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SCHREYER HONORS COLLEGE

DEPARTMENT OF SUPPLY CHAIN AND INFORMATION SYSTEMS

FUTURE APPLICATION OF INTERNET OF THINGS (IOT) IN SUPPLY CHAIN OF COMPANY D

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ABSTRACT

The purpose of this thesis is to analyze the opportunities of Internet of Things (IoT) within company D and recommend technologies which will positively impact company D's supply chain. The thesis includes information about company D's process flow which helps pick key nodes where these technologies can be installed. It also includes an adoption framework which defines if company D is an early or late adopter.

The research further expands on new technologies available in the near future like Demand Sensing, Prescriptive Analysis, etc., and technologies which will dominate the industry in the long run like Artificial Intelligence (AI). The near future technologies are further categorized through their application in the SCOR framework.

The thesis establishes the position of company D in the adoption framework and gives recommendations on technologies to implement in the short and long run. Lastly, the thesis outlines the limitations and risks associated with the adoption.

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Chapter 1

Introduction

The fast pace of the present-day world has invariably affected all aspects of our lives. Consumers now expect a higher service level with faster deliveries, breaking out from the traditional brick and mortar experience and moving towards online shopping or e-commerce. As convenient as this change is for the consumers, it is making the back-end process for the manufacturers/distributors/suppliers extremely complicated. Companies are pivoting from the conventional supply chain models and are embedding high levels of innovation and technology in the same.

While these changes greatly improved the efficiencies of the underlying supply chain processes, present supply chain advancements are centered not only towards further improving these efficiencies but also towards improving the double bottom line for the companies. Supply chain has reached to a critical point where further investments would not be justifiable only with process improvement but the return on those investments should be clearly visible in the profits and future growth of the company.

Adoption of new technologies at each step of the supply chain process connecting to the Internet of Things (IoT) will be able to give companies that advantage in the future growth and double their bottom line.

The remainder of this thesis will be structured as follows. The next section (Chapter 2) will give a background on the history of supply chain and the changes throughout the years due to technological changes; it will also talk in brief about the future technologies which will be further expanded on in the thesis. The following section (Chapter 3) will create a matrix for the adoption timeline of Internet of Things, which outlines differences between an early adopter or a late adopter. Chapter 4 will give a background about the company discussed in this thesis and further explain its process flow in terms of production and export shipment. This section will also establish if the company is an early or late adopter. The next section (Chapter 5) will go through the SCOR process for the company and suggest applicable technologies which can be adopted in each stage- Plan, Make, Source, Deliver. The thesis will further give a long term prospective on technologies in Chapter 6 and talk about Artificial Intelligence (AI) and how companies can prepare early on for future adaptation of this technology. Lastly, Chapter 7 will include final recommendations to Company D and outline the limitations and risks of adapting these new technologies.

Chapter 2

Background

In today's business world, the pace of life has increased dramatically; our surroundings are changing every day and drastic improvements are changing our lives. Gone are those days when industrial revolutions took place every few years and the advent of a new technology changes everything. Today, industrial revolutions take place every day as a new technology is introduced. These revolutions encourage the organizations adapt the change and have a first mover advantage. In terms of supply chain, the same cycle has been taking place for years and the industry has been changing rapidly to increase efficiencies, but the industry has come to a stage where only increased efficiency does not justify the investment; executives are looking for changes which will directly affect the double bottom line of the company.

History of Supply Chain Technologies

Supply chain dates back to early 1900s when it started with improving basic labor intensive work and progressed to current day complex networks. In the 1940s and 1950s, the focus of supply chain was towards Mechanization. The aim was to turn labor intensive processes to be more efficient and make good use of space with better warehouse designs and racking (Georgia Tech Supply Chain & Logistics Institute, 2015). By the 1960s this focus was shifted more towards freight transportation, specifically trucking. The invent of new computer software helped improve route planning and inventory optimization in warehouses. The 1980s marked the change in the logistics and planning with the advent of flexible spreadsheets. This development was further fueled in the 1990s with the introduction of Enterprise Resource Planning (ERP) Systems. Since then technological change has been a major part of the improvement of supply chain processes. Software like Efficient Consumer Response (ECR), Customer Relationship Management (CRM), Transportation Management Systems (TMS), Warehouse Management Systems (WMS) and Total Quality Management (TQM) revolutionized the supply chain resulting in significant benefits to both customers and the organizations (Stock, 2013).

