Digital Supply Chain Performance Metrics- A Literature Review

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Abstract

Purpose

In the previous decade, a substantial amount of research has been undertaken to measure the digitalized supply chain (DSC) performance. This paper aims to presents a systematic literature review on DSC performance measurement metrics to apprehend current practices, recognize gaps, and advocate future research itineraries.

Design/methodology/approach

To guarantee a replicable, rigorous, and transparent research process, the authors employed a systematic literature review methodology to synthesize the research. A combination of 25 keywords was used to obtain 248 scientific studies in the first step. The *Balance Score Card* (BSC) model was used to categorize 299 gathered performance metrics into four BSC perspectives.

Findings

The review highlighted the need for qualitative performance measuring metrics for DSC. During the review, only one study was identified that primarily focused on developing performance metrics for DSC. Additionally, the review identified that metrics related to Internal and financial perspectives received the most attention while the "growth and learning" perspective received the least attention. The review also identified that external partners, such as distributors and suppliers, were virtually ignored in previous literature.

Originality

Although numerous literature reviews have been conducted in the past on the performance measuring metrics for SCM, no literature review aiming to synthesize the measuring metrics for DSC has yet been undertaken.

Keywords: systematic literature review, digital supply chain, digital transformation, digitalization, performance measurement, balance score card

Paper type: Literature review

1. Introduction

In a rapidly changing world, businesses compete to serve customers with faster, cheaper, and higher quality products. As a result, the competition has shifted from firm vs. firm to supply chain vs. supply chain (Bi *et al.*, 2010; Büyüközkan and Göçer, 2018). Making it vital for a firm to continuously improve, upgrade, and invest in its Supply Chain. In the past decade, digital technologies have penetrated and improved every aspect of the supply chain, including procurement, manufacturing, distribution, and customer/supplier relations (Lu *et al.*, 2012). This adoption and reliance on digital technologies to perform business activities is referred to as "digital transformation" or "digitalization". These terms describe the integration of digital technology into all business areas to create new or modify existing business processes, culture, and customer experiences; fundamentally changing how firms operate and deliver value to customers (Nahrkhalaji *et al.*, 2018; Wei *et al.*, 2019). Therefore, the digital transformation of the supply chain is defined as the use of digital technologies to connect, integrate, and improve the business activities also involving suppliers and customers (Büyüközkan and Göçer, 2018).

Recent studies have reported several benefits of the Digitalized (digital) Supply Chain (DSC) over the traditional supply chain, including improved financial performance (Haoud and Hasnaoui, 2019; Youssef and El-Nakib, 2015), operational efficiency (Lu *et al.*, 2012; Sharma and Bhagwat, 2006; Zhao and Jiang, 2013), customer satisfaction (Jiang and Zhao, 2014; Jonsson and Gunnarsson, 2005; Zhao and Jiang, 2013), employee skills (Llach and Alonso-Almeida, 2015; Srinivas, 2007), supplier relations (Ranganathan *et al.*, 2011; Zhao and Jiang, 2013) along with a reduction in operational and manufacturing cost (Haoud and Hasnaoui, 2019; Korpela *et al.*, 2017; Di Vaio and Varriale, 2020), cycle time (Haoud and Hasnaoui, 2019), and errors (Youn *et al.*, 2014). Realizing the significant advantages offered by the DSC on firm competitiveness, many firms have started the process of full or partial digitalization of their supply chain (Wu *et al.*, 2016).

This digitalization process has opened new avenues for innovation for emerging technologies, such as the internet of things, artificial intelligence, machine learning, cloud computing, and big data. Agrawal and Narain (2018) identified eight emerging technologies potentially useful in the digital supply chain and encouraged researchers and practitioners to innovate using these technologies. On the other end of the spectrum, researchers have cautioned about the problems and difficulties digitization may create. For example, Hazen *et al.* (2014) argued that with the adoption of digitization, data generation becomes cheap and easy. As a result, an abundance of poor-quality data is produced, resulting in additional complexities and cost to manage store, and retrieve that data. Zhang *et al.* (2019) highlighted problems in the area of security and trust that arrive with the use of the advance information technologies in the supply chain.

