INTERNET OF THINGS AND ITS IMPACT ON SUPPLY CHAIN EFFICIENCY

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Abstract

The purpose of the present paper - which is conceptual in nature - is to initiate discussion of the need for and feasibility of the measurement of the impact of IOT projects on supply chain efficiency. PESTEL factors relevant to supply chains are discussed, with a focus on the IOT. The main areas of IOT applications in logistics and supply chain operations and management are described. Existing literature in this field is reviewed, and the methods used so far to measure supply chain effectiveness are explained. The paper ends with a proposal for a new methodology for the measurement of the effectiveness of IOT deployments in the supply chain, addressing specific key performance parameters, such as reliability, speed, costs, flexibility, assets and environmental footprint, and levels of the supply chain: assets, operations, processes and business model. The article is not an exhaustive treatment of the subject; instead, it aims at initiating a scientific debate on the possible methods of measuring changes in supply chain effectiveness due to the implementation of IOT solutions. Only the initial stages of research into this topic are presented.

Keywords: Supply chain, IOT, efficiency

INTRODUCTION

The Internet of Things and its applications in logistics and the supply chain are important topics discussed by practitioners and theoreticians alike. The use of IoT throughout the supply chain radically transforms every aspect of supply chain management. It ensures the accessibility of enormous amounts of data and the ability to act on this data in real time. However, no methodology has yet been developed to measure the improvement in supply chain effectiveness due to the deployment of IoT. Scientific goal of this paper is to propose such a methodology, following a discussion of the factors affecting supply chains, the areas in which IoT can be deployed in the supply chain, and the methods of measuring the effectiveness of supply chains.

1. THE IMPACT OF THE MACROENVIRONMENT ON SUPPLY CHAINS

A supply chain does not operate in a vacuum, but rather in a dynamic, constantly changing environment. This environment shapes the structure and operation of the supply chain to a significant degree. According to the PESTEL model, the following groups of factors in the more distant environment of the supply chain can be distinguished: politics, the economy, society, technology, natural environment and regulatory regime. In this classification, the Internet of Things (IoT) is part of technology. However, it is useful to discuss its impact on supply chains in a broader, holistic context.

The influence of politics is the consequence of the interplay of economic interests of various states and alliances to which they belong.Insofar as the **economy** is concerned, the growing role played by Brazil, Russia, India, China, Korea and African countries has significant impact. Supply chains leading to and from these countries will play an increasingly important role. A notable **demographic factor** is the aging of Western European societies. This translates into consumption patterns. Given the growing role of African and Asian consumer markets (which are not affected by this process), the geographical potential of supply chains can be expected to change. Increasing urbanisation is yet another important consideration. Currently, over 50% of the world's population live in cities [2]. For supply chains, this means that the trend has to be factored into models of the distribution of goods. **Technological progress** is another important determinant of supply chains. IoT has the greatest potential to drive progress. The application of IoT technology in logistics is a breakthrough innovation, set to transform the logistics industry radically. When the full potential of IoT is brought into play, logistics data becomes thoroughly transparent and data streams from different sources can be integrated as never before. Better risk management across the supply chain is one of the outcomes of this integration. IoT also created unprecedented opportunities for improvement in asset utilization in the supply chain and the use of environment-friendly solutions. This translates into greater economic and social value for the company and for society as a whole. The **natural environment** has become increasingly important in the development of supply chains. In recent years, many executives managing international businesses have pursued initiatives to reduce the carbon footprint of logistics and supply chain operations. Logistics accounts for approximately 5.5% of greenhouse gases, of which 89% is associated with transport [3]. Businesses try to reduce their consumption of energy from non-renewable sources, as well as their consumption of water, which will become a scarce resource. Measures are also being taken to reduce congestion, particularly in large cities. **Regulation** creates the framework for the operation of supply chains. Regulatory initiatives designed to protect the environment are gaining ground. To give a specific example, in January 2008, the Commission of the European Union adopted a directive requiring EU countries to generate 20% of their energy from renewable sources, and set the minimum share of biofuels at 10% [4].

