

# Defining and measuring supply chain digitalization: A systematic literature review

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**Abstract** — *The potential and opportunities in the digitalization of supply chains are immense yet our understanding of digitalization today at both firm and supply chain levels is increasingly becoming superficial. Because of this, managers cannot easily qualify and quantify the performance outcomes of their digital investment decisions. The purpose of this paper, therefore, is to explore how digitalization is perceived and measured within the supply chain management (SCM) literature. We conduct a systematic literature review (SLR) analysis of scientific articles drawn from SCM literature over 5 years (between 2017 and 2012). The findings suggest that digitalization and supply chain digitalization are popular concepts theoretically and have high potential in practice. The literature further shows a loose operationalization of the concepts “digitization”, “digitalization” and “digital transformation” across the extant literature. In addition, the findings show that the measures of the degree of digitalization are not dissimilar across firms and across the supply chains but could vary across industries.*

**Keywords** — *digitization, digitalization, digital transformation, digitalization of supply chains, supply chain management, systematic literature reviews.*

## I. INTRODUCTION

A recent McKinsey Quarterly report [1] raised the question: “(If) digital technology erodes profit and revenue growth, why aren’t companies responding with bold strategies?” The report concluded that most companies were too timid and not prepared to take bold strategies in the digital space because of the fuzziness surrounding digitalization’s impact on business performance. Some studies such as Merenda and Venkatachalam [2] and Sambamurthy et al. [3] have indeed confirmed that digitalization drives firm performance through reduction of operational costs, fosters business innovation, and offers significant opportunities in sales growth. Yet many firms have very little understanding of what digitalization is in practice [4, 5]. Büyüközkan and Göçer [6] suggest that digitalization is more than just adoption of intelligent tools, big data, automation technologies, cloud computing, Internet of Things (IoT), and even additive manufacturing (AM) as has been taunted. Some literature e.g. [7, 8, 9] has loosely described it as the

transformation and reconfiguration of business processes, products, and organizational models using high-end information technology (IT) infrastructure to create business value at both firm-level and across the supply chain.

The ubiquitous nature of the digitalization concept has resulted in misunderstandings in business application, which has significant implications for theory and practice. Luz Martín-Peña et al. [10] suggest that digitalization which is essentially a driver for business model changes is closely related to servitization and e-business applications. Pagani and Pardo [11] define digitalization as the organizational adoption of IT-based solutions using the internet. Savastano et al. [9] consider digitization as digital applications and internet-based technologies that define how organizational activities and processes are managed while Huber [4] viewed digitalization as the use of IT and software tools to create competitive advantage. As it appears now, firm-level literature on digitalization converges towards digitalization’s purpose but is not conceptually aligned.

Moreover, from a supply chain perspective, the loose understanding of digitalization, as argued by Wu et al. [12] and later by Büyüközkan and Göçer [6], limits how supply chain actors perceive customer needs within their firms and across the network. Even more specifically, how they collaborate and share information amongst themselves [13].

In this paper, therefore, we postulate that the absence of a common understanding of what digitalization is or its “quantification” increases skepticism about digital adoption at the firm level and at the supply chain level. It is important to mention that a host of firms especially within the automotive, banking, and travel industries have long used IT tools to innovate and improve productivity within their operations. The challenge today however is the reconfiguration of such capabilities to create new frontiers of value hence the concept of digitalization. As such, we specifically seek to understand, firstly, how digitalization has been defined in the literature in the last few years and secondly, how in literature, measurements of digitalization have been presented. We are keen to understand how these two questions are treated in the literature at different levels of the supply chain: i.e. at the firm level and at the supply chain level.

