Evaluation of Internet of Things (IoT) and its Impacts on Global Supply Chains

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***Abstract*— The research study aims to examine and evaluate the impacts of Internet of Things (IoT) on Global Supply Chain environments. The Internet of Things (IoT) phenomenon, being a part of a digital revolution, is currently considered as a quite profitable factor for the industries and the markets worldwide. Adopting and incorporating the latest technologies, increases competitiveness and develops new ways of communication. The IoT pervades and revolutionizes supply chain sector, influencing its management and way of structure. It is proposed that its impact on Supply Chain Management (SCM) is strong and instrumental, promising profits and innovations. The IoT systems are used more by many companies worldwide, which enjoy their benefits: delivery service improvement, financial profits, cost reducing, wastage minimization, equipment monitoring, preventing and retailers and consumer's alleviation. Although, the researchers are at the preliminary stages of the research study, this paper aims to adopt an in-depth secondary data collection method through conducting a critical literature review within the field. Through investigative understanding, the researchers aim to adopt a detailed case study approach through service based supply chain providers using a mixed research method. The outcomes and findings will further be analyzed to examine the proposed knowledge framework developed within the research. Even though there is a positive approach for the IoT expansibility dominating the public view, there are still some problems and key challenges that should be taken into consideration. The IoT complicated nature brings to light privacy, security and cost issues that should be faced and solved. However, considering its immature face, time will bring opportunities for problem solving and further development.**

Keywords*— *internet of things (IoT), global supply chains, supply chain management, digital supply chain, and service improvement.

I. INTRODUCTION

The article's main purpose is to focus on the impact of the Internet of Things (IoT) on Supply Chain Management (SCM), including definitions, information and examples about its role, its potential benefits and challenges that are faced or even may be faced in the future. To begin with, studies refers to a product, technical, organizational and technological innovation that most businesses tend to implement, taking into consideration the customer's demands about delivery service and product reliability and availability [1]. The advent of the so called Internet of Things (IoT) has implied a chance for supply chain management and logistics development and reinforcement. The fourth industrial revolution "Industry 4.0" concept is already expressed through Big Data and the IoT evolution, which encourage the area of performance, improving customer service. Studies in a company white paper suggested that by 2020 there will be almost 50 billion devices and applications connected, fact which highlights its dominating tendency and temper [2].

Research studies highlights that IoT offers massive opportunities for organisations on developing an understanding on the ways how customers use their products. This allows them to further understand and develop knowledge about their customers, while maintaining better knowledge about their customers and balance the scope of product and service linkages within the competitive marketplace. More recently, due to the developments and wider usage of technology advancements, IoT has been receiving wider interests within organisations to develop more service oriented and consumer focussed business strategies to achieve the value proposition for its consumers [3]. It is hard to imagine to develop a service offering or fulfil consumer expectations without fully understanding the scope of needs required by consumers. Hence, the adoption and that of its linkage with consumer is of paramount importance when it relates to the expectations and requirements of products and services. Likewise, organisations may determine better levels of consumer requirements by linking their key operations closer with the end user in the market. In doing so, it will further enable them to address the flexibility of positioning themselves closer to their consumer markets. In instances, some of the companies may be able to implement such strategies, however it may not be possible for all organisations to facilitate this and may have to depend upon third party companies to enable this provision [3]. This research study focusses on developing the understanding of Internet of Things (IoT) and its wider impacts on companies within the supply chain environments. The authors aim to investigate through current and focussed literature in this context that will allow further investigations using qualitative methods such as that of case study research on examining the advantages of this, both within larger organisations that of smaller companies. The wider interpretation of the concepts and findings through case study will be combined with that of the initial findings of literature presented within this paper. This allows the researchers to strengthen the objectives of their research and address the gaps derived through the literature findings through an appropriate framework to develop the linkages.

