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Application of Lean Principles along with Internet of Things (IoT) to Improve Supply Chain Efficiencies

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Abstract

Today's markets are becoming more and more competitive and volatile where the demand of products are varying at a highly unpredictable manner and companies are finding it difficult to cater to the exact market demand on time thus reducing the efficiencies of the value chain. The global operations of companies today are highly complex where the products are manufactured elsewhere and sold in various countries across the globe. It has become very tough for managers to integrate the flow of information, products and funds across the value chain efficiently as the levels of value chain increases. Few very successful Fortune 500 companies had been highly profitable because of implementing the lean principles like JIT, close co-operation with suppliers, zero defect, 5s, kaizen, etc thus helping the company to maintain low inventories, high productivity and thereby producing high quality products at the right cost. IoT had been a buzzword in today's digital world and the World Economic Forum in 2015 described IoT as one of the enablers in the 4th Industrial revolution that has taken off this decade which is about to transform the business models of many industries. This paper aims to integrate lean principles with the emerging technology enablers of the present decade and implement it by carrying out value stream mapping of the supply chain in an OEM company to arrive at a conclusion that lean operations with IoT technology innovations will lead to higher supply chain efficiencies.

Key words: *Supply chain,Lean, Transport and Logistics, Value Stream Mapping, IoT.*

Introduction

Supply chains come in all sizes and shapes. It is 'as simple as going to a farmer to buy apples or as complex as involving thousands of suppliers, manufacturers, shippers and retailers'. Simple or complex, if one of the steps fails, the entire chain fails as a result. Therefore, efficient Supply Chain Management is vital for optimum performance, cost minimization and customer satisfaction. The concept of lean by means of elimination of waste can make a supply chain even more efficient and competitive. So, along with lean principles, technologies like IoT can add a lot of value to the entire value chain. The profitability that can be harnessed is enormous. Today companies are looking out to reduce costs by investing less and thus increase the throughput of their supply chain. Cost innovation strategies are being considered as top operations priorities of most companies. Countries like India and China have already proven their skill sets in cost innovation in various fields. Now, it's time for corporations to look into their supply chain, take the leadership and innovate to make it the most efficient ones. Supply chain efficiency is being looked upon as one of the most important parameter to remain competitive and increase the overall profitability of companies.

According to a Bain & Company (www.bain.com) survey and report, "Why Companies Flunk Supply Chain 101," more than 85 percent of senior executives say improving their supply chain performance is one of their top priorities, but fewer than 10 percent are adequately tracking that performance. Only 15 percent of the companies surveyed said they had full information on sup-ply chain performance at their own companies, and only 7 percent go outside their four walls to track performance of supply chain activities at their vendors, logistics providers, distributors and customers. Another Bain & Company survey of 300 global companies states that "68 percent of managers think they have failed to optimize their supply chain savings– [1]

Lean SCM

The opportunities to remove waste from a supply chain are based on the elimination of excess inventory, time and cost. Flexible network design, along with basics such as postponement, direct shipping and VMI programs, are examples of how lean principles can be applied supply-chain-wide. In the current economic environment, organizations are starving to be more and leanerto add value to the final customer. In reality, a large number of businesses have already introduced such principles but have yet to apply this concept to their suppliers. This should convince them to do so. Every crisis presents an opportunity to introduce new concepts and paradigms; in Japanese, the word 'crisis' also means 'opportunity' or 'chance.' The so called lean principles, the effects and combination of which are essential for success, were developed by Taichi Ohno, an employee of Toyota Motors. Lean production is based on the Just In Time (JIT) philosophy and the Toyota Production System (TPS) and focuses on the elimination of waste and the minimization of stock. The customer is only willing to pay for products and activities that benefit them by adding value; activities that do not achieve this will not be tolerated and must be rapidly erased.

