CHAPTER 2

INVENTORY SYSTEM AND JIT MANUFACTURING

2.1 A MANUFACTURING SYSTEM AND INVENTORY

A manufacturing system involves processes that are used to convert raw materials into products, and it encompasses the design of the product, the selection of raw materials and the sequence of processes through which the product will be manufactured. The word manufacturing first appeared in 1683, and is derived from the Latin word manu factus, which means made by hand (Kalpakjian and Schmid, 2000). A manufacturing system includes all industrial activities, and inventory forms an integral part of it. Inventory represents a stock of physical goods that is stored for their use at latter stages. These inventories may be in the form of finished goods, in-process stages or raw materials. Chary (2005) states that a manufacturing system may have imbalances in the consumption and production rates of materials at different stages, and to prevent interruptions and imbalances it is necessary to keep stocks of inventory between different stages of the operations. Hence inventory takes care of the uncertainty involved in the usage or availability of the materials. Since it involves significant part of investment, so requires careful planning. Inventories can’t be held in stores for long time because of blockage of capital associated with them. The organization wants to recover its capital by keeping the inventories in circulation.

2.2 NATURE OF INVENTORIES

Inventories may be categorized as independent-demand inventories and dependent-demand inventories. In independent-demand inventories, the demand for an item in the inventory is independent of the demand for any other item. Finished goods are example of independent-demand inventories. Demands for these items are estimated from forecasts or actual customer orders. On the other hand,
dependent-demand inventories consist of items whose demand depends on the demand for other items also held in the inventory. Typically, the demand for raw materials and components can be calculated after knowing the demand for the finished products in which they are consumed (Gaither and Frazier, 2004). For example, the demand for an axle is dependent on the demand for automobiles, so an axle is dependent demand item. The material requirements planning (MRP) model is used for finding the dependent demand items.

2.3 INVENTORY COSTS

There are three basic costs that are associated with inventory, namely carrying or holding cost, ordering cost and shortage or stockout cost.

*Carrying cost* is the variable cost of keeping items on hand, including interest, facilities storage, material handling, taxes, insurance, labour and record keeping. It is generally estimated that carrying costs range from 10 to 40% of the value of a manufactured item (Russell and Taylor, 2006).

*Ordering cost* is associated with preparing a purchase order for a supplier or a production order for the shop. For the same item, the ordering cost is the same, and is independent of the order size. Annual ordering costs vary with the number of orders made - as the number of orders increases, the ordering cost increases.

*Shortage cost* is the cost of stockouts, and occurs when customer demand cannot be fulfilled because of insufficient inventory. It includes such costs as profits forgone through lost sales, cost of reclaiming disappointed customers, special expediting, special handling of backlogged orders, and additional production costs (Vollmann et al., 1999).
2.4 INVENTORY MANAGEMENT

Inventory management is a core operations management activity. It deals with managing inventory in the most cost-effective manner, and helps to meet the customer demand effectively and efficiently. Planning and estimation of optimum quantities of inventories and making them available at right time is of central importance to a manufacturing system. Good inventory management is often the mark of a well-run organization. It is more than a mere buying function as it happened to be in earlier days, and has strategic importance (Krajewski and Ritzman, 2000). Successful inventory management requires a system to keep track of inventory transactions, accurate information about demand and lead times, realistic estimates of inventory-related costs, and a priority system for classifying the items in inventory.

2.5 ABC CLASSIFICATION OF INVENTORY

The ABC system is a useful technique for determining which inventories should be counted more frequently and managed more closely and which others should not. It is based on the idea that only a small percentage of materials represents the majority of inventory value. This system divides inventory into three classes, namely *Class A, Class B* and *Class C*.

*Class A* inventories are very important, and represent only 20 percent of the materials in inventory and approximately 80 percent of the inventory value. They represent high valued items.

*Class B* inventories are moderately important, and represent 30 percent of the materials in inventory and approximately 15 percent of the inventory value.
Class C inventories are least important, and represent 50% of the materials in inventory and only 5% of the inventory value. Spare parts used in automobile industries fall in this category.

This classification system suggests that Class A inventories should be analyzed extensively and Class C inventories should be analyzed little.

### 2.6 INVENTORY CONTROL SYSTEMS AND MODELS

An inventory control system controls the level of inventory by determining how much to order (that is, the size of the replenishment order) and when to order. Two basic types of inventory control systems include continuous review system and periodic review system.