II. LITERATURE REVIEW

The literature review presented within this paper examines early views of the important investigations and developments within the areas of internet of things within the context of supply chains environments. The section allows for basic understanding of the context of IoT which is important from the key objective of our research study. The literature review will firstly examine a generic overview of internet of things (IoT) and how this differs from the wider developments of Industry 4.0 or the fourth industrial revolution. There is vast discussions in research and commercial environments towards the advancement of technology and that of wider implementation of technological platforms within many industries, including that of manufacturing and the whole supply chain environment. Hence, the paper then examines the relationship aspects of IoT to that of supply chain management (IoT-SCM). The unprecedented shift in technology has shaped and changed the competitive landscape, including the expectation and nature of consumer demands and that of value propositions for organisation's products and service offerings. Thirdly, the study aims to investigate some examples on IoT adoption and implementations. One of the most recent challenge faced by many organisations is that towards addressing the falling costs and the overall capacity and functionalities of newer technologies, and hence companies are adopting higher information contents within their products and processes [3]. Finally, the study explores some of the future challenges on the implementation of internet of things and its wider fulfilment to achieve an overall value chain propositions for consumers.

A. Overview of Internet of Things (IoT)

The term of the Internet of Things was first used in 1999 by Kevin Ashton on a research project at the Massachusetts Institute of Technology's AutoID lab, relating to the communication of physical objects and products through the internet. It has contributed to further practice in Supply Chain Management, since it is capable of reducing risks, costs and time, combining web-based, things–based and semantic-based elements [4]. The main characteristics are the following [1]:

- **Context:** information provision by the objects regarding to local, atmospheric or physical conditions.
- **Omnipresence:** current objects are about to communicate on a large scale.
- **Optimization:** it is presented as an expression of the object functionality.

Numerous devices are connected to the IoT, fact that proves the emerging IoT phenomenon to be promising and dominating in many fields, offering new business opportunities. Research studies also inspired by the well – known Western Union's story and its lessons to the industry world, approaches the "Internet of Everything" or "Internet of Connected Objects" (ICO) as a socio – technical phenomenon [5]. It is believed that it can influence positively existing companies, markets and the entrepreneurs to embrace innovative ideas that it offers. IoT is a network which interacts with different types of environment. The *physical* environment includes human and non - human objects linked through a wireless network which furthers their communication. The *technological* environment consists of software, hardware, technologies, data and special platforms that help objects' interactions in the physical one. A broader socioeconomic perspective includes many factors and players such as business leaders, technical or legal requirements and associations which protect consumer's privacy, who is the main target by the entrepreneurs through the IoT use, being also the most significant element in the socioeconomic environment [5]. In the IoT ecosystem there are various users, services, devices, objects and applications taking part. Each of them play an important role, since they are interconnected. Examining its main form, it has emerged from Wireless Sensor Network (WSN) and Radio Frequency Identification (RFID) technologies, which draw the communication line and network infrastructure. It includes sensors which gather device data, algorithms, cloud interface and communication interfaces (APIs) [6]. Conceptual frames and depictions of the IoT system based on qualitative and quantitative research data, show its role in industrial business relations. IoT technologies and activities encourage machine efficiency improvement, buyer – seller relationship and maintenance cost saving, through data sharing [7]. Moreover, the Industrial Internet of Things (IIoT), which is closely related to production – technical changes, tends to influence business models (BM) that most established manufacturing corporations are based on. It incorporates Information and Communication Technology (ICT) trends, suggesting smart and self – controlling products. Employees' controller role undertaking, familiarization with problem solving, customer target, collaboration and networking service are factors which contribute significantly to the IIoT context [8]. This article examines the IoT impact on Supply Chain Management, based on a survey of related published papers, presenting its role in different cases, providing examples. It also focuses on its benefits and challenges or concerns that may arise.

