The Impact of Internet of Things on Supply Chain Performance

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Abstract

Internet of Things (IoT) is a worldwide platform that creates a connected network between physical objects and devices through internet to be located, identified, and controlled. Nowadays, IoT plays a vital role in supply chain management. However, IoT shed the light for the academic researchers, there was a clear gap in exploring and investigating the impact of IoT on supply chain performance particularly in developing countries. Therefore, this exploratory study tries to fill this gap by investigating the impact of IoT on supply chain performance through semi-structured interviews on a sample of 9 companies located in Egypt. The purpose of the semi-structured interviews would be to identify the impact of IoT on the supply chain performance metrics of the chosen companies and examine the extent to which the advantages of IoT are extended to their supply chains. Purposive sampling was applied as the companies chosen would be involved in using technologies in managing their supply chains flows and operations. The findings showed that IoT would have a positive impact on supply chain performance metrics of the selected sample, with exception of very few measures that shown as no change. At the end of the study, recommendation for future work is determined.

Keywords
Internet of Things (IoT), supply chain management and supply chain performance.

1. INTRODUCTION

Supply chain organizations in the present global environment operate in a market that is increasingly complexity, and sharp competition environment was created due to the global markets. Supply chain comprises of suppliers, producers, retailers, wholesalers, distributors, and end customers. The stated partners need to be synchronized to create a balance between demand and supply (Manavalan and Jayakrishna, 2019). Moreover, to become more competitive and achieve preferred objectives of partners (Abdel-Basse et al., 2019). Supply chain management (SCM) means having the correct item in the correct volume at the correct time at the correct place for the correct price in the correct condition to the correct customer (Wu et al., 2016). Traditional supply chains are becoming more costly, complex, and vulnerable. To overcome these challenges; managing supply chain effectively is a must.

The Information Technology (IT) nowadays, plays a vital role to manage the supply chain effectively (Ross, 2002). More than ever before, information technology (IT) is permeating the supply chain at every point, transforming the way exchange-related activities are performed (Palmer and Griffith, 1998).One of most important development of IT is the Internet of Things (IoT) (Abdel-Basse et al., 2019). IoT is supposed to strengthen the supply chain integration by connecting the objects through Internet (Ping et al., 2011 and Tu, 2018 as cited in De Vass et al., 2018). The word was first coined in 1999 by Kevin Ashton, co-founder and executive director of the Auto-ID Center at MIT, for companies such as CISCO, the IoT was born in 2009, when more devices than people were connected to the Internet (Sembroiz et al., 2018).

The purpose of this paper is to investigates the impact of IoT on supply chain management performance metrics to determine whether its advantages are truly extended to benefit the supply chain partners. This paper has been prorated in a total of five sections. Section 1 of the paper is the introductory phase which shed the lights on IoT, along with the reasons of motivation for applying it to SCM. Section 2 the literature on IoT and its impact on and benefits to SCM. Section 3 is explaining the methodology of data collection via semi-structured interviews and then showing the analysis techniques. Section 4 the discussions are presented. Finally, the study concludes with a summary and limitations of the study.

2. LITERATURE REVIEW

2.1 Overview about Internet of Things

As mentioned earlier IoT was first coined in 1999 by Kevin Ashton, co-founder and executive director of the Auto-ID Center at MIT. The IoT is the next generation of internet-connected embedded ICT systems to integrate supply chain and logistics processes seamlessly in a digital environment (Naser, 2019). IoT creates a connected network between physical objects and devices through internet. IoT facilitates things to be located, identified, and controlled via global platform. This allows organizations to real-time manage, organize, and monitor their supply chains. Moreover, enhance the capability of organizations to integrate with suppliers, customers, and internal-organizational processes (De Vass et al., 2018). In addition, Lu and Weng (2018) stated that IoT are used to gather data and monitor actions through the production environment aiming to solve business problems and improve customer services. Moreover, Manavalan and Jayakrishna (2019) have defined (IoT) as: *"Technology which is intuitive, robust and scalable that enables digital transformation of the connected world through internet and communicates all the relevant information in real time across the value chain"*.

In order to achieve the innovation of IoT wireless technologies as said before, information and communication technologies (ICT) applications are required to be adopted by organizations. These applications are like enterprise resource planning (ERP), barcode, email, RFID, and warehouse management systems (WMS). The mentioned applications are helpful to collect and share data in a network of organizations on real-time basis via internet connectivity. Therefore, the usage of IoT facilitates bridging the gap between physical and digital world through synchronizing the information flow with the physical flow. Moreover, IoT has evolved from the innovations of wireless technologies sensors and internet that connects the network systems and devices wirelessly like RFID technology, which provides solutions and functions to develop the operation, supply chain, manufacturing and logistics industries (Manavalan and Jayakrishna, 2019).