Future Technologies

The growth in supply chain technologies has drastically improved operations over the years. The mass implementation of various systems like Enterprise Resource Planning (ERP), Transportation Management Systems (TMS) and Warehouse Management Systems (WMS) etc. have made the integration of data over different working sectors and organizations very seamless. However, industry leaders are now looking to integrate these different management systems and automate the process of feeding data into these systems. This gave the rise to Internet of Things or IoT.

IoT is a network of devices- sensors, actuators etc. connected through wired or wireless networks to the internet. These networks generate huge volumes of data that flow to computers for analysis (Chui, Löffler, & Roberts, 2010). In the future, this data will be fed to software or machines run on Artificial Intelligence (AI) which will be able to analyze trends and nuanced relationships. AI can make intelligent supply chain decisions like reorders, demand forecasting, inventory management etc. In addition to the IoT and AI, supply chain is also seeing a big move towards robotics and high automated machinery in manufacturing, warehousing and transportation. These robots and machinery will also connect to the IoT in the future and feed real time data. Other newer technologies like Prescriptive Analytics, Demand Sensing systems and Automated TMS etc., will pull data from the IoT and work together with AI. The future of supply chain technologies is set up to integrate across the board and take advantage of data and analysis pulled from every source possible and use it to improve and rather automate the process.

Chapter 3

Industry Adoption Timeline of Internet of Things

The urge to increasing profitability and grow is continuously driving firms to adopt these new technologies as quickly as possible. Industrial sectors are planning to invest $907 billion, approximately five percent of revenue, to new technologies like the IoT sensors, AI, 3D printing etc. These additional investments are expected to drive breakthrough revenue growth and are expected to pay back in approximately two years (Geissbauer, Vedso, & Schrauf, 2016). However, like any major revolution, this trend is slow and the organizations are taking their time to vet the technologies and make a decision to invest. This divides the industry in two groups- Early Adopters & Late Adopters.

Early Adopters

Early adopters, also known as first movers, are essentially firms which were able to integrate these changes and new technologies in their supply chain the fastest. They bear the maximum risk of failure as the processes/technologies are not tested or validated; the company experiences it as they go through the process and learn about its advantages and disadvantages. Since the early adopters bear the maximum risk of failure, they also have the highest chance of dramatic gains in efficiency and profit.

In context of these new technologies, the first movers who are able to understand and integrate them to their industrial platforms will have significant advantage over competitors

(Geissbauer, Vedso, & Schrauf, 2016). They will be able to gather more detailed data and have the right systems in place to draw analysis. According to the Industry 4.0 survey conducted by PwC in 2016, thirty-three percent of the respondents claimed a high level of digitization, that is they are already adapting the technologies and can be considered early adopters.

Late Adopters

Late adopters are comparatively reluctant to change. They prefer to scrutinize the technologies and weigh the advantages and disadvantages before changing any processes. This reduces the risk involved in the adoption as the decision to adapt is taken after considerable analysis. However, this reduces the gains compared to those received by early adopters since the industry is already saturated and the competitors may already use the technology; the late adopter may just implement it to get at par. According to the PwC survey, thirty-nine percent of the respondents are in the process of adopting these new technologies, thus they can be considered late adopters. These respondents come from a plethora of industries like Aerospace, Automotive, Chemical, Electronics, Metal etc. (Geissbauer, Vedso, & Schrauf, 2016). As shown in Figure 1, the early and the late adopters together will make up seventy two percent of digitized organization in the next 5 years.