B. IoT Relationship with Supply Chain Management

This section aims to provide the key linkage and that towards the relationship of IoT with supply chain management. To better understand and develop a wider view of different concepts that supports the development of various industries, it is very important to provide the reader with the different aspects of relationship linking the both together. Hence, it is very important not only to derive and present the real scope of this research paper in terms of the focus towards how IoT impacts global supply chains, but also other important concepts that are not possible to be addressed within this study, however are important to the wider context as there are some similarities between IoT and Supply Chain and are often considered to be linked together. The focus on industrial and supply chain context of the research findings presented within this paper starts with the initial research led by Germany and classified as the 4th Gen Industrial Revolution (I4.0 or Industry 4.0). Studies classed this as "software embedded intelligence is integrated in industrial products and systems [3, 9]. Before we address the relationship between IoT and that of Supply Chain, it is important to present the starting point of this relationship, as that of IoT and Industry 4.0. Much often, both of these concepts are jointly discussed as

IoT can be defined as a subset of industry 4.0 due to fact that IoT based solutions are often applied to environments (smart industry environment), and smart industries are often then discussed as industry 4.0 [10]. Similarly, the wider linkages and goals of industry 4.0 are achieved through the integration of IoT and cyber physical systems. Previous studies highlights towards the possibility of the integration of machines with wider systems within the environment to allow for the transformation of machines and systems in self-aware and self-learning entities [11, 12, 3]. This is achieved through big data environments supported by cloud computing where the key focus is towards machine-generated or industrial focussed rather than the traditional human generated data [13]. Hence, this research paper focusses more towards the exploration and development of understanding towards IoT and its wider impacts towards supply chain environments.

As already mentioned, RFID technology with passive and active tags depending on the environment, is considered to be instrumental for The IoT operation through microchips that allow information to be transformed and unite physical objects as they perform and "decide". Humans enter the IoT network via laptops, tablets, smart – phones and other wearable devices. Furthermore, RFID transponders can also be used for animals [5]. According to Gartner press release (2016), there are 10 unique IoT technologies: IoT security, IoT analytics, IoT processors, IoT platforms, IoT standards or ecosystems, IoT operating systems, IoT event stream processing, IoT wide - area networks, IoT short – range networks and IoT device management [14]. Current technology developments influence supply chain function, having already invited government and industry factors to participate in a new way of approaching. In supply chain field, sensor for captivating data, is already used. For example, Motorola and Ford or many other organizations use Auto – ID data [15]. Moreover, the Digital Information and Communication technology (ICT) has underlined speed importance, material volume growth and elements that develop optical, magnetic, electronic and mechanical abilities for the devices [16]. The IoT arose with the digital data services advent and is supposed to change market potentials. Its penetration has a remarkable impact on supply chain, where supply and demand relationships interact. In SCM field, "the trade – off between efficiency and effectiveness at satisfying consumer's needs may take place at various points in the production cycle and along supply chain, providing also opportunities for mass customization (MC)". Researchers mentions the instrumental contribution of the entrepreneurs in the IoT evolution, using their experience and adding innovative ideas to build new models [17, 5]. Among its benefits are: accuracy, transparency and availability of the information transported, tracking and traceability enhance, innovative management and control, strategic redesign, efficiency and performance upgrade in business sector [15]. Supply Chain's operation can be improved in many ways: cost reduction, service level and responsiveness enhance, effective collaboration. According to what is mentioned above, the companies that decide and take the opportunity to adopt the IoT solutions may enjoy its benefits and support effective supply chains. The IoT pervasiveness may lead to automation in decision making, reduce human intervention, creating a visible supply chain through special applications. Its adoption may produce profits, efficient delivery of products and services, organize production quality and raise competitiveness in business world.

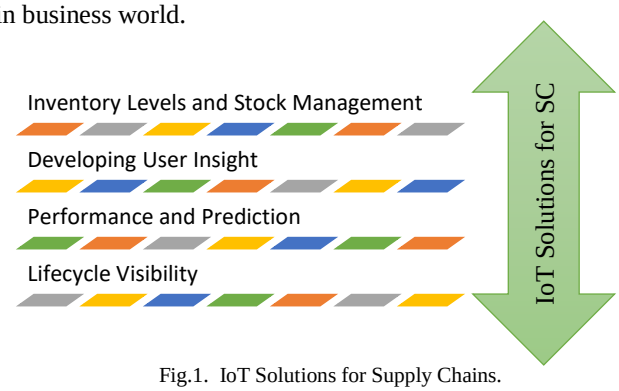

Fig.1. IoT Solutions for Supply Chains.