As part of the JIT approach which emphasizes the zero defect mentality — the correct quality part must arrive in the right place at the right time. There are5 lean principles — flow, pull, define value, value stream mapping and zero defect must be implemented into the supply chain to achieve an optimized global supply chain.

There has been a rising pressure from the financial markets which makes it very important to improve the operating margins of a company. Now, this will require an efficient production/service process. Increasing number of companies are relying on LEAN SCM - a planning concept for harmonized production and replenishment planning across the entire supply chain with close linkages to organizational processes and IT infrastructure. LEAN SCM is designed to enable production and replenishment planning across the entire supply chain in a synchronized way. LEAN SCM is influenced by two main developments: first, traditional supply chain planning and, second, the rise of lean operations. On the one hand, LEAN SCM aims to overcome the well-known drawbacks of (traditional) ERP, MRP, or APS - dependency on forecasts and their inherent complexity. On the other hand, it also aims to translate lean manufacturing principles such as production leveling, takts, and pull production into supply chain planning in order to allow for more simplified and consumption-driven processes-[3]

If we consider the logistics part of the supply chain, modern logistics contains all links in supply chain. Today, logistics just does not mean transportation and storage. Modern logistics had integrated purchasing, storage, transportation, manufacturing, wholesale, retail and after service. Hence, logistics provides integrated service for supply chain. IoT makes the service provided by logistics more intelligent, fast and convenient, visualize and flexible, thus achieving "large logistics". Applying IoT integrates the material flow, fund flow and information flow between customers and LSSC and makes profit for enterprises participated – [2]

The Internet of Things in supply chain

The Internet of Things(IoT) is often considered to be part of the Internet of the future, consisting of billions of intelligent communicating "things" or internet connected objects(ICO). The use of sensor data in the supply chain is not new. Many organizations such as Unilever, United biscuits, Motorolaand Ford, to name a few, already use auto id data (such as RFID)within supply chains(Angeles, 2005). – [6]

Soon, the visibility of inbound and outbound supply chains will be put to the test. Factories will need higher levels of visibility for inbound raw materials and parts to protect against materials shortages. Outbound order tracking will become more important as production schedules are further refined to align the assembly process, manage multiple production and distribution locations, meet customer deadlines and just-in-time delivery, and minimize overproduction. Wholesalers, retailers, and consumers also will be impacted by these technological advancements. Data currently available through smart labels, for example, will continue to be captured and tracked. Their role will become increasingly important at every phase of the manufacturing and distribution process.– [5]

Connecting vehicles and devices within vehicles using a Cloud-based vehicle network will change the land-scape of what's possible from a logistics perspective. All the connected vehicles will be able to distribute data in a very easy, generic way. That will allow for faster innovation cycles, providing more value and increased interoperability. Trucks or container vehicles won't remain as normal vehicles anymore but they are becoming beacons of data. Research firm Gartner estimates the IoT — excluding desktop and laptop computers and smartphones — will include 26 billion discrete pieces of technology by 2020 — up from about 6.4 billion in 2016. Some of those 26 billion units will be sensors on trucks, containers and even pallets. Harnessing the power of the Internet of Things in supply chain involves the identification of the hottest potential markets and getting the right products to production in a timely manner as well as laying thegroundwork for better connectivity in manufacturing environments. – [4]

