UNIT 12 JUST - IN - TIME (JIT)

Objectives

Upon completion of this unit, you will get to know:

- What is the philosophy of just-in-time(JIT) operation
- Characteristics of just-in-time system
- Pull method versus push method of operation
- Prerequisite for J3T manufacturing Benefits of ET manufacturing
- Kanban system of manufacturing.

Structure

12.1 INTRODUCTION

In financial parlance, inventory is defined as the sum of the value of raw materials, fuels and lubricants, spare parts, maintenance consumables, semi-processed materials and finished goods stock at any given point of time. The operational definition of inventory would be : the amount of raw materials, fuel and lubricants, spare parts and semi-processed material to be stocked for the smooth running of the plant. Since these resources are idle when kept in the stores, inventory is defined as an idle resource or any kind having an economic value.

Inventories are maintained basically for the operational smoothness which they can effect by uncoupling successive stages of production, whereas the monetary value of inventory serves as a guide to indicate the size of the investment made to achieve this operational convenience. The materials management department is expected to provide this operational convenience with a minimum possible investment in inventories. The objectives of inventory, operational and financial, needless to say, are conflicting. The materials department is accused of both stock outs as well as large investment in inventories. The solution lies in exercising a selective inventory control and application of inventory control techniques.

Inventory control has been attracting the attention of managers in India for a long time.

12.1.1 Raw Material, WIP, Finished Goods

For control purposes, it is very essential to study the inventory in detail- raw materials, production components, work-in-progress and finished goods inventories should be segregated as the reasons for their existence and the causes for their size are different.

Raw materials and production components are purchased from outside suppliers and the reason for their existence is to uncouple the purchasing function from the production function. The size of this inventory is depend upon factors such as internal lead time for purchase, supplier lead time, vendor relations availability of the material government import policy, in the case of imported material, the annual consumption of the materials (ABC classification) and the relative criticality of the material (VED classification).

Work-in progress inventory might exist merely because of the production cycle time or could also be maintained for decoupling successive manufacturing operations. The decoupling could be employed either for implementing an incentive scheme or to enable each of the production departments to plan independently. The size of this inventory is dependent on the production cycle time, the percentage of machine utilization, the make/ buy policies of the company, and the management policy for decoupling the various stages of manufacturing.

The finished goods inventory is maintained to assure a free-flowing supply to the customers and for this the marketing department insists on substantial finished goods inventory. The size also depends on the ability of the marketing department to push the products, the company's ability to stick to the delivery schedule of the client, the shelf life and the warehousing capacity.

Two factors which influence the inventories of all types are: the accuracy and details of the final forecast-all the inventories are geared for future requirements and are therefore sensitive to this factor-and the available storage space-the logical sequence to this factor is the shelf life of the items stored, a factor for consideration in the case of perishable goods.

12.2 STOCK POINTS IN A PRODUCTION - DISTRIBUTION

Figure 12.1 identifies the main stock points that occur in a production- distribution system from raw materials and ordering of supplies through the productivity process, culminating in availability for use. At the head of the system, we must have raw materials and supplies in order to carry out the production process. If we are to be able to produce at minimum cost and by the required schedule, these materials and supplies need to be available. Therefore, we need to develop policies for deciding when to replenish these inventories and how much to order at one time. These issues are compounded by price discounts and by the need to ensure that delays in supply time and temporary increases in requirements will not disrupt operations.

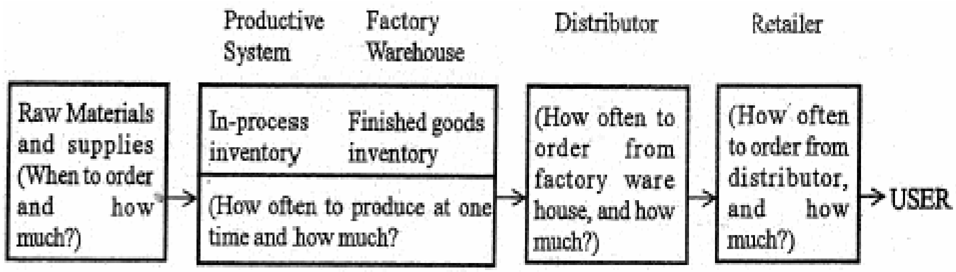

Figure 12.1 Main Stock Points in a Production-Distribution System

Adapted from Buffs, ES Modern Production/Operations Management, 7/e. Wiley Eastern Ltd.