In SC case, it may encourage optimization of shipments, fast response to changing client needs [18]. One study introduces two types of IoT inspired strategies that enhance customer value from product usage: tailoring platform, in which a provider produces many varieties of tailored products that will be offered to consumers and platform strategy, in which the provider fixes a flexible platform that customers purchase custom – made products [15]. Consequently, apart from the benefits already mentioned, IoT enhances provider and consumer relationships, since the first can improve the desired products and service quality and predict or observe the second's behavior. It is anticipated that the IoT adoption will have a strong impact on the whole society, including business industries, consumers and the academic community, which mainly mentions its benefits and the challenges that may arise. Logistics and retailing procedures have been distinctively augmented, since production and monitor systems or checkouts have complied with the new technologies. IoT applications have pervaded many different domains such as healthcare systems, food industries, insurance, education, manufacturing etc. [4]. Examples of its implementation and effects of its pervasiveness are mentioned at the following section. Figure 1 presents some of the most important IoT solutions that influence and determine SCM.

C. Examples of IoT Adoption and Implementations

As already mentioned, the IoT advent has changed rapidly socio-political, environmental and economic fields in the developing countries. In this section there are some IoT implementation cases chosen related to food industry supply chains, floricultural supply chains and the special case of China, since it is a country with the most developed IoT industry.

Chinese technology companies have adopted and developed the IoT applications rapidly and effectively to a great degree. Government's enterprise in contributing in the IoT evolution is of outmost importance. Its interest is mostly focus on surveillance effectiveness, a fact that does not concern the Chinese consumers. Their tolerance to being monitored, in contrast to the Western people, has been a significant factor for the IoT – enabled devices development. However, due to these facts, consumer's privacy seems to be violated and abused. IoT applications in China are incorporated mostly in traditional (manufacturing, agriculture) or even current (energy sources) industries [17]. Moreover, it illustrates the point that China is supposed to be the most powerful market in the IoT science,

stating that it has introduced the most revolutionary and innovative ideas in the IoT domain in comparison to former technologies (ZTE, Xiaomi case). The IoT's impact on China's industry and market is associated with IPR balance of payments, healthcare delivery, environmental protection improvement, and quality and safety issues in agricultural and food commodities management, efficient handling and productivity increasing. Notably, supply and demand factors related to modernization tendencies, such as economic interests of foreign multinational companies and potential market size, have determined the IoT performance indicators [17]. Distinctive examples of the IoT – related innovations and apps, such as Alibaba, ZTE and Xiaomi, prove China's tendency to constant deployment, not only in comparison with other developing countries, but also with progressive countries of the West.

Food supply chains are mostly considered to be complicated due to their pluralistic character. There are some issues that compose the food supply ecosystems such as: the food distribution channels, the access to water, energy and land resources in general, the crops and farms locations, the environmental conditions and the technological environments [19]. The IoT implementation in a challenging sector as a food supply chain is supposed to be, may have a social impact, apart from costs and inefficiencies reductions. In the IoT and FSC interaction, the items, actors, resources and infrastructures are virtualized [20]. Research illustrates that virtual food supply chains' concept, where network, object, process and control complexities can be handled effectively [21]. Moreover, they present another virtualization approach, the FS space platform architecture, which is defined by the IoT technology. As assumed, it enables plan, optimize and monitor processes. Consequently, the internet technology play a storage role, where there are virtual depictions of things and information linked with the product. FS ecosystem, apart from boundaries (input - output), flows and entities, includes five main network stages: agricultural / production, transport, storage, consumption and waste disposal stage [20]. The IoT tool's main goal is to create a user – friendly environment and enhance the interaction between the FCS and the environment, motivating deciding, learning and planning activities. Considering food waste management, IoT has introduced ways of reducing difficulties that most restaurants and catering companies face. China has already paid attention to Restaurant Food Waste (RFW) management, since the beginning of this decade, developing an IoT – based system, which acted positively for the governments, the public the stakeholders and the catering companies which took part [22].

