SMART Warehouse with Internet of Things supported Inventory Management System

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Abstract

The objective of this study is to unearth the potential of Internet of Things when amalgamated to the Inventory Management in a Warehouse converting the warehouse into a SMART warehouse. Data Analysis: The inferences are drawn from reports such as Gartner reports; Forrester waves etc. and focused group discussions held with managers from organizations that have decent size warehouse operations. Techniques such as brainstorming, content analysis, Grounded theory etc. were deployed to derive solutions. Findings: The current state of technology, warehousing operations, inventory systems etc. were analyzed by the researchers. The technology roadmap was validated with its applicability to warehouse and inventory management systems that will transform the warehouse into a SMART warehouse. Solutions were derived that would support the real
time data gathering from the warehouse and get consumed in different data models to manage the inventory efficiently. Researchers in this article have also explained the Service Oriented Architecture applicable to the IoT implementation in an organization that connects the three layers of an IoT landscape. The study further explains the current and future business scenario along with the pressing need of an Internet of Things supported inventory management system for transforming the warehouse into a SMART warehouse.

**Key Words:** SMART Warehouse, Inventory Management, Internet of Things, Warehouse Management, Service Oriented Architecture.

1 Introduction

*Warehouse Management:*

In the entire supply chain, there is a need to store the inventory temporarily for committing certain transactions needed for consolidation, shipment etc. The place where this inventory is stored is termed as a Warehouse. Basis processes of the warehouse remain of receiving, storing, order processing and dispatch of inventory basis, the customer orders including some value added services. Warehouse plays a crucial role in the supply chain management for the customer orders correctly served [1]. The complete management of inventory movement within the warehouse in the most efficient way in order to ensure the completion of warehouse operations optimally is termed as Warehouse Management [2].

*Inventory Management:*

Every organization needs inventory to take care of supply and logistics lead time etc. Inventory de-stresses the supply chain by infusing predictability, taking care of demand fluctuations, de-risking the unreliability of supply and at times price protection [3]. The supervision and control of this inventory is termed as Inventory Management [4].

*Internet of Things:*

Almost all the businesses today are influenced by the Internet due to the ubiquitous presence. Internet in the last five decades has grown substantially from a micro to a macro network connecting billion of users and things [5]. IoT [6] is defined as a network of
dedicated physical objects (things) that contain embedded technology to sense or interact with their internal state or the external environment. With Internet of things, the physical things are connected to the virtual world integrating with all systems [5]. Internet of Things connects people and things anytime anywhere with other things over a network [7].

2 THEORETICAL FOUNDATIONS

Essentials of Warehouse Management:

Profoundly, Warehouse Management is a system to control the entire movement and storage of inventory within the four walls of the warehouse. It encompasses the various activities of the warehouse such as managing inventory, order picking, order packing and dispatch [8]. Traditional approach of warehouses being just the distribution center has diminished and warehouse management has become a strategic business process. These developments have influenced and brought about a paradigm shift in the way inventory was managed in the warehouse [9]. There are certain trade-offs, which the warehouse manager has to accomplish. These include tangible as well as non-tangible aspects where the decision is directly linked to the strategic objectives of the organization. The trade-offs which the warehouse manager is exposed, are inventory cost versus customer service; retrieval speed versus storage capacity of the warehouse; Transaction/operation speed versus order dispatch accuracy, stock-out versus lower inventory; storage cost versus handling cost versus volume purchases etc [1]. Inventory control hence becomes a vital aspect contributing to the success of an organization [3].

Why Inventory Control?

Inventory as stated earlier is the stock of goods held by an organization in a warehouse. The function of supply of material integrated with cost optimization and other activities in order to service customer order is termed as Inventory management [17]. Inventory management is the nerve of a supply chain for an organization [17]. The management of inventory safeguards the organization against stock-outs and ensures desired customer service level [37]. Some of the other reasons for the organization to maintaining and
managing inventory are [3]:

a. **Transparency:** Inventory control enables the requisite transparency into the next processes whether it is manufacturing or a customer order dispatch from the organization. Organization can also commit against the customer order basis the inventory held in the warehouse. Inventory control also provides the buffer to bridge the gap between the plan and the actual operations [3]. The need for data is inevitable and real time data contributes to the agility of the organization where they can fine tune the operations real time while the feed can also be consumed for forecasting the demands [10].