RQ: *How is digitalization defined and measured at the firm level and at the supply chain level: do the measurement parameters at the firm level vary from those at the supply chain level?*

In answering the above research question, we contribute by offering a state-of-the-art that brings consensus to rhetorical discussions on what digitalization is and provide the starting point of how firms measure their digitalization efforts compared to their supply chain partners. This way, we demonstrate the significance of aligning digitalization practices across actors in the same supply chain, the basis for firm and supply chain (SC) integration, and performance measurement. The remainder of the paper is structured as follows. In the next section, we introduce the methodological aspects of this literature review. This is followed by the synthesis and discussion of the results. Then, the paper concludes with a presentation of the status and research issues of supply chain digitalization, and a summary of the key implications for practitioners and researchers.

## II. REVIEW METHODOLOGY

This paper is a systematic literature review (SLR) whose purpose is to identify the gaps in the current research within digitalization at both firm-level and at the supply chain level. According to Budgen and Brereton [14, pge. 1052], SLRs are a “means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest”. In their own right, SLRs are a scientific method that is evidence-based to answer a specific research question and allows process replicability [15]. We draw on the SLR process suggested by Budgen and Brereton [14] and Tranfield et al. [15] and used by several studies including [16], [17], and [18]. The process has four dominant phases: (1) the search strategy and planning the search process, (2) filtering sources for relevance to search strategy, (3) systematic mapping of results, and (4) synthesis.

### (1) *The search strategy and planning the search process*

This stage begins with the identification of key search terms informed by the purpose of the study [14]. In this case, two members of the review team agreed on two search terms: “digital supply chain (s)” and “supply chain digitalization”, the former to connote what levels of interest the study was keen on, and then later to connote the implementation process. We did not use the search term “digitalization” alone partly because of the supply chain context needed in the study, but more so because most research focuses on firms even when they are referring to the supply chain as observed by [19].

We specifically focused on the sources with a 5-year period: from 2012 to 2017. The fact that the data used in this study are just 5 years old merits some discussion since prior studies that draw on archival data has used even longer periods. Thomé et al. [20] show that some SLRs in operations management focus on longer sampling periods to build a longitudinal profile of the state of the art. The study further

adds that SLRs, which focus on short periods, say 5 years aim to capture snapshots of emergent themes within the specific research domain. This is the aim of this study in which we use sources within 5 years. Sachan and Datta [21] examine the methodologies used in logistics and SCM research using 5 years. The study of Büyükoçkan and Göçer [6] which also happens to be one of the few SLRs on digital supply chains (DSC) focuses on nuances that drive and challenge the implementation of the DSC concept and considers 6 years. Moreover, we argue that, unlike digitization, the interest in digitalization and digital transformation has only until recently come to the fore in business and management literature, see [6], [22].

The search strategy consisted of searches within online databases and within the top SCM journals as proposed in [23]. Using the two truncated search terms, “digital supply chain” and “supply chain digitalization” an initial Google Scholar search was conducted on February 6, 2018. The search within the 5 years showed that there were about 15,300 usable journal articles, periodicals, books, professional literature, and conference proceedings on the subject. It was therefore important to develop defined inclusion and exclusion criteria as shown in **Fig. 1**.

### (2) *Filtering sources for relevance to search strategy*

In part one, three (3) of most business and economics-oriented databases were considered. These include:- ProQuest (ABI Inform) with over 3000 business and management publications, EBSCOHost with over 6000 business publications, and Scopus with over 18,000 top journals. In total 297 usable sources of secondary data resulted from the databases, of these 19 were usable peer-reviewed articles and were considered for review.

First, a Boolean search was made in ProQuest and all its embedded databases e.g. ABI/INFORM Collection, ABI/INFORM Global, SciTech Premium Collection, Technology Collection, Social Science Premium Collection, etc using the following search key:

*(Digital supply chains) AND (supply chain digitization) with the following applied filters: “Peer-reviewed”, “Scholarly Journals”, “2012-2017”, “Article”, “English”*

This resulted in **290 peer-reviewed** journal articles. All 290 abstracts were reviewed in detail and only **15 articles** below matched the SC perspective.