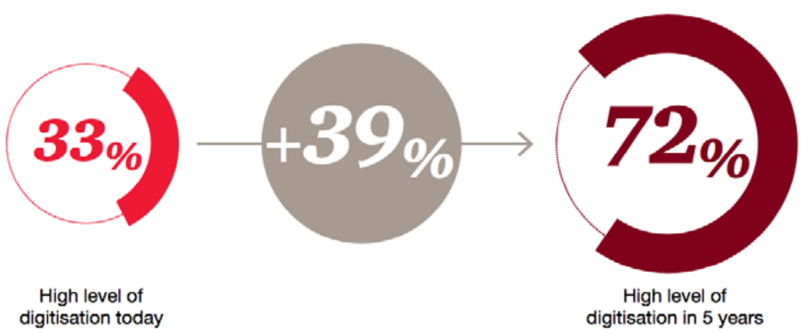

Figure 1: PwC 2016 Industry 4.0 Survey

Chapter 4

Company D Background

Company Overview

Company D is a publically owned chemicals and materials manufacturer and was founded in 1897. Company D manufactures plastics, chemicals, hydrocarbons, agrochemicals and performance plastics. With a wide product offering they are the biggest chemical manufacturer in the United States and second in the world. The company has operations spread out all over the world with thirty-five percent of the revenue coming from United States and thirty-one percent from Europe, the Middle East, Africa, and India (EMEAI). High investment in research and development is one of the key factors to success of Company D; they currently own 4,651 active US patents and 19,541 active foreign patent (Hoovers, n.d.).

Process Flow Analysis

Product Manufacturing

Company D has fairly spread out and global supply chain with 201 sited in thirty-six countries. Each product produced by the company requires specific raw material ingredients which are either transported from another company D location or from the supplier itself. A number of company D businesses also produce key raw materials in a different department at the manufacturing site which are also used in product manufacturing.

A finished product at company D can go different paths after production (Figure 2). The product can be shipped directly to an end customer location or shipped to a company D distribution location anywhere in the world from where it can be further sold to the end customer. The company also uses distributors for regions or areas of the world where company D's direct sales force is not active. The distributors cover this accessibility gap and still allow company D to sell its products. Lastly, the finished product itself could be an ingredient to another product produced by company D; in that case, the finished product makes its way to the manufacturing plant where the other product is being produced.