In the continuous review system, also called fixed order quantity system or reorder point system, a continuous record of the inventory level for every item is maintained, and an order is placed for the same quantity of an item each time that item is ordered. Whereas in the periodic review system, also called periodic reorder system or fixed interval system, the inventory is reviewed periodically at specific time intervals rather than continuously so that an order can be placed to bring the inventory level back to the desired level. It has the advantage of making adjustments in inventory to take care of any change in demand (Buffa and Sarin, 2000), but on the negative side, it has less direct control over the inventory.

The three order size models include the basic economic order quantity (EOQ) model, the economic production quantity model and the quantity discount model. The objective of these models is to determine the optimal tradeoff between inventory carrying costs and ordering costs that would minimize the total inventory cost. Several other models have been proposed that incorporate other parameters in
the basic EOQ model (Billington, 1986; Schaller, 1988; Tersine, 1988; Tersine 1992).

2.7 MATERIAL REQUIREMENTS PLANNING (MRP)

The material requirements planning (MRP) is a computer-based inventory control and production planning system, which was originated in the early 1960s in the United States. It is a logical, easily understandable approach to the problem of determining the number of parts, components, subassemblies, assemblies and raw materials that are needed to produce each end item (Gaither and Frazier, 2004; Krajewski and Ritzman, 2000). It also provides the schedule specifying when each of these items should be ordered or produced. It is useful for dependent and discrete demand items, complex products, job shop production and assemble-to-order environments (Russell and Taylor, 2006; Orlicky, 1994), and effectively helps in scheduling replenishment orders. Scott (1994) indicated that MRP can improve inventory level, lead time and customer service level. Successful implementation of MRP requires considerable employee involvement and training, data accuracy, appropriate demand patterns and reliable lead times. MRP is most valuable in industries where a number of products are made in batches using the same productive equipment (Chase et al., 2014). Today, the MRP system is the primary tool that is used for production planning, inventory control, shop floor control, costing and capacity planning by the modern manufacturer.

2.8 CAPACITY REQUIREMENTS PLANNING (CRP) and MRP

The capacity requirements planning (CRP) is related to the planning of the elements of a production system such as machine, process, facility and labour, other than material that the MRP takes care of. It is a computerized system that schedules the load according to the manufacturing capacities, and tests the master production schedule (MPS) of a MRP system for capacity feasibility.
2.9 MANUFACTURING RESOURCE PLANNING (MRP II)

It is a method for the effective planning of all resources of a manufacturing unit. It is a closed-loop MRP system that ties the basic MRP system to the financial and accounting systems. The focus of MRP II is to aid the management of a firm’s resources by providing information based on the production plan to all functional areas, and enables managers to test ‘what if’ scenarios by using simulation (Krajewski and Ritzman, 2000). Information from MRP II is used by managers in manufacturing, purchasing, marketing, finance, accounting and engineering, and is used extensively to provide benefits beyond that of MRP alone.

2.10 ENTERPRISE RESOURCE PLANNING (ERP)

MRP is currently evolved into a more comprehensive form for resource planning, known as enterprise resource planning (ERP). It is a powerful integrated information system that organizes and manages enterprise processes, and revolves around a single comprehensive database that can be made available across the entire enterprise. An ERP system consists of many software modules that help companies in managing and integrating different activities in different functional areas of a business such as accounting, sales, distribution, manufacturing, planning, purchasing, human resources and other transactions into one application software. It connects with supply chain and customer management applications, helping businesses share information both inside and outside the company, and serves as the backbone for an organization’s information needs as well as its e-business initiatives (Russell and Taylor, 2006).

SAP AG, a German software company, created a generic ERP software package to integrate all business processes together for use by any business in the world. The largest selling ERP software is SAP’s R/3 software that offers modules for sales and distribution, financial accounting, financial controlling, fixed assets management, human resources, work flow, industry solutions, materials
management, production planning, quality management, plant maintenance and project systems. ERP systems require a major commitment and investment, often require companies to modify some of their processes to accommodate the software, and take many years to implement (Gaither and Frazier, 2004). Other two top selling ERP software systems include Baan and PeopleSoft.

2.11 JUST-IN-TIME (JIT) AND ITS OTHER NAMES

Just-in-time (JIT) is a philosophy as well as a technique. It is a technique for reducing inventories. As a philosophy, its primary goal is the elimination of waste in the production system. Anything that does not add value to the product in the system is waste (Narasimhan et al., 2003). JIT systems require very little inventory because successive operations are closely coordinated. No activity should take place in a JIT system until there is a need for it (Christopher, 1998). JIT is based on planned elimination of all waste and continuous improvement of productivity, and requires all the parts or components to be made available at the time of their requirements and not before. Hence, it is one of the effective means of controlling the flow of inventory, preventing its storage and managing it effectively.

