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Enterprise information systems and cloud computing for supply chain digital transformation

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ABSTRACT*: This paper explores and analyzes the importance and the role of enterprise information systems, such as Enterprise Resource Planning Systems (ERP), Warehouse Management Systems (WMS) and Transportation Management Systems (TMS), for the digital transformation of the supply chain, as well as the role of cloud computing as one of the core Industry 4.0 technologies. The findings of our review highlight the impact of Industry 4.0 on core supply chain activities and the subsequent transformation to Supply Chain 4.0.*

KEYWORDS *–Enterprise Information Systems, Cloud Computing, Supply Chain, Digital Transformation*

I. INTRODUCTION

In recent years, organizational and technological challenges, together with disruptive innovations in Information and Communication Technologies (ICT) have drastically changed the nature and structure of the supply chains and integration with suppliers, partners and customers [1].The most recent industrial revolution is Industry 4.0, which alludes to a better approach for working, imparting and relating, in view of the availability given by the execution of the Internet and the utilization of data via the automatic collection and handling of information. Automation, digitization, decentralization, virtualization, real-time information capture and processing, and real-time communication are all characteristics of Industry 4.0 [2].

The primary goal of Industry 4.0 is the rise of digital manufacturing, often known as the "smart" factory, which entails intelligent networking, mobility, flexibility of industrial processes and interoperability, integration with customers and suppliers, and the adoption of novel business models. Intelligent networks based on cyber-physical systems are the distinguishing feature of the fourth industrial revolution [3]. At the same time, other core Industry 4.0 technologies, such as cloud computing, combined with new models of enterprise information systems are transforming supply chains and business ecosystems, thus influencing management strategies to adapt in this evolving environment [4]. Although Industry 4.0 is a prominent topic among academics and practitioners, its application and impact on supply chain management is still an issue that needs further exploration [5].

The aim of this paper is to analyze the importance of Industry 4.0 in the transformation of supply chains and to explore the role of enterprise information systems and cloud computing as a key driver for success in the digital age.

II. INDUSTRY 4.0

The term Industry 4.0 (I4.0) was introduced in 2011 during the Hannover Fair, in the context of a program run by the German government to promote industry digitalization. In the following years, according to Liao et al. [6], several countries started similar initiatives (“Smart Manufacturing” in USA, “La Nouvelle France Industrielle” in France, “Future of Manufacturing” in UK, “Innovation in Manufacturing 3.0: in South Korea, “Made in China 2025” in China, “Super Smart Society” in Japan etc.). At the same time, large and multinational companies created consortiums and started investing in I4.0 projects, indicating that the leading industrial powers and stakeholders consider this new industrial period as strategic [3], while academia also contributed to the discussion and analysis of the topic through conferences, publications and research projects [6]. It should be noted though, that although the discussion about the concepts and the issues concerning I4.0 adoption and impact is still open, there are scattered academic efforts and initiatives towards Industry 5.0, the fifth industrial revolution that focuses on societal goals, prosperity, resilience, sustainability and human-centric development [7].

The German Academy of Science and Engineering defined I4.0as the technical integration of human-machine interactions via Cyber Physical Systems (CPS) and the usage of the Internet of Things (IoT) in industrial operations [8].In the following years it has been described in a variety of ways by several authors, but it generally refers to the promotion of interconnection and computerization in the traditional industry, enabled

by the recent rapid improvements in technology. In other words, I4.0 is about connecting people, components and systems in order to provide self-guided, dynamic, real-time value-added linkages across the value chain [9]. According to Ghadge et al. [4], the core I4.0 technologies are big data analytics, autonomous robots, cloud computing, simulation, industrial internet of things, additive manufacturing, augmented reality, business intelligence and cyber security.

Moreover, the objectives of I4.0 are to offer mass IT-enabled customization of manufactured goods, automatic and flexible adaptation of the production chain, tracking of parts and products, facilitation of communication between parts, products and machines, application of human-machine interaction paradigms, IoT-enabled production optimization in smart factories, and provision of new services and business models of interaction in the value chain [10].

III. SUPPLY CHAIN DIGITAL TRANSFORMATION

Supply chain encompasses a set of cooperating partners (suppliers and/or manufacturers of raw materials, semi-finished and finished products, distributors, wholesalers and retailers) that work together in order to produce, transform, provide and deliver final products or services to end consumers [11].