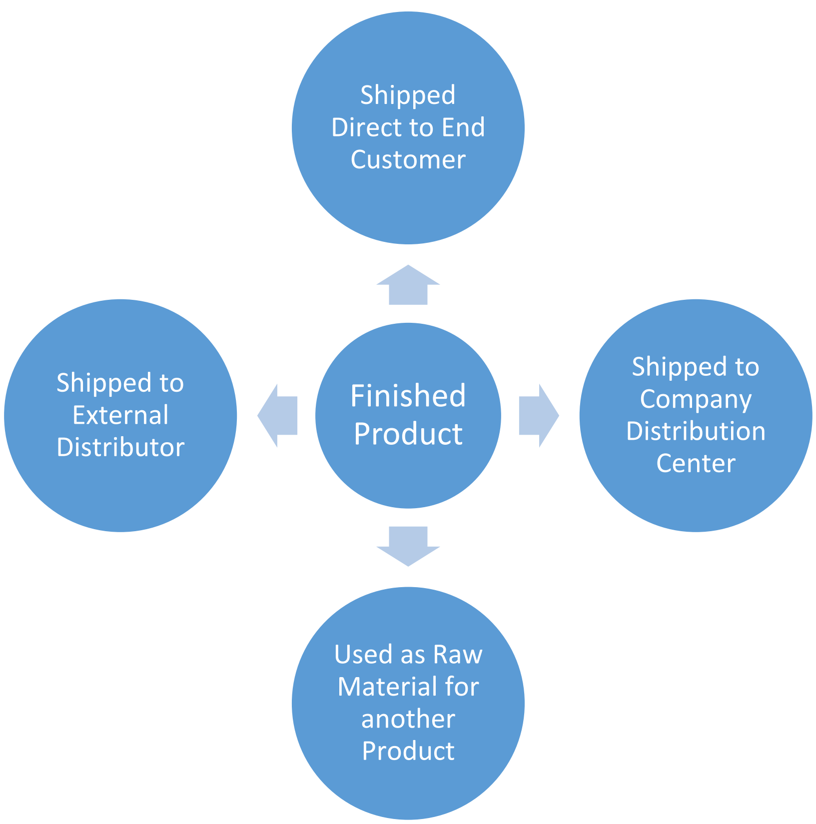

Figure 2: Finished Product Outlet Map

Export Shipments

With an extensive supply chain spread all across the world, tremendous amounts of finished goods are shipped to different parts of the world. As seen in Figure 3, the shipment starts from the company D's manufacturing site where the product is export packed. After packing, the shipment makes it way from the manufacturing facility to a city location (generally near a port). This journey can be done in various ways- barge, rail car or truck, depending on the location and the time frame. Once the shipment makes its way to the city location, it is then redirected to the freight carrier who takes the shipment further. The freight carrier then transports the shipment to the loading area where it goes through customs clearance at the export location. With the customs clearance and proper paperwork, the shipment is loaded on to the ship and makes it way to the destination port. As the shipment reaches the destination port, it goes through another round of customs clearance. After the clearance, the shipment is free to be transported to the customer, depending on the shipment agreement, the customer may take responsibility of the shipment at this point or company D may use ground transportation like truck, rail, etc. to deliver it to the customer site.

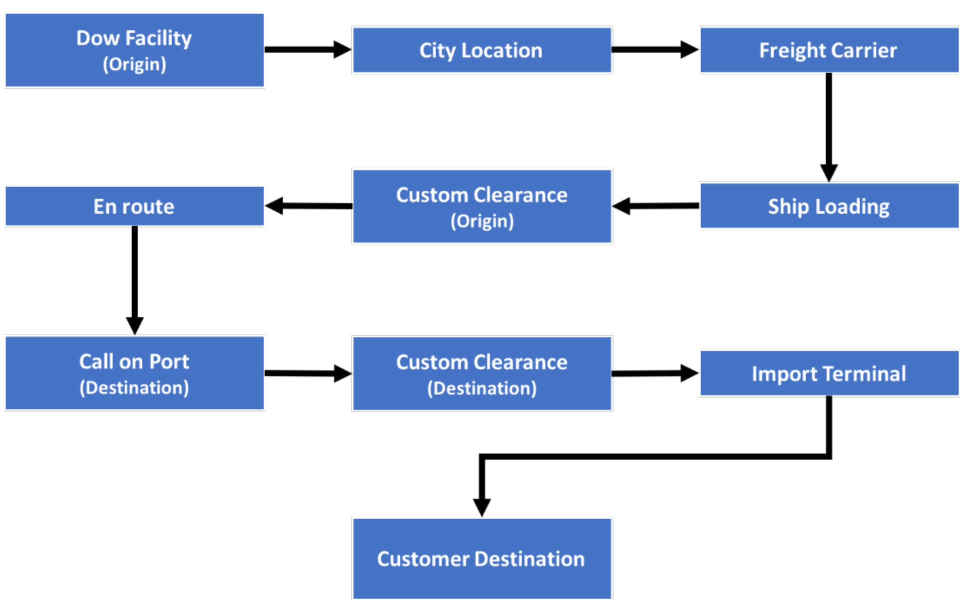

Figure 3: Export Process Map

Early or Late Adopter

Company D has always been on the edge of innovation and technological improvement. As a leader in the chemical industry, the company has adapted all the new technologies available and have added efficiency. It is really hard to clearly place company D in the adopter matrix because there are certain areas where the company has achieved increased advancement but lacks in other areas.

From an industrial IoT standpoint which entails process/manufacturing, company D can be considered an early adopter; they have been using advanced sensors and management systems to collect and manage data. However, this data does not go outside to other departments and stays internal. Whereas, from an overall IoT standpoint which involves integrating all the departments and having a collective data hub, company D can be considered a late adopter. The company has increasingly used tracking technologies like RFID, GPS, etc. to track in-route shipments. In addition to the tracking devices, they also adapted new cloud based systems like GT Nexus.

Overall, after looking at the past trends of the company and the industry and insight from company D's executives, Company D can be considered a late adopter.