2. THE INTERNET OF THINGS IN THE SUPPLY CHAIN

The term "Internet of Things" was introduced for the first time in 1999 by Kevin Ashton in a Procter & Gamble (P&G) presentation [5]. The term IoT refers to data-processing devices connected to the global network, capable of communicating with one another without human intervention. Currently, no more than 1% of all physical devices that could be connected to the Internet are in fact connected [6]. It is expected that over the next decade IoT will generate USD 8 trillion in revenues from innovation, better asset management, logistics and supply chain operations, increased productivity of labour and enhanced customer experience. IoT brings benefits to logistics operators, their clients and end users. It helps improve quality and predictability, and drive down costs (including environmental costs). With IoT, it becomes possible not only to monitor assets in supply chains, but also to process enormous amounts of data transmitted by devices connected to the Internet. Proper use of this data helps businesses streamline their legacy logistics operations and processes. The main IoT application areas in the supply chain include: fleet management, vehicle movement, tracking of assets and energy consumption, production monitoring, monitoring of people, equipment and real estate (eg. distribution centres, warehouses), as well as risk management in supply chains. Vehicles are assets that are especially "ripe" for IoT deployment in the supply chain. IoT creates opportunities for improving traffic security and its optimisation. IoT also creates unprecedented opportunities for tracking of traffic, transport conditions and cargo security. It is the latest generation of track-and-trace solutions, which make it possible to track goods meter by meter, second by second. Modern sensors, such as the Smart sensor from DHL, can monitor temperature, humidity, light intensity and unexpected events. IoT technology can also significantly enhance the operation of distribution centres, which are important supply chains links. It creates many opportunities for effective management of the flow of information and products, inventory levels, security of people and equipment, and energy consumption in distribution centres. IoT also helps with optimisation of asset utilisation. With all vehicles and equipment in a distribution centre connected to a central system, their use can be monitored. IoT also enables efficient energy management in a distribution centre. Standard lighting accounts for 70% of energy consumption. With networked heating, ventilation, air conditioning and lighting devices, energy consumption can be controlled in line with demand. This kind of solution helps reduce CO_2 emissions and overhead costs of the distribution centre [7]. Since IoT is so important for the effectiveness of the supply chain, methods for its measurement before and after the implementation of an IoT solution need to be developed.

3. METHODS FOR MEASURING THE EFFICIENCY OF SUPPLY CHAINS

Efficiency is defined as a "positive outcome, effectiveness, efficacy, productivity" [8] and can refer to "the best outcomes of production, distribution, sales and promotion." Efficiency can also mean "the evaluation of outcomes with respect to the purpose and utility of action [9]." International methodological standards include the following measures of the outcomes of innovation: the share of new products in sales, the share in sales of products in the launch phase, the effects of the efforts to promote innovation, and the impact of innovation on the efficient use of factors of production [10]. These indicators cannot be used to evaluate the impact of innovation on the supply chain. Indicators measuring the impact of innovation on the general operation of an enterprise are also used. Supply chain efficiency measurement requires comprehensive indicators, reflecting the performance of entire supply chains, rather than their individual elements. Dimensions of efficiency, such as quality, costs and time, are commonly employed in studying supply chains [11]. Authors of the A.T. Kearney report entitled "Insight to Impact" distinguished traditional and "new" efficiency categories. They listed the following traditional categories of efficiency: quality, time and operating costs. To this list they added new supply chain efficiency categories, the result of interactions between the traditional categories. These include: responsiveness, leanness and agility, that is, the speed with which the system, supported by the intelligent use of information, is able to attain the optimal cost structure [12]. Two approaches to the measurement of the efficiency of supply chains are dominant in the literature: the Balanced Scorecard adapted to the needs of supply chains, and SCOR [13]. The application of the Balanced Scorecard approach to the evaluation of supply chain performance has been proposed by P. C. Brewer and T. W. Speh [14] and by H. J. Bullinger et al [15]. The indicators relate to four Scorecard perspectives and three levels of the supply chain, namely, operations, processes and the supply chain. However, analysis of the literature has shown that most of the indicators constructed in this way relate to logistics internal to the organization, while ignoring the achievements of the entire supply chain [16]. The SCOR (*Supply Chain Operations Reference*) model consists in comparing standard supply chain processes with the best practices established on the basis of the experience of SCC companies. SCOR was developed to analyse supply chains and enable the participants (manufacturers, suppliers, distributors and retailers) to assess their efficiency and to introduce improvements in the flow of goods, labour and information SCOR is based on six distinct management processes: Plan, Source, Make, Deliver, Return, and Enable. Supply chain performance measures can be built on the basic SCOR processes. A. Gunasekaran and others have created supply chain performance indicators by considering the processes of planning, purchasing (supply), production and delivery on the operating, tactical and strategic levels of the supply chain [17].