JIT is known by some other names (Gather and Frazier, 2004) such as continuous flow manufacturing, CFM (as used by IBM), stockless production or repetitive manufacturing system (as used by Hewlett-Packard), short cycle manufacturing (as used by Motorola), Toyota System or Toyota Production System, TPS (as used by several Japanese firms). In the late 1970s, the JIT philosophy was accepted in the West by its new name Kanban System. Some other names for JIT used in Western countries included zero inventory production system (ZIPS), material as needed (MAN), minimum inventory production system (MIPS), nick of time, frugal manufacturing and keep materials moving manufacture. Lean manufacturing or lean production is a popular term that many companies use today to refer the philosophies and approaches embodied in JIT. The principle of JIT can
be applied to all the functions of a company and not just operations (Adam and Ebert, 2003) along with service organizations to make them more efficient.

2.12 THE ORIGIN OF JIT

The basic idea of JIT was originally developed and brought to a notice by the Toyota Motor Company in Japan (Shingo, 1981; Ohno, 1982; Sohal et al., 1988). Taiichi Ohno, a former shop manager and later vice president of Toyota Motor Company, is the individual generally credited with the development of JIT, who is often called ‘Father of JIT’. The JIT philosophy gradually developed and was accepted as one of the important management principles. By the mid 1970s, many of the Japanese industries had adopted this principle and were using it for managing manufacturing activities (Sohal et al., 1988). Initially, this approach was not known by its current name JIT but by the name Toyota Production System, as its source of origin was in Japan. However most of the ideas embodied in JIT were combined and implemented earlier by an American automobile company, the Ford Motor Company, about 50 years before JIT evolved (Gaither and Frazier, 2004). Henry Ford, the founder of the company, presented his approach to production, which was similar to JIT (Ford, H., 1926).

2.13 THE LEAN MANUFACTURING AND JIT

The lean manufacturing was originally known as JIT manufacturing. It began as an effort to eliminate waste (particularly inventories), but it evolved into a system for the continuous improvement of all aspects of manufacturing operations. Womack and Jones (1990) coined the term ‘lean manufacturing’ in context of the Toyota Production System (TPS), which is widely recognized as the most efficient manufacturing system in the world. Lean manufacturing is both a philosophy and a collection of management methods and techniques that focuses on eliminating waste and streamlining operations by closely coordinating all activities. It achieves high-volume production and minimal waste through the use of just-in-time inventory
methods. The objective of lean manufacturing is to reduce costs by lowering raw material, work-in-process (WIP) and finished goods inventory to an absolute minimum. It seeks to achieve balance with the work content and physically links the manufacturing processes together so that the output of one process is directly consumed into the next downstream process. It does not produce in anticipation of need, and produces only necessary items in necessary quantities at necessary times. Inventory is viewed as a waste of resources and an obstacle to improvement. Lean manufacturing is based on doing more with less, that is, it involves fewer inventories, fewer workers and less space, and concentrates on eliminating all types of wastes from a manufacturing system. It seeks to reduce the nonvalue-adding wait, scheduling and queue times to zero. The resulting, often significant, reduction in manufacturing lead time is the basis for all the associated benefits of lean manufacturing (Hobbs, 2004). The activities are arranged in such a manner that each production unit delivers to the next unit the input it requires in order to proceed with the next stage of manufacture and delivers the input just in time for the work to begin (Christopher, 1998), and the inventory held by a company is measured in terms of hours of production rather than in days or months (Karmarker, 1989; Ward, 1994).

2.14 THE JIT MANUFACTURING APPROACH

The JIT approach considers the production activity in totality in contrast to traditional approach of manufacturing, where different functions are considered in isolation. One of the key goals achieved through JIT approach is to reduce the inventory including work-in-progress (WIP) and finished goods parts to its minimum level, preferably zero. It emphasizes on the necessity of a well-designed production system for the efficient production of perfectly defect free goods (McMohan and Browne, 2000), and ensures that all the elements of the supply chain in a production system work effectively in order to know the exact shipping and replenishment requirements of a product. It necessitates the requirement for small shipments to be made more frequently to meet the precise time requirements of the customer
Christopher, 1998). The JIT approach emphasizes on waste reduction, total quality control and devotion to customer (Adam and Ebert, 2003), and requires strong commitment and discipline on the part of organization and even Toyota Motor Company took 20 years to implement JIT system. It seeks to achieve zero lead time and a lot size of unity. The concept of zero lead time is ideal and unrealistic, but a manufacturing system that strives to keep the lead time minimum can render more flexibility to meet the short-term fluctuations in market demand.

