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Reasons for Upgrading to Supply Chain 4.0

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ABSTRACT: Supply Chain (SC) 4.0 can offer many benefits and optimization to Supply chain Management (SCM). In this literature review paper, the motives of implementing SC 4.0 are identified as: Increase the overall SC efficiency and productivity, while reducing waste among the processes; Provide higher accuracy and agility in the fields of forecasting and planning; increase the flexibility of the supply chain and enable the hour-glass SCM; Eliminate any possible delay and human interaction for intermediate links and steps within SCM such as ordering refill, updating paces for production flow, invoicing, etc; Reduce manpower input along the supply chain and make it possible for the human-free SCM with high standardization and customer satisfaction; Reduce both system and human errors along the supply chain, as well as the risk for human safety; Reduce lead times and increase customer service levels by moving production closer to consumers, shortening the supply chain; Increase customization options, with reduced costs of changeover, better forecasting and reduced inventory; Move up the value chain, from offering a product to offering a service.

Keywords: Supply chain 4.0, Industry 4.0, Logistics 4.0, Supply chain management, Motives, Digitalization.

Abbreviations: SC, supply chain; SCM, Supply chain management; BDA, Big Data Analytics; IoT, Internet of Things; AM, Additive manufacturing; CAD, Computer Aided Design; AR, Augmented reality.

I. INTRODUCTION

Industry 4.0, which is considered as the fourth industrial revolution, promotes many industries and sectors of business with its related emerging technologies and innovative concepts. With the focus of connectivity, automatization, and digitalization towards operations and optimization, the future blueprints of those industries and sectors seem to be promising and revolutionary. In the supply chain sector, supply chain (SC) 4.0 represents applying Industry 4.0 innovations and technologies such as the Internet of Things, advanced robotics, big data analytics, additive manufacturing, etc. into the supply chain management segment to improve the operational and business performance with promoted customer satisfaction [1].

Currently many studies towards this topic are undergoing and have attracted much attention. Bukova, Brumercikova, Cerna & Drozdziel [2], suggested in their paper The Position of Industry 4.0 in the Worldwide Logistics Chains that SC 4.0 will add proper autonomy to processes in the supply chain and supply chain management 4.0 will address the balance and boundary between autonomous processes and human planning. Decision making will be more data driven, more data demanding and decisions will be made faster and within an increasingly flexible supply chain. Amarala, Barretoa, & Pereiraa [3], stressed the importance of technical components in SC 4.0. Software, sensors and robots are envisioned in the factory and warehouse floor. Autonomous vehicles perform short hauls between vertically integrated supply chain partners. The integration and interaction of these technical systems will shape and determine best practices within the supply chain 4.0. However, those positive outcomes are just one tip of the iceberg, and with large potentials, SC 4.0 is believed to contribute more to the industries and optimize the overall structure of different supply chain scenarios.

According to Frederico, Garza-Reyes, Anosike, & Kumar [4] and their analysis of reviewed material, there is no clear consensus on what dimensions of supply chain management are encompassed by SC 4.0. However, disruptive technologies are mentioned as a dimension of SC 4.0 in almost all of the literature under review in their paper. The authors concluded that there seems to be consensus among the research community that disruptive technologies play an important role in the SC 4.0 concept. In this report, firstly in section 2 an analysis of the most common related technologies to SC 4.0 will be listed out with a focus on their positive impacts on SCM. Secondly, an introduction of the smart factory will be presented as one of the vivid examples of SC 4.0 in the future which demonstrates the collaborating utilization of the technologies. Last but not least, the conclusion of the motives towards SC 4.0 will be summarized.

II. MATERIALS AND METHODS

This paper has been based on a literature review. The most recently published articles have been prioritized. Scholarly papers and journals have been used primarily, however, other relevant company specific material have also been included. The university library online search engine has been the primary database. Key phrases have been: Supply chain management 4.0, Industry 4.0 and Logistics 4.0. The key phrases have also been used in conjunction with disruptive technologies such as Internet of Things, Artificial Intelligence and Cloud Computing.

III. RESULTS AND DISCUSSION

As there is not one but several definitions of SC 4.0 and what it encompasses, for the purpose of this paper, a few key technologies have been chosen. These are some of the disruptive technologies mentioned in the literature study [4]. The best approach to understanding the motives for SC 4.0 is to investigate the motives for these individual disruptive technologies first; and second, to apply them in combination with each other.

A. Big Data Analytics

According to Kwon, Lee & Shin [5], Big Data Analytics (BDA) is defined as "technologies (e.g. database and data mining tools) and techniques (e.g. analytical methods) that a company can employ to analyze large-scale, complex data for various applications intended to augment firm performance in various dimensions".