The SCOR model uses a supply chain strategic matrix to identify the strategic features of a given supply chain [18]. Within this matrix, two perspectives can be distinguished: the client's perspective and the internal perspective of the supply chain. The matrix helps determine the current and target states for each performance attribute (property) of the supply chain. It is considered normal that a supply chain can achieve top scores only for some performance attributes. These should be the attributes that are most important from the perspective of the given supply chain.

Most publications on supply chains focus either on the dimension of innovation, or on the dimension of efficiency. There is a dearth of studies combining the two perspectives. The exception is the work of J. Trienkenes and collaborators [19]. The authors of this study have developed an innovation-efficiency matrix. It contains the main innovation and efficiency categories for a fruit supply chain. The innovation categories (product, process, marketing and organizational innovation) are based on Eurostat and OECD data. Efficiency categories for the fruit supply chain - efficiency, responsiveness, quality and agility - are based on research done by other authors. Efficiency indicators depend on the specific nature of a given industry, company, client or key success factors. Because of the diversity of conditions affecting the supply chain, the choice of the key success factor depends on the specific supply chain and its unique features.

4. PROPOSAL OF A METHODOLOGY FOR THE MEASUREMENT OF THE EFFICIENCY OF IOT DEPLOYMENTS IN THE SUPPLY CHAIN

It seems that the best way to measure the efficiency of IoT deployments in the supply chain is to use the effectiveness of innovation in the supply chain measurement matrix, described by the author in earlier studies. This method can be used to measure the efficiency of a supply chain both before and after IoT deployment, which can give an insight into the growth of supply chain effectiveness after such a deployment. The presented matrix is the result of literature review discussed above. The matrix features key performance parameters, such as reliability, speed, costs, flexibility, assets and ecology (environmental footprint), and levels of the supply chain: resources, operations, processes and business model. The matrix is illustrated by **Figure 1**.

The matrix gives the possibility of measuring efficiency performance for each supply chain level combined with each key performance parameter. Performance indicators for each supply chain level combined with each key performance parameter have to be defined according to supply chain character, sector, and goals to be achieved by a given supply chain.

Examples of performance indicators are given in **Table 1**.Once the indicators of the efficiency of innovation for supply chains operating in a given industry have been determined, one can measure the efficiency of IoT deployments in the supply chain. The first step is to collect the necessary data, and enter it in the supply chain innovation effectiveness matrix. Two matrices should be generated. One should contain "input" data, reflecting the situation before the deployment of IoT, and the other should contain "output" data, reflecting the situation after the deployment of IoT in the supply chain under study.