IOT Architecture

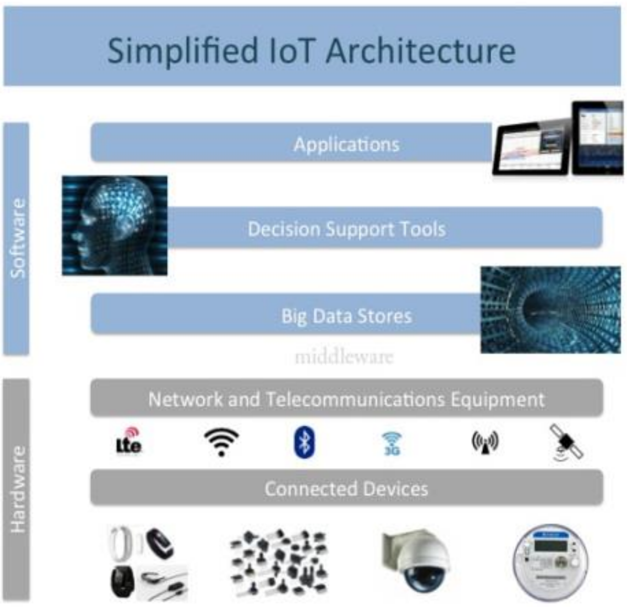


Figure 1 - Simplified IOT architecture – [7]

The above diagram sheds light on the architecture on which IOT platforms are built.

The foundation layer to IoT is ***the Connected Devices***. These devices contain processors, memory and sensors that enable to discover details about the device, its history, its current operating state or abou

t the environment it is located. Sensors include such things gyro / fingerprint reader, /barometer / RG B ambient light / gesture / heart rate /accelerometer / proximity / compass / GPS / temperature sensors, etc. These sensors when coupled together, enables them to become smart not just on sensing data but also to accept remote commands and take an action.
The next layer has ***the network and communication*** devices loaded with the sensors. Sensors are connected to common cloud networks. Networks such as Wi-Fi, Bluetooth, 4G, GPS, etc have the power to provide necessary bandwidth to interconnect these devices.
The Big Data Stores are the next important layer of the architecture. The data collected and stored in cloud cannot be useful unless it is processed into valuable information for business intelligence. This intelligent data is then fed to decision support systems for the top management to take decisions based in it. It's here that business Analytics comes into picture.

Decision Support Systems **-** Without automation, the sheer quantity of data becomes unmanageable and largely unstable.
The filtering, post processing of the data is the first step. The second step is toprovide business rules to that data which is generally known as Event Processing. These processes create the triggers that advice the applications to act to make important decisions and take actions based on the current state of the data being received.

The Application layer is where the business functionality lives. It involves complex piece of scheduling software that has multiple data points from sensors to launch an action like automatic procurement of a material when the inventory is about to attain the re-ordering level. This can be utilized as e-Kanban systems. – [7]
Currently, the majority applications of the IoT are based on the EPC network of RFID. RFID is a non-contact automatic identification technology. It uses the radiofrequency electromagnetic waves through space coupling (alternating magnetic field or electromagnetic fields) to achieve noncontact transmission of information between the reader and the classified tractable moving objects (objects with RFID tags attached).

The **Raspberry Pi** is a series of credit card –sized single-board computers/micro controllers developed in the United Kingdom by the **Raspberry Pi** Foundation. Many projects are being developed on this platform using Java Microedition (ME) with pre-configured I/O libraries. The sensors mounted on the goods as well as the trucks like GPS, temperature and pressure sensors communicate to the servers to which the Raspberry micro controllers are connected to. This enables real time data collection and monitoring for further analysis and decision making.Then there is the logistics management system where the transport vehicle location is monitored in real-time. Once the vehicle fails to move along the scheduled routes or leave the route to pull private goods, etc., a warning will be given immediately. The logistics management system in major includes user management, vehicle management, site management, order management, and distribution management modules.

Application of IoT in Transport and Logistics (T & L)
Intelligent logistics is based on a wide use of the internet of things. It makes use of the advanced information collection, information processing, information flow and information management technologies, and completes a number of basic activities through the whole moving process including the transportation, warehousing, distribution, packaging, loading and unloading. It can help to maximize profits for the supply and provide the best service for the demand while consuming the least

natural and social resources and maximizing the protection of the whole intelligence community logistics management system in the ecological environment. - [10]

Transport and logistics (T & L) are fundamentally about moving things from one place to another. Therefore, the main service components of T&L can be categorized into the things that move and the things that do the moving—**the "demand"** and **"supply"** sides of logistics. The supply side includes warehouses, where goods are stored and forwarded; a transport network (roads/tunnels/sea/air); and the vehicles/vessels/crafts that are used to move goods from suppliers to warehouses and, ultimately, the customer. The capacity, efficiency, manageability, reliability, and, of course, cost efficiency which T&L companies can provide are the key drivers of value on the supply side. Naturally, the common supply-side IoT applications currently focus on improving these drivers and reducing cost (table 1).