As a part of the conversion process within the productivity system we have in process inventories, which are converted to finished good inventories. The finished goods inventory levels depend on the policies used for deciding on the production lot sizes and their timing and on the usage rates determined by distributor's orders. High volume items would justify different policies for production and inventory replenishment than medium - or low - volume items. The production lot size decisions and their binning are very important in relation to the economical use of personnel and equipment and may justify continuous production of a high volume item. On the other hand, low volume items will be produced only periodically in economic lots. Again, we will need policy guidelines to determine the size of buffer inventories to absorb the effects to production delays and random variations in demand by distributors.

The functions of distributors and retailers are those of inventorying products to make them available. Distributors and retailers often carry a wide range of items, and they need replenishment policies that take into account this kind of complexity. They commonly place routine orders periodically, ordering a variety of items from each supplier. Price discounts are often an additional factor to consider.

Although the details of problems may differ at each level in the production-distribution system, note that at each level the basic policy issues are in the inventory replenishment process, focused on the order quantity and when to order.

12.3 JUST-IN-TIME

Just-in-Time (JIT) is a Japanese innovation, and key features of this were perfected by Toyota. Some facets of the management practices Toyota developed are ideologically related to Japan's unique customs, culture, and labour - management relations. However there is nothing uniquely Japanese about JIT production and it is usable anywhere. The concepts have been applied successfully in many companies throughout the world. JIT production means producing and buying in very small quantities just in time for use. It is simple hand to mouth mode of industrial operations that directly cuts inventories and also reduces the need for storage space, racks, conveyors, forklifts, computer terminals for inventory control and of course material control personnel. Products are assembled just before they are sold, subassemblies are made just before the products are assembled, and components are fabricated just before the subassemblies are made - so work-in-process (WIP) inventory is low and production lead times are short. To operate with these low inventories, the companies must be excellent in other areas. They must have consistently high quality throughout the organizations. To achieve this quality and coordination, they must have the participation and cooperation of all employees. So TIT manufacturing or manufacturing excellence is a broad philosophy of continuous improvement. More important, the absence of continuous improvement. More important, the absence of extra inventories creates an imperative to run an error free operation because there is no cushion of excess parts to keep production going when problems crop up, causes of error are rooted out, never to occur again.

The JIT transformation begins with inventory removal. Fewer materials are bought, and parts and products are made in smaller numbers; that is the lot size inventories thereby decrease. This immediately results in work stoppages. Production comes to standstill because feeder processes breakdown or produce too many detectives and d-there are no buffer stock to keep things going on. Once this happens, analysts and engineers try to solve the problems and keep things going on. Each round of problem exposure and solution increases productivity and quality too.

Just-in-time (JIT) is a philosophy of improvement through aggressively discovering and resolving any problems or weaknesses that impede the organization's effectiveness and efficiency. Basically, it seeks to eliminate all waste within the organisation, including the waste of underutilizing the talents, skills, and potential of its employees. Anything that does not contribute to add in value for an internal or external customer is considered waste. The philosophy originated in manufacturing operations, but its concepts have been applied in other area such as a means of work, service and distribution. JIT can be very effective and powerful as a means of improvement.

Activity A

What is Just-in-time (JIT) production? How does it differ from Manufacturing Resource Planning (MRP)? What is MRP-JIT system?

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Activity B

Visit a repetitive manufacturing facility in your area. What are the major causes of inventory? Be sure to ask about lot sizes and setup times. Would a JIT system work in this facility? Why and why not?

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12.4 CHARACTERISTICS OF JUST-IN-TIME SYSTEMS

Just-in-time systems focus on reducing inefficiency and unproductive time in the production process to improve continuously the process and the quality *of* the produce or service. Employee involvement and inventory reduction are essential to JIT operations. Just-in-time systems are known by many different names, including zero inventory synchronous manufacturing , lean production, stock less production (Hewlett- Packard), material as needed (Harley - Davidson), and continuous flow manufacturing (IBM). In this section we discuss the following characteristics of JIT systems : People involvement, Team Work, Discipline, Total quality management, pull method of material flow, small lot sizes, short setup times, uniform workstation loads, standardized components and work methods, close supplier ties, flexible work force, product focus, automated production, and preventive maintenance.