		CRITERION of EFFICIENCY	SUPPLY CHAIN MANAGEMENT LEVEL: Resources / Operations / Processes / Buissnes model
Efficiency perspective	CLIENT'S	RELIABILITY	Performance of the supply chain (on the levels of resources, operations, processes and the business model) in delivering: the right product to the right destination at the right time in the right condition and packaging, in the required amount, with the required documentation, to the right customer
		SPEED	The speed with which the supply chain delivers (on the levels of resources, operations, processes and the business model) products to customers
		AGILITY	The agility with which the supply chain (on the levels of resources, operations, processes and the business model) responds to changes in the marketplace, so as to maintain or gain competitive advantage
	INTERNAL	COSTS	The costs associated with the operation of the supply chain (on the levels of resources, operations, processes and the business model)
		ASSETS	The efficiency of the organization in managing fixed assets and working capital (on the levels of resources, operations, processes and the business model) in order to meet demand
	THE ENVIRONMENT	ECOLOGY	The ecological footprint of the supply chain (on the levels of resources, operations, processes and the business model)

Figure 1 Effectiveness measurement matrix
Source: original research based on: [18] [19] [20].

Table 1 Examples of indicators of the efficiency of IoT deployment in the supply chain

	Criterion of efficiency					
Supply chain management level level	Reliability	Speed	Agility	Costs	Assets	Ecology
Resources (eg. human resources, IT, means of transport, means of production)	- number of human errors - number of breakdowns of means of transport - number of breakdowns of means of production	- time needed to allocate resources for non-routine operations (reaction time)	- number of situations in which resources were used flexibly to meet market demand (eg. how many times additional means of transport / production were deployed) at the request of a client	- resource costs (eg. labour, energy, man-hours, machinery, etc.)	- return on assets tied up in resources	- energy consumption associated with resources - fuel consumption associated with resources - water consumption associated with resources - emissions of harmful substances associated with resources
Operations (eg. loading and unloading of goods)	- number of operations executed flawlessly and on time (eg. loading and unloading of goods)	- time needed to complete an operation (eg. loading and unloading of goods, - number of operations executed on time	- number of occasions when operations were customized to meet market demand (eg. number of additional loading / unloading operations executed on client request)	- cost of operation (eg. loading / unloading of goods)	- return on assets tied up in the operation	- energy consumption due to operations - fuel consumption due to operations - water consumption due to operations - emissions of harmful substances due to operations
Processes procurement production delivery returns	- number of orders filled flawlessly (without mistakes and on time)	- time required by the process - number of orders (supply, production) completed on time	- number of occasions when the process responded flexibly to market demand	- *COGS* - supply chain management costs	- rate of return on fixed assets tied up in the supply chain during a given period - rate of return on working capital - cash-cash cycle length	- energy consumption due to processes - fuel consumption due to processes - water consumption due to processes - emissions of harmful substances due to processes
Business model	- reliability of response throughout the supply chain (from design to sales)	- promptness of response throughout the supply chain (from design to sales)	- ability to accommodate customer requests throughout the supply chain (from design to sales)	- costs generated by the model in the logistics flow layer throughout the supply chain (from design to sales)	- rate of return on fixed assets tied up throughout the supply chain (from design to sales) - rate of return on working capital throughout the supply chain - cash-cash cycle length throughout the supply chain	- resource consumption and emissions of harmful substances throughout the supply chain (from design to sales)

Source: [21]

CONCLUSIONS

The methodology presented in this article can be used to measure the efficiency of a supply chain before and after IoT deployment. The measurement takes into account such parameters as reliability, speed, costs, agility, resources and ecology (environmental footprint), and levels of the supply chain: assets, operations, processes and business model. Though this is a conceptual paper, and no research has been done yet to prove the usefulness of the proposed measures, it is hoped that it will stimulate a scientific debate of the question whether the availability of a common methodology would ensure comparability of data within an industry, as well as between industries, taking into account their distinguishing characteristics, and whether, based on the above data, it will be possible to develop a set of best practices for the the implementation of IoT in the supply chain.

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