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Potential effects of smart innovative solutions for supply chain performance

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The study aimed at exploring the impact of three smart innovative solutions, i.e., Internet-of-Things, Big Data Analytics, and Cloud Computing on supply chain performance. Collecting data by questionnaires administered to a sample consists of supply chain managers of industrial firms. The results pointed out that these three smart solutions significantly and positively lift firms' supply chain performance. That is, the hypotheses that Internet-of-Things, Big Data Analytics, and Cloud Computing have significant impacts on supply chain performance were supported. Therefore, the study concluded that for industrial firms to improve supply chain performance, such smart solutions should be assessed and applied. The study contributes to both academics and practitioners through providing empirical results on concurrent impacts of three advanced technologies in supply chain management context.

1. Introduction

These days, firms need new structures of supply chains to cope with many potential risks and to raise supply chain performance (Rahman et al., 2022). One proposed effective solution to improve firm performance is through using new technologies to enhance production quality, lead-time as well as cost and waste management (Dossou & Nachidi, 2017; AlTaweel & Al-Hawary, 2021; Al- Quran et al., 2020; Agyabeng-Mensah et al., 2020). According to Preindl et al. (2020), such new types of supply chains can be achieved through a combination of mobile, cloud and smart systems. Such systems are popularized using several terms such as Internet-of-Things (IoT), Big Data Analytics (BDA), Cloud Computing (CC). The focus of this study is on IoT, BDA, and CC. These new systems as deemed as smart innovative solution have many potential impacts for supply chain management such as developed supply chain performance, sensible performance monitoring, enabled supply chain tracking, superior supply chain forecasting, increased supply chain agility, and enhanced supply chain integration (Dossou & Nachidi, 2017; Ghadge et al., 2020; Preindl et al., 2020; Fatorachian & Kazemi, 2021; Cankaya et al., 2018). De Vass et al. (2018) investigated the impact of IoT on supply chain integration and supply chain performance using data from retail companies and found a positive impact of IoT capability on these two response variables. Surveying mining manages, Bag et al.'s (2020) results pointed out that BDA management capability and BDA talent capability have significant impacts on green product development and employee development, which in turn impact innovation and learning performance and hence sustainable supply chain performance. In terms of CC impacts, there is a positive impact of information sharing supply chain visibility (Kochan et al., 2018) and then supply chain performance (Cao et al., 2017; Al-Nawafah et al., 2022; Alshawabkeh et al., 2022).

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However, research on the impacts of smart innovative solutions (i.e., IoT, BDA, and CC) on supply chain performance is still little in the local region, then, this study aims at fulfilling a research gap regarding such impacts by answering a research key question: do smart innovative solutions impact supply chain performance as perceived by supply chain managers in industrial firms? This question was formalized in terms of three hypotheses related to the impacts of IoT, BDA, and CC on supply chain performance.

The next section of this study presents literature review and hypotheses development, followed by research methodology, i.e., research sample and data collection, research measurements, research theoretical model, as well as validity and reliability, in section 3. Section 4 illustrates research results and discussion, subsequently, research implications, conclusion, and future research directions are illustrated in section 5.

2. Literature review and hypotheses development

2.1 Smart innovative solutions

In line with the organizational capability theory, which recommends that firms should develop new capabilities to improve their performance (de Vass et al., 2018; Al-Hawary & Al-Syasneh, 2020; Rafati, 2022), smart innovative solutions are regarded as additional capabilities that firm can used to improve organizational performance and particularly supply chain performance. In the current study, these smart innovative solutions refer to IoT, BDA, and CC.

Simply, IoT is a set of devices linked together to communicate data (Aeknarajindawat, 2019). Hence, the aim of IoT or industrial Internet-of-Things (IIoT) is sharing information that is collected from objects to be used for making effective decisions (Pal & Yasar, 2020). IoT that can be used in supply chain management include wireless sensor networks (WSN), global positioning system (GPS), and geographic information systems (GIS) (Eldahamsheh et al., 2021; Al-Rakhami & Al-Mashari, 2021).

