H. Bent, this software facilitates the collection and statistical analysis of data. It is predominantly utilized in the domain of human sciences and offers the capability to present the analyzed data through tables and graphical visualizations (Field, 2009).

5.1.2 Chi-square Test

Chi-square Test is defined as a hypothesis-based test, the aim of which is to study the relationship between two qualitative variables. It is used to:

- A goodness-of-fit test - this method combines the distribution observed in the sample with the theoretical distribution.
- A homogeneity test - this method combines more than one observed distribution.
- A test of independence - this method is used to determine whether there is a relationship or association between two variables.

5.1.3 Questionnaire

The questionnaire serves as a principal mechanism for gathering quantifiable information, typically structured as a sequence of queries designed to elicit responses. Upon subsequent analysis, these responses have the potential to offer significant insights into the research question at hand (Boulan et Henri, 2015).

5.1.4 Data Sources and Preparation

The data used in this study comes from a variety of sources, including shipping lines, transport companies, and Tanger MED staff.

6. Impact of Supply Chain Digitalisation

6.1 Data Analysis

We are analysing the impact of supply chain digitalisation and performance.

Table 1: Observation of samples

	Valid		Missing		Total	
	N	Percentage	N	Percentage	N	Percentage
Depending on your experience, digitisation of the supply chain	107	100.0%	0	0.0%	107	100.0%

Note: Yield generated after digitisation has been implemented.

Table 2: Cross-tabulation of supply chain digitalisation and performance

Workforce		Yields generated after the introduction of digitisation		
		Increase	Stay the same	Total
	Has a real impact on the supply chain	58	18	76
Depending on your experience; digitising the supply chain	Just a process that companies will have to follow	10	21	31
	Total	68	39	107

Table 3: Chi-square tests of supply chain digitalisation and performance

	Value	DDL	Asymptotic significance (bilateral)	Meaning exact (bilateral)	Meaning exact (one-sided)
Pearson chi-square	6,617 ^a	1	0,010		
Correction for continuity ^b	4,911	1	0,027		
Likelihood ratio	6,519	1	0,011		
Fisher exact test				0,015	0,014
N of valid observations	107				

In order to investigate the correlation between the digitalization of the supply chain and its consequent impact on logistical performance, we posit two hypotheses. The first hypothesis (H0) postulates that a significant relationship exists between supply chain digitalization and enhanced performance. Conversely, the second hypothesis (H1) asserts that no significant relationship exists, thereby implying that digitalization exerts no influence on logistical performance.

For the purposes of this analysis, we establish a significance level denoted by alpha α set at 0.05, which represents a 5% risk of incorrectly inferring the presence of a relationship. In our empirical sample, the asymptotic significance (two-tailed) is recorded at 0.010, a value that is less than the pre-defined α (0.05). This suggests a statistically significant correlation, leading us to conclude that the digitalization of the supply chain indeed has a substantial influence on the augmentation of organizational output. Specifically, the impact is quantified by a factor of 58. Based on these findings, we accept the null hypothesis (H0) and reject the alternative hypothesis (H1).

We analyse the digitisation of the supply chain and the reduction of failures thanks to digitisation.

Table 4: Observation of samples

	Valid		Missing		Total	
	N	Percentage	N	Percentage	N	Percentage
Digitisation of the supply chain is satisfactory	107	100.0%	0	0.0%	107	100.0%

Note: Digitisation has reduced failures in the logistics process.

Table 5: Cross-tabulation of supply chain digitalisation and logistics process failures

Workforce		Digitalisation has reduced breakdowns in the logistics process		
		No	Yes	Total
Digitalisation of the supply chain is satisfactory	No	0	29	29
	Yes	23	55	78
Total		23	84	107

Table 6: Chi-square tests for digitisation of the supply chain and failures in the logistics process

	Value	DDL	Asymptotic significance (bilateral)	Meaning. exact (bilateral)	Meaning. exact (one-sided)
Pearson chi-square	4,228 ^a	1	,040		
Correction for continuity ^b	2,658	1	,103		
Likelihood ratio	6,504	1	,011		
Fisher exact test				,083	,041
N of valid observations	107				

H₀: digitalisation has reduced breakdowns in the logistics process.

H₁: digitalisation has no influence on reducing breakdowns in the logistics process.

According to the chi-square test, we find that the asymptotic significance (0.040) is less than 5%, so digitisation of the supply chain has an effect on reducing failures in the logistics process. This allows us to reject H₁ and accept H₀.

We analyse the relationship between the digitalisation of the supply chain and the costs incurred.