Chapter 5

Application of IoT technologies across the SCOR Model

Discussing the process flow maps for company D in Chapter 4, it was easy to understand the overall functioning of the organization very well. This understanding was further expanded by looking into the Supply Chain Operations Reference (SCOR) model for company D. Examining the model allowed for the identification of a key node in each step to adopt these new technologies.

Stage 1: Plan

In reference to the SCOR model, planning remains the absolutely most important process in the supply chain. It is essential to make sure that everyone in the organization is aligned to the same goals and is given the right information. Demand and Supply planning and management are part of this process.

Demand forecasting is the stepping stone to any manufacturing supply chain. The forecasted demand data acts as the basis to forecast the actual quantities of finished product which the company will produce. Using these quantities of finished products, the procurement team will work on quantities of raw material needed from the suppliers. The whole process is managed using DRP (Distribution Requirement Planning), MPS (Master Production Schedule) and MRP (Materials Requirement Planning) tables.

Demand sensing technologies can be implemented in this stage to increase the accuracy of the demand forecasts. Demand sensing is centered around a specialized type of monitoring focused on the identification of changes that occur in near-real or real time (Hymanson, 2015). These signals are communicated through data accumulated over the years using sensory systems. This system, once developed correctly, can be further expanded to supporting demand management decisions. The credibility of the forecast increases dramatically with demand sensing as it identifies and incorporates structured and unstructured data sources like market segment data, collaborative customer data, sales and marketing data (Hymanson, 2015). The system also provides information about patterns and abnormalities that may cause supply chain disruptions and stores them for future reference in the system.

In addition to demand forecasting in the planning stage, newer technologies are expected to integrate and suggest how the supply chain should operate. This technology/system is called prescriptive analysis; the idea is that the system has the ability not only to sense and forecast demand but also to holistically look at the whole supply chain, optimize any or all factors and depending on circumstances, modify the chain accordingly (Geissbauer, Vedso, & Schrauf, 2016). Prescriptive analysis will use the big data including data used in demand sensing to guide supply chain managers in the decision-making process and even make autonomous decisions. Managers can feed the system with additional external data such as economic indicators and include algorithms to make the decision more precise while the system is also programmed to be self-learning. The degree to which this system will be able to provide cognitive results will also depend on the how well the company integrates all the data to make the overall supply chain whole (Geissbauer, Vedso, & Schrauf, 2016).

Stage 2: Source

Moving forward in the SCOR process, the next step outlines the process of gathering all the raw materials and infrastructure needed to produce the finished product. Companies and executives work on finding the most effective ways to store the raw material inventory, make sure the supplier network is updated in time with essential information like order quantities, delivery method, payment, etc. The core objective of this step is to set the stage for manufacturing and prepare to solve any disruptions which might occur.

There is a great potential in the Internet of Things to streamline the procurement process in the next five to ten years. A report published by Accenture Strategy outlines three fundamental ways these companies will improve their procurement activities: through its ability to substantially increase traceability of products and materials across the entire supply chain; to enhance a company's use of analytics to improve decision-making; and to enable a company to challenge the status quo for key processes (both procurement processes and those specific to the company's industry) (Nowosel, Terrill, & Timmermans, 2015).

Transparency and a smooth communication channel between the supplier and the manufacturer is essential to adding efficiency to the supply chain. Over the years, companies have upgraded to SAP systems which connect the two organizations using Electronic Data Interchange (EDI) transactions, but in the future, this will be further taken a step by IoT. IoT will allow the companies to track the product throughout the supplier's supply chain and see where it is in the manufacturing, packaging and shipping process and also check for in-stock quantities. This traceability will allow the buyer to better plan for any delays or contingencies and allow for the supplier and the manufacturer to work together to increase efficiencies. Better quality control can also be exercises on the product with this improved visibility.

Improved analytical abilities will also revolutionize the sourcing process. Sensory systems can be added to inventory systems to check for low stocks and have the cognitive system place an automatic order to the supplier to replenish stocks through the IoT network. In addition, with more data collected in the future, systems like predictive analysis can be installed which will be able to anticipate and respond to future developments that could affect the business (Nowosel, Terrill, & Timmermans, 2015). The predicative analysis can be updated with advanced algorithms relating to prices of commodities which are key components of the raw material and the algorithms can determine the price and risk of availability and price hike with that commodity. The analysis system can be further programmed to self-learn and save trends and abnormalities.