In the same vein, the concept of BDA emerged due to a critical need for dealing with large volumes of data stored in big datasets, which are challenging to process by traditional database management systems. BDA is required to provide a sufficient storage of large volume of data (volume), collected at an adequate rate (velocity) from different sources such as social media with structured and unstructured formats (variety) that should be reliable data (veracity) with potential benefits for making real time decisions (Oncioiu et al., 2019).

Cloud systems are remote servers used for storing data that harvested from devices, business systems, sensors and equipment (Khalayleh & Al-Hawary, 2022; Ghadge et al., 2020). Jiang (2019, p. 58327) defined CC as "a supercomputing model that combines server resources with a large amount of information stored on mobile terminals, individuals, and other terminal devices". Attaran (2020, p. 8) described CC as "a cost-effective way to run applications, store data, and accomplish other IT tasks". In supply chain management context, Bhoir and Principal (2014, p. 4) defined CC as "a set of services that provide SCM functions to any cloud user in an efficient, scalable, reliable and secure way" and indicate that CC as an on-demand service is characterized by its use over time in line with changes, sharing information to improve partners' collaboration (Huchzermeier & Cohen, 1996; Mohammad, 2019; Purwanto et al., 2022).

2.2 SC performance

Scholars utilized various approaches to assess supply chain performance. According to Pettit et al. (2019), there are three approaches that can be used to evaluate supply chain performance, which are hierarchical, perspective, and process-oriented approaches, as the first one refers to the operational, tactical, and strategic levels, the second one signifies models such as the balanced scorecard, the third one describes process integration. Alshawabkeh et al. (2022) added that supply chain performance can be understood based on three key potentials: supply chain capability to meet customer demands by providing timely goods delivery, supply chain speed in terms of flexibility, as well as supply chain commercial value. Shee et al. (2018) asked respondents to rate the current performance in comparison with their competitors in areas such as manufacturing costs, delivery reliability, quality, and firms' sustainable performance. Aeknarajindawat (2019) indicated that supply chain performance can be assessed using different measures that are related to customer perceptions, using innovative technologies such as Internet-of-Things, organizational internal capabilities, and financial aspects such as the value that the organization adds to its shareholders.

2.3 Potential impacts of smart innovative solutions for SCM

Generally, Industry 4.0 technologies have numerous impacts on business firms, particularly their supply chains. These impacts include increasing traceability of material and goods so as make precise SC forecasting and SC planning, improving information-sharing and warehousing intelligence and therefore improve supplier performance, as well as improve vehicles and machines performance through monitoring of locations and vehicles speed, in addition to monitoring products conditions during transportation, automating physical tasks, faster rates of delivery, and shipments tracking (Darnall et al., 2008; Ghadge et al., 2020). Hence, smart innovative solutions are very important for supply chain management. According to Sillanpää (2015, p. 290), supply chains have "to be made more streamlined, lead-time to be decreased, excess processes need to be eliminated".

One potential impact of Internet-of-Things is that it solves problems related to information sharing (Dossou & Nachidi, 2017). de Vass et al. (2018) indicate the most important part of Internet-of-Things is using real time data, which means enhanced integration of supply chain and customers as well as quick responses to market changes. Other potential impacts of Internet-of-Things include amending supply chain productivity, enhancing quality controls, boosting supply chain capabilities, and achieving faster rates of delivery (Ghadge et al., 2020; Preindl et al., 2020; Fatorachian & Kazemi, 2021).

Big data analytics, on the other hand, make sense of large volumes of data and cloud computing enhances information sharing (Ghadge et al., 2020). Preindl et al. (2020) added that big data analytics are essential to entirely take advantage of data to clued-up decision-making processes. Another benefit of BDA for supply chain management is using forecasting techniques to improve manufacturing performance, estimating supply chain sustainability, and analyzing logistics performance (Oncioiu et al., 2019). BDA is useful for developing products, predicting market demand, making supply chain decisions, optimizing supply chain distribution, and gaining customer feedback (Oncioiu et al., 2019). Moreover, cloud computing as an advanced technique to store large volume of data (Jiang, 2019) has several potential impacts like supply chain visibility enlargement (Kochan et al., 2018), supply chain performance enrichment (Cao et al., 2017; Shee et al., 2018). A summary of these potential impacts is reported in Table 1.