2.2 IoT and SCM:

- *IoT role in SCM*

According to the well-known book by Chopra and Meindl (2010), SCM is the management of all the supply chain assets and flows (financial, information, and product/materials) and should have as a main goal the maximization of the supply chain surplus, the overall value generated. However, supply chain not only connects suppliers, manufacturers, and customers, but also connects several layers in upstream side and end users who are benefited from the value of product or services in downstream side. This means, that the entire supply chain network should be economically managed and integrated to reach optimum productivity (Manavalan and Jayakrishna, 2019). IoT provides a new environment for supply chain practitioners as it links machines, products, people, and supply chain managers (Banker , 2014, DeGroote et al., 2013 and Eddy, 2014 cited in Li, B. and Li, Y., 2017). IoT technology has allowed supply chain traceability with complete information that traditional technology could not be achieved (Zhou and Piramuthu, 2015). Additionally, it fosters more efficient and effective supply chain management through enabling process integration and information communication (Li, B. and Li, Y., 2017).

- *IoT benefits SCM:*

IoT gives several benefits to SCM, as many authors mentioned that in their studies, such as Aich et al. (2019) stated that the benefits of implementing IoT in managing supply chains are as follows: Information continuity and traceability, Information accessibility, Link between Information flow and material flow, and Decrease in the code of conduct violation and fraud. According to Evtodieva et al. (2020) numerous benefits conducted while applying IoT

in managing SC; Predictive analytics for Demand Forecasting, Warehouse automatization and this will decrease the huge costs related to it, Chatbots in Procurement which will reduce cost of transactions and sales cycle time by replacing humans in the procurement processes, Intelligent transportation systems, Revealing a real-time information about cargo location provide possibility to monitor and manage incoming and inside facility flows through "Location Tracking", and Sensitive goods monitoring. Furthermore, Gunawardena et al. (2018) stated that the IoT as an enabler for suppliers, customers, and internal integration will provide Sharing information with vendors who use IoT technology and this can improve understanding the joint planning, forecasting and partnerships. Moreover, Mostafa et al. (2019) illustrated a diagram showing all the functions in supply chain that gain benefits while applying IoT, as shown in Figure 1.

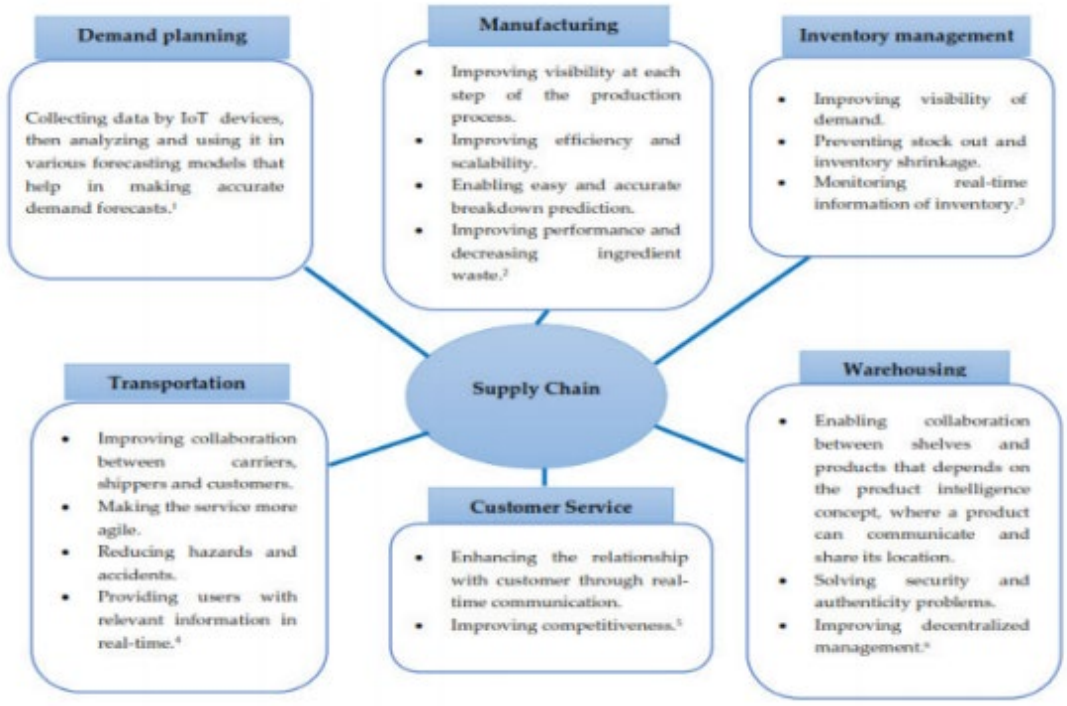

Figure 1. Benefits of using IoT in SCM functions. Mostafa et al. (2019)

