Uncertain Supply Chain Management 10 (2022) 1203–1210

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

The impact of supply chain 4.0 technologies on its strategic outcomes

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A B S T R A C T

The aim of this study is to explore the impact of supply chain 4.0 technologies (e.g., big data and Internet-of-things) of the strategic outcomes of supply chain 4.0. The required data was collected via a questionnaire from a sample consisting of 211 employees from construction companies in Jordan. The results point out that big data and the Internet of things have significant impacts on the strategic outcomes of supply chain 4.0. Hence, it was concluded that supply chain technologies are pivotal drivers of supply chain strategic outcomes. Based on these results companies are called to adopt and integrate Industry 4.0 technologies into their supply chains to improve supply chain long-run performance. Scholars were also encouraged to investigate the impact of supply chain 4.0 technologies on other constructs such as supply chain resilience.

Article history:
Received May 10, 2022
Received in revised format June 20, 2022
Accepted August 18 2022
Available online
August 18 2022

Keywords:
Supply chain 4.0
Big data
Internet of things
Strategic outcomes of supply chain 4.0

1. Introduction

Industry 4.0 gained great attention from both academics and practitioners (Al-Alwan et al., 2022; Frederico et al., 2019). Then, numerous works were conducted in this regard such as Industry 4.0 and opportunities for sustainability (Ghobakhloo, 2020; Bag et al., 2021; Jamwal et al., 2021), readiness, drivers and barriers to adopt Industry 4.0 technologies (Maisiri et al., 2019; Machado et al., 2019; Muscio & Ciffolilli, 2020; Raj et al., 2020; Stentoft et al., 2021; Al-Shormana et al., 2021), Industry 4.0 contribution to performance of industrial and logistic companies (Dalenogare et al., 2018; Ślusarczyk et al., 2020; Eldahamsheh et al., 2021), assessment of Industry 4.0 technologies (Xuet al., 2018; Bai et al., 2020; Oztemel & Gursev, 2020), implementation of Industry 4.0 technologies in industrial companies (Frank et al., 2019; Zheng et al., 2021),and cybersecurity challenges of Industry 4.0 (Culot et al., 2019).

On the other hand, a specific vein of the literature focused on Industry 4.0 and supply chain management (e.g., Luthra & Mangla, 2018; Koh et al., 2019; Ivanov et al., 2019; Da Silvaet al., 2019; Garay-Rondero et al., 2020; Li, 2020; Hahn, 2020; Núñez-Merinoet al., 2020; Devet al., 2020; Ghadgeet al., 2020; Fatorachian & Kazemi, 2021; Birkel & Müller, 2021; Ivanov & Dolgui, 2021; Caiadoet al., 2021; Sharmaet al., 2021; Kayikci et al., 2022; Wamba & Queiroz, 2022; Alshawabkeh et al., 2022;).Specifically, some studies highlight an integrated concept namedSupply Chain 4.0 (SC4.0) (Tjahjonoet al., 2017; Dossou, 2018; Muthusami & Srinivsan, 2018; Frederico et al., 2019; Cañas et al., 2020; Sobb et al., 2020, Markov & Vitliemov, 2020; Ali & Aboelmaged, 2021; Al-Nawafah et al., 2022; Al-khawaldah et al., 2022; Alamsjah & Yunus, 2022). For these authors, SC4.0 is used mainly to emphasize the application of Industry 4.0 technologies in supply chains.

A successful application of SC4.0 means utilizing Industry 4 technologies to improve supply chain performance standards and achieve strategic goals (Frederico, 2021). Frederico et al. (2019) identified four requirements of SC4.0, which are managerial and capability supporters (e.g., information technology infrastructure and leadership support), process performance requirements (e.g., supply chain responsiveness and flexibility), technology levers (e.g., Internet of things, big data analytics), and strategic outcomes (e.g., customer focus, supplier focus, and cost reduction). It is expected that Industry 4.0 technologies are critical drivers of SC4.0 (Tjahjonoet al., 2017; Garay-Rondero et al., 2020). However, studies on the

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doi: 10.5267/j.uscm.2022.8.008

effects of Industry 4.0 on supply chains are still limited (Li & Li, 2017; Frederico et al., 2019). In order to contribute to the literature on SC4.0, the aim of this study is to empirically investigate the impact of SC4.0 technology levers such as big data and Internet of things on the strategic outcomes of SC4.0.