Though DSC has several advantages over the traditional supply chain, the adoption of digital technologies is not easy or cheap. It has both short-term and long-term effects on firm performance and competitiveness. To control/monitor the process and quantify benefits obtained from DSC, effective Supply Chain Performance Measurement systems (SCPMS) are needed. Performance Measurement Systems can reveal the gap between planning and execution that can help firms identify problems and areas of improvement (Chae, 2009). Several studies in recent years have measured the performance of DSC systems using self-developed criteria and metrics. These metrics vary in nature and have focused on different aspects of DSC. This study will summarize and synthesize these metrics using the Balance Score Card (BSC), developed by Kaplan and Norton (1992). One key advantage of using BSC lies in its flexibility and ability to be implemented in different supply chain systems and organizations (Yongvanich and Guthrie, 2009). BSC adopts a holistic approach in measuring performance, assuring that the system performs well as a unit, not just individual links. Therefore, this paper aims to review the scientific studies measuring the performance of DSC to answer the following Research Questions (R.Q.s).

1. What is the current state of research in DSC performance literature?
2. What are the most used metrics for performance measurement?
3. Which aspects of the DSC performance measurement literature requires further attention?

2. Theoretical background

Supply chain management is the process of managing suppliers, manufacturers, warehouses, and stores to produce and distribute goods in the right quantity, at the right location, at the right time, to minimize system-wide costs while satisfying the service-level requirements (Simchi-Levi *et al.*, 2000). Traditionally, these integrations are discrete and take place in a series of soiled steps (Büyüközkan and Göçer, 2018). With the increase in global uncertainty and ever-changing customer demands, this discrete method of managing a supply chain is no more valid. It lacks the speed, transparency, flexibility, and timely actionable information needed to remain competitive in the current business environment (Büyüközkan and Göçer, 2018). Digital technologies can provide solutions to some of the most pressing challenges in supply chain management by reducing complexity, cost, and increasing volume and flexibility, leading to higher service levels (Agrawal and Narain, 2018), by directly linking suppliers and customers and vice-versa. Unlike traditional supply chains, DSC heavily relies on systems (e.g., software, hardware, communication networks) that support activities performed by globally distributed partners to buy, make, store, move, and sell a product (Bhargava *et al.*, 2013). In other words, in a traditional supply chain, organizational structures are bound by their geography/function, act in silos, and are reluctant to share information openly. On the contrary, DSC makes systems reliable, agile, and effective by distributing information, facilitating collaboration and communications across digital platforms (Raab and Griffin-Cryan 2011). In the traditional supply chain, technology is used to collect, store, and present data, while in DSC, technology is used to make strategic decisions (Wei, Alias, and Noche 2019). Therefore, DSC can be defined as, the new interconnected intelligent system that extends supply chain application beyond local/ single company, to improve customer service and business performance (Wu *et al.*, 2016).

This reliance on digital technologies acts as a double-edged sword. On the one hand, they make supply chains faster, efficient, and reliable. On the other hand, they introduce a higher level of complexity and variables into the system that require more sophisticated metrics to measure its performance (Cho *et al.*, 2012; Mondragon *et al.*, 2006; Ralston *et al.*, 2015). These metrics are used for "*assessing and controlling progress, highlighting achievements, enhancing understanding of key processes, identifying potential problems (e.g., bottlenecks), and providing insight into possible future actions, among others*" (Ahi and Searcy, 2015, p. 361). They enable top management to convey firm objectives in measurable and straightforward terms that allow firms to standardize the processes and define goals clearly (Magretta and Stone, 2002). In the absence of appropriate measures, firms cannot implement strategy, manage