Table 1. Common applications of IoT for logistics supply (warehouses, trucks, planes, etc.)

Capacity sensing	Planning & reporting	Route optimization	Energy management	Fault detection & resolution
Systems that can detect and communicate open spaces in a warehouse, port, or parking lot	Systems that can detect and analyze events such as traffic accidents within a delivery network, allowing for more accurate delivery dates	Tools that can map the shortest or most fuel-efficient route for delivery vehicles, for example	Tools that monitor and enable decision making about the use of fuel, lighting, and heating/ cooling within vehicle fleets and facilities	Systems that can monitor fleets of vehicles, aircraft, or ships for faults and maintenance needs, improving uptime for the fleet

The demand side, on the other hand, includes goods to be transported and the customers expecting the goods. The value to customers is determined by the time, security, traceability, and condition of their cargo. Similarly, current IoT use cases focus on improving those factors and include environment monitoring, threat detection and prevention, and real-time traceability down to unit level (table 2).

Table 2. Common applications of IoT for logistics demand (customers, packages, containers, etc.)

Environment monitoring & management	Threat detection & prevention	Real-time traceability
Systems that can monitor and adjust the temperature at which a package is maintained	Tools that can help detect unauthorized openings of shipping containers, helping to prevent and reduce theft	Systems that can track and track not just vehicles or shipments but individual items

Thus far, T&L companies have implemented IoT technologies mostly as track-and-trace applications, intending to decrease network complexity. For example, GPS asset tagging can be used to optimize routes by plotting the real-time locations of trucks and deliveries and using analytics to draw the shortest or most fuel-efficient route between them. Adaptation on the supply side requires a wider scope, integrating multiple external suppliers and distributors throughout the supply chain. In order to avoid such kinds of issues, all participants in the value chain should be connected to a single data system. This helps in reducing the idle time across the supply chain by integrating not only logistics firms and suppliers and distributors in their supply chains but also customers and possible business partners. –[10]

Tools such as a supply-chain risk-monitoring tool offered to customers can take advantage of current knowledge of postal strikes, road closures, natural disasters, and other events that a worldwide fleet gathers, and allows customers to see their supply chain's impact in real time. They can even use the tool to adjust the timing or mode of shipments to minimize the disruption from world events.–[7]

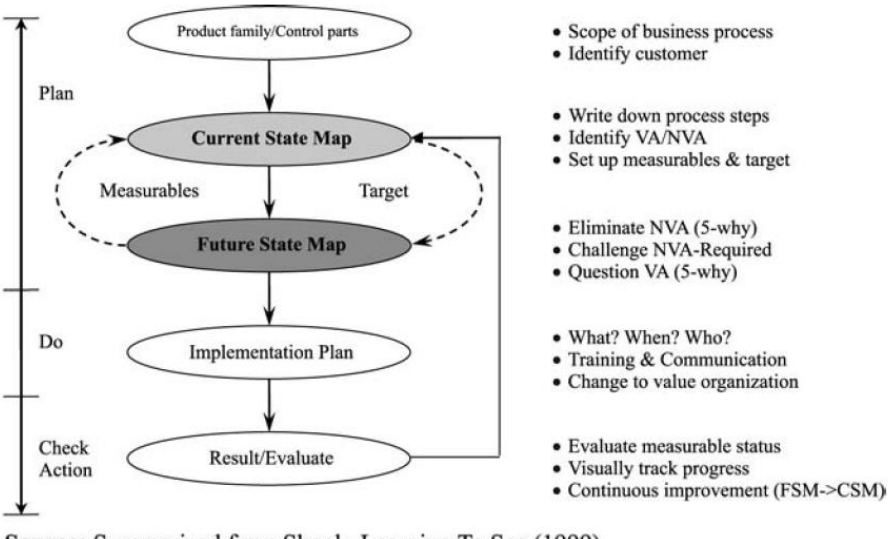
Value Stream Mapping (VSM)

