ANALYSIS AND STUDY OF WAREHOUSE MANAGEMENT SYSTEMS

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Abstract - *Inside the walls of the warehouse, the utilization of every component—space, people, inventory and equipment—will impact the bottom line in profound ways over time. Warehouse Management enables us to analyze these components continually, so we can conserve effort, fill orders faster and more accurately, save space and reduce inventory. In this paper, a preliminary simplified layout of a warehouse using the quantities and sales data obtained from two frontrunners in shoe manufacturing is designed. The data has been analyzed and arranged in terms of the volumetric distribution of the goods, using extensive analysis through pivot tables, pie charts, tables and bar graphs. The proposed layout for the warehouse has been provided towards the end. The paper considers various theoretical considerations to keep in mind before designing a warehouse. It also looks at the need for warehousing, the functions performed by warehousing, and the principles required for designing the layout of a warehouse, with due considerations of the material handling principles for material movement inside the warehouse. In the second part of the analysis, simple linear regression models are utilized to analyze and organize data for effective determination of the future demand trends in the shoe manufacturing industry and determine the future scope of expansion for demand adjustment. In the final part of the analysis, inventory management policies are utilized, both Continuous Review Policy and Periodic Review Policy, to determine the average inventory level requirements for the warehouse. Finally, Review Policy most suitable for each product line is determined.*

***Key Words*: warehouse management, continuous review policy, periodic review policy, inventory management, square root law, linear regression**

1. INTRODUCTION

1.1 WAREHOUSE MANAGEMENT

Warehouse can play a key role in the integrated logistics strategy and its building and maintaining good relationships between supply chain partners. Warehousing affects customer service stock-out rates and firm's sales and marketing success. A warehouse smoothens out market supply and demand fluctuations. When supply exceeds demand, demand warehouse stores products in anticipation of customer's requirements and when demand exceeds supply the warehouse can speed product movement to the customer by performing additional services like marking prices, packaging products or final assemblies.

Warehousing can be defined as a location with adequate facilities where volume shipments are received from production center, which are then broken down in to particular order and shipped onwards to the customer. Warehousing is an integral part of any logistics system. The warehouse is a link between producer and customer. Warehouse Management provides the insight into your inventory and the warehouse management tools to help you increase customer satisfaction and reduce costs. Warehouse Management exchanges information with many other functional areas in the solution including Logistics, Production and Trade, to help improve your overall business performance. Warehouse Management is used to optimize Inventory, Labor, Physical Space, and Time.

1.2 FUNCTIONS OF WAREHOUSING

Warehouses are basically intermediate storage points in the logistics system where raw material, work in process, finished goods and good in transit are held for varying duration of times for a variety of purposes. The warehousing functionality today is much more than the traditional function of storage.

The following are the main functions that warehousing serves today:

Consolidation: This helps to provide for the customer requirement of a combination of products from different supply or manufacturing sources. Instead of transporting the products as small shipments from different sources, it would be more economical to have a consolidation warehouse. This warehouse will receive these products from various sources and consolidate these into shipments, which are economical for transportation or as required by the customers.

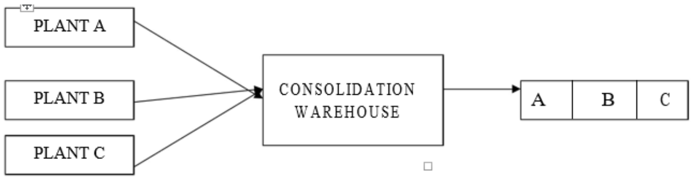

Fig. 1.1 Consolidation Block Diagram

Break bulk: As the name suggests, the warehouse in this case serves the purpose of receiving bulk shipments through economical long-distance transportation and breaking of these into small shipments for local delivery. This enables transportation economies with combination of long-distance bulk transportation, break bulk warehousing, and short distance small shipments in place of long-distance small shipments.

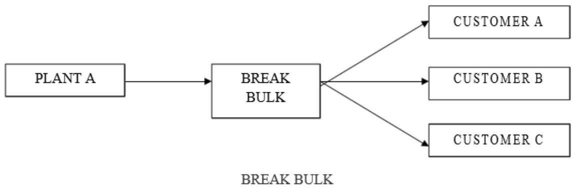

Fig. 1.2 Break Bulk Block Diagram

Cross docking: This type of facility enables receipt of full shipments from a number of suppliers, generally manufacturers, and direct distribution to different customers without storage. As soon as the shipments are received, these are allocated to the respective customers and are moved across to the vehicle for the onwards shipments to the respective customers at these facilities. Smaller shipments accompanying these full shipments are moved to the temporary storage in these facilities awaiting shipments to the respective customers along with other full shipments.

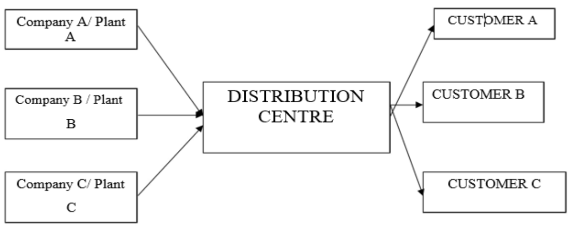

Fig. 1.3 Cross Docking Block Diagram

Product mixing: Products of different types are received from different manufacturing plants or sources in full shipment sizes. These products are mixed at these warehouses into right combination for the relevant customers as per their requirements. Some products that are commonly required inmost product mixtures are kept in constant storage at these warehouses and continuously provided for the product mixture shipments requiring these.

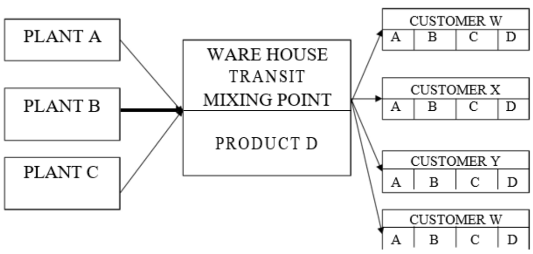

Fig. 1.4 Product Mixing Block Diagram

Stock piling: This function of warehousing is related to seasonal manufacturing or demand. In the case of seasonal manufacturing, certain raw materials are available during short periods of the year. Hence, manufacturing is possible only during these periods of availability, while the demand is full year around. This requires stockpiling of the products manufactured from these raw materials. An example is mango pulp processing. On the other hand, certain products like woolens are required seasonally, but are produced throughout the year, and thus need to be stockpiled as such.

Postponement: This functionality of warehousing enables postponement of commitment of products to customers until orders are received from them. Manufacturers or distributors for storing products up to the packaging stage utilize this. These products are packaged and labeled for the particular customer only on receipt of the order.

Positioning: This permit positioning products or materials at strategic warehouses near the customers. These items are stored at the warehouse until ordered by the customers when these can be provided to the customers in the shortest lead-time. This function of warehousing is utilized for higher service levels to customers for critical items and during increased marketing activists and promotions.

Assortment: Assortment warehouse store a variety of products for satisfying the requirements of customers. For example, retailers may demand different brands of the same product in small quantities rather than larger quantities of the single brand.

Decoupling: During manufacturing, operation lead-times may differ in order to enable production economies. Thus, the batch size and the lead-time of production may differ in consecutive operations. This decoupling of operations requires intermediate storage of materials required for the subsequent operation.

Safety stocking: In order to cater to contingencies like stock outs, transportation delays, receipt of defective or damaged goods, and strikes, safety stocks have to be maintained. This ensures that, on the inbound side production stoppages do not occur, and, on the outbound side customers are fulfilled on time.

1.3 NEED FOR WAREHOUSING

Seasonal production: The agricultural commodities are harvested during certain seasons, but their consumption or use takes place throughout the year. Therefore, there is a need for proper storage or warehousing for these commodities, from where they can be supplied as and when required.

Seasonal demand: There are certain goods, which are demanded seasonally, like woolen garments in winters or umbrellas in the rainy season. The production of these goods takes place throughout the year to meet the seasonal demand. So, there is a need to store these goods in a warehouse to make them available at the time of need.

Large-scale production: In case of manufactured goods, the production takes place to meet the existing as well as future demand of the products. Manufacturers also produce goods in huge quantity to enjoy the benefits of large-scale production, which is more economical. So the finished products, which are produced on a large scale, need to be stored properly till they are cleared by sales.

Quick supply: Both industrial as well as agricultural goods are produced at some specific places but consumed throughout the country. Therefore, it is essential to stock these goods near the place of consumption, so that without making any delay these goods are made available to the consumers at the time of their need.

Continuous production: Continuous production of goods in factories requires adequate supply of raw materials. So, there is a need to keep sufficient quantity of stock of raw material in the warehouse to ensure continuous production.

Price stabilization: To maintain a reasonable level of the price of the goods in the market there is a need to keep sufficient stock in the warehouses. Scarcity in supply of goods may increase their price in the market. Again, excess production and supply may also lead to fall in prices of the product. By maintaining a balance in the supply of goods, warehousing ensures price stabilization.