Stage 3: Make

After carefully analyzing the demand forecasts and preparing for manufacturing by ordering the right quantity of raw materials in time, the make step comes in play which is the actual manufacturing process of the company; the core of the organization lies in this step. It includes packaging, managing the production network, equipment and facilities, etc.

There is a tremendous scope in this stage of the SCOR process for the implementation of new technologies. The companies can connect their manufacturing machinery with the existing IoT network of the firm which includes all other data derived from or fed to demand sensing, prescriptive analysis and predictive analysis. This will integrate the whole company network holistically and all the data can be gathered at one place and be strategically used across systems.

New technologies also create the possibility of upgrade in machinery in terms of advanced automation and robotics. Companies like ABB, KUKA Systems Group are already working on automated machinery which will be highly autonomous and will require minimal human labor. These machines are equipped with advanced sensors and tracking systems which are able to trigger alerts in case a part needs maintenance. These sensors will also be able to do predictive maintenance which means that they can track trends of maintenance and breakdowns and will be able to predict future interruptions and help plan better. (O'Halloran & Kvochko, 2015). Specifically, Thames Water, the largest provider of drinking and waste-water services in the UK, is using sensors, analytics and real-time data to anticipate equipment failures and respond more quickly to critical situations, such as leaks or adverse weather events (Accenture, 2014). The automation also increases safety and ease for workers as they can use these technologies in harsh locations without being there; this makes operations like mining, marine operations, etc., much more safe and efficient. Industries such as oil and gas, chemicals, metals, mining and utilities are also using wearable and connected sensors to address worker safety (O'Halloran & Kvochko, 2015).

Stage 4: Deliver

The last and the final step in this SCOR model is what joins the product to the consumer. It is especially important because it directly affects the customer experience with the organization. Over the years, various technologies like RFID, GPS tracking, etc., have proliferated this area but there is a dire need for more innovation. Companies are investing millions of dollars into faster and more efficient transportation methods like drones and driverless vehicles. In 2016, Budweiser used the first ever driverless vehicle to make a delivery in Colorado (Newcomer & Webb, 2016) whereas Amazon started private trials of drone delivery in the United Kingdom (McFarland, 2016).

Over the years, these innovative transportation methods will be available in wide scale and will be adopted by all organizations. The biggest advantage with these systems is that they can be connected to the IoT and be controlled remotely. In addition to that, they will continuously collect real time data on transportation routes, lead times, disruptions like traffic, bad weather, etc. Over a period of time, this will create a data center which can further be fed to cognitive systems like Transportation Management Systems (TMS). These systems will be able to analyze the existing data and give up route suggestions, average lead times from historical data, frequent issues with a particular route, etc. The system can also be fed real time weather information which will further improve the accuracy of the forecast and take in consideration any weather delays. With the help of sensors inside vehicles, bottlenecks can be identified, where the product gets damaged in transit and account of theft and tampering. The system will also be able to calculate loads of the shipment both in terms of weight and dimensions and allow for maximum full truckloads.

Lastly, better traceability of the shipment will allow customers to plan better and the added precision in the overall system will allow organizations to improve their fill rates.

Chapter 6

Application of Artificial Intelligence (AI) using Internet of Things (IoT)

As Chapter 5 talked about the application of new technologies throughout the SCOR process, a better understanding was developed on how new technologies can affect an organization's supply chain at different stages. The underlying theme behind most of the technologies is the dire need of data. This data is collected by the numerous sensory systems put in place throughout the supply chain. Interestingly enough, there are so many more nodes and situations where data can be gathered, this may not seem to be practical or useful at that time but this will add to the collection of information for the company. This collection can be considered "big data" which can be used to feed to these new systems like demand sensing, prescriptive analysis and predictive analysis. In addition to the technologies mentioned in Chapter 5, the future holds great possibilities for the application of Artificial Intelligence (AI) or machine learning, using this big data which companies will accumulate over years. SCM World defines Artificial intelligence as "the use of computers to simulate human intelligence, specifically including learning – the acquisition and classification of information, and reasoning – finding insights into the data" (Manenti, 2017). In simple words, AI is a system which can replicate human intelligence, that is, process information, come to a conclusion, logically analyze the problem and self-learn from the results.