Similarly, floricultural supply chains belong to those who are virtualized according to the industry's challenges and demands. It is a supply chain type in which supply and demand relationships and levels seem to be unpredictable, due to the product's sustainability, maintenance and decay tendencies and sensitivities. In current floricultural sector, there is a physical product pass through auction houses from international growers to international customers. Physical and well – maintained situation of the commodities raises control, quality, and inspection issues [23]. The IoT perspective, as already known, is related to virtual representations and depiction of the physical products and objects meeting digital world and way of communication and exchange. It is considered to revolutionize and contribute effectively in virtualization process and implementation in supply chain management. Location, time and human involvement, senses and participation in such procedures, are substituted by state – of – the art systems. In accordance with [24], the IoT sector is enhanced by middleware or identification, sensing and communication technologies and accessible applications. As they illustrate, these three main kinds of technologies develop data capture (via RFID or barcoding), sensors which check the products condition and object information exchange between supply chain participants. Growers, producers, auction places, traders, logistic service providers, suppliers of logistic assets and retailers are the main key protagonists in floricultural supply chain, that similarly with food supply chains gets benefit from the IoT implementation [23]. The IoT technology takes virtualized supply chain one step further by making a notable and promising progress.

D. IoT Implementation – Future Challenges

Despite the numerous IoT benefits and advantages offered in the cases mentioned, there are some concerns expressed about challenges and difficulties existing. Privacy and security are considered to be the most burning issues. Security and privacy risks derive from its complexity and constant mobility tendency, combining various data and devices. Moreover, due to its immature nature and functioning, it still incorporates devices with limited connection abilities. Moreover, protection absence leads to violation and adulteration cases, which should be directly and strictly avoided. Referring to data provenance process which mitigates such risks, present some main problems or challenges which conflict the IoT systems implementation [25]. Firstly, data are vulnerable to security violations, fact that may lead confidential and private information to be exposed. Secondly, the IoT systems tend to mix or reuse different components, fact that raises the interoperability at query tools' issue. Thirdly, data should be transformed in different formats and indexed according to the user's search desire. Furthermore, excessive data production should be reduced and controlled, so that negative consequences and resources' depletion to be avoided [25]. Adding to what has been reported, research studies highlight that flexibility of the IoT applications, considering multiple consumers' traffic, should be seriously taken into consideration. As already mentioned at the beginning of this section, privacy and security threats tend to concern public opinion for the IoT. Studying the case of India, have gathered potential challenges to IoT adoption and spread, including privacy and security [26]. In privacy, internet connected devices and products can be infringed and traced, so strict and severe safety measures should be taken. Similarly, security considers taking into consideration the fact that a luge number of devices worldwide are connected in the IoT network, there is a need of protecting personal or confidential information and data. Even though there are billions of devices connected and activated in this internet system, it seems to be costly and slow at financial profits' attributions. Noteworthy is also the fact that skilful and well – trained users, including civilians or workforce, would contribute in overcoming such problems. Current companies and markets should be familiarized with new business models and improve their interior organization. Additionally, "poor internet connectivity" problem raises the need of high

accessibility worldwide, since the IoT technologies have pervaded human's everyday life [26]. Many companies are increasingly stretched towards addressing new ways to compete in global markets to enable them to facilitate the value propositions and value added services within the markets through resources and cost reduction measures. Although, this study has not been focussing on addressing any human or physical resources implications within the organisations, further investigations on the organisational and managerial expectations and that towards its implications can be researched further to increase the overall value within the supply chain environments.

