UNDERSTANDING THE CONCEPT OF SMART SUPPLY CHAIN

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Abstract

In today's uncertain and turbulent markets, the most modern supply chains worldwide ensure real-time information exchange between partners. One could observe technological evolution that enables high level of information sharing based on smart devices and smart systems. The challenge today is to create and manage smart supply chain - supply chain full of new technologies that make possible processes automation, inventory tracking, real-time monitoring and that enable interaction between supply chain members, clients and also between the technologies themselves. Furthermore, smart means supply chain which is intelligent and capable to make some decisions without human involvement.

The purpose of this paper is to understand a new and relatively undefined concept of smart supply chain which development is natural consequence of supply chains adaptation to technological development. The paper presents existing perspectives relating to smart supply chain in order to make an attempt to identify smart supply chain characteristics, stages of its development as well as to analyse impact of Industry 4.0 on supply chain structure and features.

Keywords: Smart supply chain, Intenet of Things, Industry 4.0, Logistic 4.0, adaptive supply chain, trust

1. INTRODUCTION

Supply chain form organisations that are involved in moving products and services typically from suppliers to end customers. Between entities complex flows of materials, money and information could be identified. Today's supply chains are global, extensive, constantly changing and therefore more vulnerable and difficult to manage than ever before. The number of transnational companies, spread geographically, involving more and more companies and introducing new products with shortened life cycle is still increasing [1].

One of the trends that modern supply chains must cope with is Industry Revolution 4.0. Typical for 4th Industrial Revolution are automation and data exchange on a large scale, cyber-physical systems (CPS), Internet of Things (IoT) or cloud computing. Revolution 4.0 was initially introduced into manufacturing but also created new challenges and intensive need of changes in functioning of traditional supply chains. Industry 4.0. is defined even as "a new level of organization and control over the entire value chain of the life cycle of products" [2].

The purpose of this paper is to understand a new, relatively undefined concept of smart supply chain which development is natural consequence of supply chains adaptation to technological development. The paper is based on a literature review. The analysis included relevant journal articles available in the EBSCO, Elsevier and Emerald databases. In the study articles containing terms "supply chain" and "smart" or "IoT", "Industry 4.0" and "Logistic 4.0" in titles, keywords or abstracts were selected. The literature review was then extended on some paper included in references of articles selected at first step.

The research was conducted to integrate existing perspectives relating to smart supply chain in order to make an attempt to identify smart supply chain characteristics, stages of its development as well as to analyse impact of Industry 4.0 on supply chain structure and features.

2. SMART SUPPLY CHAIN - MAIN CHARACTERISTICS

Smart supply chain (SSC) is relatively undefined concept. Some authors define is as modern interconnected business system which extends from separated, local, and single-company applications to wide and systematic implementations in supply chain [3, 4].

In literature better identified are smart supply chain attributes. Butner [1] argues that smart supply chains that are: instrumented, interconnected and intelligent. According to Wu *et al.* [3] smart supply chain has six characteristics - it is instrumented, interconnected, intelligent, automated, integrated and innovative. Smart supply chain is also described using three features namely: connection, collaboration and customization [5].

Smart supply chain is *interconnected* because all entities, assets, IT systems, products are connected [3] and because it is characterised by "unprecedented levels of interaction with customers, suppliers, and IT systems in general, but also among objects that are monitoring or even flowing through the supply chain" [1]. Smart supply chain is characterised by usage of various and advanced Information and Communication Technologies (ICT) (or Information, Communication, and Production Technologies if emphasizing connection to manufacturing environment [5]) to improve the flow of information between different objects, IT systems and enterprises. ICT are of fundamental significance for information and knowledge interchange at both organizational and supply-chain levels. Interconnectivity enables data collection and real-time communication across all supply chain stages, intelligent decision making, and efficient and responsive processes to better serve customers - "more information, better decision, better process, even better product would be what smart supply chain can and should produce" [3].

SSC it is combination of the physical and digital world. It refers to the combination of using cyber-physical systems (CPS) and smart products and services. Cyber-physical system is „physical and engineered system, that operations can be monitored, coordinated, controlled and integrated by a computing and communication system"; it includes: sensors, actuators, control processing units, and communication devices [6]. Embedded computers and networks monitor and control physical processes where physical processes affect computation and vice-versa [7]. Cyber-physical systems enable increasing control, transparency and efficiency of the production process [7] and facilitates the connection between machines and human-beings creating possibilities to be flexible and react to the changes of customer demand [8]. An integral part of CPS is Internet of Things (IoT) - "set of physical devices (machines, products etc.) connected through network with capability of exchanging information about themselves and surroundings" [9]. Smart supply chain one could called *automated* because of process flows being automated [3] and *intelligent* - making large-scale decisions relating to the perspective of whole supply chain [4] and especially capable of learning and making some decisions by itself, without human involvement as well as to predict future scenarios [1]. K. Butner argues that today's supply chains must become a lot smarter to deal effectively with risk and meet business objectives [1].