This Value Added and Non Value Added concept were derived mainly from Toyota production System (TPS). "Waste" is defined as anything that interferes with the smooth flow of production (Macduffie and Helper, 1997). The eight wastes highlighted in TPS are overproduction, waiting, conveyance, overprocessing, excessinventory, movement, defects and unused employee creativity, out of which the biggest one being overproduction (Monden, 1998; Liker, 2004). The VSM is a lean supply chain tool used by TPS to identify between wasteful and necessary value-adding activities. VSM begins by listing all operations, and classifies them into VA and NVA (includingwaste). The VA activities are those that customers are willing to pay money for tangible goods or intangible functions. The NVA work includes the eight wastes of TPS. The application of VSM in the TPS not only identifies VA/NVA activities for waste elimination, but also the status of their lead time in the supply chain from incoming parts to finished good delivery. – [8]

A value stream is nothing but the diagrammatic representation of activities required to transform a customer request into a good or service. Creating a VSM is essentially one of the prominent steps of a lean process because VSM involves looking into the current state, identifying the value added and non-value added activities from the customer point of view and them eliminating the waste which can be complimented with the use of technology.

TheVSM of the Indian subsidiary of a Japanese company namely, XYZ India Limited who manufacture automation equipment for process industries was studied and the process starting from the moment a purchase order is placed by a customer to the moment the product is delivered to customer had been analyzed with respect to lean principles. The company manufactures various types of products. For easiness of plotting the VSM, only one product class called Differential Pressure (DP)transmitters had been considered to draw the VSM as the lead time for different products are different.

Currently the whole process from the moment a P.O is placed by a customer till the time product delivery happens at customer location takes 6 (+/-) 1 week on average. The main aim of applying lean principles supported by IoTin the supply chain of XYZ India Limited is to reduce the process lead time which can deliver more competitiveness for the company as few potential large size orders were being lost to its competitors due to more lead time in comparison to the company's competitors. The product is highly recognized by all process industries globally as a highly reliable product with high quality standards. A reduction in process lead times can help XYZ India Limited to win more number of orders and improve overall customer satisfaction levels.



Source: Summarized from Shook, Learning To See (1999)

Figure 2 – VSM Improvement cycle – [8]

Current State VSM

The current state VSM consists of the value stream map has captured the *"as-is condition"* of the process and used as a baseline to analyze the different kinds of waste which can be eliminated using lean tools and technology. – [11]

The current value stream map had been obtained after studying the entire processes involved from order processing to getting the material ready for dispatch to customer location. Inputs from various departments like Sales, OPD, manufacturing, centralized material handling and Logistics were obtained after discussion with corresponding officials. In the present VSM, the main time consuming processes had been studied which are contributing to major delays and lean principles along with IoT and digitalization had been applied for streamlining the value chain. The current VSM has a lead time of 54 days (8weeks approximately).