Table 7: Observation of samples

	Valid		Missing		Total	
	N	Percentage	N	Percentage	N	Percentage
In your experience; digitising the supply chain	107	100.0%	0	0.0%	107	100.0%

Note: digitisation is expensive.

Table 8: Cross-tabulation of supply chain digitisation and costs incurred

Workforce		Digitalisation is costly		Total
		No	Yes	
	Has a real impact on the supply chain	21	55	76
Depending on your experience; digitising the supply chain	Just one process for companies to follow	21	10	31
	Total	42	65	107

Table 9: Chi-square tests of supply chain digitisation and costs incurred

	Value	DDL	Asymptotic significance (bilateral)	Meaning exact (bilateral)	Meaning exact (one-sided)
Pearson chi-square	5,448 ^a	1	,020		
Correction for continuity ^b	3,929	1	,047		
Likelihood ratio	5,408	1	,020		
Fisher exact test				,034	,024
N of valid observations	107				

H₀: digitising the supply chain generates additional costs,

H₁: digitising the supply chain has no effect on costs.

According to the chi-square test, the asymptotic significance (two-tailed) equals 0.020, which is a value less than 0.05, allowing us to conclude that the digitisation of the

supply chain has a relationship with costs, so we take hypothesis 0 and reject hypothesis 1.

After analysing the questionnaire responses using the chi-square test, we deduce 3 results.

- The first is that digitising the supply chain has a positive impact on performance.
- The second is that digitisation of the supply chain has an effect on reducing logistical failures.
- The third is that digitalisation not only has a positive impact, but can also have a negative one, in terms of the costs borne by businesses.

6. Discussion

Our empirical analysis elucidates that the digital transformation of supply chains unlocks a plethora of advantages for corporate entities, collaborative partners, the environmental landscape, and the macroeconomy. Specifically, digitalization of the supply chain augments visibility across the entire operational process, allowing organizations to effectively monitor inventory levels, thereby mitigating the risks associated with stockouts or overstocking. This enhanced oversight also enables more accurate forecasting of customer demands and expedites order processing. Concurrently, end consumers benefit from real-time tracking and timely updates on the delivery status of their orders, which in turn elevates the overall customer experience and fosters trust and loyalty between consumers and businesses. In an environmental context, the digitalization of logistics contributes to eco-friendly practices by facilitating optimal route selection for transportation, mitigating carbon emissions, advocating the use of sustainable materials, and promptly identifying defective batches, thereby minimizing energy wastage. However, the journey toward digital transformation is not devoid of challenges. Firstly, the adoption of digital technologies necessitates the acquisition of vast amounts of data, which is often plagued by issues of incompleteness, inaccuracy, or inconsistency. These data-related challenges can impede informed decision-making. Secondly, the transition to a digital supply chain demands substantial investments in technological infrastructure, as well as resource allocation for employee training and change management. This creates a barrier to entry for many organizations, particularly when the return on investment (ROI) is not immediately discernible. Lastly, the collaborative nature of digitalizing the supply chain involves an assortment of stakeholders, including suppliers, manufacturers, logistics providers, and retailers. Ensuring alignment and commitment among these diverse entities can pose significant challenges. Despite these limitations, the digitalization of supply chains remains a pivotal development, offering substantial benefits that far outweigh the associated challenges.

7. Conclusion

This manuscript emanates from an empirical field study, specifically employing a questionnaire, aimed at ascertaining the tangible effects of supply chain digitalization on

organizational performance and customer engagement modalities. The advent of digitalization has accorded firms the capability to optimize logistical procedures, curtail expenditures, elevate efficiency, and augment visibility throughout the supply chain continuum. Our investigation further underscores the instrumental role of emergent technological apparatuses like the Internet of Things (IoT), blockchain, and Artificial Intelligence (AI) in enhancing supply chain transparency. These technologies facilitate the meticulous tracking of goods, offer real-time intelligence on their geolocation and state, bolster traceability within the supply chain, and mitigate the likelihood of fraudulent activities. Nonetheless, it is imperative to acknowledge that the digital transition of the supply chain is accompanied by an array of challenges, encompassing data privacy concerns, technological dependency, and cybersecurity vulnerabilities. Therefore, organizations must exercise due diligence in recognizing these challenges, necessitating a cultural shift within corporate environments, skillset enhancement, and sustained investment in technological infrastructure and hardware. Broadly construed, the ultimate success of supply chain digitalization hinges on an organization's proficiency in calibrating an equilibrium between the operational dividends and the prospective hazards associated therewith.

Conflict of Interest Statement

I certify that I have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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