Similarly, although this study only focusses towards addressing the initial understanding of internet of things and its impacts to global supply chains, it should further expand and extend to include other industries including that of manufacturing and service focussed environments. The authors wish to address this with the development of a conceptual framework that aims to provide a detailed overview of how some of these technological advancements, including that of IoT and Industry 4.0 can be utilised towards delivering a service value as well as more generic development and attainment of a competitive advantage. Through the advancements of technology and that of IoT, it presents a unique proposition towards value creation and enhances the facilitation of better customer service. The next section of this paper addresses some of these research gaps in further detail and highlighting the unique proposition towards the challenges and that of the impacts of IoT and its adoption.

III. Research Gaps

This research mainly focusses on the evaluation of internet of things (IoT) concepts and wider impacts on global supply chains. The study aims to address some key founding research gaps identified through literature and that of our findings that will provide companies, adopters and that of other researchers who are considering to develop further understanding of IoT, its advantages and implications and towards its implementations within their environments. This also serves the purpose of future research studies in facilitating the foundations of IoT within the context of its adoption. Some of the early research gaps identified through out investigative study were:

- Value Creation and Competitive Advantage – our study focused towards the adoption of IoT in supply chain context; however future studies should enhance the suitability towards other sectors such as manufacturing, retail and service sectors.
- Investment and Resources – IoT and that of its wider functionalities requires investment and resourcing, not just in terms of the technology, but human and other technical resources;
- Strategic Direction and Objectives – companies should also aim to align the implementation and change as the core aspect of their objectives and direction for future;
- Business Models and Competitive Advantage – with the advancements of IoT, its unique possibilities for value generation and maintaining a competitive advantage, future research studies should focus towards the opportunities for new business models to address this change;
- Organisational Goals – businesses and organisations should clearly assign and develop both short term advantages and long term goals that will benefit the company through the IoT implementation;
- Markets and Global Connection – any IoT implementation should be considered and observed as a continuous change process, both internal and external facing environments of the organisation.

IV. Conclusion And Future Research

The article has focused on the impacts of the IoT on SCM. Firstly, it referred to its main characteristics, the way it appeared in industry and the way it functions and develops. Unquestionably there is an intense conversation about its revolutionary character and penetration in the world's industries and markets' domain. Consequently, its impacts are numerous, since it has pervaded in supply chain's sector imposing changes and new ways of operation. As it is mentioned, the IoT technology, in many cases, which is presented as a socio - economical or socio - technical phenomenon, has acted positively improving provider's and consumer's relationship, reducing excessive costs or human involvement, saving time, increasing and reinforcing control, responsiveness, automation and monitoring procedures. It is also of great interest the fact that there are many entrepreneurs who suggest innovative ideas and do not hesitate to pioneer in the IoT sector, contributing to its development. According to this fact, competitiveness, optimization of transportations and shipments are constantly improving, since there is an interactive relationship between entrepreneurs and the IoT systems. Referring to the three cases chosen as examples of the IoT impact on SC, it is mentioned that Chinese government's opportunities and policies have lead and contributed to the IoT revolution, but on the other hand, cyber – control processes imply its main attempt to monitor the Internet [17]. This case gives birth too many thoughts around human privacy and divides public opinion about tracking and monitoring. In food and floricultural supply chains, due to their complicated character, virtualization process is still at an early stage, fact that highlights the need of expanding the IoT's abilities in SC operations. Finally, despite the positive changes that the IoT has caused, there are some doubts expressed, due to its immature situation. There are accessibility, privacy and security risks that should be mitigated. Researchers also suggested data provenance as a form of solution about trustworthiness and data derive safety [25]. Moreover, future survey should be carried out about ownership and multiple representations management, especially in virtualization cases [23]. There is still a need of further improvement which could be accomplished through investments, new models' developments and researches on different types of industries and participants, so that solutions will be found. However, the fact that the IoT has remarkably

revolutionized SCM, should not be neglected in any case. Future studies should also aim towards the wider acknowledgement of small and medium sized enterprises who have sufficient resources and understanding to develop on IoT implementation. Our study is an early attempt to develop the understanding and that of impacts of IoT on global supply chains that will enable the future development of a framework to provide the clear linkages between the adoption and implementation of IoT within businesses.

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