12.4.1 People Involvement

Probability all management efforts have some behavioural aspects, because management is working through other people to accomplish the organization's objectives. Management plans and decisions only lay the groundwork. This is the resulting human behaviour that determines a company's success or failure. Such terms as zero inventory and stock less production have given some people the impression that JIT is only an inventory program. JIT has a strong human resources management components that must be recognized if the technical component is to be fully successful. Much of the success of JIT can be traced to the fact that companies that use it train their employees to have the appropriate skill, give them responsibility, and coordinate and motivate them.

The JIT philosophy of continuous improvement and minimization of waste considers waste to be any activity that does not add value to the product or serve the customer in some way. One form of waste that is inconspicuous and difficult to combat is the underutilization of human talent. JIT seeks to utilize more fully the creative talents of employees, suppliers, subcontractors, and others who may contribute to the company's improvement.

Businesses ultimately succeed or fail because of their people. JIT is no exception to this rule. Because JIT is a system of enforced problem solving, having a dedicated work force committed to working together to solve production problem, is essential. JIT manufacturing, therefore, has a strong element of training and involvement of workers in all phases of manufacturing.

12.4.2 Teamwork

First, and foremost, a culture of mutual trust and teamwork must be developed in an organization. Managers and workers must see each other as co-workers committed to the company's success.

Successful people involvement steams from a culture of open trust and teamwork in which people interact to recognize, define, and solve problems. Sometimes it is mistakenly assumed that this component is just another program, such as a suggestion program or a quality circle program. People involvement can include these programs and others, such as adhoc project teams that focus on specific improvement targets and semi-autonomous work teams whose membership seldom changes. The involvement components of JIT is much broader than a program or two: it is a management style and a permanent company wide attitude of teamwork. So that each person works to improve the company. People are encouraged to suggest ways to improve methods which are quickly and fairly considered, and the companies are open to trying something new that seem like a worthwhile improvement.

Another important factor that is crucial to JIT is the empowerment of workers. This means that workers are given the authority to take the initiative in solving production problems. Rather than waiting for guidance from above, workers have the authority to stop production at any time for such things as quality problems machine malfunctions or safety concerns. Groups of workers are then encouraged to work together to quickly get production going again. Once workers have identified problems. They are encouraged to meet during breaks before work or after work to discuss the problems. Having workers actively involved in problem solving is the objective of worker empowerment. People, suppliers, workers, managers and customers must all be motivated and committed to teamwork for JIT manufacturing to be effective.

12.4.3 Discipline

This open, improvement - driven atmosphere does not mean, however, that any employee is free **to** work by any method he or she choose to try. Usually there is a standard way each job is to be done. If an improvement is suggested and approved, a new standard procedure will be adopted. This standardization prevents variations in products or services which can cause defects. Defects occur- because some variation has been introduced into a material or procedure that normally products good result. When an efficient procedure that results **in** good quality is established, it is to be followed until a better way is tested and approved. You can see that creativity and openness to change are needed, but it is creativity in conjunction with teamwork and discipline that achieves consistent good quality and leads to improvements.

12.4.4 Total Quality Management (TQM)

JIT systems seek to eliminate scrap and rework in order to achieve a uniform flow of materials. Efficient JIT operations require conformance to product or service specifications. JIT systems control quality at the source, with workers acting as their own quality inspectors.

JIT manufacturing depends on a system of TQM being in place. Successful JIT manufacturing goes hand-in-hand with an organization-wide TQM culture. Just as everyone has to be involved in JIT, so also must everyone be involved in TQM. Total commitment to producing products of perfect quality every time and total commitment to producing products for fast delivery to customers have one essential thing in common Both are finely focused on the overall goal of satisfied customers.

12.4.5 Pull Method of Material Flow

Just-in-time systems utilize the pull method of material flow. However, another popular method of material flow is the push method. To differentiate between these two systems, we consider the production system for a fast food dish at a restaurant. There are two workstations. The dish maker is the person responsible for producing; this dish: the cutlets must be prepared; buns must be toasted and then dressed with ketchup, pickles, onions, lettuce, and cheese; and the cutlets must be inserted into buns and put on a tray. The final assembler takes the tray, wraps the buns in paper, and restocks the inventory. Inventories must be kept low because any buns left unsold after ten minutes must be destroyed.