1.4 SQUARE ROOT LAW

The square root law states that:

"*The total safety stock inventories in the future number of facilities can be approximated by multiplying the total amount of inventory at existing facilities by the square root of the number of future facilities divided by number of existing facilities.*"

In their aggressive effort to take cost out of logistics network, firms are searching for new ways to reduce levels of inventory without adversely effecting customer service. A currently popular approach is to consolidate inventories into fewer stoking location in order to reduce aggregate inventories and their associated cost. Correspondingly, this strategy requires the involvement of capable transportation and information resources to see that customer service is held at existing levels and is even improved whenever possible.

The square root law helps determine the extent to which inventories may be reduced through such strategy. Assuming the total customer demand remains the same, the SRL estimates the extent to which aggregate inventory needs will change as a firm increases or reduces the number of stocking location. In general, the greater the number of stoking locations, the greater the amount of inventory needed to maintain customer service levels. Conversely, as inventories are consolidated into fewer stocking locations, aggregate inventory levels will decrease. The extent to which these changes will occur is understood through application of the square root law.

Therefore

$$X2 = X1 \sqrt{N2/N1} \qquad (1.1)$$

Where:

N1= number of existing facilities
N2= number of future facilities
X1= total inventory in existing facility
X2= total inventory in future facility

1.5 NUMBER OF WAREHOUSES

The number of warehouses is another decision parameter impacting a number of cost variables and customer service. If customer service is taken in cost terms as cost of customer dissatisfaction, the number of warehouses will affect transportation, inventory, warehousing and customer dissatisfaction costs.

Transportation costs initially decreases with increasing number of warehouses. This is due to the transportation economies obtained by having large-volume long-range transportation from consolidation warehouses and short-range small-volume transportation from break-bulk warehouses. However, as the number of warehouses increases beyond a certain value, the transportation cost starts increasing due to large number of transportation trips in –between the larger numbers of warehouses. Inventory costs continuously increases with the increasing number of warehouses because the increased space available needs to be utilized and firms increase the commitment of inventory at these warehouses beyond those actually needed. Transit inventory costs continuously decrease with the increased number of warehouses due to the shorter transportation times between the larger number of warehouses. The warehousing costs increase with more warehouses due to the maintenance and facility costs associated with each warehouse. For the same space, a single warehouse incurs less warehousing cost than two warehouses. The increasing number of warehousing leads to increasing customer service levels, thus, decreasing customer dissatisfaction cost.

1.6 WAREHOUSE LOCATION

Warehousing is important to the firms since it improves service and reduces cost improvements in service are gained through rapid response to customer requests (time utility), which is a primary factor leading to increased sales. The manufacturing plant, and customer and market locations affect the location decision regarding warehouses. A traditional classification by Edgar Hoover classifies warehouse locations as market-positioned, manufacturing-positioned, or intermediately positioned.

Market positioned warehouses: Market-positioned warehouses are located near to the customers and markets (point of product consumption) with the objective of serving them. These generally have a large variety and low volume of items to service local requirements. Such warehouses reduce cost by providing place utility. A Market-positioned warehouses functions as a collection point for the products of distant firms with the resulting accumulations of product serving as the supply source for retail inventory replenishment. This approach allows large and cost-effective shipments from the manufacturer with lower-cost, local transportation providing service to individual retailers. Market-positioned warehouses may be owned by the firm or the retailer (private warehouses), or they may be an independent business providing warehouse service for profit (public).

Manufacturing positioned warehouse: Manufacturing positioned warehouse are located near to the manufacturing facilities in order to support manufacturing on the inbound side and to facilitate assortment-creation and shipping on the outbound side. Improve customer services and manufacturing support achieved through type of warehouse which acts as the collection point for products needed in filling customer orders and material needed for manufacturing.

Intermediately positioned warehouse: Intermediately- positioned warehouse are those located between manufacturing and market-position warehouses. These help in consolidation of assortments for shipments from different manufacturing facilities. A firm may have many manufacturing plants located, for economic reasons, near the sources of raw material. Under these conditions the cost-effective warehouse may be at some intermediate point.

1.7 WAREHOUSE LAYOUT AND DESIGN

To understand layout and design, some background information on a typical warehouse's base space requirements is necessary. This discussion of space requirements relates quite closely to the discussion of basic warehouse operations. Before looking specifically at eh types of space a firm need, we comment briefly about determining how much space a firm requires.

This first step in determining warehouse space requirements is to develop a demand forecast for a company's products. This means preparing an estimate in units for a relevant sales period (usually thirty days) by product category. Then the company will need to determine each item's order quantity, usually including some allowance for safety stock. The next step is to convert the units into cubic footage requirements, which may need to include pallets and which usually include an allowance of 10 to 15 percent for growth over the relevant period. At this point, the company has an estimate of basic storage space requirements. To this the company must add space needs for aisles and other needs such as lavatories and meeting rooms. Warehouse commonly devotes one-third of their total space to non-storage functions. Many companies make these spaces decision through computer simulation. The computer can consider a vast number of variables and can help product more requirements good software packages are available. One additional warehouse space requirements provide an interface with the transportation part of the logistics system- receiving and shipping. While this can be operating, efficiency usually requires two separate areas. In considering these space needs a firm must choose whether to use the dock area outside the building or to unload goods out of the vehicle directly into the warehouse. The firm has to allow or turnaround space and possibly for equipment and pallet storage. Also important are areas for staging goods before transportation and for unitizing consolidated shipments. In addition, this area may need space for checking, counting and inspecting. The volume and frequency of the throughput are critical in determining receiving and hipping space needs.

Another space requirement in physical distribution warehouses is for order packing and assembly. The amount of space these functions need depends upon order volume and the product's name along with the materials-handling equipment. This area's layout is critical to efficient operations and customer service.

A third type of space is the actual storage space. In a warehouse, a firm must use the full volume of the cubic storage space as efficiently as possible. A firm can derive the amount of storage space from the analysis described earlier in this section and it will largest single area in the warehouse. As with the order picking area, a firm has to consider storage area layout in detail. We cover this topic in a subsequent section.

Finally, a firm must consider three additional types of space. First, many physical distribution warehouses have space for recouping- that is, an area to salvage undamaged parts of damaged cartoons. Second administrative and clerical staff generally requires office space. Finally, rest rooms and, employee cafeteria, utilities and locker rooms require miscellaneous space. The amount of space these last three categories require depends upon a number of variables. For example, the average amount of damaged merchandise and the feasibility of repacking undamaged merchandise determine recouping space needs. The space requirement for a cafeteria and locker rooms depend on the number of employees.

Layout and design principles: While the discussion thus far has delineated a typical warehouse's various space needs, we need to consider layout in more details. We first consider some general layout design principles and then examine layout in the context of the space category previously. The most commonly accepted warehouse design and layout principles are as follows:

First, use a one-story facility wherever possible, since it usually provides more usable space per investment dollar and usually it is less expensive to construct.

Second, use straight-line or direct flow of goods into and out of the warehouses, to avoid backtracking.

Third principle is to use efficient materials handling equipment and operations. The next section explores materials-handling fundamentals. Among other benefits, materials-handling equipment improves efficiency in operations.

Fourth principle is to use an effective storage plan on the warehouse. In other words, the firm must place goods in the warehouse in such a way to maximize warehouse operations

The fifth principle of good layout is to minimize aisle space within the constraints that the size, type, and turning radius of materials-handling equipment impose. We must also consider the products and the constraints they impose.

The sixth principle is to make maximum use of the building's height-that is to utilize the building's cubic capacity effectively. This usually requires integration with materials handling. Though vehicles capable of maneuvering in small aisles and stacking higher than conventional materials can be very expensive, such equipment offers potentially large overall systems savings because using height costs works best when items are regularly shaped and easily handled, when order selection is the middle stage of activity.

A company should not make warehousing decisions once and then take them for granted; rather, the company should monitor productivity regularly during warehouse operations. While monitoring methods vary widely, the company should set goals and standards for cost and order-handling efficiency and then measure actual performance in a n attempt to optimize the warehouse's productivity. By improving productivity, a company can improve its resources uses increase cash flow, profits and return on investment; and provide its customer with better service. To begin a productivity program, a company should divide warehouse operations into functional areas and measures each areas productivity, utilization and performance, focusing on improvements in labor, equipment and making comparisons with standards if they exist. Repeating measurements can show relative trends. There is no single measure of warehouse productivity, but the method the company chooses must have the following attributes validity, coverage, comparability, completeness, usefulness, compatibility and cost effectiveness. [4]

1.8 VALUE ADDITION

The warehouse serves several values adding roles in a logistics system. Companies will sometimes face less than truckload (LTL) shipments of raw material and finished goods. Shipping goods long; distances at LTL rates is costlier than shipping at full truckload or carload rates. By moving the LTL amounts relatively short distances to or from a warehouse. Warehousing can allow a firm to consolidate smaller shipments into large shipment: (a car load or truckload) with significant transportation savings. For the inbound logistics system, the warehouse would consolidate different suppliers LTI shipments and ship a volume shipment (TL) to the firm' plant. For the outbound logistics system, the warehouse would receive a consolidated volume shipment from various plants and ship LTL shipments to different markets.