Table 1
Potential impacts of SCM smart innovative solutions

Smart solutions	Potential impacts	Authors
Internet-of-Things (IoT)	- Simultaneous performance communication. - Amended SC productivity. - Enhanced quality controls. - Better decision making process. - Developed SC flexibility. - Sensible performance monitoring. - Enabled SC tracking. - Supported in-time decision making. - Boosted SC capabilities. - Faster rates of delivery. - Solving problems of information-sharing.	Dossou and Nachidi (2017) de Vass et al. (2018) Aeknarajindawat (2019) Attaran (2020) Ghadge et al. (2020) Preindl et al. (2020) Fatorachian and Kazemi (2021)
Big data analytics (BDA)	- Instantaneous problem solving. - Superior SC and logistics forecasting. - Making better decisions. - Enhanced inventory management. - Enriched value of SC data. - Increased SC agility. - Better customized products. - Clued up strategic SC decisions.	Raman et al. (2018) Oncioiu et al. (2019) Bag et al. (2020) Ghadge et al. (2020) Preindl et al. (2020) Fatorachian and Kazemi (2021)
Cloud Computing (CC)	- Enabled storage of large volume data. - Enhanced SC integration. - Data quick access from different SC points. - Improved SC performance - Improved SC visibility. - Connected multiple SC points.	Cao et al. (2017) Shee et al. (2018) de Vass et al. (2018) Singh et al. (2018) Kochan et al. (2018) Aeknarajindawat (2019) Jiang (2019) Attaran (2020) Fatorachian and Kazemi (2021).

On the basis of the abovementioned potential impacts, it was expected that these smart innovative solutions have significant effects on SC performance. Also, this expectation is drawn by the empirical results that underlined a significant and positive impact of smart innovative solutions on supply chain performance (Raman et al., 2018; de Vass et al., 2018; Aeknarajindawat, 2019; Mostafa et al., 2019; Ben-Daya et al., 2019; Oncioiu et al., 2019; Ahmed et al., 2021; Benzidia et al., 2021; Fatorachian and Kazemi, 2021). In order to investigate these impacts from the perspectives of SC managers in industrial firms, the following three hypotheses are suggested:

H$_1$: *IoT significantly lifts SC performance.*
H$_2$: *BDA significantly lifts SC performance.*
H$_3$: *CC significantly lifts SC performance.*

3. Methodology

3.1 Research sample and data collection

Managers in industrial firms represent the population of this study. A random sample consisting of 120 managers was selected to gather the required data. The members of the sample should have information about firms supply chain operations and technology solutions that can be used to enhance these operations. As the study is carried out to explore managers' perceptions on the impacts of smart innovative solutions (IoT, BDA, and CC) on supply chain performance, a questionnaire (5-point Likert scale) was developed to cover these perceptions. It was distributed to 120 managers working in industrial firms in different industries. A total of 109 questionnaires were used for data analysis purposes.

3.2 Research measurements

IoT was measured using five items adopted from de Vass et al. (2018) with minor changes in terms of remote control of supply chain processes, tracking of supply chain entities, making sufficient supply chain decisions, and using real time information to adjust supply chain tasks. BDA was measured using five items developed based on previous studies (e.g., Oncioiu et al., 2019; Bag et al., 2020) to capture managers' perceptions on BDA benefits for supply chain performance. CC was also measured using five items based on previous works (e.g., Cao et al., 2017; Jiang, 2019) to explore benefits of CC for supply chain performance. Five items were adopted from de Vass et al. (2018) to measure supply chain performance. These items cover supply chain flexibility, costs of supply chain management and goods, sales per employee, and cash cycle time.

3.3 Research theoretical model

The theoretical model as shown in Fig. 1 displays three links between smart innovative solutions and supply chain performance as presented in terms of three hypotheses (H1, H2, and H3). Smart innovative solutions are presented in the model by Internet-of-Things, Big Data Analytics, and Cloud Computing.