Organizations are implementing BDA to manage their supply chains to be able to keep a competitive advantage by forecasting demand in a rapidly changing market [6]. According to the article Big data and the supply chain: The big-supply-chain analytics landscape (Part 1) [7], Big Data Analytics is now an opportunity to improve the "supply chain decision-making, all the way from the improvement of front-line operations, to strategic choices, such as the selection of the right supply chain operating models". Some areas where BDA is being implemented within the supply chain is in Sales, Inventory and Operations (e.g. improve planning process and demand capabilities). One example mentioned is that, "Blue Yonder has developed data intensive forecasting methods now deployed into retailing where 130,000 SKUs and 200 influencing variables generate 150,000,000 probability distributions every day" [7]. Furthermore, implementing BDA has allowed the company better forecasting, understanding their logistics needs, reduce inventory and avoid stockouts. Another example of data derived from BDA has led Amazon to patent an approach that they have named "anticipatory shipping". This means that the company is able to package and ship items to their delivery network prior to customer order [7].

Based on the literature reviewed BDA will become even more crucial while Industry 4.0 is becoming fully implemented; this will be due to all the additional data available through integration.

B. Autonomous Robots

According to Bahrin and colleagues [8] in the article "Industry 4.0: A Review on Industrial Automation and Robotic" states that, Autonomous Robots are considered one of the Nine Technologies Transforming Industrial Production. These robots are designed to carry-out tasks with minimal to no human interaction. As mentioned in, "Using autonomous robots to drive supply chain innovation" [9] autonomous robots are able to adapt to their surroundings, learn and make decisions on their own and as the technology improves, they will have more human like functions. These robots' designs differ in size, functionality, intelligence as well as costs. Organizations are investing more towards this innovation since it allows them to work closely with humans. This in turn allows them to turn it increases their efficiency, reduce production mistakes, labor safety risks and reduce lead times among other benefits. For instance, some companies have already incorporated autonomous robots to their supply chain e.g. Kuka LBR company has implemented the "Iiwa which stands for intelligent industrial work assistant". This robot was created for industrial applications for the cooperation of humans and robots to perform sensitives tasks. Moreover, it also allows the robot to develop like human skills to become fully autonomous [8]. Furthermore, the advantages of implementing this innovation enhances the supply chain overall.

C. Internet of Things

Internet of Things (IoT), sometimes called the Internet of Everything or Industrial Internet of Things, is a concept that emerged within Supply chain management during the 1990s. At first the idea was to combine RFID technology with the internet in order to achieve better supply chain performance [10]. However, with the growth of wireless networks and connected devices, such as phones and watches, the applications and potential implications have become greater [11].

Today, IoT applications has grown into a vision of a global communications network where machines, systems, programs and devices are interacting constantly and instantaneously with one another, achieving integration and coordination on a massive scale [12].

IoT is considered to consist of layers, a networking layer, a service layer and an interface layer. Consumers are familiar with the sensor layer as these sensors can be found in many different applications today such as watches, cars, mobile devices etc. The networking layer is the communications facilitator that allows sensors to transfer data and measurements to a node, such as via wireless internet. The service layer is less intuitive to the consumer, however, Lee & Lee [12] uses another categorization, "middleware", and describes it as a software layer allowing heterogeneous devices and sensors to communicate. The service layer or middleware layer is thus a layer that resembles the platform of a smartphone or a PC computer, allowing different sensors and programs to collaborate. The last layer is the interface layer. Again, intuitive to the consumer, this layer is the display where the operator can categorize and make sense of the information gathered by the connected devices and sensors.

IoT has the potential to positively impact supply chain performance, from factories and production lines to warehousing and inventory management. Today IoT is used for tracking within transport but also by retail and service industries to gather data on visitors and sales to improve service levels. IoT is used in cold-chain logistics, providing data on actual temperature, humidity and additionally to monitor if packages have been opened during transport. Within the SC 4.0 framework, IoT's greatest potential is for the device-to-device communication. This requires a system able to interpret and take action to mitigate without human intervention. In the cold chain example mentioned above, a smart system should be able to control the temperature inside the cargo hold without human intervention [12].