The flow of materials is from the dish maker to the final assembler to the customer. One way to manage this flow is by using the push method, in which the production of the item begins **in** advance of customer needs. With this method, management schedules the receipt of all raw materials (e.g., vegetables, buns, and condiments) and authorizes the

start of production, all in advance of the dish needs. The dish maker starts of production no. of dish (the capacity of the griddle) and, when they are completed, pushes them along to the final assembler's station, where they might have to wait until he is ready for them. The packaged dishes then wait on a warming tray until a customer purchases one.

The other way to manage the flow among the dish maker, the final assembler, and the customer is to use the pull method, in which customer demand activates production of the item. With the pull method, as customer purchase dish, the final assembler checks the inventory level of dish and, when they are almost depleted, orders six more. The dish maker produces the six dish and gives the tray to the final assembler, who completes the assembly and places the dish in the inventory for sale. The pull method is better for the production of dish: The two workers can coordinate the two workstations to keep inventory low, important because of the ten-minute time limit. The production of dish is a highly repetitive process, setup times and process times are low, and the flow of materials is well defined. There is no need to produce to anticipated needs more than a few minutes ahead.

Firms that tend to have highly repetitive manufacturing processes and well-defined material flows use just-in-time systems because the pull method allows closer control of inventory and production at the workstations. Other firms, such as job shops, producing products in low volumes with low repeatability in the production process, tend to use a push method such as MRP. In this environment a customer order is promised for delivery on some future date. Production is started at the first workstation and pushed ahead to the next one. Inventory accumulates in anticipation of shipping the completed order on the promised date.

12.4.6 Small Lot Sizes

Rather than building up a cushion of inventory, users of JIT systems maintain inventory with lot sizes that are as small as possible. Small lot size have three benefits. First, small lot sizes reduce cycle inventory, the inventory in excess of the safety stock carried between orders. The average cycle inventory equals one-half the lot size: As the lot size gets smaller, so does cycle inventory. Reducing cycle inventory reduces the time and space involved in manufacturing and holding inventory,

Second, small lot size help cut lead times. A decline in lead time in turn cuts pipeline (WIP) inventory because the total processing time at each workstation is greater for large lots than for small lots. Also, a large lot often has to wait longer to be processed at the next workstation while that workstation finishes working on another large lot. In addition, if any defective items are discovered, large lots cause longer delays because the entire lot must be inspected to find all the items that need rework.

Finally, small lots help achieve a uniform operating system workload. Large lots consume large chunks of processing time on one workstation and therefore complicate scheduling.

12.4.7 Short Setup Times

Reduced lot sizes have the disadvantage of increased setup frequency. In operations where the setup times are normally low, small lots are feasible. However, in fabrication operations with sizable setup times, increasing the frequency of setups may result in wasting employee and equipment time. Theses operations must reduce setup times to realize the benefits of small-lot production.

12.4.8 Uniform Workstation Loads

The JIT systems work. best if the daily load on individual workstation is relatively uniform. Uniform loads can be achieved by assembling the same type and number of units each day, thus creating a uniform daily demand at all workstations. Capacity planning, which recognizes capacity constraints at critical workstations, and line balancing are used to develop the monthly master production schedule.

12.4.9 Standardized Components and Work Methods

The standardization of components, called part commonality or modularity, increases repeatability. For example, a firm producing 10 products from 1000 different components could redesign its products so that they consist of only 100 different components with large daily requirements. Because the requirements per components increase, so does repeatability; that is, each worker performs a standardized task or work method more often each day. Productivity tends to increase because workers learn to do the task more efficiently. Standardization of components and work methods aids in achieving the high-productivity, low-inventory objectives of JIT systems.

12.4.10 Close Supplier Ties

The JIT philosophy may extend beyond the walls of the company applying JIT, to include, its suppliers. It has an impact on the entire logistics system, or "supply chain." Because JIT systems operate with very low levels of inventory, close relationships with supplier are necessary. Stock shipments must be frequent, have short lead times, arrive on schedule, and be of high quality. A contract might require a supplier to deliver goods to a factory as often as several times per day. Purchasing managers focus on three areas: reducing the number of supplier, using local suppliers, and improving supplier relations.