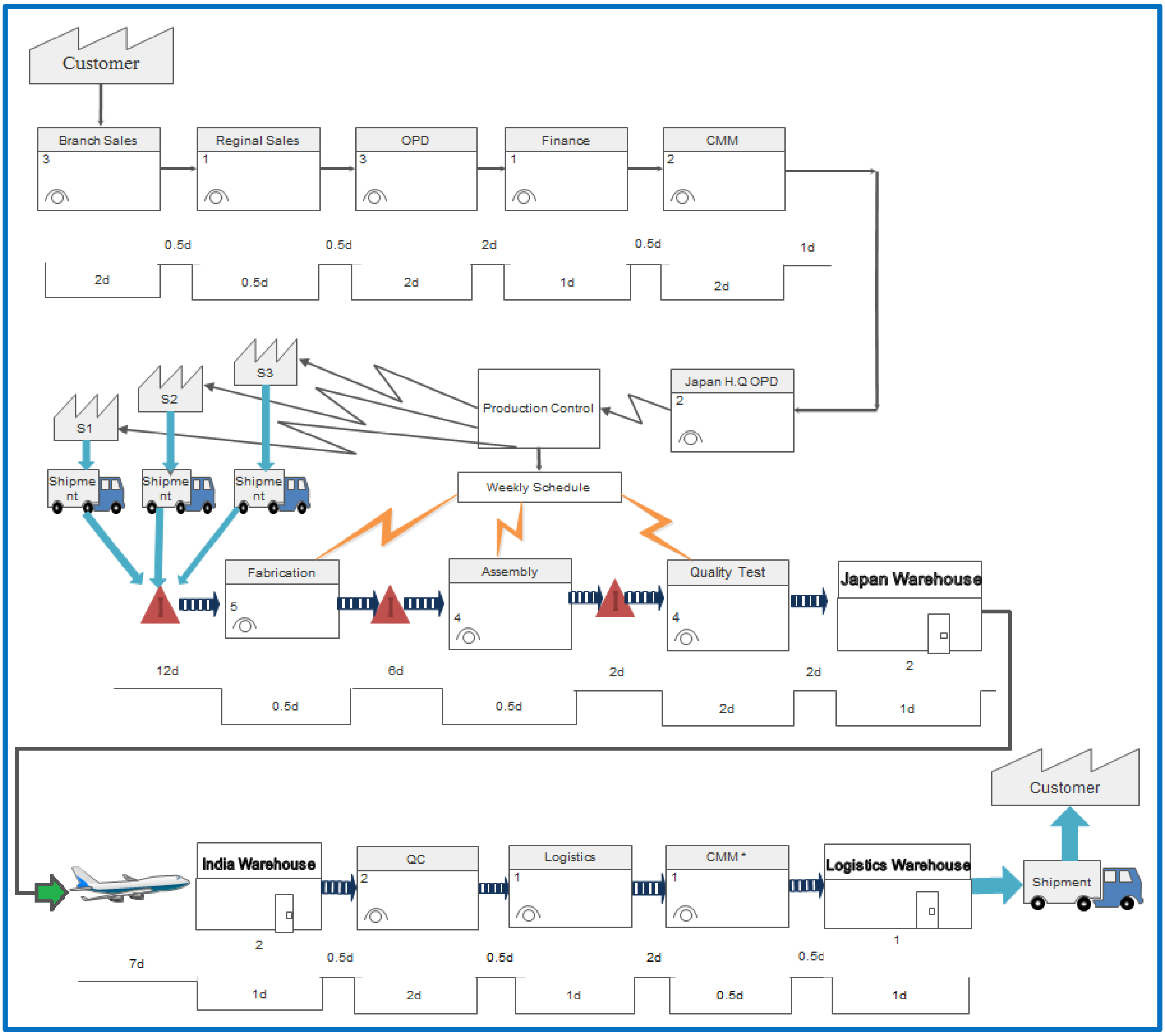


Figure 3 – Current state VSM

Future State VSM

After analysis of the current state VSM, if the order processing process is taken into consideration, few non-value added activities like redundant or excessive paper work can be done in parallel using IoT cloud computing which enables real time monitoring and exchange of data within several departments. This allows few processes not to wait for its predecessor process to complete in order to start processing a purchase order, thus reducing the number of inter-dependencies