A second warehousing function may be customer order product mixing. Companies frequently turn out a product line that contains thousands of "different" products if we consider, color, size shape and other variations. When planning orders, customers often want a product line mixture- for example, five dozen, four cup coffee pots, six dozen ten cup coffee pots with blue trim and ten dozen red trim and three dozen blue salad bowl sets. Because companies often produce items at different plants, a company that did not warehouse goods would have to fill orders from several locations causing differing arrival times and opportunity for mix-ups therefore a product mixing warehouse for a multiple product line leads to efficient order filling. By developing new mixing warehouses near dense urban areas, firms can make pickups and deliveries in smaller vehicles and schedule these activities at more optimum times to avoid congestion.

In addition to product mixing for customer orders, companies sing raw materials or semi-finished goods (e.g. auto manufacturer) company move carloads of terms mixed from a physical supply warehouse to plant. This strategy not only reduces transportation costs from consolidation but also allows the company to avoid using the plant as a warehouse. This strategy will become increasingly popular as increased fuel expenses raise transport costs and firm increase the use of sophisticated strategies such as materials requirements planning (MRP) or just in time (JIT) system.

Cross -Docking is an operation that facilitates the product mixing function. In cross docking operations products from different suppliers arrive in truckload lots but instead of being placed into storage for later picking they are moved across the warehouse area waiting trucks for movement to particular customers. The incoming materials are picked from the delivering truck from temporary storage locations to fill a specific order and moved across the deck to a truck destined for the customer. The whole process is completed in a matter of hours. Excess product and small items are stored temporarily to await scheduled deliveries and to permit sorting of inbound loads of mixed products.

A third warehouses function is to provide service. The importance of customer service is obvious. Having goods available in a warehouse when a customer places an order, particularly if the warehouse is in reasonable proximity to the customer usually leads to customer satisfaction and enhances future sales. Service may also be a factor for physical supply warehouses. However, production schedules, which a firm makes in advance, are easier to service than customers while customers' demands are often uncertain physical supply stock outs costs sometimes seem infinite.

A fourth warehousing functions is protection against contingencies such as transportation delays vendor's stock outs or strikes. A potential trucker's strike will generally cause buyers to stock larger inventories than usual; for example, this particular function is very important for physical supply warehouse in that a delay in the delivery of raw material can delay the production of finished goods. However, contingencies also occur with physical distribution warehouses- for example, goods damaged in transit can affect inventory levels and order filling.

A fifth warehousing function is to smooth operations or decouple successive stages in the manufacturing process. Seasonal demand and the need for a production run along enough to ensure reasonable cost quality are examples of smoothing- that is preventing operations under overtime conditions at low production levels. In effect, this balancing strategy allows a company to reduce its manufacturing capacity investment.

As we can see warehouse functions can make important contributions to logistics systems and company operation. However, we must also view warehousing in a trade-off context; that is warehousing's contribution to profit must be greater than its cost.

1.9 PLANNING AND COORDINATION OF FLOWS

Co-ordination is the backbone of overall information system architecture among the participants of the value chain. Coordination results in plans specifying: (i) Strategic objectives, (ii) Capacity constraints, (iii) Logistical requirements, (iv) inventory deployment, (v) Manufacturing requirements, (vi) procurement requirements and (vii) Forecasting.

(i) Strategic Objectives detail the nature and location of customers, which are matched to the required products and services to be performed. The financial aspects of the strategic plans detail resources required to support inventory, receivables, facilities, equipment and capacity.

(ii) Capacity Constraints coordinate internal and external manufacturing requirements for given strategic objectives, capacity constraints identify limitation, barriers or bottlenecks within manufacturing capabilities and determine appropriate outsource requirements.

(iii) Logistics Requirements specify the work that distribution facilities, equipment and labor must perform to implement the capacity plan. Based on inputs from forecasting, customer orders and inventory status, logistics requirements specify value chain performance.

(iv) Inventory Deployments are the interfaces between planning/coordination and operations that detail the timing and composition of where inventory will be positioned from an information perspective, inventory deployment specifies the what, where and when of the overall logistics process. From an operational viewpoint, inventory management is performed as a day-to-day event.

(v) Manufacturing Plans are driven from logistical requirements and result in inventory deployment. The primary output is a statement of time-phased inventory requirements that drives master production scheduling (MPs) and manufacturing requirements planning (MRP). The output from MRP is a day-to-day production schedule that can be used to specify material and component requirements.

(vi) Procurement Requirements schedule material and components for inbound shipment to support manufacturing requirements. Purchasing coordinates decisions concerning supplier qualification, degree of desired speculations, third party arrangements and feasibility of long-term contracting.

(vii) Forecasting utilizes fast data, current activity levels and planning assumptions to predict future activity levels. The forecasts predict periodic (monthly or weekly) 'sales levels for each product, forming the basis for logistical requirement and operating plans.

Operational Requirements: The second aspect of information requirements is concerned with directing operations to receive, process and ship inventory as required supporting customer and purchasing orders. Operational requirements deal with: (i) order management, (ii) order processing, (iii) distribution operations, (iv) inventory management, (v) transportation and shipping and (vi) procurement.

(i) Order Management refers to the transmission of requirements information between value chain members involved in finished product distribution. The primary activity of order management is accurate entry and qualification of customer orders.

(ii) Order Processing allocates inventory and assigns responsibility to satisfy customer requirements. In technology-rich order processing systems, two-way communication linkage can be maintained with customers to generate a negotiated order that satisfies customers within the constraints of planned logistical operations.

(iii) Distribution Operations involve information flows required to facilitate and coordinate performance within logistics facilities. The key to distribution operation is to store and handle specific inventory ill little as possible while still meeting customer order requirements.

(iv) Inventory Management is concerned with using information to implement the logistics plan as specified.

(v) Transportation and Shipping information directs the movement of inventory. It is also necessary to ensure that required -transportation equipment is available when needed.

(vi) Procurement is concerned with the information necessary to complete purchase order preparation, modification and release while existing overall supplier compliance.

The overall purpose of operational information is to provide the detailed data required for integrated performance of physical distribution, manufacturing support and procurement operations whereas planning/coordination flows provide information concerning planned activities, operational requirements are needed to direct day-to-day work.

1.10 MATERIAL HANDLING

"Material handling is defined as the art and science of moving, packaging and storing of substances in a form."

Other definitions include:

a) Creation of time and place utility

b) Movement and storage of material at the lowest possible cost through the use of proper methods and equipment.

c) Lifting, shifting and placing of material which effect in a saving in money, time and place.

d) Art and science of conveying, elevating, packaging and storing of materials.

1.11 MATERIAL HANDLING PRINCIPLES

Certain principles have evolved to guide facility layout to ensure efficient handling of materials. Although, there are no hard and fast rules, they do provide effective guidelines for the efficient movement of materials in most facility layouts.

Principle 1: Materials should move through the facility in direct flow pattern, minimizing zigzagging or backtracking.

Principle 2: Related production processes should be arranged to provide for direct material flows.

Principle 3: Mechanized materials handling devices should be designed and located so that human effort is minimized.

Principle 4: Heavy and bulk materials should be moved the shortest distance during processing.

Principle 5: The number of times each material is handled should be minimized.

Principle 6: Systems flexibility should allow for unexpected breakdowns of material handling equipment, changes in production system technology, etc.

Principle 7: Mobile equipment should carry full loads all the times.

These seven principles can be summarized as follows:

1. **Eliminate Handling:** If not, make the handling distance as short as possible.

2. **Keep Moving:** If not, reduce the time spent at the terminal points of a route as short as possible.

3. **Use simple patterns of material flow (the simplest path is a straight-line path of flow which minimizes the handling distance between two points).** If not, reduce backtracking, crossovers and other congestion producing patterns as much as possible.

4. **Carry pay loads both ways:** If not, minimize the time spent in 'transport empty' by speed changes and route locations.

5. **Carry full loads:** If not, consider increasing the size of unit loads, decreasing carrying capacity, lowering speed, or acquiring more versatile equipment.

6. **Use Gravity:** if not, try to find another source of power that is reliable and inexpensive. In addition to the above guidelines, there are certain other very important aspects of materials handling, such as the following:

   a. Materials handling consideration should include the movement of men, machine, tools and information.
   b. The flow system must support the objectives of receiving, sorting, inspecting, inventorying, accounting, packaging and assembling.

Since the consideration and objectives do conflict, it is essential to take a systems decision followed by delicate diplomacy to establish a material movement plan that meets service requirement without subordinating safety and economy.