Typically, one of the first actions undertaken when a JIT system is implemented is to pare the number of suppliers. Xerox, for example, reduced the number of its suppliers for 5000 to just 300. This approach puts a lot of pressure on these suppliers to deliver high-quality components on time. By placing a bigger percentage of its business with its business with its best suppliers, the company can improve its quality and the reliability of receiving items. The partnership is a long term agreement so the companies can develop a smooth working relationship. The desire is for the supplier to become an extension of the company so that the supply chain is a seamless organization that works to serve the ultimate customer better than any competing supply chain could. The JIT company can also benefit from the supplier's expertise by having supplier representatives participate in the design phase of few products and recommend improvements. They also work with their suppliers vendors, trying to achieve JIT inventory flows throughout the entire supplier chain.

It can be beneficial to a supplier to work in such a relationship, particularly with a high volume manufacturer. When a company reduces the number of suppliers for an item, the volume of purchase from the remaining supplier or supplier can increase dramatically.

Continuous improvement is central to the philosophy of JIT and is a key reason for its success.

12.4.11 Flexible Work Force

Workers in flexible work forces can perform more than one job. When the skill levels required to perform most tasks are low, a high degree of flexibility in the work force can be achieved with little training. In situations requiring higher skill levels, such as at the Hi-tech industries, shifting workers to other jobs may require extensive, costly training. Flexibility can be very beneficial. Workers can be shifted among workstations to help relieve bottlenecks as they arise without resorting to inventory buffers. This is an important aspect to the uniform flow of JIT systems. They can also step in and do the job for those on vacation or out sick. Although assigning workers to tasks they don't usually perform may reduce efficiency, some rotation relieves boredom and refreshes workers.

12.4.12 Product Focus

A product focus can reduce the frequency of setups. If volumes of specific products are large enough, groups of machines and workers can be organized into a product layout to eliminate setups entirely. It volume is insufficient to keep a line of similar products busy, group technology can be used to design small production lines that manufacture, volume, in families of components with common attributes. Changeovers from a component in one product family to the next component in the same family are minimal.

12.4.13 Automated Production

Automation plays a big role in JIT systems and is a key to low-cost production. Sakichi Toyota, the founder of Toyota, once said "whenever there is money, invest it into machinery". Money freed up because of JIT inventory reductions can be invested in automation to reduce costs. The benefits, of course, are greater profits, greater market share (because prices can be cut), or both. Automation should be planned carefully, however, many managers believe that if some automation is good, more is better. That isn't always the case.

12.4.14 Preventive Maintenance

Because JIT emphasizes finely tuned material flows and little buffer inventory between workstations, unplanned machine downtime can be disruptive. Preventive maintenance can reduce the frequency and duration of machine downtime. After the technician has performed routine maintenance activities, he/she can rest other parts that might need to be replaced. Replacement during regularly scheduled maintenance periods is easier and quicker than dealing with machine failures during production. Maintenance is done on a schedule that balances the cost of the preventive maintenance program against the risks and costs of machine failure.

Another tactic is to make workers responsible for routinely maintaining their own equipment and develop employee pride in keeping their machines in top condition. This tactic, however, typically is limited to general housekeeping chores, mini lubrication, and adjustments. High-tech machines need trained specialists. Doing even simple maintenance tasks goes a long way toward improving machine performance.

12.4.15 Production Methods

Processes are designed so that there is less specialization of workers. The physical layout is arranged so that a worker can operate two or three different machines, thus providing flexibility in processes that might precedes the assembly line. The benefits that result from this organisation of multi-function workers are:

- reduction of inventory between what would otherwise be separate processes
- decrease in the number of workers required, resulting in a direct increase in productivity
- increased worker satisfaction because of more broadly defined jobs
- multi-functional workers can engage in teamwork

There are three elements of job standardization that are included on a standard operation sheet stacked up for all workers to see:

Cycle time, operations routing, and standard quantity of work in process.

Based on the computed cycle time that is derived from market demand, the aggregate number of workers required to produce one unit of output in the cycle time is determined. Rebalancing may then be necessary to schedule for minimum labour input for a given output objective. The standard quantity of work input for a given output objective. The standard quantity of work in process indicates the in-process inventory required for smooth flow.

The smoothing of production is regarded as the most critical element in the Just-in-Time objective. As will be described in more detail under the heading Kanban which follows, workers go to the preceding process to withdraw the required parts and components for their operations. If there are fluctuations in the rates at which these materials are withdrawn, then the preceding process must hold buffer in-process inventories to give off the-shelf service. The required in-process inventories would increase also for upstream processes. This results in the objective of minimizing production fluctuations in the final assembly line by scheduling small lots of individual models, and focusing "all out" efforts on minimizing setup times for all processes.