- *IoT impacts SC Performance:*

However, IoT has a major impact on supply chain performance as the Supply chain information systems based on IoT are capable to coordinate and integrate internal and external activities of enterprises (Cui, 2015). Although, supply chain performance management is an essential function in effective supply chain management, scholars have acknowledged the impact of IoT on supply chain performance, as shown in Table 1 in a chronological order.

Table 1: Articles related to the impact of IoT on supply chain performance.

Year	Author(s)	Brief about the articles' aims
2015	Chen	This paper simulated complex system by linked physical and digital objects with relationships while enhancing decision-making performance efficiency for green inventory management.
2017	Rezaei et al.	The author purposed of this paper is to develop an Internet of Things (IoT)-based framework for supply chain (SC) performance measurement and real-time decision alignment
	Zhang et al.	A conceptual model was established for the IoT-enabled perishable food supply chain with two-echelon supply hubs. The performance of supply chain has improved when implementing the proposed model, as is demonstrated by a case study.

2018	Dweekat and Al-Aomar	his paper presents a framework that integrates IoT as a real-time data capturing technology with business process modeling concepts (based on the SCOR model) to develop a computerized real-time DSCPM system to improve supply chain performance.
	De Vass et al.	They investigated the ground reality of IoT use in Australian retailers to drive their supply chain performance.
	Gunawardena et al.	this study investigates the use of IoT in enhancing the integration of suppliers, customers and internal activities of the retail supply chain to improve supply chain performance.
2019	Naser	The author examined the adoption of IoT in the supply chain environment and its reflection on the supply and company performance
	Mostafa et al.	He presented a proposed framework to implement the IoT in warehousing management, which can help in providing real-time visibility of everything in the warehouse, increasing speed and efficiency, and preventing inventory shortage and counterfeiting, this proposal gives an effective roadmap for enterprises to improve their warehouses by using the Internet of Things.
2020	Kaya	The author developed a conceptual framework for predicting the advantage of the Industrial Internet of Things (IIoT) on supply chain performance.
	Mastos et al.	They provided evidence of the impact of an IoT solution on the sustainable supply chain management (SSCM) performance, through conducting a case study from a scrap metal producer that operates in the lift industry and a waste management company is presented, in order to illustrate how the deployment of a state-of-the-art industry 4.0 solution has the potential to improve sustainability both in the firm level and in the supply chain level
	Ljung and Capadrutt	They investigated the role IoT-technologies have in enabling supply chain visibility and connectivity, and the impact on supply chain performance
	He and Gu	The authors intended in their study to reveal the acting principle of the IoT and its implications for big-data analytics on the supply chain operational performance

After reviewing such literatures that related to the impact of IoT on supply chain performance, the researchers of this study concluded that there are few studies addressed such topic, as well as there is no previous study referred to investigating the impact of IoT on supply chain performance metrics in developing countries. As a result, this paper will fill the gap by investigating impact of IoT on supply chain performance metrics in developing countries through semi-structured interviews with different experts in the industrial field in Egypt.

3. RESEARCH METHODOLOGY

As stated before, there was an apparent lack of research of how IoT impacts the supply chain performance metrics in developing countries. Therefore, the researchers of this research try to fill the gap through conducting an exploratory study using semi-structured interviews on a sample of 9 companies from different sectors. Purposive sampling is applied as the companies chosen would be involved in tracking their products via technologies. The interviewees' profiles are displayed in Table 2. The purpose of the semi-structured interviews would be to identify the impact of IoT on the supply chain performance metrics of the chosen companies. The interviews were conducted via emails, and their schedule had 5 questions in addition to using Gunasekaran et al.'s (2004) "Supply Chain Performance Metrics Framework" which outlines thirty two measures divided into three main categories i.e. strategic, operational and tactical, in order to ask the interviewees about the impact of IoT on each of these measures.