2. LITERATURE REVIEW

Warehouse Design and Control: Framework and Literature Review

In this project we analyze problems that are encountered during the (re)design of a warehouse or a warehouse subsystem. We determine clusters of publications concerning specific problems as well as open areas for future research. A design-oriented approach on the other hand primarily aims at a synthesis of a large number of both technical systems and planning and control procedures.

A Review of Warehousing Models

In this section we present an overview of models and algorithms proposed in the literature for warehouse design, planning and control. In doing so, we follow the classification of problems at a strategic, tactical or operational level. Apart from the design problems, we briefly discuss some previous literature overviews and some papers on warehouse design methods.

Warehouse Literature Overviews

In 1971, 1982 and 1983 respectively, Miebach, Matson and White and J\1cGinnis et al. reviewed the operations research and material handling literature. They concluded that important gaps in the research fields existed and that most research seemed to concentrate on rather limited problems. In 1992, Goedschalckx created a WWW-page1 with an extensive list of publications.

Warehouse Design Methods

Ashayeri and Geldel's review the literature concerning warehouse design and concluded that a pure analytical approach, as well as an approach that solely uses simulation, will in general not lead to a practical general design method. However, they suggest that a combination of the two approaches may lead to a good design method. Ashayeri and Goetschalckx provide a step-wise general design procedure. Duve and Boeker propose a step-wise design method for warehouse design and provide several examples. Yoon and Sharp suggest an elaborate conceptual procedure for the design of an orderpick system.

Warehouse Design Problems: Strategic Level

At the strategic level, two problem dusters have been identified: one dealing with the selection of systems and equipment based on technical capabilities, and the second one dealing with the design Of the process flow and the selection of warehouse systems based on economic considerations. Roll et a1. proposed a systematic procedure for determining the size of a warehouse container.

In conclusion, the number of publications concerning design problems on a strategic level appears to be limited, despite the fact that at this level the most far-reaching decisions are made. Most publications analyze the performance of a warehouse in order to be able to compare the system with alternative ones. Only one publication explicitly analyzes multiple competing warehouse systems.

Warehouse Design Problems: Tactical Level

At the tactical level, most decisions concern the determination of resource dimensions and the design of the organization. Determining the size and layout of conventional warehouses has been the topic of several publications. Berry and Bassan et a1. analyze the layout of a conventional warehouse. They provide an optimization model to determine the optimal dimension of the layout, in order to minimize handling distance, handling time, space utilization or costs. Rosenblatt and Roll present a design procedure comprising both simulation and analytical methods in order to determine the size and layout of a conventional warehouse, concentrating on the storage capacity. Also, they present an analysis of the required storage capacity as a function of product and order characteristics.

Warehouse Design Problems: Operational Level

At the operational level, most decisions concern the assignment of tasks to, and the scheduling and control of people and equipment. EIsayed and Unal derive analytical expressions to evaluate batching algorithm. Van den Berg and Sharp propose a procedure based on linear programming for product allocation in a warehouse consisting of a forward and a reserve area, to minimize the costs of order picking and replenishment. Ratliff and Rosenthal present an algorithm for the routing in a conventional warehouse, based on dynamic programming, which focuses on the maximum throughput. Guenov and Reaside analyze three heuristics for two-dimensional item picking in a conventional warehouse. Graves at a1 evaluate the impact of sequencing and class-based storage policies on warehouse performance, based on analytical expressions for continuous racks and numerical procedures for discrete systems. Future work will concentrate on the development of a complete reference model and a systematic design approach for warehousing systems. In particular tradeoffs between costs and operational performance of integrated systems will be the subject of future studies.

3. THEORETICAL OVERVIEW OF WAREHOUSE MANAGEMENT SYSTEMS (WMS)

It is a key part of the supply chain and primarily aims to control the movement and storage of materials within a warehouse and process the associated transactions, including shipping, receiving, put away and picking. The systems also direct and optimize stock put away based on real-time information about the status of bin utilization. Warehouse management systems often utilize Auto ID Data Capture (AIDC)technology, such as barcode scanners, mobile computers, wireless LANs and potentially Radio-frequency identification (RFID) to efficiently monitor the flow of products. Once data has been collected, there is either batch synchronization with, or a real-time wireless transmission to a central database. The database can then provide useful reports about the status of goods in the warehouse.

The objective of a warehouse management system is to provide a set of computerized procedures to handle the receipt of stock and returns into a warehouse facility, model and manage the logical representation of the physical storage facilities (e.g. racking etc.), manage the stock within the facility and enable a seamless link to order processing and logistics management in order to pick, pack and ship product out of the facility. Warehouse management systems can be standalone systems or modules of an ERP system or supply chain execution suite. The primary purpose of a WMS is to control the movement and storage of materials within a warehouse – you might even describe it as the legs at the end-of-the line that automates the store, traffic and shipping management. In its simplest form, the WMS can data track products during the production process and act as an interpreter and message buffer between existing ERP and WMS systems. Warehouse Management is not just managing within the boundaries of a warehouse today; it is much wider and goes beyond the physical boundaries. Inventory management, inventory planning, cost management; IT applications & communication technology to be used are all related to warehouse management. Warehouse management today also covers the container storage, loading and unloading.

Even production management is to a great extent dependent on warehouse management. Efficient warehouse management gives a cutting edge to a retail chain distribution company. Warehouse management does not just start with receipt of material but it actually starts with actual initial planning when container design is made for a product. Warehouse design and process design within the warehouse is also part of warehouse management. Warehouse management is part of Logistics and SCM.

Warehouse Management monitors the progress of products through the warehouse. It involves the physical warehouse infrastructure, tracking systems, and communication between product stations.

Warehouse management deals with receipt, storage and movement of goods, normally finished goods, to intermediate storage locations or to final customer. In the multi-echelon model for distribution, there are levels of warehouses, starting with the Central Warehouse(s), regional warehouses services by the central warehouses and retail warehouses at the third level services by the regional warehouses and so on. The objective of warehousing management is to help in optimal cost of timely order fulfillment by managing the resources economically.

4. ANALYSIS OF SPACE ALLOCATION FOR WAREHOUSE OF COMPANY 'X' AND 'Y'

We have taken the sales data for a company X and Y for the period of last 12 months (January 2016- December 2016). A single firm owns these companies and thus their warehousing is done at the same Distribution Centre. In these companies, there are different types of product classification.

Classification of Products:

1. **On the basis of Business Units**
   There are various business units present in the firms:

BU RUNNING
BU FOOTBALL
BU TENNIS
BU ACCESSORIES
BU TRAINING APP MEN
BU ATHLETICS APP
BU OUTDOOR
BU TRAINING FTW
BU YOUNG ATHLETES
BU OTHERS
BU RBK TRAINING
BU RBK RUNNING
BU CLASSICS

2. **On the basis of Division**
   There are 3 divisions of products in both the companies:

FTW – FOOTWEAR
APP – APPARELS
A&G – ACCESSORIES & GEARS

The sales invoices generated during the given period were analyzed and each company's share in terms of volume is given by:

Table 4.1 Percentage distributions of sales invoices

Brand	Quantity	% Distribution
Company X	8239689	70.262
Company Y	3487383	29.738
Total	11727072	100

We can take these values as:

Company X – 70%

Company Y – 30%

4.1 PROPOSED PLAN:

We are proposing 2 Product Storage & Distribution Plans for different product classification.

1. Volume-wise distribution and storage of BUSINESS UNITS for companies X and Y.
2. Volume-wise distribution and storage of DIVISION WISE PRODUCTS for companies X and Y.

4.2 VOLUME-WISE DISTRIBUTION AND STORAGE OF BUSINESS UNITS FOR COMPANIES X AND Y

After analyzing the given data with the help of Pivot Tables, Lookup and indexing features of Microsoft Excel, the following results are obtained.

Table 4.2 Business Units wise breakup of sales invoices

					Division		
BRAND	BU TYPE	INVOICES	QUANTITY	QUANTITY WISE DISTRIBUTION	FTW	APP	A&G
X	BU RUNNING	30763	1833093	22.25	86%	14%	0%
X	BU FOOTBALL	12716	412326	5.01	24%	51%	25%
X	BU TENNIS	11995	338446	4.11	25%	75%	0%
X	BU ACCESSORIES	11868	1348292	16.37	0%	0%	100%
X	BU TRAINING APP MEN	11762	974305	11.83	0%	100%	0%
X	BU ATHLETICS APP	10870	525672	6.38	0%	100%	0%
X	BU OUTDOOR	10134	532445	6.46	99%	1%	0%
X	BU TRAINING FTW	9889	641653	7.79	100%	0%	0%
X	BU YOUNG ATHLETES	6312	341799	4.15	45%	55%	0%
X	BU OTHERS	7661	241904	15.65	44%	46%	10%
Y	BU RBK TRAINING	21935	1713463	49.13	23%	52%	25%
Y	BU RBK RUNNING	17157	1363435	39.10	88%	11%	1%
Y	BU CLASSICS	5126	267328	7.67	73%	27%	0%
Y	BU OTHERS	3148	128619	4.10	53%	39%	8%

The table gives a clear idea about the following parameters:

1. Number of Invoices Generated
2. Quantity of Business Unit
3. Volume-Wise Distribution of Business Units

The results show that the most frequent Business Unit for the company X is BU RUNNING followed by BU ACCESSORIES and so on.