Given your current understanding of Japanese business practices, would you like to work for a Japanese corporation in your homeland? What would be the positive aspects? The negative aspects?

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12.5 THE JUST-IN-TIME MANUFACTURING PHILOSOPHY

For years manufacturing firms have sought to provide products with the most value for lowest cost. Now the leading firms provide products with the most value for lowest cost with the fastest response time. Quick response to market demands provide a powerful, sustainable competitive advantage. Indeed, time has emerged as a dominant dimension of global competition, fundamentally changing the way organization compete?' It is no longer good enough for firms to be high-quality and low cost products. To successes today, they must also be first in getting products and services to the customer fast. JIT is the weapons of choice today in reducing the elapsed time of this cycle.

12.5.1 Prerequisites for JIT Manufacturing

The basic idea of JIT is rather simple- drastically reduce work-in-process (WIP) inventories throughout the production system. In this way, products flow from suppliers to production to customers with little or no delays or interruptions beyond the amount of time they spend being produced at work centers in manufacturing. The overall objective of JIT manufacturing is to reduce manufacturing lead times, and this is achieved by drastic reduction in WIP. The result is a smooth, uninterrupted flow of small lots of products throughout production.

Most successful JIT applications have been in repetitive manufacturing, operations where batches of standard products are produced at high speeds and high volumes with materials moving in a continuous flow. The Toyota automobile factories, where the notion of JIT may have started, are perhaps the best example of the use of JIT in repetitive manufacturing. In these factories, the continuous of products makes planning and control rather simple, and JIT works best in these shop-floor situations. Successful use of JIT is rare in large highly complex job shops where production planning and control is extremely complicated. Smaller, less complex job shops have used JIT, but these companies have taken many steps to change operations so that they behave somewhat like repetitive manufacturing. We will discuss more about this in the next section.

JIT does not come free-certain changes to the factory and the way it is managed must occur before the benefits can be realized. Among these changes are:

1) Stabilize production schedules.
2) Make the factories more focused.
3) Increase production capacities of manufacturing work centers.
4) Improve products quality.
5) Cross-train workers so that they are multi skilled and competent in several jobs.
6) Reduce equipment breakdowns through preventive maintenance.

12.6 ELEMENTS OF MANUFACTURING

We will discuss JIT by examining its important components, and controlling production, and several of its ongoing activities.

12.6.1 Eliminating waste

Eliminating waste of all kinds is the deep-seated ideology behind JIT Shigeo, a JIT authority at Toyota, identified seven waste in production that should be eliminated. Table 12.1 lists and describes these waste.

Table 12.1: Toward Eliminating Waste in Manufacturing

A recognised JIT authority and engineer at the Toyota Motor company, Shigeo Shingo, identifies seven wastes.

1. **Overproduction:** Make only what is needed now.
2. **Waiting:** Coordinate flows between operations and balance load imbalances by flexible workers and equipment.
3. **Transportation :** Design facility layouts that reduce or eliminate materials handling and shipping.
4. **Unneeded production :** Eliminate all unneeded production steps.
5. **Work in Process (WIP) inventories :** Eliminate by reducing setup times, increasing production rates, and better coordination of production rates between work stations:
6. **Motion and Effort :** Improve productivity and quality by eliminating unnecessary human motions, make necessary motions more efficient, mechanize, then automate.
7. **Defective products :** Eliminate defects **and** inspection. Make perfect products.

***Source** : R Hall, Attaining Manufacturing Excellence (Homewood, IL: Dow Jones- Irwin 1987) 26.*

12.6.2 Enforced Problem Solving and Continuous Improvement

In traditional manufacturing in-process inventories allow production to continue even if production problems occur : thus, high machine and worker utilization is achieved. If defective products are discovered, machines malfunction, or material stock outs occur, in process inventory can be used to feed what would otherwise be idle workers and machines. The in-process inventory covers up production problems in traditional manufacturing. Behind JIT is the continuous drive to improve production process and methods. Toward that end, JIT strives to reduce inventories because high inventory levels are thought to cover up production problems. By drastically reducing in-process inventories, production problems are uncovered and production stops until the causes of the production problems are solved. Only when the machine is fixed, the quality control problem is solved, or the cause behind the stock out is found and corrected only then can production begin again.