Second, a Boolean search was made in EBSCO Host using the following search key:

*In BUSINESS JOURNALS COMPLETE/“Digital Supply Chain” AND “Supply chain Digitalization”/in “titles” AND “abstract” AND “keywords”/ “2012-2017”/“peer-reviewed journals only”*

This resulted in **6 peer-reviewed** journal articles. All 6 abstracts there were reviewed in detail and only **3 articles** below fitted the supply chain perspective.

Thirdly, the Boolean search in SCOPUS was made using the following search key:

*TITLE-ABS-KEY (“digital supply chain» AND «supply chain digitization”) AND PUBYEAR > 2011 AND PUBYEAR <*

2017 AND (LIMIT-TO (DOCTYPE, "ar" AND (LIMIT-TO (LANGUAGE, "English"))

The result was 1 peer-reviewed journal article, which was relevant and included for review.

Given the challenges associated with databases such as coverage, overlap, and changeability of databases [24], we also considered journal searches in the second part. Several studies have been conducted to identify the top journals within the field of SCM. Watson and Montabon [25] identified a total of 318 journals and propose 9 of these as the top tier journals with a strong operations management orientation, the basis for which academic evaluations for tenure and promotions could be carried out within the SCM. Sachan and Datta [21] used 3 top SCM journals to assess the common methodologies used by SCM researchers. Chapman and Ellinger [23] used 10 journals to establish the influence of the top SCM journals beyond the fields' domain. For this paper, we elected to use the journal lists provided by [21] and [23]. We conducted non-Boolean searches in the 10 journals but running 2 attempts per journal (first digital supply chain AND later supply chain digitalization). The results are shown in **Table 1**. It is important to mention that we only use the Boolean operator "AND" only to indicate the 2 attempts made per journal search in order to reduce the repetition of the same search strings and not as a Boolean search operator.

**Table 1.** Searches in select SCM journals and the results\*

Focal journals list [21],[23]	n
International Journal of Logistics: Research & Applications	00
International Journal of Logistics Management	07
Int. Journal of Physical Distribution & Logistics Management	07
Journal of Business Logistics	00
Journal of Supply Chain Management	00
Logistics Information Management/ now JEIM	06
Supply Chain Management: An International Journal	08
Supply Chain Management Review	00
Transportation Journal	01
Transportation Research, Part E.	04
<b>Total</b>	<b>33</b>

\*The search strings can be made available as a supplementary data file.

### III. SYNTHESIS AND DISCUSSION

With regard to definitions, we found three dominant concepts: digitization, digitalization, and digital transformation, which were used interchangeably and often confused with each other in the literature. On one hand, digitization (DTZN) is generally understood to mean the conversion of analog to digital while digitalization (DTLZN) refers to the use of digital and data-based technologies to improve work processes and change how customers and companies engage and interact with each other [22]. Digital transformation (DT) on the other hand is associated with the adoption of digital technologies to empower employees and drives cooperate culture change [36]. In that sense, digitization infers internal process optimization: it is the first step towards digitalization and digital transformation [36].

In general, most of the reviewed literature offered no definitions: a few articles that did, presented imprecise descriptions often as non-explicit definitions of the concepts.

We identified eight (8) almost concrete definitions that are summarized in **Table 2**. These definitions suggest that there is no common definition of SC digitalization in the extant literature. Often the literature is referring to one thing but implying another. However, all the underlying descriptions agree on the transformative nature of SC digitalization on SC performance in general. Xue et al. [26] claim that digitalization, in general, tends to stimulate firms to further digitize their SC operations.

With regard to the first part of the RQ, one can argue that while definitional convergence is a vital underly for intellectual discussions and knowledge development on this topic, it is not the most important aspect within digitalization literature. The digitalization literature looks at role and impact as the most important dimensions where digitization is an operational construct, while digitalization and digital transformation are strategic constructs associated with business model evolution.

With regard to the measurement of SC digitalization, 14 articles addressed the measures and metrics theme of this paper's RQ and are summarized in **Table 3**. In general, it appears that measurement is function of impact. Three high-impact areas of DSC seem to stand out in the literature (see **Fig. 1**) namely: the focus on digitally secure SCs[32], better engagement with key SC actors [26], [29], and stronger SC integration [30] [31].