The difference between the technologies mentioned in Chapter 5 and Artificial Intelligence is that AI is more robust and autonomous in its functioning. The technologies mentioned earlier do display AI like functions and cognitive abilities but they are not remotely as advanced as what the future holds. The reason behind this is that there is not enough data available to feed in the system to get such advanced results, nor are the different systems interconnected well enough to reuse the results of one in the other. AI is slated to run many aspects of supply chain without any human interactions, it will be able to make decisions on its own and communicate them to stakeholders. The system will also be a great source in catastrophic situations where AI will be able to react instantaneously with the best solution; this will be possible with the real-time data fed to the AI system.

However, adaptation of AI will require substantial groundwork by companies in the next few years. Creating a large spread IoT network which can collect real-time data from every step of the supply chain will greatly help companies reach that goal. In the meanwhile, these sensors can be put to use with the technologies available in the near future which will also familiarize organizations to work with such systems and get accustomed to it. This will prepare the organization’s workforce to work with more complex systems of the same sort like AI.

Chapter 7

Concluding Remarks

Recommendations

Company D has always been welcoming to new technologies; the existing technologies are increasing the efficiency of the overall supply chain and reaping good results. Chapter 3 established that company D is considered a late adopter of technology; under this assumption, Company D should continue to adopt more IoT technologies slowly. The company has been analyzing the IoT world for a bit now and it will be a good move to upgrade before they are left behind their competitors.

In the short team, the first step will be to consolidate any existing IoT sensors and data points and evaluate what systems can be put in place using this existing data. The next step will be to look for specific data points which are needed to feed into the systems mentioned in Chapter 5 like Demand Sensing, Prescriptive Analysis and Predictive Analysis. Company D should further enable the IoT infrastructure to gather those missing data points and move forward with installing these analysis systems. The efficiencies generated by these systems will certainly outweigh the investments over the years.

In the long run, Company D should continue to explore the IoT network and prepare themselves to adopt AI framework as mentioned in Chapter 6. These systems will aid company D to get ahead in the industry and use data in the best way possible and get counterintuitive results.

Limitations and Risks

A majority of the new technologies coming up, including the ones discussed in Chapter 5 are connecting us to the Internet of Things using the world-wide web and local networks. This creates a security and privacy risk factor since all the data is available on the cloud; companies are more prone to security breech as compared to data stored on a local network. However, in the future, the use of cloud computing and IoT is imperative. This will call for major upgrades in security infrastructure not only for the companies like company D but also for the overall industrial world. Security is a major concern, but it should not hold back companies and lose out on considerable financial gains through efficiencies.

The adoption of new technologies may also create a fundamental issue of not being able to collaborate with existing systems. This will make the adoption process much more difficult as all the processes, data and the workflow will have to be shifted to the new system. In addition, executives and personnel will have to be retrained to learn the new system. The whole process will be very time consuming and expensive. This will also create a huge disruption in the supply chain which can affect the productivity of a company. This loss in productivity is very unpredictable, since it is hard to establish how long the transition will take.

Lastly, even though as late adopters, companies have a good idea about the cost structures and the return on their investments, adaptation of new technologies still calls for a concern about the returns. It is possible that a certain technology may work better in a certain industry or an organization than others and reap higher returns. Thus, it is highly recommended to weigh the benefits to the risks and decide when and if the organization wants to invest in a certain technology. Similarly, Immature technologies display a higher level of risk since there are not as many applications of the technology out there and the companies are unable to weigh the benefits with the risks. However, the gains from a successful immature technology are significant which justifies the risk factor.

In conclusion, companies are recommended to do thorough due diligence before investing in any technology. A wrong step to improve efficiencies can in contrast decrease efficiencies as well.

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