operations, and track performance over time (Bremser and Chung, 2005). Therefore, these measures should be embedded in the system at the time of planning and selected depending upon the goals and type of supply chain (Dweekat *et al.*, 2017). Over the years, different supply chain performance measurement models were developed to standardize and robust the system. These models put forward different methods and processes to measure the performance effectively. Citing the lack of tools to grasp a holistic view of firm performance, Kaplan and Norton (1992) proposed the BSC. They argued that BSC would provide a quick and comprehensive view of the business to the top management. Today, BSC is among the most widely used performance measurement model (Saleheen *et al.*, 2018a). Ever since its introduction, BSC has been widely used for measuring firm performance, particularly the performance of the supply chain (Bigliardi and Bottani, 2010; Dweekat *et al.*, 2017; Marimin *et al.*, 2017) including the performance of DSC (Bremser and Chung, 2005; Dweekat *et al.*, 2017; Liang, 2015). Unlike the majority of the models available at that time, BSC included both financial and non-financial measures (Duarte *et al.*, 2011) that monitor the overall firm performance over time (Saleheen *et al.*, 2018b). BSC measures firm performance in the following four perspectives (Kaplan and Norton, 1992): Customer perspective (value-adding view)**,** by focusing on delivering value to customers; Financial perspective (shareholders' view), by focusing on delivering value to shareholders; Internal perspective (process-based view)**,** by focusing on promoting efficiency and effectiveness in processes; Growth and learning perspective (future view)**,** by focusing on sustaining innovation and change capabilities, through continuous improvement and preparation for future challenges.

We advance the notion that the overall performance of the DSC can be measured using these four perspectives.

3. Methodology

To answer the research questions, a systematic literature review following Okoli's (2015) guidelines was conducted. Systematic literature reviews are transparent, evidence-based activities (Tranfield *et al.*, 2003) that report the decisions, procedures, and conclusions made by those conducting the study (Cook *et al.*, 1997). Similar to the methodology adopted by Ammirato *et al.* (2020) and Grimaldi *et al.* (2017) in their respective literature reviews, our methodology is organized in the following three steps: paper location, paper selection, paper analysis.

3.1 Paper location

The articles included in the review were retrieved from several queries submitted to the database *Scopus* without specifying the time frame in January 2020. We searched for the multiple combinations of keywords including "digital supply chain", "e-supply chain", "smart supply chain", " digitalization" AND "metrics", "performance", "benefits". The keywords were selected based on a preliminary review of the literature and using a form of brainstorming. The complete list of the keywords and combinations used is presented in Table I. The search resulted in 248 articles that were examined for the study. Forty-five research articles appeared in multiple research queries; additionally, authors could not access three articles through either an online search or an interlibrary loan. In the next phase, the remaining 200 articles were analyzed. Figure 1 summarizes the methodology of this study.

3.2 Paper selection

After removing the duplicates and inaccessible articles, the remaining 200 articles were subjected to further exclusion criteria. The exclusion criteria included (i) articles not published in English, and (ii) articles with no mention of the DSC and its performance in their title or abstract. After rigorously analyzing and reviewing the remaining 46 articles, an additional exclusion of 29 articles was made. These additional exclusion criteria focused on the article's objective: an article was excluded if it did not discuss the metrics to measure the performance of DSC. As a result, 17 articles were identified as relevant to the study. The references of all relevant articles were also investigated to expand the literature. A total of 9 articles were identified from the bibliography, making the final number of articles used in this study to be 26. Table II presents the list of articles along with type and year of publication.

[Table I here]

[Table II here]

3.3 Paper analysis

The analysis was carried out by carefully reading each full paper and recording the metrics used for measuring DSC performance. A total of 299 different metrics were identified and recorded. The recorded 299 metrics were classified into the four BSC perspectives categories. Different metrics used with a similar focus were merged into one KPI. For example, "supply chain management cost", "transaction cost", "system cost", and others were merged into the “Operational Cost” KPI. Similarly, “system response time”, “data transmission speed”,

"number of steps in procurement cycle", and others were merged into "Operational Speed" KPI. To measure the performance in one KPI, the data from several metrics can be needed, and the combination of several individual metrics will dictate the performance in the related KPI.