D. Cybersecurity

Lezzi, Lazoi & Corallo [13] listed the cybersecurity risks associated with Industry 4.0 in their study Cybersecurity for Industry 4.0 in the current literature: A reference framework. Risks such as data transfer, denial of service, data tampering, eavesdropping, jamming, malware, physical destruction and more are identified. Cybersecurity becomes increasingly important to a company that finds itself more and more dependent on its digital infrastructure to maintain its business processes. As cloud technologies are increasingly used, company specific security has to take the cloud service providers security into account and the control is thus diminished. Researchers point out that the growth in number of access points into the digital world of a company such as wireless networks, electronic point of sales, cloud databases and other sensors coupled with the cultural shift of employees to work and access data anywhere, anytime, create a growing problem. Adding to the problem is the use of social media and personal IT services on company owned networks and computers. In supply chain management, the trend is towards integration and sharing of data within the supply chain. The company is seen as an actor in a chain and the competition on the market is between chains rather than individual companies. This adds further to the argument for moving away from the firewall and barrier thinking of cybersecurity in the past. The weakest link in the chain can lie well outside of the specific company cybersecurity mandate and yet attackers find their way inside the digital realm of the company via the chain [14]. The risks are on both sides of the aisle, either you stay away and lose competitiveness or you get into the fray and expose yourself to cyber risks. A study conducted by IBM on IoT implementation in automotive industries concluded that 87% of manufacturers surveyed are implementing the technology in their processes and on their factory floors without a full assessment of risks. On the same note, 87 % of the manufacturers also had no formal program for IoT cyber security in place [15]. IoT and Cloud technologies are two new technologies that expose companies to cyber security risks. Conversely, as pointed out in the article Hacking Industry 4.0 [16], these technologies are not necessarily less secure compared to what they replaced. Cyber-attacks are simply a natural byproduct of the implementation of new technologies. The increasing difficulty of maintaining the barrier between the digital world of the company and the outside has moved the focus away from the firewall thinking of past into a risk mitigation and resilience focus [14]. Verizon, one of the largest US telecommunications companies, publishes an annual report on cyber security, the Verizon Data Breach Investigations Report. 2019's report is based on 41'686 incidents. The statistics show that 71 % of perpetrators are motivated by financial gains and 25 % of attacks are motivated by espionage and gaining strategic information. As for the origin of the attacks, 39 % can be traced to organized crime and 23 % originate from nation-state or state-affiliated groups [17].

E. The Cloud

The Cloud is essentially computing as a service. The Cloud has enabled computing companies to build on economies of scale and competence and offer computing services as a subscription. The buyer gets access to computing without having to source for software, hardware or personnel. Fast and available internet access in combination with cloud technology has evolved into new business opportunities and concepts and at the same time reduced costs and increased adaptability and service levels [18, 19]. The Cloud is a critical aspect of industry 4.0; it is the link between digital and physical, and the enabler of Cyber Physical Systems. The integration of sensors and physical objects with data storage and software is what enables the production business model to transform into production as a service. Just as the automotive industry talks about mobility as a service, so will industrial manufacturing companies, the service of heating, electricity, maintenance, access etc. The product offering is extended and expressed in a new language, and the cloud is the facilitator [20].

Interoperability and standardization are key in ensuring that softwares can make sense of data. As the number of connected devices and sensors grow fast, the challenge will be to make sense of them all, now and through the product life cycle [20]. The Cloud is oftentimes expanded to encompass Cloud Based Manufacturing, this concept is of a smart factory where connected devices communicate within a network and a software is able to allocated resources and determine production and changeovers at a minimum cost. This conceptual factory can be fed with information from EPOS and perfectly match market demand. It also allows for mass customization if changeover times are minimal. Cloud based manufacturing can be extended further into Cloud Based Design and Manufacture. This concept further enables mass customization even at the design stage. The idea is to use a product development model of collective, open access, social network platforms. This merges the Social Product Design idea and cloud based manufacturing [21].

F. Additive Manufacturing

Additive manufacturing (AM) also known as 3D-printing, is a new industrial production technology which can manufacture a physical object by using Computer Aided Design (CAD) software or 3D object scanners to direct hardware machines to deposit the raw materials "layer upon layer in precise geometric shapes [22].AM is considered as the revolutionary approach to the process of industrial production, since it enables, among most common production scenarios, the production attributes of lighter in weight, stronger in intensity, sooner in production lead time, and less in material waste. In addition, through AM, the more specialized and individualized product can be manufactured in much better efficiency due to its operational principles and the advantage of digital flexibility.

When it comes to AM's implementation on supply chain, the technology is proved to have much potential and considered still in its sunrise segment[23]. AM can provide many positive contributions in optimizing the supply chain. The most obvious benefit is reducing the waste of raw materials in the upstream of supply chain in production. Due to the special principles of how AM works, it can enable the theoretical 100% utilization of the raw materials. Furthermore, it can possibly avoid the production logistics process of material waste handling, and require a relatively low supply capacity of raw materials when producing the same amount of the product with traditional manufacturing approaches [24].