Smart Supply Chain Management is based on the use of data obtained from production lines, warehouses logistic centers. To collect, store and analyse the information in real time, IoT technologies, Radio Frequency Identification (RFID), sensors, indicators, Global Positioning Systems (GPS) are essential. Even data from social media can be analysed [10]. Dynamic processing of large amounts of data in real time is Big Data Analytics. In the IoT context, attention is paid to the enormous possibilities of using mobile technologies, mobile devices and related services. Other meaningful Logistics 4.0 technologies, applied especially in warehousing and transport, are e.g: wearables (smart watches, glasses), augmented reality applications, or autonomous vehicles (drones) [11]. Smart supply chain "full of sensors, RFID tags, meters, GPSs, and other devices and systems" [1] and with "information being machine-generated" [3] is *instrumented*.

Smart supply chain is based on integration of smart factories and value chains. Customers and supply chain partners can be connected and communicate through information systems. New solutions are based on a cloud-based system [12] - platform for resource sharing and collaboration [4], accessible regardless of the location. Communication affects mutual understanding, conflict resolution, increasing trust and influence

development of relationships [13]. According to Li and Lin [14], information exchange facilitates the coordination and integration of processes within the supply chain and improvement of the results of the entire supply chain. Therefore, smart supply chain could be described as more *integrated* (based on integration of processes and supply chain partners collaboration), and in consequence more *innovative* - developing new innovative solutions, meeting new requirements [3].

The main purpose of smart supply chain management is to satisfy individual customer needs and deliver individualized products in the most efficient way. Processing huge amounts of data, better controlling of production and logistic operations by the demand reported by the customer will result in creating value through constantly introducing new products and services to the market [8], as well as introducing products designed according to the wishes of the individual customer. The feature of smart supply chain, however, is not only customization - it is *mass individualization*. Mass individualization is when customers are „involved in designing the options of their product to fit their exact individual needs and desires" differently to mass customization when manufacturer offers to customers optional product choices (customer feel as if designing the product but are only selecting some options) [15].

To sum up smart supply chain are: interconnected, automated, intelligent, instrumented, integrated, innovative and concentrated on individual client's needs.

3. STAGES OF SMART SUPPLY CHAIN DEVELOPMENT

Understanding of the smart supply chain concept requires identification of the steps of its development.

Generally smart supply chain is defined as modern interconnected business system which extends from separated, local, and single-company applications to wide and systematic implementations in supply chain [3, 4]. Consequently as main stages of SSC development could be identified [4]: early phase (with local implementation of some smart applications); intermediate phase (with the implementation of some isolated system for example an intelligent factory or service); and advanced phase (characterized by the implementation of smart solutions integrating processes in whole supply chain).

Basic elements for smart supply chain development are: Big Data implementation including IoT infrastructure, adequate information system, advanced analytics, data mining and business intelligence, process automation and improvement, supply chain collaboration, supply chain integration, process and product innovations [3], so smart supply chain is based on modern technologies, knowledge sharing and real collaboration between entities. Crucial element contributing to supply chain members cooperation is trust. It leads to better communication and affects the supply chains performance [16-17]. Smart supply chains should be featured not only by high level of trust between supply chain members but also between information systems and information technologies. New issue worth considering in SSC is technology trust. It is required as human-human relationships are replaced with human-technology relationships [18]. Supply chains will be more integrated and even greater will be the scope of the data exchanged. IoT market value in the world in 2025 will reach the level of 4 to 11 trillion of USD [McKinsey Global Institute Report, 2015] Designing, implementation and improvement of smart supply chain is neither an easy nor a short-term process. It requires a comprehensive strategy oriented to identifying the resources of the chain in terms of their interoperability, and then implementing smart applications for their optimal use [19]. Successful supply chains must view information as strategic asset [20].

SSC is characterised by unlimited possibilities of effective and efficient information management overwhelming human perception and possibilities. Smart supply chain:

- automatically balances supply and demand based on historical forecasts and predictive algorithms [21];
- fast and intelligently adapts to internal and externally generated disturbances [22];
- and automatically optimises production of goods and services [11].

However, in the future smart supply chain will be more intelligent- more digital, self-managed [12] capable to solve problems, able to adapt to new conditions and tasks, modifying behaviour, and self-learning. Smart supply chains structures will be more dynamic and temporary [12]. Thanks to the use of 3D printing and possibility to printing product by consumer, supply chains will shrink, turn local and the number of entities engaged in the process of creating value of products will be reduced [23].

Consequently, it could be identified:

1) Initial phase - with local applications such as e-sourcing or RFID tags implementation;
2) Early phase - with the implementation of isolated system for example an intelligent factory or service;
3) Intermediate phase - characterized by the implementation of smart solutions integrating processes in whole supply chain [3] (integrated, based on high scope of the data exchange and high level of trust);
4) Advanced phase - characterized by digitality, dynamicness and temporariness, with ability to adapt to the needs of the market and resources used.