From the literature, five measurement themes in DSC literature emerged (**Table 3**). They include (1) business process efficiency (2) digital assets and stock, (3) digital transactions, (4) revenue from digital infrastructure, and (5) digital investments. These are further discussed below.

(1) In theme #1, firms adopt digitalization as a way to become more efficient on one hand and a tool for measurement hence *business process efficiency* [42].

The literature suggests that firms want to invest in digitalization tools in the hope that they can perform better operationally such as in [28,33,45], but also attain internal digital congruence with their SC partners as such as in [36]. This can be measured based on the quality of the relationships enabled by digital SCM systems between the firm and its key suppliers and customers [26,27], the level of knowledge sharing [27], and improvement SC performance compared to existing technologies [30,33].

(2) In theme #2, *digital assets and stock* emerged from the literature that addressed technology utilization literature. Better digital asset utility translates to minimization of lead time, better relationships with customers and suppliers, waste reduction, cost mitigation, and reduced market response time [34].

Digital asset utility is measured by the extent to which organizations use enterprise-wide systems to realize digital business strategies and whose success depends on the level of utilization of ES data in their decision-making processes [38].

Fig. 1. The review protocol and emergent themes

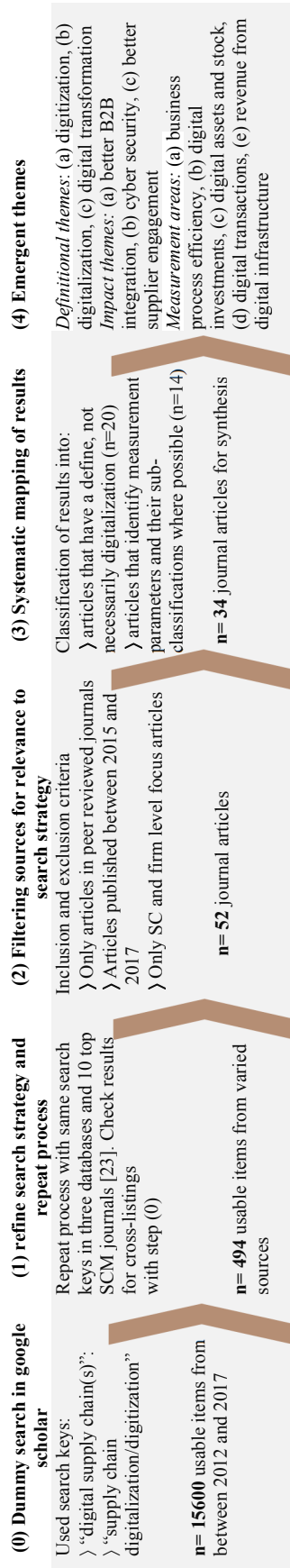


Table 2. Digitization(DTZN), Digitalization (DTLZN) & Digital Transformation (DT)

Definitions	DTZN	DTLZN	DT
Haddud et al. [29] ... the strategic and operational exchange of information among SC actors to enhance communication	X	X	
Kothman and Faber [30] ...a disruptive technology for interaction and transaction with business partners.	X		
Fletcher et al. [31] ...a tactic in SC to coordinate with business partners through an integrated environment.	X	X	
Azuara et al. [32] .... technologies that make it easier for SC actors to access each other's product data.		X	
Oettmeier and Hofmann [33] ... technologies that modify how SCs operate and facilitates customization		X	
Rylands et al. [34] ...methods for customized manufacturing and getting more designs to the market faster.	X		
Matt et al. [35] ...transformation of the firm's products, processes, and organizational aspects owing to new technologies.			X
Kane e et al. [36] ... digital capabilities where the firm's activities, people, culture, and structure are aligned with its organizational goals			X