4. Results and Discussion

As a result, a total of 37 KPIs were identified. The result of the analysis is presented in Table III. The analysis results show that the internal perspective received the most attention, with seventeen KPIs (184 metrics). In comparison, growth and learning received the least consideration with only three KPIs (19 metrics), highlighting the fact that not an equal amount of attention is paid towards different performance perspectives. Figure 2 reports on the frequency of each KPI.

[Table III here]

[Figure 2 here]

A total of 299 metrics to measure DSC performance were collected during the literature review and were categorized into four BSC perspectives. Performance related to firms' internal working, particularly in operations, product quality, and financial returns, were most widely measured, indicating that these three areas raised significant interest in the adopting firms. The use of these collected metrics to measure the DSC performance into four BSC perspectives is discussed in the following subsections. The summary of the discussion, highlighting gaps, research questions, and future directions are presented in Table IV.

[Table IV here]

4.1 Financial Perspective

Profitability, growth, and shareholder value are common financial goals that measure the bottom-line improvements of firms' activities. Kaplan & Norton (1992) emphasized that well designed financial control measures can improve overall firm performance. Our review identified several studies that have measured and reported the positive impact of digitalization of the supply chain on the financial performance of firms (Haoud and Hasnaoui, 2019; Lu *et al.*, 2012; Di Vaio and Varriale, 2020; Youssef and El-Nakib, 2015; Zhao and Jiang, 2013). As reported in Table III, the most used metrics in financial perspective are associated with the KPIs of "operational cost" and "return on investment". Hence, digitally transforming firms focus on cost reduction and initial investment. Though the ultimate goal of all these activities is to increase profit, surprisingly, the metrics to measure it appeared only three times. Though

growing body of literature is reporting on potential environmental benefits of digital technologies, the review identified only one study (Shibin *et al.*, 2017) that measured performance in this dimension, highlighting the dire need of metrics and studies to measure DSC in this area.

4.2 Customer Perspective

Every business aims to fulfil customer demands at the right time, at the right price, and with the right product. Supply chain is crucial for serving these demands. The introduction of digital technologies has helped firms in achieving these goals. It has not only decreased firms' response time to customer demands by streamlining the process (Lu *et al.*, 2012). But also has improved the overall firm performance that leads to increased customer satisfaction (Jiang and Zhao, 2014; Zhao and Jiang, 2013). The review identified that KPIs related to "on time delivery" and "responsiveness to customers" were most frequently measured. Surprisingly, the KPIs related to "customer ease of use" and "delivery reliability" received little attention. These findings are in line with Dweekat et al. (2017) literature review on SCPMS. They argued that most of the models available are too inward-looking and ignore the importance of the supply chain's external parts, including customers. Focus should be paid to measure their satisfaction to assess the supply chain's performance thoroughly.

4.3 Growth and Learning perspective

Growth and learning metrics focus on assessing the firms' learning curve to meet customers' current and future expectations. This perspective concentrates on evaluating firms' ability to innovate, improve, and learn to meet emerging customer needs (Kaplan and Norton, 1992). Employee training is essential in this regard, as reported by Hafeez et al., (2010), after measuring the DSC performance in dimensions of coordination, efficiency, and finance. This was also evident in the current review as the metrics associated with measuring "employee skills" received the most attention in this perspective. As reported in Table III, the growth and learning perspective received the least attention. However, studies have argued on the positive impact of digitization of the supply chain on firm innovativeness, employee skills, and growth potential (Haoud and Hasnaoui, 2019; Llach and Alonso-Almeida, 2015; Scuotto *et al.*, 2017; Shamout and Elayan, 2018). Future studies need to pay increasing attention to this important performance perspective.