According to Tjahjono et al. [12], there are four interconnected supply chain levers: from move to sell, to buy, and to store. Procurement is a big part of the "purchase" lever. The business lever is in charge of all the operations and tasks involved in acquiring services or items from vendors. The term "make" refers to the creation of commodities or services and specifies the procedures for converting inputs into outputs or end products. Due to shorter product life cycles and demand fluctuation, store functions or warehouse operations, notably inventory management, have evolved in recent decades. The term "move" refers to the logistics of distributing and transporting goods from one location to another at the appropriate time. The "sell" or fulfillment process ensures that the orders are delivered on-time. Depending on their reliability and on-time delivery, this supply chain function might create a big difference between firms. Gaining market share and keeping current clients are possible with proper order fulfillment management.

Organizations need a digital supply chain built on visibility, sustainability and enhanced customer experiences in order to overcome the difficulties of volatility and uncertainty. In other words, supply chain transparency reduces process complexity by increasing the visibility of upstream and downstream supply chain operations [13]. Organizations must apply and live the idea of supply chain management to enhance their supply chain surplus and expand their competitive advantage [14].

In order to establish a modern supply chain, Industry 4.0 is expected to impact significantly supply chains, business models and operations. In the context of supply chain management, researchers refer to Industry 4.0 as the digital supply network (DSN), E-Supply Chain, Supply Chain 4.0, E-logistics, or Logistics 4.0 [15].

The supply chain benefits from I4.0 in a variety of ways. The goals of Industry 4.0 are to shorten the time it takes to supply products to clients, decrease the time it takes to respond to an unexpected event, and prompt a significant improvement in decision-making quality [3]. Moreover, I4.0 can help firms manage complex and dynamic processes in their supply chain, as well as large-scale manufacturing and customer integration. Lastly, I4.0 can potentially improve sales, operations planning and logistics [15].

As mentioned in Garay-Rondero et al. [16] the most relevant definitions of Digital Supply Chain include: i) an intelligent, value-driven network that leverages new approaches with technology and analytics to create new forms of revenue and business value through a centric platform that captures and maximizes the utilization of real-time information emerging from a variety of sources, and ii) an intelligent best-fit technological system that is based on the capability of massive data disposal and excellent cooperation and communication for digital hardware, software, and networks to support and synchronize interaction between organizations by making services more valuable, accessible, and affordable with consistent, agile and effective outcomes.

The fundamental I4.0 enablers and characteristics are transforming the core of supply chains and especially procurement, production and distribution [1]. However, it is vital to note that dealing with the digital transformation of supply chains entails more than merely digitizing all knowledge and information flows. As a result, it is critical to emphasize that the entire structure and all processes, managerial components, and chain flows are changing due to emerging and customized markets that require quick reactions [16]. On the other hand, issues such as lack of digital harmonization or lack of standards, lack of skilled personnel, lack of skilled management teams and lack of data security and protection, are factors that influence the process of digital transformation of the supply chain and should be considered and managed appropriately [17].

IV. ENTERPRISE SYSTEMS AND CLOUD COMPUTING

Supply Chain 4.0 requires, among others, systems and technologies that may improve organization's flexibility and adaptability to market changes, as well as responsiveness to the demands of customers. Enterprise

resource planning systems (ERPs), warehouse management systems (WMS) and transportation management systems (TPS) are systems on which an efficient and robust Supply Chain 4.0 must rely and utilize, according to Barreto et al. [3]. Moreover, logistics management, database administration, and demand forecasting and planning are the primary areas where cloud computing can be used effectively. Assimilation of cloud computing would encourage supply chain members to work together as it would improve resource and information sharing. It would also improve the adaptability to variations in demand [13].

Implementing the Supply Chain 4.0 paradigm will significantly change how warehouses operate today [3]. According to Zekhnini et al. [13], with the use of Industry 4.0 technologies such as Cloud Computing and Internet of Things (IoT), supply chain management becomes more effective and efficient, with lower operating costs, higher inventory accuracy, more effective product tracking, less waste processes and increased warehouse productivity [18].

