The Impact of Industry 4.0 on Supply Chain Management

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***Abstract*— Industry 4.0 includes technologies such as Internet of Things (IoT), Big Data Analytics, Smart Factory, Cyber Physical Systems, Blockchain, Machine Learning and Artificial Intelligence. Supply Chain is a field which involves numerous day to day activities such as planning, procurement, warehousing, transportation etc. With such activities also comes a huge amount of data. In order to manipulate and derive some analysis out of this data, and also effectively manage and coordinate the working of different activities simultaneously, there is huge scope for human misjudgment or errors which would lead to unoptimized inventory and increased costs. With digitization being adopted by various Supply Chain Industries, the above mentioned risks could be eliminated with the adoption of different technologies under Industry 4.0.**

***Keywords*—** *Industry 4.0, Supply Chain Management, Internet of Things (IoT), Big Data Analytics, Smart Factory, Cyber Physical Systems, Blockchain, Machine Learning.*

1. Introduction

The fourth phase of the Industrial Revolution (Industry 4.0) include numerous technologies that are enabling rapid development in various sectors. The Internet of Things (IoT) refers to various devices being linked together on the internet and collecting/sharing data amongst each other. Big Data refers to operations dealing with high volume and high velocity data which is being generated in almost every field today. Smart Factory is a concept that enables the digitization of the manufacturing process by interlinking different machines and production systems. A cyber physical system is where all physical processes are monitored by a computer-based algorithm. Blockchain is a decentralized technology enabling peer to peer communication and transparency of all transactions happening on the network. Machine Learning enables systems to learn from data, detect patterns and ultimately make decisions with minimum intervention from humans [1].

Industry 4.0 is playing a major role in various management sectors including Supply Chain Management. The levers of a Supply Chain network such as manufacturing, procurement, logistics warehousing and fulfillment are also greatly benefitted with the introduction of these technologies which shall be discussed in the further chapters [2].

The benefits provided by including Industry 4.0 with Supply Chain also include greater transparency and accuracy, data backed decisions which optimize inventory and costs, increase in collaboration between different sectors of a Supply Chain network, improved warehouse management and greater agility to the network [3].

2. Industry 4.0 Technologies and their role in Supply Chain

2.1 Internet of Things (IoT)

The Internet of Things (IoT) refers to system of various inter-linked devices that share and collect data over a wireless network. These devices could be medical devices, RFID chips, smart devices, mobile sensors etc. These devices are capable of measuring factors such as location, temperature, movement, handling and other factors. The information from these devices are collected and incorporated on a single platform (Internet) [4].

2.1.1 Role of IoT in Supply Chain

With the help of the IoT technology, we can effectively track various products and shipments. The storage conditions of these products could also be monitored thus enhancing storage and quality management. IoT devices can be attached to different raw materials / packaging materials / storage containers / finished goods in order to track their locations. With the help of these devices, the speed and movement of different materials and goods can be tracked thus enabling the prediction of different lead times and how they move through the network.

Manufacturers and suppliers can also retrieve a lot from such information which in turn will reduce handling times and efficient processing of materials. Storage conditions of different materials play a key role in the quality of the finished product. Hence with the help of IoT, storage conditions can be monitored thoroughly. Attaching these devices to goods at a distribution center also helps in finding them quickly which ensures accurate identification. Overall, the IoT improves the administrative and management responsibilities in a Supply Chain network [5].

2.2 Big Data Analytics

Big Data analytics refers to the process of using various analytical techniques on structured, semi structured and unstructured data which varies in size from terabytes to zettabytes. Data plays a key role in every field and hence it is important to make use of measures that help analyze this data.

2.2.1 Role of Big Data in Supply Chain

Big Data plays a major role in inventory management. It enables managers to get a detailed overview of all operations and identify bottlenecks within the network. Big Data analytics can be used in inventory management in order to select warehouses based on its proximity to different suppliers and customers. This in turn reduces distribution costs. When it comes to planning, the historical data can be used to analyze demands patterns and hence accordingly prepare for future orders.

Big Data Analytics can also be used to identify consumer behavior and usage/order patterns. Every consumer generates data based on their searches and orders. This data is consumed and as a result inventory is managed in different geographical locations based on consumer's data and choices within that geographical location. This data is also used to suggest similar products to consumers in order to increase sales. Big Data can be used to streamline E-commerce processes by improving algorithms to predict accurate delivery dates and increase warehouse automation.

Big Data can be incorporated with IoT where in all the data collected by devices on the IoT network can be analyzed and thus optimize inventory and other processes within the Supply Chain Network [6].