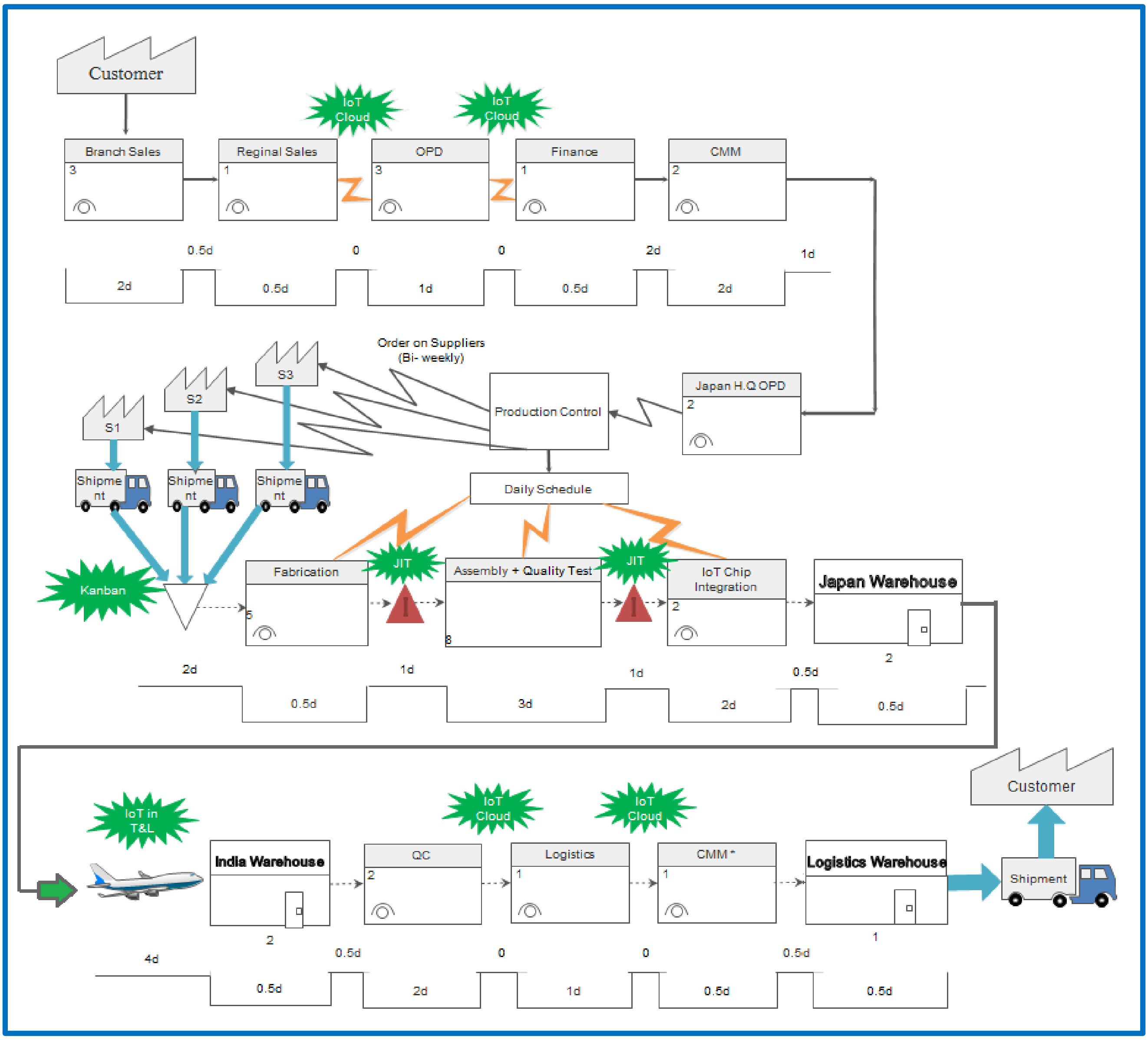


Figure 4 – Future state VSM

Within the manufacturing process in Japan, the production schedule which used to be circulated on weekly basis to the suppliers is to be made bi-weekly. AKanban system should be put in place before the fabrication process. 'Kanban' refers to 'visual cards' and this enables a successful pull/JIT system ultimately resulting in the production being enabled by customer demand. Hence, automatic re-ordering of raw materials from suppliers shall benefit the entire value chain. The Kanban has been designed as e-Kanban using IoT where sensors detect the replenishment quality which is already programmed in the sensors of each raw material store package. When an order is placed in India and once the Finance team clears it, even before the issue of source document by CMM (Centralized Material