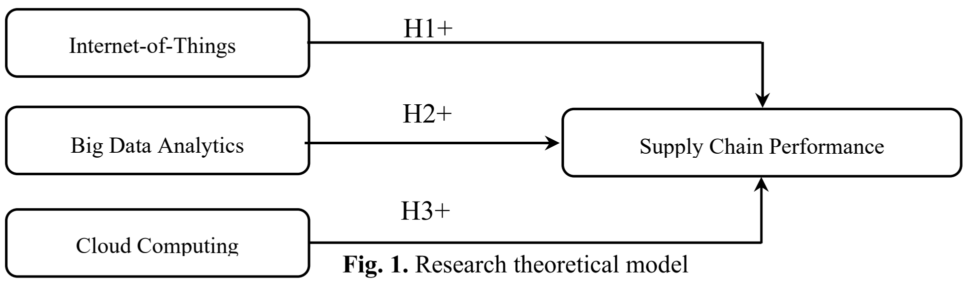

Fig. 1. Research theoretical model

3.4 Validity and reliability

Validity was measured using convergent and discriminant validity (). Factor loadings and the average variance extracted (AVE) was used for measuring convergent validity and the square roots of AVE values were utilized to assess discriminant validity. factor loadings should be higher than 0.70 (Chang et al., 2016; Mohammad, 2020; Boudlaie et al., 2022; Mukhlis et al., 2022), AVE values should be greater than 0.50 and the square roots of the AVE values should be higher than the correlation of each variable with the remaining variables (Mandal et al., 2016; Shee et al., 2018). Cronbach's alpha coefficients and composite reliability (CR) should also exceed 0.70 (Kircaburun et al., 2021).

Table 1
Results of validity and reliability

Variables	Items	Convergent validity		Discriminant validity				Reliability	
		FL	AVE	IoT	BDA	CC	SCP	α	CR
Internet-of-Things (IoT)	IOT1	0.874	0.750	**0.866**				0.916	0.937
	LOT2	0.923							
	LOT3	0.861							
	LOT4	0.832							
	LOT5	0.836							
Big data analytics (BDA)	BDA1	0.936	0.817	0.655	**0.904**			0.944	0.957
	BDA2	0.905							
	BDA3	0.922							
	BDA4	0.894							
	BDA5	0.859							
Cloud computing (CC)	CC1	0.897	0.720	0.650	0.591	**0.848**		0.902	0.928
	CC2	0.853							
	CC3	0.866							
	CC4	0.815							
	CC5	0.808							
Supply chain performance (SCP)	SCP1	0.844	0.745	0.563	0.535	0.558	**0.863**	0.915	0.936
	SCP2	0.878							
	SCP3	0.829							
	SCP4	0.877							
	SCP5	0.886							

FL: Factor Loadings; AVE: Average Variance Extracted; Cronbach's alpha coefficients; CR: composite reliability.
Inner values of Variance Inflation Factors (VIF): IoT = 2.153, BDA = 1.910, and CC = 1.889.
Model fit statistics: SRMR (0.062) < 0.08, NFI (0.874) is close to 1.

Referring to the results of validity and reliability in Table 1, it was noted that the minimum requirements of the measurements validity and reliability are guaranteed. Factor loadings (FL) of IoT (0.832-0.926), BDA (0.859-0.936), CC (0.808-0.897) and SCP (0.829-0.886) are higher than 0.70. AVE values of IoT (0.764), BDA (0.817), CC (0.720), and SCP (0.745) are greater than

0.50. All square roots of AVE values of IoT (0.874), BDA (0.904), CC (0.848), and SCP (0.863) are higher than correlations with other related variables. These results represent the indicators of convergent and discriminant validity. Cronbach's coefficients of IoT (0.923), BDA (0.944), CC (0.902), and SCP (0.915) are above the average of 0.70, and CR values of IoT (0.942), BDA (0.957), CC (0.928), and SCP (0.936) are above 0.70. Table 1 shows that the current data is free of collinearity problems as the values of the variance inflation factor (VIF) are less than 2. As well, the structural model fits the present data well as SRMR value is smaller than 0.08 and NFI value is close to 1.

4. Results and discussion

The results of hypothesis testing using SmartPLS3.0 software as shown in Figure 2 indicate that the smart innovative solutions (IoT, BDA, and CC) are significantly and positively related to supply chain performance. These results were reached based on the results of T-statistics, which were 2.211, 2.354, and 3.008 for IoT, BDA, and CC, respectively. In order to illustrate the path coefficients of IoT, BDA, and CC on supply chain performance, Figure 3 was elucidated. Fig. 2 shows that the highest t-value (3.008) was for CC, followed by a t-value of (2.354) for BDA, and a t-value of (2.211) for IoT. On the other hand, Fig. 3 shows that the path coefficient of CC (0.272) is higher than the path coefficient of IoT (0.248), which is greater than the path coefficient of BDA (0.211). A summary of these results can be seen in Table 2. Basically, the results confirm that the three hypotheses (H1, H2, and H3) that suggested in this study are supported by the current data, which was collected from managers of supply chains in a number of industrial firms.