For company Y, the most frequent Business Unit is found out to be BU RBK TRAINING followed by BU RBK RUNNING and so on.

The percentage distribution of each business unit gives us the relative storage allocation in the warehouse for each unit.

This can be shown as a Pie chart as follows:

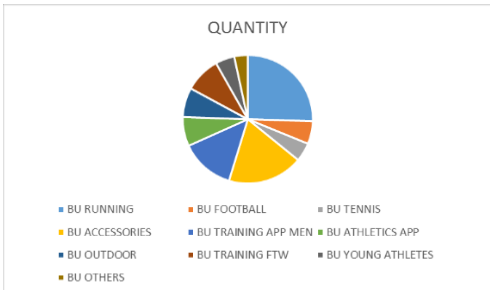

Fig. 4.1 Pie chart showing volumetric distribution

The Bar Graph is shown as follows:

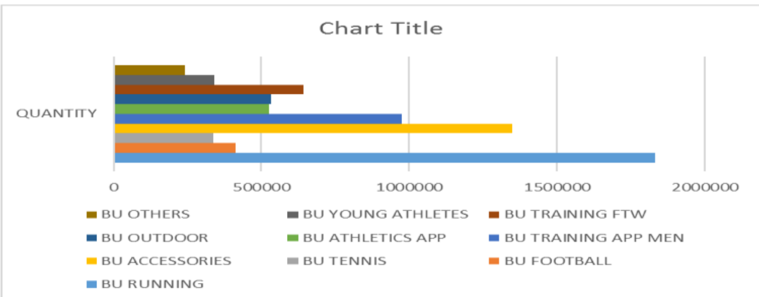

Fig. 4.2 Bar graph showing volumetric distribution

4.3 VOLUME-WISE DISTRIBUTION AND STORAGE OF DIVISION WISE PRODUCTS FOR COMPANIES X AND Y

After analyzing the given data with the help of Pivot Tables, Lookup and indexing features of Microsoft Excel, the following results are obtained.

Table 4.3 Division wise absolute breakups of sales invoices

COMPANY	DIVISION			
	A&G	APP	FTW	Grand Total
X	1555287	3144565	3537057	8239689
Y	462998	1162888	1861497	3487383
Grand Total	2018285	4307453	5398554	11727072

These are the Volume-wise Distribution of products based on their DIVISION.

The percentage wise distribution is obtained as follows:

Table 4.4 Division wise percentage breakups of sales invoices

COMPANY	DIVISION		
	A&G	APP	FTW
X	18.87555465	38.1636	42.9271
Y	13.27637372	33.3456	53.378

This shows that:

1. For Company X, the order of product sales in terms of divisions is FOOTWEAR> APPARELS> ACCESSORIES & GEARS.
2. For Company Y, the order of product sales in terms of divisions is FOOTWEAR> APPARELS> ACCESSORIES & GEARS.

Thus, Overall Footwear division is the most frequent division of all.

Knowing the percentage distribution of different Divisions, we can allot the storage area such that the most frequent division takes the most space followed by the other divisions having less volume of sales.

4.4 SIMPLIFIED PROPOSED WAREHOUSE LAYOUT

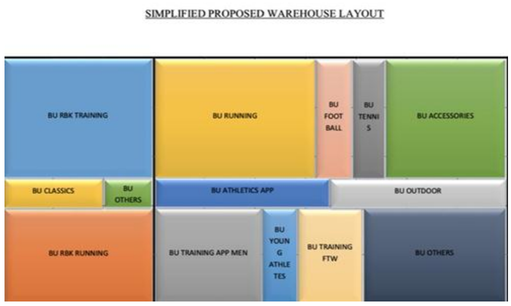

Fig. 4.3 Simplified proposed warehouse layout

4.5 INTERPRETATION:

Companies are constantly trying to find ways to improve performance and warehouse operations is area where supply chain managers can focus to gain maximum efficiency for minimum cost. To get the most out of the operation, a number of best practices can be adopted to improve productivity and overall customer satisfaction. Although best practices vary from industry to industry and by the products shipped there is a number of best practices that can be applied to most companies. When considering the level of effort involved in warehouse operations, the greatest expenditure of effort is in the picking process. To gain efficiencies in picking the labor time to pick orders needs to be reduced and this can be achieved in a number of ways. Companies with the most efficient warehouses have the most frequently picked items closest to the shipping areas to minimize picking time. These companies achieve their competitive advantage by constantly reviewing their sales data to ensure that the items are stored close to the shipping area are still the most frequently picked. Warehouse layout is also important in achieve greater efficiencies. Minimizing travel time between picking locations can greatly improve productivity. However, to achieve this increase in efficiency, companies must develop processes to regularly monitor picking travel times and storage locations. Warehouse operations that still use hard copy pick tickets find that it is not very efficient and prone to human errors. To combat this and to maximize efficiency, world class warehouse operations had adopted technology that is some of today's most advanced systems. In addition to hand-held RF readers and printers, companies are introducing pick-to-light and voice recognition technology. In a pick-to-light system, an operator will scan a bar-coded label attached to a box. A digital display located in front of the pick bin will inform the operator of the item and quantity that they need to pick. Companies are typically using pick-to-light systems for their top 5 to 20% selling products. By introducing this system companies can gain significant efficiencies as it is totally paperless and eliminates the errors caused by pick tickets. Voice picking systems inform the operator of pick instructions through a headset. The pick instructions are sent via RF from the company's ERP or order management software. The system allows operators to perform pick operations without looking at a computer screen or to deal with paper pick tickets. Many world-class warehouse operations have adopted voice picking to complement the pick-to-light systems in place for their fast-moving products.

5. DEMAND FORECASTING USING SIMPLE LINEAR REGRESSION MODEL

5.1 THEORETICAL OVERVIEW OF REGRESSION MODELS

Regression, in the simplest of terms, means falling back. Regression Models are used to predict trends from already present data to gain valuable insights.

A Linear Regression Model utilizes raw existing data, and utilizes that to determine the relationship existing between two variables. One of the variables is the dependent variable, while the other is the independent variable.

Thus, Linear Regression Models help us establish a relationship between two variables using existing data, and then help us predict future trends/values of one variable given the other.

In this Chapter, we utilize the simple linear regression model, the formula for which has been mentioned below. [7]

Equation of the regression line: $Y = aX + b + E$ (5.1)

$$a = \frac{(\sum y)(\sum x^2) - (\sum x)(\sum xy)}{n(\sum x^2) - (\sum x)^2} \quad (5.2)$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad (5.3)$$

Where Y = dependent variable (Demand)

X = independent variable (Month)

a,b = linear regression coefficients

E = dummy variable

5.2 DATA ANALYSIS

We analyzed and sorted the available company data using pivot tables in Microsoft Excel. The results have been shown in a tabular form below.

5.2.1. DATA ANALYIS FOR COMPANY 'X'

Table 5.1 Month wise sales breakup for Company X

Month	BU RUNNING	BU ACCESSORIES	BU ATHLETICS APP	BU FOOTBALL	BU TENNIS	BU TRAINING APP	BU OUTDOOR	TOTAL DEMAND
Jan-16	84688	114003	1145	28341	38877	18733	34683	476479
Feb-16	144668	74702	1504	42406	37279	23428	56266	666657

Mar-16	146554	148869	10030	28414	33486	22852	53193	787513
Apr-16	122232	138193	5635	21386	27024	14007	45483	651030
May-16	152573	56245	9428	19155	15975	7509	34054	454841
Jun-16	197269	126312	60701	31157	30879	25859	43393	791384
Jul-16	158356	142801	68362	58090	26414	37103	47710	750408
Aug-16	165592	150021	94112	43919	26286	29310	56078	854323
Sep-16	203814	135869	117050	42158	39994	24322	69007	951319
Oct-16	241607	137874	92702	38988	33480	20520	49661	911195
Nov-16	215740	123403	65003	58312	28752	18261	42917	944540
TOTAL	**1833093**	**1348292**	**525672**	**412326**	**338446**	**241904**	**532445**	**8239689**

LINEAR REGRESSION CHART:

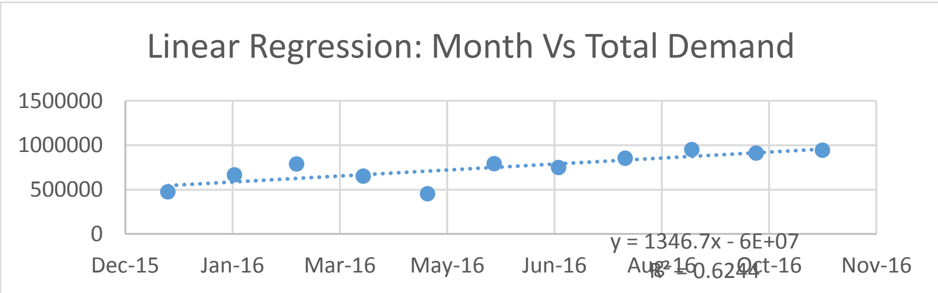

Fig. 5.1 Linear Regression Chart for Company X

FORECAST TABLE:

Table 5.2 Demand forecast for Company X

Month	Total Demand	Estimated Demand
Jan-16	476479	#N/A
Feb-16	666657	#N/A
Mar-16	787513	#N/A
Apr-16	651030	#N/A
May-16	454841	#N/A
Jun-16	791384	#N/A
Jul-16	750408	#N/A
Aug-16	854323	#N/A
Sep-16	951319	#N/A
Oct-16	911195	#N/A
Nov-16	944540	#N/A
Dec-16	#N/A	995173.2545
Jan-17	#N/A	1036191.691
Feb-17	#N/A	1077210.127
Mar-17	#N/A	1118228.564
Apr-17	#N/A	1159247
May-17	#N/A	1200265.436

FORECAST CHART:

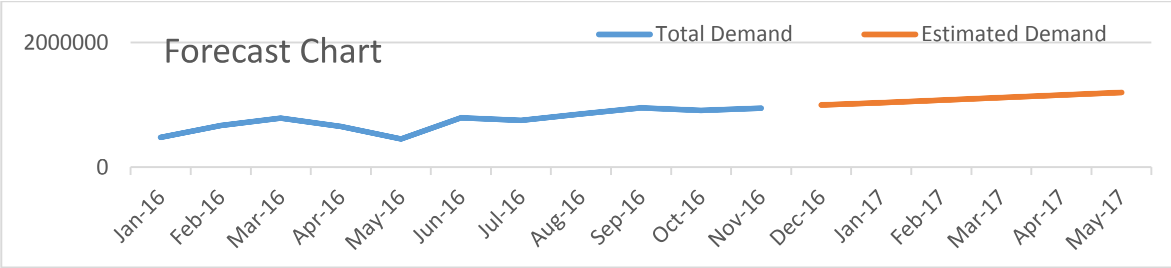

Fig. 5.2 Forecast Chart for Company X

KEY INSIGHTS:

- The demand for Company X's products has been gradually increasing since the past year. Our model predicts that these growth trends would continue in the future for the next 6 months.
- The demand invoices are set to increase by 27% for the next 6 months as per the calculations based on the model.
- **R= coefficient of determination= 0.6244.** The coefficient of determination shows how linear the scatter plots are to the regression line. This value shows the fact that the demand is comparatively scattered along the regression line for company X, since the value of R for company X is less than the value of R for company Y.
- Thus, in order to meet the increased demand, the warehouse would need to allocate an additional space of 27% to the original layout planned.

5.2.2 DATA ANALYSIS FOR COMPANY 'Y'

Table 5.3 Month wise sales breakup for Company Y

Month	BU CLASSIC	BU RBK TRAINING	BU RBK RUNNING	BU RBK OTHER	BU RBK KIDS SPORT	BU RBK KIDS CLASSIC	BU RBK TLAF	TOTAL DEMAND
Jan-16	6257	111804	41848	16	5749	12	0	165686
Feb-16	18716	126928	80510	20	8597	712	0	235483
Mar-16	21213	138328	142693	557	23838	1309	0	327938
Apr-16	8393	126231	88130	108	7386	415	0	230663
May-16	19324	84535	77685	19	10157	67	0	191787
Jun-16	18756	138174	112590	491	14886	896	0	285793
Jul-16	25023	207378	119214	64	13510	610	0	365799
Aug-16	29744	193893	137620	676	13140	1595	0	376668
Sep-16	34431	246575	174815	139	11049	377	0	467386
Oct-16	44910	177099	176887	13	8803	412	572	408696
Nov-16	40561	162518	211443	2642	11504	2462	354	431484
Total	**267328**	**1713463**	**1363435**	**4745**	**128619**	**8867**	**926**	**3487383**

LINEAR REGRESSION CHART:

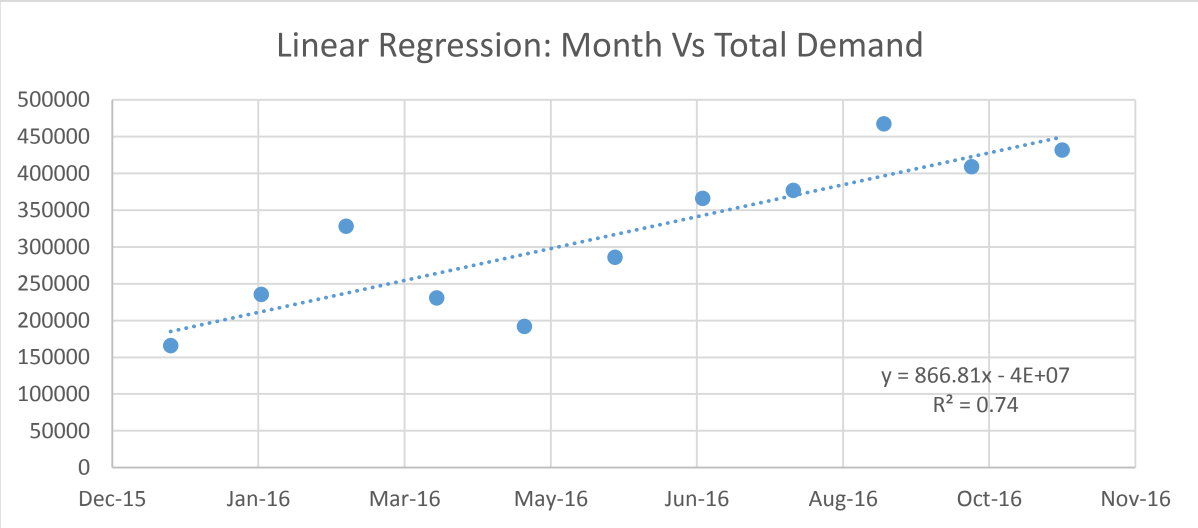

Fig. 5.3 Linear Regression Chart for Company Y

FORECAST TABLE:

Table 5.4 Demand forecast for Company Y

Month	Total Demand	Estimated Demand
Jan-16	165686	#N/A
Feb-16	235483	#N/A
Mar-16	327938	#N/A
Apr-16	230663	#N/A
May-16	191787	#N/A
Jun-16	285793	#N/A
Jul-16	365799	#N/A
Aug-16	376668	#N/A
Sep-16	467386	#N/A
Oct-16	408696	#N/A
Nov-16	431484	#N/A
Dec-16	#N/A	475555.2545
Jan-17	#N/A	501975.3273
Feb-17	#N/A	528395.4
Mar-17	#N/A	554815.4727
Apr-17	#N/A	581235.5455
May-17	#N/A	607655.6182

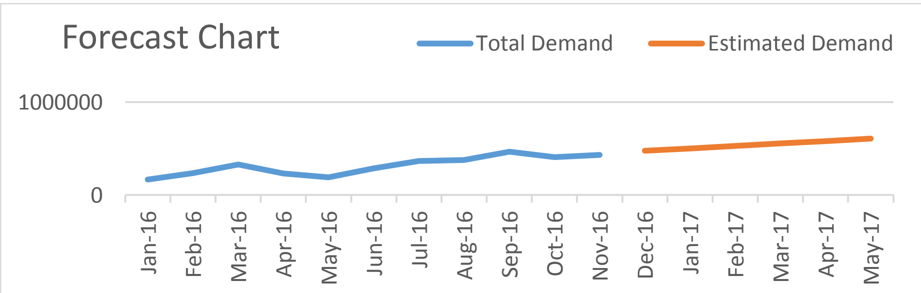

Fig. 5.4 Forecast Chart for Company Y

KEY INSIGHTS:

- The demand for Company X's products has been gradually increasing since the past year. Our model predicts that these growth trends would continue in the future for the next 6 months.
- The demand invoices are set to increase by 39% for the next 6 months as per the calculations based on the model.
- **R= coefficient of determination= 0.74**. The coefficient of determination shows how linear the scatter plots are to the regression line. This value shows the fact that the demand is comparatively closer along the regression line for company Y, since the value of R for company Y is more than the value of R for company X.
- Thus, in order to meet the increased demand, the warehouse would need to allocate an additional space of 39% to the original layout planned.

5.3 INTERPRETATION:

Warehouses are vital cogs in the industrial machinery that help to store and manage goods. Proper planning of the warehouse is essential for establishing a smooth and efficient manufacturing process for a company.