### 2.15 PUSH SYSTEM VERSUS PULL SYSTEM

In a push system, a schedule is prepared in advance for a series of workstations, and each workstation pushes its completed work to the next station (Russell and Taylor, 2006), that is, the production of the item begins in advance of customer needs. For example, the MRP system uses push method of materials flow.

In a pull system, schedules for producing the item are not followed, but only those items are produced that are actually needed, that is, the customer demand activates the production of the item. Products go directly from upstream stages of production to downstream stages with little inventory between stages. Here the emphasis is on reducing inventory levels at every stage of production, and it prevents overproduction and underproduction. The JIT system uses pull method of materials flow.

### 2.16 WASTEFUL ACTIVITIES IN JIT

Shigeo Shingo identified seven types of wastes relating to setup time, waiting time, lead time, motion, transportation and quality of a product. These wastes do not add any value to the product, and can be eliminated completely or reduced to a minimum level through continuous improvement in the production system. Wasteful tasks simply increase production costs and reduce competitiveness.
2.17 SUPPLY CHAIN MANAGEMENT (SCM) IN JIT

A supply chain is a network of all activities that are connected with the flow and transformation of goods and services from the raw materials stage to the finished products and their deliveries to the customers, including purchasing, warehousing, inspection, production, materials handling and shipping and distribution (Wisner et al., 2015; Simchi-Levi et al., 2016). Computers and tools of information technology allow real-time, online communications throughout the supply chain. In the absence of a strong supply chain there is always uncertainty about the deliveries of the orders, which can ultimately result in poor-quality customer service.

Supply chain management (SCM) manages the flow of information through the supply chain in order to attain the level of synchronization among the members of the supply chain to make it more responsive to customer needs while lowering costs (Meredith et al., 2015). It is one of the most important strategic aspects of inventory management. Contracting with the wrong suppliers or choosing the wrong mode of transportation can result in poor-quality materials and late deliveries.

JIT uses minimum inventory, so inventory management in JIT is very critical. For better inventory management control, supply chain management should be effective and dependable, and it requires close collaboration, cooperation and communication among members of the supply chain.

2.18 FACILITY LAYOUT IN JIT

Facility layout represents the physical arrangement of machines, processes, departments, utilities, workstations, customer service areas, storage areas, people, equipment and space within an existing or proposed facility (Gaither and Frazier, 2004; Russell and Taylor, 2006; Krajewski and Ritzman, 2000). The facility decisions affect how efficiently workers can do their jobs and how much and how
fast goods can be produced, hence it has impact on both quality and productivity. The layout should be such that there are no hindrances in the flow of materials or inventory, and people around the facility can move smoothly. Conventional manufacturing units use process layout, where workstations are grouped according to functional requirements leading to high manufacturing lead time. On the other hand, JIT uses product layout where facilities are arranged around the product’s route to reduce the lead time.

2.19 KAIZEN AND JIT MANUFACTURING

Kaizen is a Japanese word that evolved in mid 1980s, and refers to continuous improvement. Behind JIT is the continuous drive to improve production processes and methods. Kaizen has tremendous power to improve the organization’s environment, and can produce miraculous results. It is kaizen, which has completely changed the face of Japanese industries and made them global leaders of their products. There is always a scope for improving the system even if the system is working very near to its fullest capacity. Facilities, support systems and skills are continuously required to be improved upon (Besterfield et al. 2001) to eliminate all the potential wastes from the manufacturing system. Through continuous improvement, zero defects, zero set-up time, zero handling and zero breakdowns can be realized, which in turn, can help to remove the bottlenecks in the production line, thereby ensuing free and smooth flow of inventory. Kaoru Ishikawa evolved the concept of quality circles which represented a small group of employees including workers and managers to address quality problems. It helped in controlling product quality at the source. The term autonomination, which means automatic detection of defects during production, was coined by Toyota as a quality control measure. A machine automatically stops when it detects a bad part. A worker then stops the line. On finding the defects, an investigation into the causes of the problem is initiated and corrective action is taken to stop it further (McMohan and Browne, 2000). A system of flashing lights, called andon that uses different light colours for different situations, is another tool of continuous improvement. A green light means that there
are no problems, an amber (yellowish colour) light means that production is falling behind and a red light means that there is a serious problem.

2.20 QUALITY ASPECTS IN JIT MANUFACTURING

JIT largely depends on the quality of products and services. Standardization, automated equipment, workforce commitment, preventive maintenance etc. are important tools that can be used to improve the quality. It leads to achieve the overall goal of satisfied customers.