Secondly, through AM, a more LEAN supply chain can be realized with a promoted customer service level. For one thing, a product can be manufactured much shorter in lead time by using AM than the by using other approaches, due to its elimination of the time-consuming steps in assembly processes. As a result, the manufacturers will be less necessary to keep a large amount of inventory to be prepared for the fluctuating demand, as they are able to produce in a JIT basis to serve the downstream. For another thing, through setting AM machine stations or flexible service points among the key locations of the supply chain network, AM can promote a more agile supply chain performance from the manufacturers to their customers [25]. A vivid example can be together with the connectivity solution for the AM machines to the ordering platform of the customers, a customer can directly send an demand order to the platform with the preferred time window and location for pickup, while the machine will manufacture the item within the right time at the perfect place to offer the customer a timely and customer-friendly service. Currently, many companies are attempting to implement AM within their manufacturing-related processes and try to tap AM's potentials. For instance, Daimler Group has invested large capital in 3D-printing the metal components of some essential sections of their vehicles and engines for the aftermarket in order to promote the agility and cost-efficiency for its aftermarket supply chain [25]. While in other industry, similar attempts of using AM to promote and restructure the supply chain network are undergoing, together with the application of using AM with other technologies such as IoT and the Cloud.

G. Augmented reality

Augmented reality (AR) is the visual promotion technology which can not only present the scenes and objects in the reality, but also incorporate the additional wanted information to augment the view [27]. Using AR devices such as AR wearable eyeglasses and AR windscreens to present the corresponding real-time and real-location information can be considered as an effective and intuitive way during the working processes when the worker needs to focus on multiple tasks or is occupied with both hands. In the supply chain sector, AR can contribute to those manpower-involving tasks such as delivery transport, warehouse material handling, and some other machine operating processes [28]. One practical function for AR in SCM is towards the order picking process in a warehouse, known as "pick by vision". AR eyeglasses can guide the worker to the exactly items for a cart picking trip with intellectual calculation result for the optimal picking route and real-time situation; in addition, the AR glasses can also show the worker in which way and position the items are situated in the cart will the cart's capacity be most optimized[29]. Another helpful function of AR for the SCM is to simulate the facilities setting on site with visual outcomes before the real implementation and without interrupting the ongoing activities on site. For instance, sometimes due to the increase of capacity or the new generation of product, it is necessary to change the current facilities or relocate the original ones. In this situation, AR tools can contribute to provide intuitive visual outcomes, such as identifying the potential bottlenecks of space, the connectivity efficiency between lines and routes, etc. [30].

IV. CONCLUSION

As more and more industries are undergoing transformation to an overall more digitalized, autonomous, and connected operational ecosystem, SC 4.0 is a perfect match for the conceptual reference of how to set the supply chain sector to this promising panorama of future. The technologies presented in the section above are collectively the drivers behind the concept of Supply chain 4.0. Applied in combination, they facilitate the smart factory of the future. Robots are interconnected using IoT, and via the cloud they are able to collaborate and make decisions regarding production and logistics. Each item moving through the system has a digital twin, enabling full visibility of inventory. The factory is data driven, enabled by big data analytic capabilities and access to real-time information regarding downstream sales. The movements of products and parts are carried out by autonomous robots. Since no human involvement is needed, the scale can be reduced without compromising profitability. Logistics is no longer dependent on scale and smaller parcels can be distributed autonomously, shortening lead time. Nearshoring to customers is facilitated by the reduction of labor costs in manufacturing, lead times can be reduced further while the customization of products can be increased. With changeover times reduced and constant feedback from sales, mass customization is enabled. Additive manufacturing further distributes manufacturing, challenging the economies of scale approach that has concentrated production to a few sites and increased supply channels. In the interface among cyber, machines, and human, AR can be used to erase the barrier of communication. Last but not least, cyber security will be a concern to any digital system. The security aspect will move away from firewalls towards risk mitigation and early detection, consequences have to be minimalized as the exposure to cyber threats will increase.

To sum up, although many challenges are along the way towards enabling SC 4.0 and realizing the blueprint in reality, such as technical bottlenecks and maturity, hardware limitations, regulatory and legal restrictions, capacity cost, etc., it is still reasonable to believe that implementing SC 4.0 would be a promising future trend for many industries driven by the practical motives and abundant returns.

V. FUTURE SCOPE

Although with the implementation of some of emerging technologies, many brilliant achievements in SCM have already been reached as well as potentials of their functions have been foreseen, contests are on the road. Hence, future studies are invited to identify the challenges for SC 4.0.

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