On the other hand, analyzing consumer trends is an important factor that can be used to estimate, and thereby rework, the design of such warehouses.

In this report, we have tried to analyze the basic elements required to plan an efficient warehouse, concluding with volumetric analysis for space allocation inside the warehouse using a contract-warehousing model.

The second part of our analysis focuses on the demand side of the equation, in which we have tried to correlate and forecast demand trends for the two companies in the given case. This information can be effectively utilized to rework and restructure the warehouse dynamically to meet the future needs.

6. INVENTORY MANAGEMENT ANALYSIS

6.1 THEORETICAL OVERVIEW OF INVENTORY POLICIES

6.1.1 ECONOMIC ORDER QUANTITY (EOQ)

EOQ stands for Economic Order Quantity. It is **a measurement used in the field** of Operations, Logistics, and Supply Management. In essence, EOQ is a tool used to determine the volume and frequency of orders required to satisfy a given level of demand while minimizing the cost per order.

6.1.1.2 The Importance of EOQ

The Economic Order Quantity is a set point designed to help companies minimize the cost of ordering and holding inventory. The cost of ordering an inventory falls with the increase in ordering volume due to purchasing on economies of scale. However, as the size of inventory grows, the cost of holding the inventory rises. EOQ is the exact point that minimizes both these inversely related costs.

$$\boldsymbol{EOQ} = \sqrt{\boldsymbol{2\ K\ D/h}} \qquad (6.1)$$

Components of the EOQ Formula:

D: Annual Quantity Demanded

Q: Volume per

K: Ordering Cost (Fixed Cost)

h: Holding Cost (Variable Cost)

6.1.2 CONTINUOUS REVIEW POLICY (S,S)

Whenever the inventory position drops below a certain level, s, we order to raise the inventory position to level S.

The reorder point is a function of:

– The Lead Time

– Average demand

– Demand variability

– Service level

The reorder point (s) has two components:

- To account for average demand during lead time:

L * AVG (6.2)

- To account for deviations from average (we call this safety stock)

z * STD * √L (6.3)

Z is chosen from statistical tables to ensure that the probability of stock outs during lead-time is within limits. Z indicates the probability of the service demand being met. A 97% service level indicates that out of 100 deliveries, 97 would be completed on time. [8]

- Since there is a fixed cost, we order more than up to the reorder point:

Q=√(2 *K *AVG)/h (6.4)

- The total order-up-to level is:

S = Q + s (6.5)

- Average Inventory Level is

Q/2 + z * STD * √L (6.6)

6.1.3 PERIODIC REVIEW POLICY (BASE STOCK POLICY)

Each review echelon, inventory position is raised to the base-stock level.

The base-stock level includes two components:

- Average demand during *r+L* days (the time until the next order arrives):

(r + L) * AVG (6.7)

- Safety stock during that time:

z * STD * √(r+L) (6.8)

- Base Stock Level is:

(r + L) * AVG + z * STD * √(r+L) (6.9)

- Average Inventory Level

[(r + L) * AVG]/2 + [z * STD * √(r+L)] (6.10)

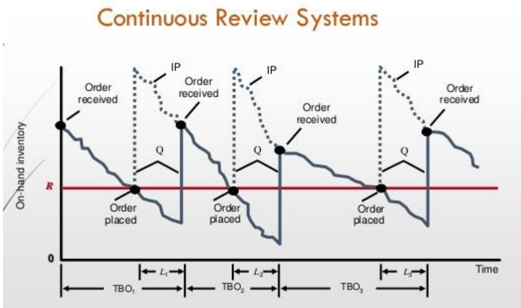

Fig. 6.1 Continuous Review System

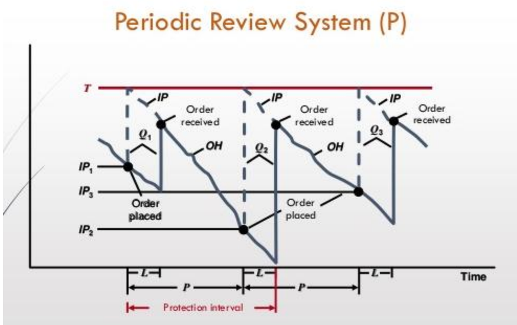

Fig. 6.2 Periodic Review System

6.2 ANALYSIS OF INVENTORY POLICIES FOR COMPANY

Table 6.1 Demand trends for Company X

Month	BU RUNNING	BU ACCESSORIES	BU ATHLETICS APP	BU FOOTBALL	BU TENNIS	BU TRAINING APP	BU OUTDOOR	TOTAL DEMAND
Jan-16	84688	114003	1145	28341	38877	18733	34683	476479
Feb-16	144668	74702	1504	42406	37279	23428	56266	666657
Mar-16	146554	148869	10030	28414	33486	22852	53193	787513
Apr-16	122232	138193	5635	21386	27024	14007	45483	651030
May-16	152573	56245	9428	19155	15975	7509	34054	454841
Jun-16	197269	126312	60701	31157	30879	25859	43393	791384
Jul-16	158356	142801	68362	58090	26414	37103	47710	750408
Aug-16	165592	150021	94112	43919	26286	29310	56078	854323
Sep-16	203814	135869	117050	42158	39994	24322	69007	951319
Oct-16	241607	137874	92702	38988	33480	20520	49661	911195
Nov-16	215740	123403	65003	58312	28752	18261	42917	944540
TOTAL	**1833093**	**1348292**	**525672**	**412326**	**338446**	**241904**	**532445**	**8239689**

6.2.1 DEMAND TRENDS FOR COMPANY X

Table 6.2 Cost analysis for Company X

BU	AVG (MONTHLY)	STD (MONTHLY)	Fixed Cost (K) (weekly)	Holding Cost per unit (h) per week
BU RUNNING	166644.8182	44936.53652	36385.46672	60
BU ACCESSORIES	122572	30476.3565	26762.54489	20
BU ATHLETICS	47788.36364	43403.46295	10434.17931	40
BU FOOTBALL	37484.18182	13225.52284	8184.349595	30
BU TENNIS	30767.81818	6956.889733	6717.889202	25
BU TRAINING	21991.27273	7780.137943	4801.605779	15
BU OUTDOOR	48404.09091	10139.62034	10568.61808	40

Assumptions:

- Lead Time: 2 weeks
- Service Factor ‘z’ (97%): 1.88
- Fixed Cost (monthly): 10,00,000

- Fixed Cost 'K' (weekly): 233644.8598
- Allocation for Company X: 163551.4019

6.2.2 CONTINUOUS REVIEW POLICY

Table 6.3 Continuous review policy for Company X

BU	AVG (WEEKLY)	STD (WEEKLY)	AVG DEMAND DURING LEAD TIME	SAFETY STOCK	REORDER POINT	OPTIMUM ORDER QUANTITY	ORDER UPTO LEVEL	AVERAGE INVENTORY LEVEL (weekly)	AVERAGE INVENTORY LEVEL (monthly)
BU RUNNING	38935.71	21708.47	77871.41	57544.82	135416.23	6871.91	142288.14	60980.77	260997.70
BU ACCESSORIES	28638.32	14722.88	57276.64	39027.40	96304.04	8754.62	105058.66	43404.72	185772.18
BU ATHLETICS	11165.51	20967.86	22331.01	55581.59	77912.61	2413.53	80326.14	56788.36	243054.18
BU FOOTBALL	8757.99	6389.14	17515.97	16936.34	34452.31	2185.99	36638.30	18029.33	77165.54
BU TENNIS	7188.74	3360.82	14377.49	8908.85	23286.34	1965.57	25251.90	9891.64	42336.20
BU TRAINING	5138.15	3758.52	10276.30	9963.09	20239.38	1813.70	22053.08	10869.94	46523.33
BU OUTDOOR	11309.37	4898.37	22618.73	12984.59	35603.33	2444.63	38047.96	14206.91	60805.56

6.2.3 PERIODIC REVIEW POLICY

Table 6.4 Periodic review policy for Company X

BU	AVG (WEEKLY)	STD (WEEKLY)	AVG DEMAND DURING (r+L)	SAFETY STOCK	BASE STOCK LEVEL	AVERAGE INVENTORY LEVEL (monthly)
BU RUNNING	38935.70518	21708.47175	244516.2285	102274.3956	346790.6242	224532.5099
BU ACCESSORIES	28638.31776	14722.87754	179848.6355	69363.39967	249212.0352	159287.7174
BU ATHLETICS	11165.50552	20967.8565	70119.37468	98785.15982	168904.5345	133844.8472
BU FOOTBALL	8757.986406	6389.141468	55000.15463	30100.94814	85101.10277	57601.02545
BU TENNIS	7188.742566	3360.816296	45145.30331	15833.70122	60979.00453	38406.35287
BU TRAINING	5138.147833	3758.520746	32267.56839	17707.39286	49974.96126	33841.17706
BU OUTDOOR	11309.36703	4898.367315	71022.82498	23077.51382	94100.3388	58588.92631