2.21 SUPPLIER SELECTION IN JIT MANUFACTURING

The cooperative relationship between supplier and customer helps in sharing useful information, reducing costs and improving quality. Long-term relationships with suppliers with a few suppliers are needed to avoid uncertainty and ensure the quality of the supplied materials. The factors like delivery schedules, product quality and mutual trust and cooperation are the requirements for supplier selection.

2.22 KANBAN SYSTEM IN JIT

Kanban is the Japanese word for card. In context of JIT, kanban is a manual system used for controlling the movement of parts and materials that respond to signals of the need, that is, demand for delivery of parts or materials (Stevenson, 2015). Toyota was one of the first and most important developers of the kanban system (Narasimhan et al., 2003). It is an effective tool to reduce the level of inventory on the shop floor level, that is, in-process inventory (WIP). It is a pull system and is driven by the demand at the lowest point in the supply chain (Christopher, 1998). There are two types of kanban cards, namely withdrawal kanban (also called conveyance kanban, C-Kanban) and production kanban (P-Kanban). The withdrawal kanban is a card that authorizes the movement of goods,
and shows the quantity of items to be withdrawn from the preceding process by the subsequent one. On the other hand, the production kanban is a card that authorizes production of goods, and shows the quantity to be produced by the preceding process (Russell and Taylor, 2006; Buffa and Sarin, 2000). The kanban system forms an integral part of JIT production system.

2.23 SYNCHRONOUS MANUFACTURING AND JIT

The synchronous manufacturing approach is based on the theory of constraints (TOC) developed by Eliyahu Goldratt, an Israeli physicist, in the late 1970s. The basic premise is that the flow of material through a manufacturing facility can be more efficient and more rapid through focusing on and managing a limited number of key constraints (Narasimhan et al., 2003). The concepts of TOC were developed into computer software called optimized production technology (OPT), which is a complete production-planning and control information system that is particularly appropriate for complex job-shop environments. By developing the amount of work to be done at each workstation, OPT, given a mix of products, finds the bottlenecks in the production processes. When manufacturing is truly synchronized, its emphasis is on total system performance and not on only localized measures such as labour or machine utilization (Chase et al., 2014). It can significantly result in reduction in lead time.

2.24 BENEFITS OF JIT MANUFACTURING

The JIT system offers the following benefits (Krajewski and Ritzman, 2000; Martinich, 2005; Russell and Taylor, 2006; Meredith et al., 2015; Stevenson, 2015):

- It reduces the inventory levels drastically.
- It greatly reduces the lead time.
- It improves the product quality because of worker involvement in solving the causes of production problems.
- It eliminates wastes in production and material.
- It improves customer responsiveness.
- It reduces the overall cost of inventory.
- It reduces the purchasing costs.
- It increases the equipment utilization and productivity.
- It increases the organizational discipline and managerial involvement.

### 2.25 Suitability of JIT

JIT can be successfully implemented in repetitive manufacturing environments, where standard products are produced in high volumes at high speeds with materials moving in a continuous flow (Gaither and Frazier, 2004). The repetitive manufacturing involves simple planning and control because of continuous flow of products, which makes JIT work best in the shop-floor situations.

### 2.26 Success Stories of JIT

The JIT philosophy as well as the JIT manufacturing system have been successful not because of their ability to reduce the inventories drastically to their lowest levels, but because of their ability to recognize the fact that excessive inventories are the symptoms of a poorly organized manufacturing system. The successful applications of JIT have been predominantly in smaller, more focused factories and in repetitive manufacturing environments. Firms like Northern Telecom, Xerox, Hewlett-Packard, Motorola, General Electric, Honda, Toyota, Sony and Boeing are using JIT as a weapon in speeding market responsiveness (Gaither and Frazier, 2004). In the manufacturing industries, the automotive industry has used JIT philosophy to its highest level and has gained maximum. Toyota Motor Company of Japan, the originator of JIT philosophy, is the leading automobile manufacturer in the world. Its products are well known for their quality. Although JIT production is most effective in manufacturing system, some companies in the service sector have also applied it effectively. In the service sector, the benefits from
the JIT system can be achieved if their operations are repetitive, have reasonably high volumes and deal with tangible items such as sandwiches, mail, cheques or bills (Krajewski and Ritzman, 2000). Retail industries are frontrunners in service sectors to implement JIT philosophy successfully. Wal-Mart, Home Depot and Kmart are a few names in this category. Other service units include hospitals, banks, post offices and airline industries. Using kanban system of JIT philosophy, it has been successful in serving freshly prepared foods (Martinich, 2005).