Table 3. Measures and metrics of supply chain digitalization

Articles	Measures (Fig. 1)	Examples of metrics from DSCI [43]	Level of analysis in the literature
[28],[30],[33],[41],[42],[45]	Business process efficiency e.g. improved response time due to process automation	% age of perfect orders due to process automation	○ ⊕ ○
[32],[34],[37],[38]	Digital assets utility, e.g. level of demand forecasts accuracy	Quality of demand data from supply chain collaborations	○ ⊕ ○
[26],[37],[40],[42]	Digital transactions e.g. change in revenue from digital supply chain actions	% age of revenue generated through digital channels	○ ⊕ ○
[27],[31],[37],[41]	Digital revenue e.g. changes in revenue from platform utilization by suppliers	% age of revenue facilitated by digital technologies	○ ⊕ ○
[27],[31],[36],[39],[42]	Digital investment e.g. total spend on digital supply chain technologies	Number of dedicated FTEs with data science competence	○ ⊕ ○

○ Firm ⊕ supply chain ○ other, e.g. dyad, supply network

- (3) In theme #3, *digital transactions* emerged from the view that real-time access to data has a direct effect on the SC performance (efficiency and responsiveness) whose value can be measured through (i) new touchpoints, the timing of product returns, and quality of information [40] and, (ii) the transaction volume from digital assets [26].

In fact, the notion of data-driven supply chains (DDSC) as an enabler of process automation and SC visibility is associated with this theme. DDSC allows for better SC collaboration in design, production, delivery, and service of complex customer orders due to better information exchange, coordination, activity integration, and responsiveness [37].

- (4) In theme #4, *revenue from digital infrastructure* is associated with themes 1 and 5. It infers that the value of digital investments should be seen in improvements in the SCM processes which has a direct impact on the financial performance of firms [27].

Digital investments in technology usually focus on quality management and control systems, and time reduction (in product design, cycle, manufacturing, and delivery). The diffusion of these technologies in SCM reduces transport and warehousing costs, the level of inventories across the entire SC, and increases production speeds and response times [41]. As a result, the impact is better financial performance [27].

- (5) In theme #5, the level of digitalization is measured by the nature of *digital investments* the firm makes [27]. The transition from digital investment to implementation forms the basis for digital SC transformation which is a measurable construct.

Digital investments are the future of flexible manufacturing [39]. They offer SCs leverage for co-creation, co-production, and co-consumption [31]. Such investments however imply a high cost of acquisition, after purchase utilization and added complexity [39].

In sum, the measures of supply chain digitalization are based on the impact of specific technology investments that firms make internally and with their supply chain partners. When firms invest in 3D printing, AM, automation and robotics, cyber-physical platforms, IoTs/IoS (Internet of Services), unmanned aerial vehicles, virtual reality technologies, etc. they expect better performance within their operations and across their supply chains. The basis for measurement are the metrics tied to their direct performance: they want to get the best return on investment (ROI) outcomes [43]. In addition, the literature suggests that firms measure the impact of the supply chain digitalization investments not just at the firm level but also across their supply chains.

#### IV. CONCLUSION

This paper has conducted a SLR to establish how digitalization is defined and measured at the firm level and at the supply chain level, and if measurement parameters at the firm level vary from those at the supply chain level. The findings have demonstrated the following things: (1) the literature presents several loose definitions but most of these definitions can be grounded in three often interchangeable

concepts: digitization, digitalization, and digital transformation. (2) the literature demonstrates that the measures and metrics firms use in the measurement of digitalization are not well developed yet, and do not vary significantly between the firm level and the supply chain level. This is partly because the literature has not delineated digitalization at the firm level from digitalization at the supply chain level. It is inherently tautological to do so. The goal of digitalization is to create seamless interactions among supply actors often using similar technologies. The metrics of measurement as the literature shows inherently tend to be the same as well.

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## VI. REFERENCES (Part II)\*\*

\*\*Includes reviewed articles: Can be provided as a supplementary data file.