JIT is really a system of enforced problem solving. There are few safety factors in JIT. Every material is expected to meet quality standards, every part is expected to arrive exactly at the time promised and precisely, at the place it is supposed to be, every worker is expected to work productively, and every machine is expected to function as intended without breakdowns. Managers in JIT manufacturing have a choice. They can put a huge effort into finding and solving the causes of production problems, or they can live with an intolerable level of interruption. One of the approaches to implementing a JIT program is to reduce in-process inventories incrementally in small steps. At each step, different production problems have been removed.

But the job eliminating production problems is not over. Vigilance in continuing to study potential problem areas is needed to ensure continuous improvement. Japanese manufacturers have long practiced what they called kaizen, the goal of continuous improvement in every phase of manufacturing. Managers may encourage workers to reduce in process inventories a step further to see if any production problem occur, thus identifying a target for the workers to eliminate. Machine setups may be studied with workers and managers working to strip away the fat so that setups are almost instantaneous. Japanese manufacturers have long used the term less than a minute set up, meaning that their goal is to have all setups take less than a minute.

12.6.3 Benefits of JIT Manufacturing

Some of the benefits that a JIT system provides are:

1) Inventory levels are drastically reduced.

2) The time it takes for products to get through the factory is greatly reduced, thus enabling factories to engage in time based competition, using speed as a weapon to capture share.

3) Product quality is improved, and the cost of scrap is reduced. Product quality improves because of worker involvement in solving the causes of production problem and with smaller lots, defective parts are discovered earlier.

4) With less in-process inventory, less space is taken up with inventory and materials handling equipment. Workers are closer together so that they can see each other, communicate more easily, work out problems more efficiently, learn each other's jobs, and switch job as needed. This promotes teamwork an-tong workers and flexibility in work assignments.

5) Because the focus in manufacturing is on finding and correcting the causes of production problems, manufacturing operations are streamlined and problem-free.

12.7 JIT PURCHASING

The same pull type approach in JIT is applied to purchasing shipments of parts from suppliers. In JIT purchasing, supplier use the replacement principle of Kanban by using small. Standardize containers and make several shipments daily to each customer. If Kanban is used by a supplier. Kanban cards authorize the movement of containers of parts between the supplier's shop and the customer. In such arrangements, suppliers are ordinarily located near their customers. JIT therefore not only reduces in-process inventories by using Kanban, but raw-materials inventories are also reduced by applying the name principles to suppliers.

The essential elements of JIT purchasing are as follows:

1) Supplier development and supplier relations undergo fundamental changes. The nature of the relationships between customers and suppliers shifts from being adversarial to being cooperative. The Japanese call these relationships subcontractor networks and costs and improving quality, and even financing are often shared by customers and suppliers.

2) Purchasing departments develop long-tern relationships with suppliers. The result is long-term supply contracts with a few suppliers rather than short-term supply contracts with many suppliers. Repeat business is awarded to the same suppliers, and competitive bidding is ordinarily limited to new parts.

3) Although price is important, delivery scheduled, product quality, and mutual trust and cooperation become the primary basis for supplier selection.

4) Suppliers are encouraged to extend JIT methods to their own suppliers.

5) Suppliers are ordinarily located near the buying firm's factory, or if they are same distance from the factory, they are usually clustered together. This causes lead times to be shorter and more reliable.

6) Shipments are delivered directly to the to the customer's production line. Because suppliers are encouraged to products and supply parts at a steady rate that matches the use rate of the buying firm. Company-owned hauling equipment tends to be preferred.

7) Parts delivered in small, standard-size containers with a minimum of paperwork and in exact quantities.

8) Delivered material is of near-perfect quality. Because suppliers have a long-term relationship with the buying firms and because parts are delivered in small lot sizes, the quality of purchased materials tends to be higher.

12.8 THE KANBAN SYSTEM

Accomplishing the Just-in-Time objective rests on systems for determining production methods, and the information system called Kanban. Both of these concepts contributed to the objective of having the right number of parts or components at the right place at the right time.

The Kanban system is a unique Japanese information system that "harmoniously" controls the production quantities in each process.

The Kanban system is a simple information system used by a Work Centre (WC) to signal its supplier WC to send a container of an item and to authorize the supplier WC to make another container of the particular item. The name comes from the Japanese word kanban, which means "card" or "sign". Originally a card was used to signal the supplying work center. A WC can use any of a variety of methods to trigger resupply by its supplier WC. For example, a flashing light, the empty container itself, or a message on a computer terminal can communicate a request for more material. We discuss the two-card kanban system to provide some detail about how it is linking work centers.