4.4 Internal Perspective

Internal performance measures are critical for assessing the performance and effectiveness of actions towards achieving firm goals. Factors related to cycle time, quality, and productivity have a significant impact on firm performance and should be measured to assess the firm internal performance (Kaplan and Norton, 1992). The operational benefits of DSC measures include increased productivity (Hafeez *et al.*, 2010; Haoud and Hasnaoui, 2019), overall supply chain performance (Lu *et al.*, 2012; Ranganathan *et al.*, 2011; Tarofder *et al.*, 2017), better scheduling and resource utilization (Di Vaio and Varriale, 2020), and flexibility (Youn *et al.*, 2014). The internal perspective received the most attention from DSC performance measuring literature. Metrics related to efficiency, reliability, speed, flexibility, and quality were used the most. Highlighting the fact that the most important output firms demand from the digitalization of supply chain activities is the firm's internal performance. Surprisingly, key barriers in adopting digital technologies such as "data security" and "ease of use" received limited attention, indicating a significant gap in DSC performance measurement literature.

5. Conclusions and Limitations

Based on Okoli's (2015) methodology to conduct a systematic literature review, this research reviewed 26 scientific publications to provide state of the art on metrics for digital supply chain literature, and the answer proposed the R.Q.s. The first R.Q. "*What is the current state of research in DSC performance literature?*" is reported in detail in the discussion section in the context of four BSC perspectives. The subsections reported on different studies that have measured and reported the performance of DSC. Several studies present metrics to measure DSC performance; however, still, a gap exists. As reported in Table II, the number of studies per year is somewhat limited, despite calls for more studies.

The second R.Q., "*What are the most used metrics for performance measurement?,* was answered in the results section. In general, metrics related to Internal and financial perspectives receive greater attention. The metrics focused on measuring performance in dimensions related to "operational efficiency", "operational speed", "error rate", "system reliability", "system flexibility", "operational cost", "on time delivery", "supplier relation", "Information availability ", "inventory level", "return on investment", were used ten times or more. The complete list of KPI and related metrics frequency has been presented in Table III.

In response to the third and final R.Q., "*Which aspects of the DSC performance measurement literature requires further attention*?", further studies should focus on developing specific

metrics for measuring DSC performance. The only study that was identified during our literature review, focusing on developing metrics for DSC performance was by Sambasivan et al. (2009). This lack of metrics has resulted in a relatively small number of studies focusing on measuring the DSC's performance. The call for quantitative measures (Lima-Junior and Carpinetti, 2017) and empirical studies (Ranganathan *et al.*, 2011) is still not satisfied. Additionally, the reviewed studies do not pay equal attention to measure performance in all four perspectives suggested by BSC. For example, the "internal perspective" received the overwhelming amount of consideration (61% of metrics focused on it), and the "growth and learning perspective" received the least attention (6% of metrics focused on it). Another fact that highlighted the need for further research was the inability of metrics to reflect the adoption and advantages of firms' digital technologies. The majority of the studies we reviewed used perception-based traditional measures to assess the performance of DSC.

Supplier performance is crucial for meeting a firm's flexibility, cycle time, and quality goals that are essential to achieve higher DSC performance. Surprisingly no or very little attention was paid towards measuring supplier's performance as a result of target firm adoption of digital tools, leaving a significant gap in this crucial area of research. Another shortcoming of the existing literature was noted in its inability to incorporate external factors, such as government (trade policies, environmental regulations), competitors (new units, price changes), and newer technologies. No efforts were made towards incorporating these factors into the supply chain to receive early feedback or warnings. In conclusion, we argue that there is still a need for empirical studies to test available metrics and a need for theoretical studies to develop appropriate metrics.

We recognized that there are some limitations to the study. First, although *Scopus* covers a wide range of peer-reviewed publications, it does not include all reputable peer-reviewed publications. Therefore, using different search terms and additional databases beyond *Scopus* may have resulted in identifying other metrics. Additionally, the inclusion of technical reports might have been useful as well. Second, the use of BSC to categorize all available metrics may have wrongfully categorized them into one of the available four perspectives. We recognize here that the original study may have used the metric in a different context.

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