Management) team, the order details can be fed into the IoT cloud database of the Japan manufacturing facility which helps the Japan OPD (Order Processing Department) to initiate the procurement process with the suppliers. Since the parts are standardized, suppliers are already grouped into Tier 1, 2 and 3 and thus time would not be wasted in deciding the suppliers for each order. Thus, the real time demand is established. This IoT cloud database is shared with the Indian team, Japanese team and even the Tier 1 suppliers in Japan. Hence, real time order processing takes place together at 3 locations.The idle time between fabrication, assembling and quality testing had been greatly reduced due to Just-In-Time (JIT) inventory management. The assembly and quality testing departments had been proposed to be grouped together. Earlier, the quality testing department used to wait for the completion of each lot of material from the Assembly process line. But now that both departments are grouped together, the idle time between each has been eliminated since each transmitter assembled can be directed towards quality checking. An extra process has been added after fabrication which deals with the IoT chip programming and stamping on each box of finished product. Pre manufactured IoT smart chips would already be available in inventory. This enables the real time tracking and easy material identification within the Japanese and Indian warehouses. Along with that, IoT stamping on each box helps faster air delivery from Japan to India and the promised date of material delivery to customer is shared with the 3rd party logistics provider so that each pallet is exported to India at the right time. Earlier, the materials used to be transported to a hub (for example Indonesia) and the material used to wait there in a intermediary distribution center (D.C) until the next connecting flight to India is scheduled. But with IoT in place, since the logistics provider is aware of the end customer delivery date, he doesn't transport the material to hub before the departure time of the aircraft. Now, the transpiration is completely synchronized to avoid delays from airport to airport transfer. Thus, sufficient lead time is saved in this process. Once the material reaches Bangalore airport and after customs clearance is completed, the material reaches the Indian Operations warehouse. Even at this stage, the documentation part of logistics and CMM team can be done in parallel using IoT cloud sharing once Q.C team completes the final testing. The proposed future state VSM has achieved 64.86 % reduction of Non-value added activities thus delivering the product within 1 month of P.O receipt from customer.

Comparison of current state and future state VSM

Variable	**Before**	**After**	**Improvement**
Total Lead Time (days)	**54**	**29.5**	**45.38%**
C/T Non-Value added (days)	**37**	**13**	**64.86%**

Conclusion

As observed from the future state VSM, the lead time had been reduced to 29.5 days (4.2 weeks) which is approximately 1 month, using the principles of Pull, thereby saving 24.5 days in total. This lead time reduction will result in abundant value addition to customers as well as the organization by gaining back the confidence of customers hence enabling XYZ Pvt. Ltd to boost its overall sales revenue. As per Lean principles, this 45% improvement in process speed and capability will result in higher process efficiency and customer satisfaction. The reduced lead time can become a USP for its products as XYZ Pvt. Ltd is now able to deliver the material faster than its competitors with superior product quality. The reduction in total lead time will also result in higher bottom line profits contributing to the better operations profitability.

Further research is recommended in the area of advanced IoT applications which could streamline various complex industry processes. As per World Economic Forum (WEF), Industry 4.0 had already set new standards thus revolutionizing the way business is done in various industries. The realization of a connected and secure world will lead to the emergence of new business opportunities and millions of dollars in profits earned. Hence, the companies who succeed in improving their supply chain efficiencies will have a upper edge over its competitors, thus helping them survive any upcoming industry bursts and strive to survive as world's leading corporations.

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