b. **Volatile Customer Demands:** In the current era, customers get exposed to different brands, which results in changes of their choices and preferences quite frequently. Customer centric organizations have to take into account this volatility in demands from the customers and strategize their inventory planning accordingly [3]. To counter the customer behavior and to maintain the service levels, organizations also deploy analytical models which are utilized to forecast the demand and plan for the inventories accordingly. Real time data feeds help in fine-tuning these models so that they remain relevant to the existing market conditions [10][35][36].

c. **Erratic Supplies:** An optimized inventory control system does save the organization against erratic and unpredictable supplies of products to the warehouse. Basis consumption pattern, the suppliers are awarded long-term contracts i.e. a purchase order clearly mentioning the interspaced delivery schedule. The terms and conditions state the penalties for non-delivery of the goods[3]. Since it is a long-term commitment, the quantities demanded have to be based upon strong forecasting model outputs that are dependent on a large volume of data. Different types of models such as Time Series model and Causal method of forecasting are deployed by organizations to predict the future demands [10].

d. **Safeguarding Price fluctuation**[3]: Organizations while ordering inventory fundamentally look at few facets such as, impact of cost inflations, economic order quantities, time of delivery etc. Impact of cost inflations requires some real time data to get into the decision making model. Committing an order quantity does not require funds but organizations deal for assured and lower price of the products to be bought. The delivery dates stated are of the fu-
From the above important scenarios discussed, there is an eminently need of data deriving for the optimum inventory planning. This need of data is immense and humanly impossible and infeasible to capture [11].

**Inventory Control Techniques:**

It is proven that the shortfalls in the inventory control result in serious problems for the organization such as production delays, dissatisfied customers, and inventory getting piled up resulting in obsolescence [12]. To decide on right amount of inventory that suffices the customer orders and operating with profitability needs certain techniques and methodologies to be followed. Inventory management further becomes extremely grave with a large number of unique parts to be stored called as stock keeping units (SKU) [13]. Further, there are some costs associated with inventory that need to be understood such as cost of part, labor, storage space, obsolescence, theft etc. that are generally clubbed and termed as inventory holding costs [3]. Organizations invest heavily in raw material, work in progress and finished goods inventory and therefore it serves as a huge potential for cost saving that is achieved by deploying appropriate inventory control techniques [14]. The different techniques used in Inventory control are [15][16][17]:

a. **ABC Analysis**[15][16]: The inventory analysis in this method is done basis the unit cost of the material. All the parts in the warehouse are classified into three categories. A being the highest cost items where the investments are on the higher side, while C being the low cost items where the inventory costs are lower and B stands in-between A and C. Arduous efforts are required to manage the A category items which is top 20% contributing to 80% of sale value. A category parts need tiring levels of monitoring as compared to B and C. After A category, the next 20% of the inventory is regarded as B category, and rest 60% is C category.

b. **Just in Time (JIT) Method**[13]: This method ensures that the product reaches as per the customer demand which depends upon the customer behavior. Accuracy is gained by tracking the patterns of customer buying, seasonal demand and the geographical location factors. The positive side of this approach is nil inventories theoretically, while misreading the customer demand resulting in
shortages or obsolescence could be the possible negatives.

c. Frequency (Fast, Slow and Non-moving) Analysis: Customer demands are never similar for the entire range of SKUs. The frequency of part movement is also used to categorize the parts into Fast, Slow and Non-moving. The treatment given to each category is different with diverse strategies of procurement adopted [14]. The data gathered about the movement of parts helps in planning the inventory in the most appropriate and optimal way. The planning in this case includes not just ordering the parts, procuring as per the lead-time but also the storage of parts. Storing the fast moving parts at ground level or at a much more accessible place improves the warehouse efficiency [1].

d. Vital, Essential & Desirable (VED) Analysis[18]: Perception and usability drives this classification where the inventory is categorized into vital, essential and desirable. Inventory categorized as vital needs to be in stock unfailingly while a minimum stock of essential is sufficient at all times. Desirable inventory is the one where the operations can continue with or without it.

e. Safety Stock Method[15][16]: This method of calls for holding some inventory to take care of exigencies such as, increased consumption, sudden high demand, delay in receipts etc. The quantity of inventory to be held is decided basis the consumption of the part for a defined period such as a year and the lead-time i.e. the time it takes for the part to arrive once ordered on the supplier. The thumb rule for considering lead-time is a maximum of 100 days to minimum of 60 days.

f. Economic Order Quantity (EOQ) Method[17]: This technique of inventory management is used to govern the optimum inventory order quantity that would strike the lowest order cost and carrying cost. It calls for deriving the optimum quantity that is ordered by the organization on its suppliers which brings about a balance between the two opposing costs i.e. procurement costs and inventory holding costs.