2.3 Smart Factory

Smart Factory is a concept which focusses on the automation of manufacturing processes. A smart factory will have machines performing its operations automatically with the help of some software. Various developments have taken place in the filed of robotics which could be widely used in a Smart Factory. All equipment are present in the physical layer. The network layer consists of all the links between different machines / equipment. The middle layer / cloud application layer takes care of data management. With the incorporation of IoT, data being generated by various devices is collected and pushed onto the cloud and this provides a medium to monitor all machines on one platform. The data is then pushed onto the application layer where various planners can make use of this data to effectively plan, for example – Supply Chain Management, Product Management, Quality Control & Management etc. With the help of a Smart Factory, other entities in the Supply Chain network can also look at the developments taking place at the manufacturing stage [7].

2.3.1 Benefits of a Smart Factory

A Smart Factory greatly reduces the costs such as order management and material handling costs. It also reduces the inventory holding costs. It also helps in increasing flexibility by adapting to different manufacturing environments and requirements. There would be a considerable improvement in the maintenance of machinery at factories with regular alerts with the help of technology. A smart factory would have the capability of automatically understanding data such as demand with the help of Machine Learning techniques and hence accordingly enable them to respond with better agility. Since the whole manufacturing process is automated, it increases the pace at which all developments take place and hence increase productivity [8].

2.4 Cyber Physical Systems

A Cyber Physical System consists of computation, networking and physical processes. Various embedded computers and networks are in charge of the physical processes taking place. These systems also have a feedback loop where the physical processes affect the computations taking place and vice versa.

2.4.1 Role of Cyber Physical Systems in Supply Chain

The management of Supply Chain is challenged by the presence of complex production and transportation networks. Dealing with these complexities will require high operational flexibility. In order to accomplish that, a Cyber Physical System would help since it not only deals with the physical aspects, but it also deals with the informational aspects.

Cyber Physical Systems have three levels to it. Firstly, the connection level is where data is

gathered by inter-linking different machines and products. Secondly, is the conversion level where raw data from the previous level is converted into some meaningful form. In the case of Supply Chain, for example the vibrations being generated from a particular machine is the raw data being generated in the connection level. This data is then converted in conversion level to fetch some meaningful data about how well the machine is performing. Thirdly, is the cyber level. At this level, complex data analysis takes place. It might also involve the use of deep-learning algorithms. For example, in Supply Chain at this level, past data such as demand is taken into consideration in order to predict or forecast the future demands and finding out at which locations or periods the demand is more / continuous or if the demand is less / not continuous. These processes would improve the performance of a Supply Chain network [9].

2.5 Blockchain

A Blockchain system is a decentralized system that enables peer to peer transactions and also accounts for complete transparency. Each record / transaction is stored in the form of blocks. The information with respect to each block can be viewed by all peers within that network. Blockchain's hashing algorithms make sure the blocks created on the network are tamper proof and hence provide a secure platform to perform different transactions between different peers. All blocks on the network are connected to each other which makes it easier to access a particular block.

2.5.1 Role of Blockchain in Supply Chain

One of the biggest advantages of incorporating Blockchain with Supply Chain is that it provides complete transparency and traceability of different products. Information ranging from raw materials used to manufacture a product, to which particular consumer the product was delivered to can all be stored on the blockchain and be accessed by peers within the network. This is mainly beneficial in industries like the food & beverages, clothing, electronics etc. Storage conditions for specific products can be monitored with the help of Blockchain. Any changes to these conditions will hence be visible over the network. Since Blockchain stores data of the entire Supply Chain network and the transactions happening within the network, it improves the efficiency of managing and accessing all this information by making it available on a single platform. This eliminates the need of maintaining a separate database too. It also provides for alternate choices of payment in different industries, for example Bitcoin. The evolution of Smart Contracts in Ethereum Blockchain also enables to include business logic which would improve the efficiency of operations taking place over the network. It also establishes a sense of trust among different consumers who are provided with complete information about their purchased product. An easy means of tracking orders and shipments also accounts for reduction in cost for movement of items. The information stored on the Blockchain with respect to the Supply Chain network is completely secure with complex hashing algorithms being used [10].

2.6 Machine Learning & Artificial Intelligence

Machine Learning is a method used to perform data analysis by building a model that automatically learns from data and provides us with outputs or analysis that it has learned from the data. Every model built using Machine Learning is first trained with some set of data, after which it is tested on a completely new set of data to see if it is providing accurate results. There are various methods in order to do so. It is also used to recognize different patterns and trends that help in forecasting certain situations. Major languages used to perform Machine Learning are Python and R since they have many inbuilt packages that help in building a model.

2.6.1 Role of Machine Learning and Artificial Intelligence in Supply Chain

Machine Learning in Supply Chain will be most impactful when it comes to inventory optimization. Inventory optimization is one of the key tasks in a Supply Chain network in order to prevent situations where there is less or no stock available (stock-outs) or there is excess stock available. Planners use data such as forecast, lead times, Economic Order Quantities (EOQs) in order to calculate Safety Stock that should be present at different Plants and Distribution Centers. Instead of performing these tasks manually, we can make use of Machine Learning in areas like Demand Forecasting, analysis of suppliers based on lead times. Demand Forecasting can be achieved through Machine Learning by training a model with historical forecast values at different time periods so that it can predict correct forecast values for the same time periods in the future as well. The model can take into account all scenarios ranging from spikes in demand during peak seasons and vice versa. Models can be made to perform an analysis as to which suppliers to take into account based on their lead times. Lower the lead times, the faster a particular material or product is delivered. With trained models like these, it is easy to calculate the Safety Stock that needs to be present at different locations [11].