Table 2: Summary profiles of the interviewees:

Code	Job Title	Years of Experience	Main business
A	Purchasing Section Head	9	Food Industry
B	Supply Chain Specialist	12	Fast-Moving Consuming Goods (FMCGs)

C	Procurement Manager	20	Pharmaceutical Industry
D	CRM team-leader	3	Logistics services
E	Procurement Specialist	5	Textiles Industry
F	Logistics Supervisor	15	FMCGs
G	Retail Banker	7	Banking sector
H	Engineer	4	Commercial Sector
I	Marketing Department Manager	15	Maritime Transport

4. STUDY FINDINGS

4.1 Basic information on the companies

The first part of the interview focused about the interviews job positions, for how long they are having experience in the related fields and understanding the main business of the companies they are employing at. The interviews were conducted with 9 employees in 9 different companies, which are divided into "6 companies" in manufacturing sector and "3 companies" in service sector, as shown in Table 2. However that this study focus about the role if IoT as a technology in supply chain management, it was necessary to ask the interviewees about whether they are using any kind of technology to manage their products' flow along their supply chains. All of them stated that they are using technology in their supply chains for managing and tracking their flow of product as shown in Table 3.

Table 3: Technologies used by interviewees' companies for tracking their products along supply chains.

Code	Technology
A	SAP ERP
B	ORACLE Supply Chain ERP
C	RFID
D	Oracle ERP international System
E	RFID, Bar codes
F	Tracklick software
G	Online banking
H	GCEW system
I	Navis and CATOS systems

It had been showed that all the interviewees are currently using different types of technologies in order to track the products and manage the flow of their supply chains. At the end of this part, the interviewees were asked whether they have the potential to implement the IoT in their operations and supply chain management and all of them were extraordinarily welcomed about the idea.

4.2 The impact of IoT on Supply Chain Performance

To investigate the potential impact of implementing IoT technology on the interviewees' supply chains, the researchers used the supply chain performance metrics framework by Gunasekaran et al. (2004) to reveal the change on performance whether positive, negative or no change. The performance metrics are divided into three main categories: strategic, tactical, and operational. Table 4 shows the impact of implementing IoT on the supply chain performance metrics of the selected sample of companies.

Table 4: The Supply Chain Performance Metrics Framework

Level	Performance Metric	Impact		
		Positive	Negative	No Change
Strategic	Level of customer perceived value of product	6		3
	Variances against budget	5		4
	Order lead time	9		
	Information processing cost	9		
	Net profit Vs productivity ratio	5		4
	Total cycle time	9		
	Total cash flow time	7		2
	Product development cycle time	5		4
	Range of products and services	7		2
	Flexibility of service system to meet customer needs	7		2
	Effectiveness of enterprise distribution planning	9		
Tactical	Customer query time	9		
	Accuracy of forecasting techniques	9		
	Planning process cycle time	9		
	Order entry methods	9		
	Human resource productivity	8		1
	Supplier delivery performance	9		
	Supplier lead time against industry norm	9		
	Supplier pricing against market	2		7
	Efficiency of purchase order cycle time	9		
	Efficiency of cash flow method	5		4
	Percentage of defects	5		4
	Cost per operation hour	9		
	Capacity utilization	9		
	Utilization of economic order quantity	9		
	Effectiveness of delivery invoice methods	9		
	Percentage of finished goods in transit	9		
Operational	Quality of delivered goods	9		
	On time delivery of goods	9		
	Percentage of urgent deliveries	9		
	Information richness in carrying out delivery	9		
	Delivery reliability performance	9		

The previous table clearly shows the impact of implementing IoT on the sample companies chosen is either positive or negative or no change. Regarding the strategic level, the majority of supply chain performance measures were almost positively impacted by implementing IoT, except few interviewees stated that few of such measures wouldn't be affect.

Concerning the tactical level, also it had been showed that most of the supply chain measures are positively impacted by implementing IoT, except few of them with no change choice such as "Supplier pricing against market", as the price considered as internal decision by the suppliers according to different aspects and the nature of the product itself. Moreover, some of the interviewees stated that few of the measures will not be change while implementing the IoT, such as "Efficiency of cash flow method" and "Percentage of defects". Finally, as regards for the operational level all the interviewees stated all of the supply chain measures will be positively affected. As a result, it can be concluded that IoT will positively affect the supply chain performance and it will be necessary to be followed and implemented by organizations to gain its numerous advantages.

5. CONCLUSION AND FUTURE WORK

The effect of IoT on supply chain performance becomes essential in today's academic research. However, evocative evidence to explain the role of IoT in and its impact on supply chain performance is vital to be investigated. Nevertheless, academic literature was found to have an outstanding gap in research that addressed the impact of IoT on companies' supply chain performance measures – particularly within developing countries and this research was an attempt to fill this gap. Through findings of this study using the semi-structured interviews, all the interviewees spoke positively about the outcomes of IoT deployment in their companies to improve supply chain performance for their strategically, technically, and operationally levels.

Further research would be recommended to further investigate the drivers and barriers of implementing the IoT along the supply chains and operations in developing countries.

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