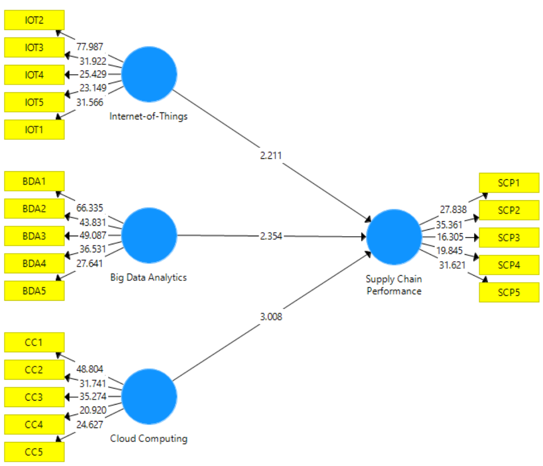

Fig. 2. T-statistics of IoT, BDA, and CC

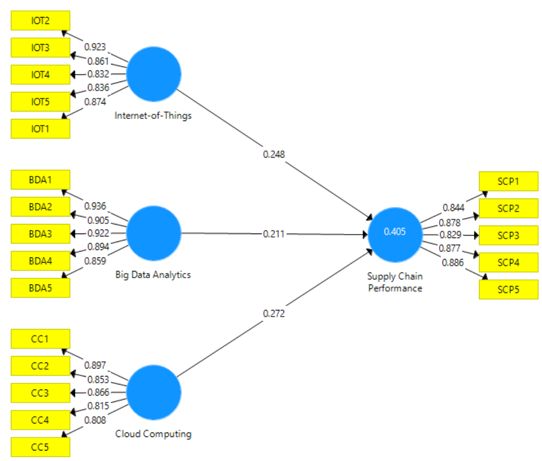

Fig. 3. Path coefficients of IoT, BDA, and CC

Table 2

Results of hypotheses testing

	Research variables			β-value	t-value	p-value	Results
H_1	IoT	→	SCP	0.248	2.211	0.027	Supported
H_2	BDA	→	SCP	0.211	2.354	0.019	Supported
H_3	CC	→	SCP	0.272	3.008	0.003	Supported

In fact, similar results were found by previous works. De Vass et al. (2018)reported a significant and positive impact of IoT on supply chain performance, Bag et al. (2020) revealed a significant and positive impact of BDA on supply chain performance, in addition, Cao et al. (2017) and Kochan et al. (2018) pointed out a similar impact of CC on supply chain performance.

5. Implications, conclusion and future research directions

5.1 Research implications

The study contributes to the literature supply chain performance through providing new insights about smart technologies that can be used to improve such as construction. By the current results, researchers are provided a piece of information about the impacts of three key smart solutions, which are Internet-of-Things, Big Data Analytics, and Cloud Computing, on supply chain performance. This study empirically investigated the simultaneous impacts of these solutions on supply chain performance and, therefore, lessened a research gap in this regard. Supply chain performance in developing countries still below the desired levels (Aeknarajindawat, 2019), therefore, this study sought to provide firms with smart solutions that can guide their supply chain performance to an advanced level if adequately implemented. The results of this study are drawn by the perspectives of supply chain manners, which means that these solutions are required to lift supply chain performance. However, researchers and firms are required to study how industrial firms can apply these smart solutions and gain benefits from their potential impacts.

5.2 Conclusion

It was concluded that smart innovative solutions such as Internet-of-Things, Big Data Analytics, and Cloud Computing are promising enablers of supply chain performance of industrial firms due to their various potential impacts that can achieved using these smart solutions such as improved supply chain flexibility and integration, enhanced supply chain visibility, effective supply chain tracking, timely supply chain decisions, faster rates of delivery, and enhanced customized products.

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