3. Levers of Supply Chain being benefitted by Industry 4.0

3.1 Planning and Execution

This process in Supply Chain mainly focusses on making sure there is a steady balance between supply and demand. With Industry 4.0, these processes can be automated and more data driven which will help in providing accurate results. All planners will be able to respond to sudden change in requirements in real time and can easily track different orders and their movement.

3.2 Procurement & Manufacturing

Demands, manufacturing capacity, holding capacity, location of suppliers are few parameters that are taken into account for Procurement of materials for a particular product. With live data being fed from technologies that come under Industry 4.0, it will streamline all procurement operations and hence there will not be any need of maintaining any buffer safety stock.

3.3 Logistics

With technologies being used to track the movements of shipments and other environmental factors, transportation costs are greatly reduced since situations or overheads like delay in delivery, lack of vehicles, damage of products are most likely to be avoided and hence eliminate the risks of incurring losses.

3.4 Warehousing

With the inclusion of Industry 4.0, warehousing operations are much easier to monitor. Inflow and outflow of goods are accurately monitored from the warehouse. Accessibility of specific goods from a range of goods is also improved. Storage conditions can also be monitored at the warehouse easily. Overheads such as wrong delivery to a warehouse or wrong pickups from a warehouse can also be avoided [12].

4. Improved statistics

Various companies have performed surveys in order to find out how organizations in the Supply Chain field are benefitting from including technologies that fall under the Industry 4.0. As per a survey conducted by McKinsey & Company, various measures have improved with the incorporation of different technologies.

Firstly, due to increase in efficiency of various operations, there is steep increase in service levels / orders being placed that are being fulfilled and hence there is a great reduction of about 65 to 75% in lost sales which can be truly beneficial for an organization. Secondly, with better management of warehouse and transportation, their costs have fallen by 15 to 30%. This in turn contributes to huge savings for the company. Thirdly, planners are greatly benefitted with the help of automated analysis of data which provides accurate and promising results as compared to manual analysis. This again contributes to great savings as it reduces Supply Chain / service costs by 50-80%. Lastly, many organizations have a tendency to keep excess stock at locations which could go into waste. With the help of technologies like Machine Learning, there was as much as 35 to 75% reduction in inventory to be maintained at different locations thus reducing wastage of goods [13].

Table 1. Performance statistics of an Industry 4.0 enabled Supply Chain

Parameter	Depreciation (in %)
Loss in Sales	65-75
Warehouse and Transportation costs	15-30
Supply Chain Admin Costs	50-80
Inventory	35-75

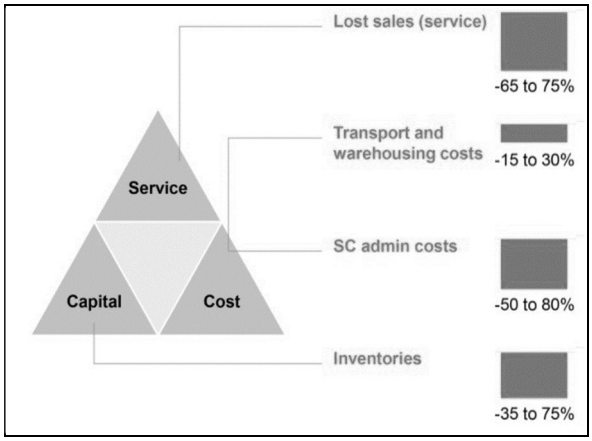

Figure 1. Different Supply Chain categories being benefitted by Industry 4.0 technologies

5. Conclusion

The aim of this paper is to recognize different technologies like Internet of Things (IoT), Big Data, Smart Factory, Cyber Physical Systems, Blockchain and Machine Learning that are part of Industry 4.0 and how they play a role in efficiently developing the Supply Chain Industry. These technologies help in effectively managing and coordinating different supply chain related activities. They also help in deriving patterns and in-depth analysis from the data being generated which helps planners plan efficiently. With such results, industries are able to optimize their inventory by not loading excess stock at different locations which is resulting in great reduction of losses and costs.

Though the advantages of enabling a digital supply chain are significant, it would be difficult to incorporate all these technologies on a single platform and make them work in harmony since each technology have a unique way of being implemented. Further studies would include to propose methods that would enable the use of these technologies on an integrated platform and interlink their inputs and outputs so that they are automatically fed into the system.

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