2. Literature review and hypotheses development

2.1 Definition of supply chain 4.0

Using Industry 4.0 technologies in supply chains results in an emerging concept known as SC4.0. Hence, a key difference between digital supply chains and traditional supply chains is that the former use Industry 4.0 technologies. Frederico et al. (2019: 22) defined SC4.0 as a transformative and holistic approach to supply chain management that employs disruptive Industry 4.0 technologies to streamline supply chain processes, activities, and connections in order to deliver major strategic benefits for all supply chain stakeholders. For Ferrantino and Koten (2019: 104), SC4.0 refers to "the re-organization of supply chains – design and planning, production, distribution, consumption, and reverse logistics – using technologies that are known as "Industry 4.0". Therefore, SC4.0 is defined as managing supply chains based on advanced technologies such as Internet of things and big data analytics to achieve different objectives.

2.2 Dimensions of supply chain 4.0

Reviewing the literature to propose a novel conceptual framework of SC4.0, Frederico et al. (2019) identified four main dimensions, which are managerial and capability supporters, technology levers, requirements of process performance, and strategic outcomes. These dimensions and their related sub-dimensions are summarized in Table 1.

Table 1
Dimensions of Supply Chain 4.0

Dimensions	Sub-dimensions
Managerial and capability supporters	Information technology infrastructure, human resources and organizational skills, supply chain coordination, leadership support, awareness of supply chain 4.0 benefits and requirements, supply chain strategic vision, and compliance requirements of supply chain 4.0.
Technology levers	Examples: Internet of things, big data analytics, artificial intelligence, cloud technologies, mobile applications, smart machines, and smart products.
Process performance requirements	Interoperability among technology levers, supply chain 4.0 integration, collaboration and transparency, supply chain 4.0 responsiveness, supply chain 4.0 flexibility, supply chain 4.0 efficiency, and indicators of performance measurement.
Strategic outcomes	Customer focus, supplier focus, cost reduction and profitability, and strategic impacts such as competitiveness and brand image improvements.

Source: Frederico, Garza-Reyes, Anosike, and Kumar (2019).

2.3 Technology levers of supply chain 4.0

Frederico et al. (2019) recognized 21 types of Industry 4.0 technologies including Internet of things (IoT), big data analytics (BDA), cloud computing (CC), 3D printing, and robotics. These five technologies are the most commonly discovered in the literature (Koh et al., 2019; Ferrantino & Koten, 2019). For the present study, the first two technologies (i.e., IoT & BDA) were studied in terms of their effects on the strategic outcomes of Supply Chain 4.0.

2.3.1 Big data

Big data refers to collecting and analyzing large and complex data sets that cannot be processed using traditional applications. Oguntimilehin and Ademola (2014) defined big data in terms of six elements: volume (size of data), velocity (speed of data received and processed), variety (types of data as structured and unstructured from different sources), variability (flows and trends of data over time), value (commercial benefits of data), and complexity (data relationships). Zakir et al. (2015) regarded big data as a methodology of data analysis supported by advanced technologies used to support processes like data capture, data storage, and data analysis. The authors indicate that big data analytics refer to processing unstructured data from numerous sources such as online searches, mobile transactions, sensor-engendered data, as well as user-created digital content such as images and blog posts. Many benefits of BD were reported in the literature, enabling decision makers to make real-time decisions (Ramirez-Peña et al., 2020) as well as improving competitiveness of firms (Oguntimilehin & Ademola, 2014). Generally, big data benefits have been classified into four categories: transactional benefits, transformational benefits, informational benefits, and strategic benefits. The first category includes benefits such as decreasing communication and operation costs, saving in supply chains, and improving employee productivity. The second one covers lifting employee skills, cultivating novel business opportunities, and intensifying capabilities. The third category encompasses allowing easier and quicker access and refining data management. Finally, strategic benefits of big data involve building a competitive advantage, launching links with other organizations, assisting faster responses to changes, cultivating client relations, and boosting products and service quality (Raguseo, 2018).