The formula used to derive EOQ is:

$$EOQ = \sqrt{\frac{2 \times \text{Demand} \times \text{Re - ordercost}}{\text{CarryingCost}}}$$

(17)
g. Scarce, Difficult & Easily available analysis[18]: This method groups the inventory based upon the sourcing or lead-time. Different strategies of stocking norms are required to each of these categories and the underlying data is vital for the decision-making.

3 INTERNET OF THINGS ASSISTED INVENTORY MANAGEMENT SYSTEM FOR A SMART WAREHOUSE:

The researchers have emphasized on the warehouse management and the inherent inventory control techniques that organizations adopt basis its applicability and suitability to the business. To establish the usage of IoT solutions for an inventory management system that makes the warehouse smarter, focused group discussions were conducted with digital experts. A semi structured questionnaire was deployed during these discussions. Tools such as brainstorming, content analysis and text analytics were used to arrive at the right inferences. The solutions mentioned below were derived out of the secondary data analysis and the focused group discussions were conducted with the industry digital experts. One of the crucial element echoed by all the experts was connect of the entire control of inventory that lies on the thrust on data availability. The need for a single collaborative platform for data exchange is inevitable [19]. Internet today has become the fastest and the largest network for data exchange globally connecting billion of things. Evolution in the network domain and ubiquitous presence of internet gave rise to the concept of Internet of Things. Fundamentally, the things as referred in the term Internet of Things are self-sufficient sensors having the capability of collecting and transmitting the real time data over the Internet making them smarter [20]. Real time data infuses the requisite agility within the organization processes to take care of the volatility in the customer demands [5]. Data is accessed remotely as the sensors connect to the internet and transfer the data over the Internet. This enables the control and analysis of data in an isolated fashion away from the location where actually the data is gathered [21]. The foundation of IoT is based upon the coordinated and collaborative work done by the sensors and
the communication technologies to reach common goals. IoT has demonstrated a strong growth in the past and further promises to be the next big thing of the future [22]. Internet of things has the potential to help business achieve the tangible benefits as a part of the return of investment in IoT. Better inventory management, higher visibility to the management by virtue of collaboration improved life cycle management etc. are some of the visible benefits post implementation of IoT. The unique identification of the source of data empowers the system to interact at an individual sensor level and build its own interaction history that is capitalized further. The sensors currently have undergone drastic evolutions such that business logic can be configured, executed on the same [7]. It has gained a prominent position in the technology road map of organizations especially due to the capability of real time data capture. The real time data is collated from physical things i.e. sensors that have unique identifiers to detect the point of data source [5]. This is one of the most significant points in the warehouse as it triggers the next level processes for the warehouse. There is an interplay between the sensors i.e. physical things, placed in the warehouse at appropriate locations and the digital identifiers that enable and unleash the basic idea of inventory movement tracking [23]. Traditional ways have suffered from an intrinsic issue of lag in the information transfer, giving rise to the supply chain inefficiencies due to delay etc. With the help of IoT, real time data is gathered and transmitted over the internet, streamed into the business models enabling quick real time decisions [5]. Operationally in the warehouse, the IoT can be positioned to track the receipt of material, real time monitoring of stocks, detection of stock-outs and effective tracking of batches, FIFO (First In First Out) for parts having shelf life etc. [7]. The technologies involved in IoT that focus on identification and tracking include RFID (Radio Frequency Identification), bar codes to some extent and smart sensors. Out of which RFID is widely used due to the identification and tracking capabilities. Other benefits of RFID include simplifying business processes, reduced labor cost, increasing accuracy of the movement and location of inventory and constantly rallying of business efficiencies [22].