The volume and size of information gathered and analysed will be even greater as the consequence of possibility to connect to any network: big transnational companies, small local supplies, as well as power grids and even the least accessible transport systems [24].

4. SMART SUPPLY CHAIN ADVANTAGES

Next step to smart supply chain understanding was identification of its advantages.

First of all smart supply chain is characterized by better access to information and acquisition of information with better quality (defined as accuracy, availability, timeliness, internal connectivity, external connectivity, completeness, relevance, accessibility, and frequency of information updating [25]). Information management within the supply chain is crucial to supply-chain success, and it is one of the biggest areas that need constant improvement [26]. All devices and sensors enable the obtaining of large amount data (big data) that can be used to increase the supply chain effectiveness and efficiency. Big Data could be described by 4V formula - it is high volume (a lot of data is being gathered), high velocity (speed of data generation and processing is increasing), high variety (different sources and formats of data being collected) and high value data (significance of data is tremendous) [27].

The use of different possibilities of data gathering and processing in smart supply chains enable products tracking, prediction of eventual anomalies during production, gathering and analysing data about demand, stock and sales. Real-time monitoring, improvement of data accuracy and provided unprecedented visibility lead to better inventory management: level reduction, prevent stock outs, and avoid excess stocks [3, 4]. Real-time tracking of trucks and people leads to accurate and timely delivery, lower transport cost and increase safety and security of supply chain. It is possible to record data about the location and condition of transported goods, plan optimal route and schedules of deliveries or automatically analyse data about emissions and fuel consumption. Simulations - thanks to mapping of the real world in virtual models will be used more extensively [28]. Logistics 4.0 solutions are also recommended for the most complicated and often previously not analysed problems like avoidance of empty miles and empty container management [29]. Complete information increases also level of transparency - information could be available for all supply chain members.

Among the benefits can also be mentioned great impact of smart supply chains on customer satisfaction. The tendency is to change business models from the push to pull, from “we sell what we have“ to "we produce what we sell”. However, implementations of IoT solutions are now used in this both kinds of supply chains [30]. Production of individualized products supports using 3D printers [12]. It is known that e.g. today’s customers expect omnichannel delivery - possibility to choose favourable channel and delivery method [5] but in identification of new trends in client’s behaviour, their needs, data collected from social media may help.

Transparency and higher levels of visibility are pointed as main features of smart supply chain [1, 4, 8]. The visibility especially relates to inventories and possibility to monitor its levels anytime and from anywhere in the chain. Better visibility of demand could influence enhancement of decision making and improve supply chain responsiveness. Smart supply chains are also called resilient - adapting to strategies and operations to changes in the environment to reduce the risk of activity [1]. Barreto *et al.* specify their dynamic reconfigurability and design towards achieving lean, agile, resilient and green character [6]. Other relevant benefits are increased flexibility [22], quality standards, efficiency and productivity [8].

Concluding, smart supply chains are characterised mainly by visibility, velocity, versatility and responsiveness (3V+R formula) [26]. Supply chains outstanding in the 3V+R characteristics are adaptive supply chains (having the features of flexible, responsive and resilient).

The barriers of smart supply chain implementation are fear of change, insufficient skills and knowledge or immature technologies [29]. Employment in Industry 4.0 will increase [17], but the role of employees is expected to change - they will have more responsibility [4]. It is anticipated that digitalization will not replace humans in their works, because always involvement of people in controlling of the processes will be needed [6].

5. CONCLUSIONS

One of the biggest issues in today's uncertain and turbulent environment is ensurement of real-time information exchange between supply chain partners. For improvement of the flow of information between different objects, IT systems and enterprises, advanced Information and Communication Technologies implementation are fundamental. The challenge today is to create and manage smart supply chain - supply chain full of new technologies that make possible processes automation, inventory tracking, real-time monitoring and that enable interaction between supply chain members, clients and also between the technologies themselves. The most important technologies are CPS, IoT, Big Data and smart manufacturing.

In the paper the concept of smart supply chain was describe. First its main attributes were analysed. According to the research smart supply chain is: interconnected, automated, intelligent, instrumented, integrated, innovative and concentrated on individual client's needs. Then four stages of SSC development were introduced. Last stage was presented as characterized by digitality, dynamics and temporariness, as well as ability to adapt to the individual needs of the client. Generaly, smart supply chains could be defined as intelligent, dynamic and adaptive networks based on cyber-physical systems (CPS) and Internet of Things (IoT), integrating manufacturing and logistics systems, characterized by abilities: to quickly respond to the changing demand; make optimal use of resources; collect, process and use of information; and build temporary and dynamic cooperation networks.

Smart supply chain is characterized by better access to information of better quality. The use of different possibilities of data gathering and processing in smart supply chains enable improvement of data accuracy and provided unprecedented visibility and transparency of data for all supply chain members. Smart supply chains characterised mainly by visibility, velocity, versatility and responsiveness (3V+R formula) could be described as adaptive supply chains.

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