2.3.2 Internet of things

There is no common definition of IoT but basically it refers to communications between physical things via the Internet to realize valuable purposes (Haddud et al., 2017). It links products, machines, individuals and members of supply chains together (Li & Li, 2017). In supply chains context, IoT has been defined as a network of digitally connected physical devices that sense, monitor, and interact within a firm and between the organization and its supply chain, enabling agility, visibility,

tracking, and information sharing to support timely supply chain planning, management, and coordination (Ben-Daya et al., 2019: 4721). Numerous benefits of IoT are informed in the literature. Examples are communications and real time responses (Ramirez-Peña et al., 2020), developing supply chain responsiveness and agility, improving transparency of local and international logistic operations, enhancing Just-in-Time manufacturing, and reducing inventory levels (Haddud et al., 2017).

2.4 Strategic outcomes of supply chain 4.0

For Frederico et al. (2019), strategic outcomes of supply chain 4.0 refers to four key factors, which are customer focus, supplier focus, cost reduction and profitability as well as strategic impacts like competitiveness enhancement and brand image enlargement. In their study on the impact of Industry 4.0 implementation on supply chains, Ghadge et al. (2020) indicated that the most important strategic drivers of adopting Industry 4.0 in supply chains are developing new business models and creating new values to increase competitiveness. Moreover, Yu et al. (2021) point to the importance of Industry 4.0 in facilitating the strategic outcomes of supply chains in different aspects such as supply chain innovation, supply chain resilience, and supply chain responsiveness. The current study adopts the four strategic outcomes of SC4.0 suggested by Frederico et al. (2019). In this regard, the authors highlight the significance of SC4.0 in producing faster responses to customer requirements based on supply chain efficiency and flexibility, aiding suppliers to enhance their processes of production planning through collaboration and transparency, reducing costs based on suppliers' operational improvements and responsiveness to customer requirements result in increasing profitability and consequently competitiveness, as well as strategic impacts of SC4.0 such as increasing competitiveness, and business value.

2.5 Effect of big data and strategic outcomes of supply chain 4.0

Big data has numerous benefits such as increasing a firm's responsiveness to changes, building good relationships with its customers and other firms, and enhancing the quality of its products and services (Raguseo, 2018). The literature proposes that big data driven supply chains showed a significant effect on supply chain performance measurements such as customer responsiveness and supply chain flexibility (Gawankar et al., 2019). Raman et al. (2018) found a significant effect of big data analytics on customer demand management and customer satisfaction in supply chains. Other effects of using BD in supply chains include reducing supply chain costs (Wang et al., 2016; Jain et al., 2017), as well as furthering supply chain agility and firm's competitiveness (Raman et al., 2018; Bamel & Bamel, 2020; Wamba et al., 2020). Therefore, it was expected that BD contributes to the strategic outcomes of SC4.0 as suggested in the following hypothesis:

H_1: *There is a significant and positive effect of BD on strategic outcomes of SC4.0.*

2.6 Internet of things and strategic outcomes of supply chain 4.0

IoT has many applications in SC4.0 context such as tracking processes, activities and products within supply chains, optimizing operations of warehousing, manufacturing, and transportation (Rejeb et al., 2019). Raman et al. (2018) indicated that IoT has a significant role in terms of its real-time visibility in supply chains. Moreover, IoT has significant advantages such as increasing firm's timely responses (Ramirez-Peña et al., 2020), making supply chain flexibility, agility, and transparency better (Haddud et al., 2017). Hence, it was expected that IoT lifts the strategic outcomes of SC4.0 as proposed in the following hypothesis:

H_2: *There is a significant and positive effect of IoT on strategic outcomes of SC4.0.*

3. Research methodology

3.1 Research sample and data collection

The sample of this study consists of employees who are informed about activities and processes of supply chains in the construction industry in Jordan. A total of 211 employees were selected to participate in the study from construction companies. The required data was collected using a questionnaire distributed to the sample members. The total of 183 questionnaires was returned and 21 were excluded due to incomplete responses. That is, 162 questionnaires were used to conduct data analysis via SmartPLS 3.0 software.