**Inventory Management:** There are a number of inventory management techniques, out of which, we have listed the important ones in the previous section. It would be interesting to look at the
data requirements to enable the organizations deploy these inventory management techniques in order to manage the inventory held. The essential part of the data requirement turns out to be tracking of the part in the warehouse. Real-time part tracking information is generated with RFID sensors connected to the wireless sensor network (WSN). The RFID sensors are constantly collating the signals by way of scanning the RFID tags and transmit the information over the WSN to a common server [22]. Entire information is collated, analyzed for deriving different inferences. Researchers have identified a huge potential in this domain that is not yet exploited to its fullest potential and there is still a lot of room to improve [22]. The RFID tag is a low-cost tag converted into a smart tag by virtue of the information stored via coding the tag [21]. With the RFID tags in combination with smart shelves that are capable of tracking the parts, IoT can generate real-time data consumed by a variety of applications and analytical business models [7]. The experts concluded that numbers of business models are created to derive the various categorizations of parts in the warehouse with different thresholds configured. For e.g. a part not moved from the shelf, for a particular duration, could be determined by the model as non-moving while, another part basis its frequency of movement within a day or an hour stated as fast-moving. The movement of parts out of the shelves is also helpful in determining the demand for parts. Essentially, the state change with respect to time is sensed by the sensors and transmitted over the Internet. This recording of state changes of the design parameters is crucial for closed-looping of the decision-making process [24]. In a warehouse, the tracking of the part starts from the moment it is received in the warehouse until it is dispatched against a customer order. There are sensors that are fitted on the shelves converting them into SMART shelves. The purpose of these shelves is not restricted until the tracking of movement for doing the different types of inventory analysis. It also communicates with the internal as well as external stakeholders, which in a warehouse would be a supplier. The inventory position is communicated to the warehouse manager in the organization and to the supplier so that the supplies can be influenced. Classical used case of this system would be an IoT supported Vendor Managed Inventory (VMI) system. In case of a VMI or Consignor inventory, the responsibility of monitoring and replenishing the in-
The supplier also governs the optimization of the inventory held by the distributor [26]. The transparency of inventory position in the warehouse is necessary for VMI to function that is aided by the IoT devices in the SMART shelves [27]. Thus, instead of a reactive inventory management system and warehouse, the entire warehouse set up transforms into a proactive setup thrusting the organizational agility to service the customer demands and yet maintaining the warehouse discipline automatically. Batch management is another inventory management process that gets benefitted big time with the IoT landscape. Parts that are to be dispatched as per the batch, wherein First- in- First- out (FIFO) is mandatory, can be easily achieved by IoT landscape. These sensors (things) are working in tandem with the enterprise systems, proposing a batch number for the next process. It is noteworthy here that the discipline is attained automatically, when the system even restricts the picking of an incorrect batch from the SMART shelves [28]. IoT when implemented to the fullest can also provide inputs to the warehouse robots that can communicated with the IoT landscape. This development can prove a paradigm shift wherein the warehouses will operate with very less human intervention consuming optimum space [32]. With Internet of things, the warehouse can be translated to a SMART Warehouse with intelligent inventory management system.

4 ARCHITECTURE OF THE IOT LANDSCAPE [22]:

It is recommended to create a multi-level Service Oriented Architecture (SOA) for the Internet of Things to be implemented. IoT connects different things together to the network and hence needs an adaptive architecture to help the dynamic interactions. The interoperability requirement of IoT to work with heterogeneous devices is achieved with the SOA easily. It consists of four layers i.e. sensing layer, networking layer, service layer and the interfacing layer. Sensing layer enables the exchange of information between the heterogeneous wireless smart things. The networking layer is responsible for the communication and sharing of information be-
between the smart things and with other devices for ensuring that the tasks are completed for which the things are deployed. The service layer is similar to the middleware that aids the integration of the IoT landscape with any external application of software seamlessly. It also takes care of the service oriented issues such as communication, storage, search engines, databases etc. The interface layer can be looked upon as a subset of service layer that provides the interaction methods. It assists the interaction of heterogeneous devices that are connected via an interface profile similar to creation of a plug and play system. Together these four layers form the service-oriented architecture for IoT deployment in any organization.

5 CONCLUSION

The study revealed the fact of how the Internet of Things can achieve a paradigm shift in a warehouse turning it into a proactive, smart and increasingly efficient organizational entity. It also helps save cost for the organization increasing the productivity of the warehouse with the same resources. IoT intelligently connects the physical warehouse world to the virtual world digitally. Internet today is having ubiquitous presence empowering the evolution, implementation and spread of Internet of Things [5]. 40 billion devices are projected to get connected over the internet in the year 2020 [33]. Customers due to the easily accessible information are getting knowledgeable with each passing day. Their demands are changing and expectations are rising continuously. They are also exposed to the global competitors offering them a plethora of alternatives to choose from. This provokes the organizations to work on change managements in an agile way where the SMART warehouse becomes the backbone and supports the firm in the fierce market competition while overcoming the challenges such as demand volatility [34] etc.

References