6.2.4 COMPARISON OF REVIEW POLICIES

Table 6.5 Comparison of review policies for Company X

BU	Continuous Review Policy	Periodic Review Policy
BU RUNNING	260997.7007	224532.5099
BU ACCESSORIES	185772.1817	159287.7174
BU ATHLETICS	243054.1842	133844.8472
BU FOOTBALL	77165.54206	57601.02545
BU TENNIS	42336.19949	38406.35287
BU TRAINING	46523.33361	33841.17706
BU OUTDOOR	60805.5637	58588.92631

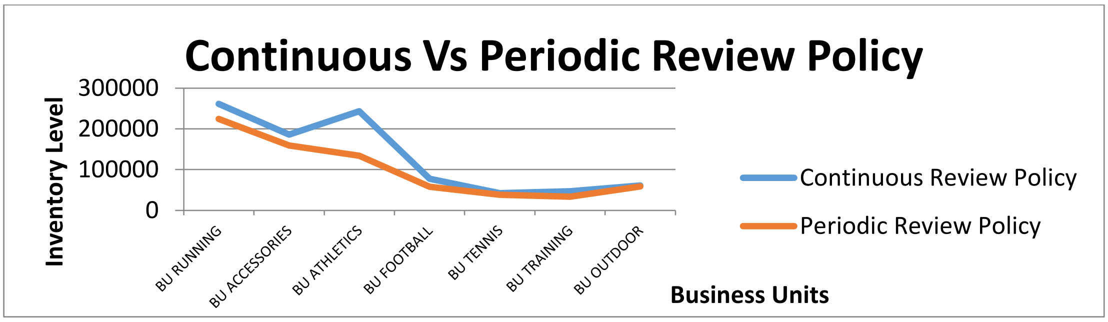

Fig. 6.3 Comparison of review policies for Company X

Interpretation:

Through extensive inventory analysis, we find out that the Periodic Review Policy is more favorable to have lower average inventory levels across a given month for the given data for Company X.

6.3 ANALYSIS OF INVENTORY POLICIES FOR COMPANY Y

6.3.1 DEMAND TRENDS FOR COMPANY Y

Table 6.6 Demand trends for Company Y

Month	BU CLASSIC	BU RBK TRAINING	BU RBK RUNNING	BU RBK OTHER	BU RBK KIDS SPORT	BU RBK KIDS CLASSIC	BU RBK TLAF	TOTAL DEMAND
Jan-16	6257	111804	41848	16	5749	12	0	165686
Feb-16	18716	126928	80510	20	8597	712	0	235483
Mar-16	21213	138328	142693	557	23838	1309	0	327938
Apr-16	8393	126231	88130	108	7386	415	0	230663
May-16	19324	84535	77685	19	10157	67	0	191787
Jun-16	18756	138174	112590	491	14886	896	0	285793
Jul-16	25023	207378	119214	64	13510	610	0	365799
Aug-16	29744	193893	137620	676	13140	1595	0	376668
Sep-16	34431	246575	174815	139	11049	377	0	467386
Oct-16	44910	177099	176887	13	8803	412	572	408696
Nov-16	40561	162518	211443	2642	11504	2462	354	431484
Total	**267328**	**1713463**	**1363435**	**4745**	**128619**	**8867**	**926**	**3487383**

Assumptions:

- Lead Time: 2 weeks
- Service Factor 'z' (97%): 1.88
- Fixed Cost (monthly): 10,00,000
- Fixed Cost 'K' (weekly): 233644.8598
- Allocation for Company Y: 70093.45794

Table 6.7 Cost analysis for Company Y

BU	AVG (MONTHLY)	STD (MONTHLY)	Fixed Cost (K) (weekly)	Holding Cost per unit (h) per week
BU CLASSIC	24302.54545	12234.2912	5373.067405	60
BU RBK TRAINING	155769.3636	47104.61655	34439.16161	15

BU RBK RUNNING	123948.6364	50779.46642	27403.89393	60
BU RBK OTHER	431.3636364	773.1698743	95.3704993	30
BU RBK KIDS SPORTS	11692.63636	4875.654054	2585.133456	20
BU RBK KIDS CLASSIC	806.0909091	730.8852789	178.2192239	25
BU RBK TLAF	84.18181818	193.5323323	18.61181925	10

6.3.2 CONTINUOUS REVIEW POLICY

Table 6.8 Continuous review policy for Company Y

BU	AVG (WEEKLY)	STD (WEEKLY)	AVG DEMAND DURING LEAD TIME	SAFETY STOCK	REORDER POINT	OPTIMUM ORDER QUANTITY	ORDER UPTO LEVEL	AVERAGE INVENTORY LEVEL (weekly)	AVERAGE INVENTORY LEVEL (monthly)
BU CLASSIC	5678.16	5913.67	11356.33	15675.95	27032.28	1008.45	28040.73	16180.18	69251.15
BU RBK TRAINING	36394.71	22768.88	72789.42	60355.74	133145.16	12927.51	146072.67	66819.49	285987.42
BU RBK RUNNING	28959.96	24545.18	57919.92	65064.37	122984.29	5143.33	128127.62	67636.03	289482.22
BU RBK OTHER	100.79	373.73	201.57	990.67	1192.24	25.31	1217.56	1003.33	4294.25
BU RBK KIDS SPORTS	2731.92	2356.74	5463.85	6247.24	11711.09	840.38	12551.47	6667.43	28536.59
BU RBK KIDS CLASSIC	188.34	353.29	376.68	936.49	1313.17	51.82	1364.99	962.40	4119.08
BU RBK TLAF	19.67	93.55	39.34	247.98	287.31	8.56	295.87	252.25	1079.65

6.3.3 PERIODIC REVIEW POLICY

Table 6.9 Periodic review policy for Company Y

BU	AVG (WEEKLY)	STD (WEEKLY)	AVG DEMAND DURING (r+L)	SAFETY STOCK	BASE STOCK LEVEL	AVERAGE INVENTORY LEVEL (monthly)
BU CLASSIC	5678.164826	5913.667858	35658.87511	27860.86525	63519.74036	45690.30281
BU RBK TRAINING	36394.71113	22768.87581	228558.7859	107270.2418	335829.0277	221549.6347
BU RBK RUNNING	28959.96177	24545.18154	181868.5599	115638.8914	297507.4513	206573.1714
BU RBK OTHER	100.7858963	373.7257649	632.9354291	1760.721675	2393.657104	2077.189389
BU RBK KIDS SPORTS	2731.924384	2356.736341	17156.48513	11103.21296	28259.6981	19681.45553
BU RBK KIDS CLASSIC	188.3389975	353.2867342	1182.768904	1664.427954	2847.196858	2255.812406
BU RBK TLAF	19.66864911	93.54738371	123.5191164	440.7266547	564.2457711	502.4862129

6.3.4 COMPARISON OF REVIEW POLICIES

Table 6.10 Comparison of review policies for Company Y

BU	Continuous Review Policy	Periodic Review Policy
BU CLASSIC	69251.15297	45690.30281
BU RBK TRAINING	285987.4157	221549.6347
BU RBK RUNNING	289482.2208	206573.1714
BU RBK OTHER	4294.249285	2077.189389
BU RBK KIDS SPORTS	28536.58671	19681.45553
BU RBK KIDS CLASSIC	4119.081313	2255.812406
BU RBK TLAF	1079.645664	502.4862129

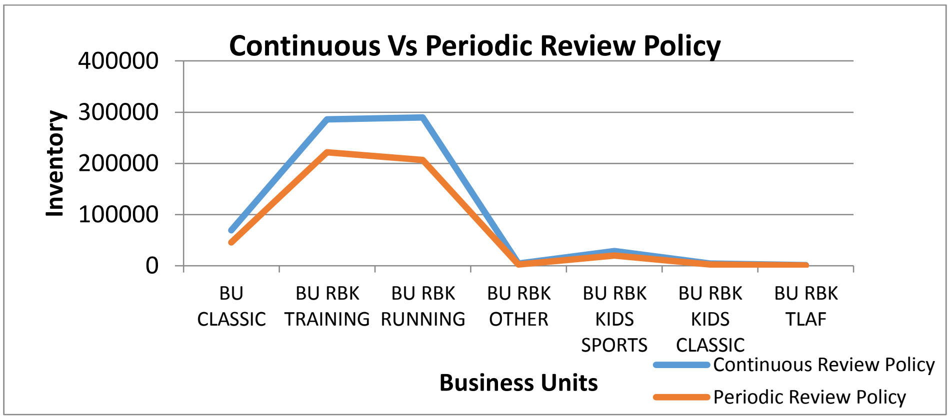

Fig. 6.4 Comparison of review policies for Company Y

Interpretation:

Through extensive inventory calculation analysis, we find out that the Periodic Review Policy is more favorable to have lower average inventory levels across a given month for the given data for Company Y.

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