3.2 Research Measures

The independent variable in this study is SC4.0. It consists of two dimensions; BD and IoT. BD in supply chain context was measured using 4 items adopted from Gawankar et al. (2019). IoT was assessed using 4 items adopted from Haddud et al. (2017). The dependent variable in the current study is the strategic outcomes of SC4.0.It was measured by 4 items related to responsiveness to customers (Gawankar et al., 2019), cost reduction, SC flexibility, and competitiveness (Frederico et al., 2019; Wang et al., 2016; Jain et al., 2017; Raman et al., 2018; Bamel & Bamel, 2020; Wamba et al., 2020).

3.3 Research proposed model

The schematic model as shown in Fig. 1 assumes that big data and the Internet of things have significant effects on the strategic outcomes of SC4.0. These assumptions refer to hypothesis 1 (H1) and hypothesis 2 (H2).

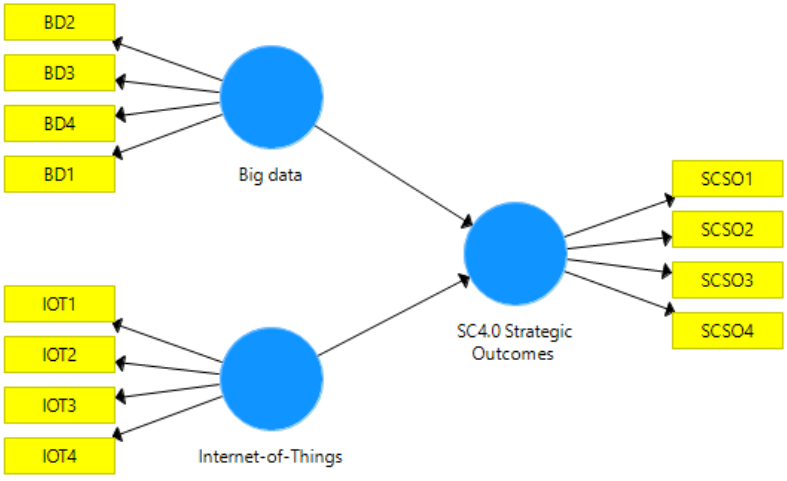

Fig. 1. Research schematic model

3.4 Reliability and validity

Reliability as tested by Cronbach's alpha (α) and composite reliability which should be less than 0.70 was assured, and validity as tested by items' factor loadings (higher than 0.50) and the average variance extracted (AVE) (higher than 0.50) was also guaranteed as shown in Table 2.

Table 2
Results of reliability and validity

Factors	Item Codes	Inner VIF	Factor loadings	Cronbach's alpha	Composite reliability	AVE values
Big data	BD1	1.235	0.940	0.963	0.973	0.901
	BD2		0.964			
	BD3		0.948			
	BD4		0.944			
Internet-of-things	IOT1	1.235	0.967	0.924	0.946	0.815
	IOT2		0.919			
	IOT3		0.852			
	IOT4		0.869			
Supply Chain 4.0	SO1	-	0.847	0.846	0.897	0.688
	SO2		0.807			
	SO3		0.948			
	SO4		0.798			

3.5 Model fit

The results of model fit as illustrated in Table 3 indicate a good level of model fit. The standardized root mean square residual (SRMR)is less than 0.08 (Perry et al., 2015; Tariq et al., 2022), the normed fit index (NFI) is close to 1 (Sleimi & Emeagwali, 2017; Alolayyan et al., 2018; AlTaweel & Al-Hawary, 2021), and root mean square residual covariance matrix (RMS theta) is less than 0.12 (Yuan et al., 2021; Mohammad et al., 2020).

Table 3
Results of model fit

Indices	Criteria	Value	Results
SRMR	Less than 0.08	0.057	Accepted
NFI	Close to 1	0.923	Accepted
RMS Theta	Less than 0.12	0.10	Accepted

4. Results, discussion and conclusion

4.1 Effect of BD on SC4.0 strategic outcomes

The first hypothesis of this study, that BD has a significant and positive effect on the strategic outcomes of SC4.0, was supported by the current data as shown in Fig. 2 and Table 2 ($\beta = 0.335$, $t = 3.99$, $P = 0.00$). In line with previous studies (e.g., Oguntimilehin & Ademola, 2014), this result indicates that big data due to some attributes improves the achievement of SC4.0 strategic outcomes. Such attributes refer to collecting a large size of structured and unstructured data flow variable from different sources to be processed in a speedy manner to yield beneficial data for commercial purposes. The effect of BD in this respect is recognized through BD benefits as cited in the literature, for example, real-time responses to customer

requirements, cost reduction, developing good relationships with customers, and improving competitiveness through flexibility, agility, as well as products and services quality (Ramirez-Peña et al., 2020; Raguseo, 2018; Wang et al., 2016; Jain et al., 2017; Wamba et al., 2020; Raman et al., 2018; Bamel & Bamel, 2020).