Specifically, deploying "smart" management through the right adoption and implementation of Warehouse Management Systems (WMS) will turn warehouse activities into future inbound logistics requirements. Transports can communicate their location and expected arrival time to an intelligent warehouse management system, which will choose and prepare a docking space, optimizing just-in-time and just-in-sequence delivery. The Radio Frequency Identification (RFID) sensors will simultaneously reveal what has been delivered and relay the track-and-trace data to the supply chain. The WMS will assign storage space based on the delivery details and request the appropriate equipment to move the goods to the correct location on its own. Once pallets have been moved to their specific places, tags will transmit signals to the WMS, providing real-time visibility into inventory levels and potentially preventing costly out-of-stock situations, as well as enhancing management decision-making capabilities for any necessary adjustments to improve clients' service levels [3]. Eventually, IoT can help to improve product quality, service quality, customer experience, and security [13].

A transportation management system (TMS) is a component of supply chain management (SCM). A TMS allows an order management system (OMS) to communicate with a distribution center (DC) or a warehouse. With the widespread adoption of IoT and the inevitable transition to Industry 4.0, a TMS system is unquestionably an integral component of the Logistics 4.0 concept. To improve the efficiency and efficacy of a logistics process, Logistics 4.0 employs real-time and online data. A TMS system allows a corporation to properly employ GPS technology to locate its vehicles on the road, monitor freight movement, negotiate with carriers, consolidate shipments, and communicate with Intelligent Transportation Systems (ITS). Cloud-based TMS is becoming a trend, as cloud services and cloud computing become more widely available. Most software companies are rapidly migrating their TMS solutions to the cloud, substantially lowering the number of on-premise installations in their clients. TMS are reshaping business strategy because they provide superior end-to-end supply chain visibility to businesses that are using them, and also boost the upper end of Return on Investment (ROI) with the rising use of mobile devices and services. TMS solutions also include smartphone apps that drivers can use to get a "breadcrumb" view of where particular trucks are at any given time [3].

An Enterprise Resource Planning system (ERP) is an information system which aims at the integration of all resources in a company or organization and consists of a set of modules running on a singular database and accessed through a common interface. Each module supports a business function, such as finance and accounting, material resource planning, production management, in ventory management, human resource management, customer relationship management etc. [19]. The next generation of ERP systems is Cloud ERP [20], which is the provision and use of an ERP system through cloud computing. This is performed mainly under the public cloud deployment model and the Software-as-a-Service (SaaS) service model, where everything is stored, operated and maintained at the provider’s data center and the ERP is used as a service through the internet and a web browser, without the need of on-premise installations [21]. The growing importance of cloud systems and services is highlighted by the report of Statista, which estimates that the worldwide market for public cloud application services/software as a service (SaaS) end-user spending will rise from 31.4 billion U.S. dollars in 2015 to 232.3 billion U.S. dollars in 2024 [22]. At the same time, enterprise spending on cloud services is rapidly growing, while spending on data center hardware and software is constantly decreasing [22]. The share of on-premise enterprise software is also declining compared to cloud-based enterprise software: the proportion of 70% on-premise and 30% cloud-based in 2016, will eventually come up to 38% on-premise and 62% cloud-based in 2027 [23].

The main benefits of cloud ERP are lower operating costs, rapid implementation, scalability, focus on core competencies, use of advanced technology, rapid updated and upgrades, improved accessibility, mobility and usability, improved system availability and disaster recovery etc. [21]. At the same time, there are challenges that have to be considered, such as security, performance, compliance and strategic risks, customization and integration limitations, loss of IT competencies and issues concerning the cooperation with the cloud service provider [21].

V. CONCLUSION

The fourth industrial revolution – Industry 4.0 and its disruptive technologies has started to transform not only companies and organizations, but also entire supply chains. In this digitally-enabled business environment, the role of enterprise information systems such as EPR, WMS and TMS, supported by cloud computing and provided to companies in the form of software-as-a-service, is vital, not only for the improvement of internal processes, but also (and mainly) for the integration of all processes and activities through the supply chain.

Further research may include empirical studies about the adoption and implementation of new forms of enterprise systems (such as cloud ERP) and Industry 4.0 technologies in small and medium enterprises, both in national and in international context, as well as the impact of these systems and technologies on supply chain and organizational performance.

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