4.2 Effect of IoT on SC4.0 strategic outcomes

The second hypothesis of this study, which is that IoT has a significant and positive effect on the strategic outcomes of SC4.0, was accepted as shown in Fig. 2 and Table 2 (β = 0.327, t = 3.60, P = 0.00). This results, in agreement with several previous works, signifies a pivotal role of IoT in attaining SC4.0 strategic outcomes such as responsiveness to customer demand, cost reduction, competitiveness, and supply chain flexibility (Frederico et al., 2019; Wamba et al., 2020; Bamel & Bamel, 2020; Gawankar et al., 2019).

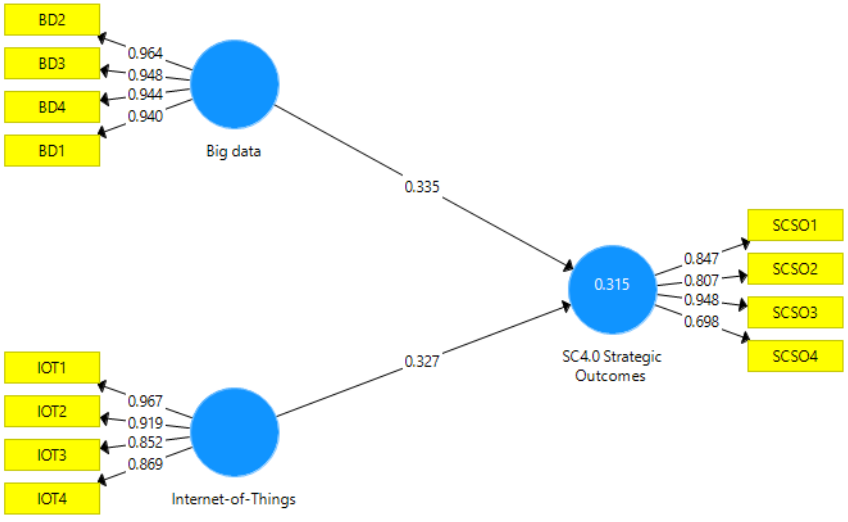

Fig. 2. Research structural model

Table 2
Effects of SC4.0 (BD & IoT) on SC4.0 strategic outcomes

Constructs and paths			β	T statistics	P value	R^2
BD	→	SO-SC4.0	0.335	3.99	0.000	0.315
IoT	→	SO-SC4.0	0.327	3.60	0.000	

4.3 Conclusion

The study aims at exploring the effects of two dimensions of supply chain 4.0, which are big data and Internet of things, on the strategic outcomes of supply chain 4.0 through testing hypotheses that assume significant effects of these two dimensions. Using the current data, the two hypotheses were supported. That is, big data and the Internet of things have significant effects on the strategic outcomes of supply chain 4.0. Based on these results, it was concluded that technologies such as big data analytics and Internet of things contribute to the strategic outcomes of supply chains such as focus on customers and suppliers, profitability and cost reduction, as well as other strategic effects like competitiveness.

5. Implications and scope of future studies

Based on the above-mentioned results and the conclusion of the current study, organizations are encouraged to integrate Industry 4.0 technologies into their supply chains to enrich their strategic capabilities. Two significant types of these technologies are big data and the Internet of things. On the other hand, the study highlights the importance of two factors affecting the way by which an organization can boost its abilities to achieve a key dimension that helps achieve its strategic objectives, as the strategic outcomes of SC4.0 is a main pillar of the organizational strategic objectives. Moreover, the study inspires scholars to conduct new studies on the relationship between Industry 4.0 technologies in supply chains and other outcomes such as supply chain resilience. However, the current study has some limitations in terms of its theoretical framework in which the relationship between two dimensions of SC4.0 and the strategic outcomes of SC4.0 were examined using a cross-sectional sample from the construction industry, therefore, it is recommended to use longitudinal samples from different industries.

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