In the two-card kanban system, one type of card, called a production card, or P-card, authorize a WC to make one standard container of a particular part specified on the card. The second type of card, called a move card, or M-card, authorizes the movement of one, container of the specified part from a particular WC to another WC as specified on the card. These cards are ordinarily recirculated and new cards are issued only when production of an item is to be started or changed significantly. The production card circulates repeatedly between the outbound material location at a WC and the work area where the item is produced. Similar card transactions link the supplier WC and the WCs that supply it. The user WC will also be linked to one or more WCs that supplies. A series of these linkages connects the final assembly operation with the WC that performs the first operations in making the product. Often, even the raw material vendor is linked with the starting operation through -a kanban signal. Kanbans picked up when one delivery is made authorize the vendor to make specified items and deliver them on the next delivery.

The kanban systems can be a very simple, inexpensive, and effective method of coordinating work centers and vendors. The organizations must be well disciplined so that there is always an authorizing kanban with every container, ensuring that only the appropriate items are produced and excessive inventory does not build up. There is also the opposite danger-that some WC might run out of material and cause work to stop at work to stop at all subsequent WCs. If this or any other pull method is to work well with small inventories, there must be no problems to disrupt production: because there simply is not enough inventory to keep the plant running while a problem is corrected.

Numeric example of Kanban system:

Example : (Adapted from Production and Operations Management by E.E.Adam and R.J.Ebert, PHI. New Delhi)

The process of making component xy943 for the Digital Maestro CD player involves five work stations. The cycle time is three minutes per item for every work station. This means that Kanban card will be returned from any work station particular to the previous work station, on average, every three minutes times the lot size: What would be the impact of reducing lot sizes from ten units to two? Using lot sizes of ten units and two units, average WIP inventory levels and flow-through times are calculated.

Solution:

WIP inventory levels:

Lot size = 10: Average WIP = 5 work stations x 10 units/lot = 50 units

Lot size = 2: Average WIP = 5 x 2 = 10 units

Process flow-through time (average)

Lot size =10: Flow-through time= 5 work stations x 10 units/ lot x 3 minutes / cycle= 150 minutes

Lot size = 2: flow-through time = 5 x 2 x 3 =-30 minutes

In the example, by reducing lot sizes from 10 units to 2 units, the CD manufacturer was able to reduce WIP by a factor of 5 from 50 to 10 units, and flow-through time also by a factor of 5, from 150 to 30 minutes. Many companies have experienced similar drastic improvements through the introduction of Kanban. For this reason, they are able to give better customer service and have lower investments in inventories than do their competitors.

Activity D

Review Shigeo Shingo's seven wastes. Which of these wastes are addressed by **the** following JIT techniques?

1) Pull production

2) Kanban

3) JIT purchasing

4) Flexibility manufacturing

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Activity E

There is a lot of discussion about but very few documented applications of JIT in service organisations. What JIT techniques would be valid in the following situations? Be prepare to explain your choices.

a) A bank

b) A restaurant

c) A copy center

d) A university

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Activity F

Suppose a JIT work center is being operated with a container size of 25 units and a demand rate of 100 units per hour. Also assume it takes 120 minutes for a container to circulate.

a) How many containers are required to operate this system?

b) How much maximum inventory can accumulate?

c) How many Kanban cards are required?

12.9 JIT IMPLEMENTATION IN INDUSTRIES

1) Kanban System at an American Toyota Motor Facility

The plant fabricated, assembled and painted four models of truck beds for Toyota light trucks, with an annual capacity of 150,000 units a year. The JIT implementation began in assembly area an then progressed through manufacturing functions to a selected number of suppliers, over a two year period. The system used material requirement planning (MRP) for overall production planning and Kanban for shop floor control.

The salient feature of JIT application are :

Company	: Toyota Motor Facility
Product category	: Truck beds
Productivity improvement	: Labour- 20%
Setup time reduction	: Significant
Inventory reduction	: Raw material - 21 % W IP - 45%
Quality improvement	: Significant
Space saving	: Significant
Others	: Warehousing cost reduced by 30%, Reduction in presses 30%, Production volume up by 40%, 30% reduction in forklifts.

2) JIT as the basis for Revitalisation at Harley Davidson Motor Co.

Harley-Davidson the dominant US producer of motorcycles, faced serious problems throughout the seventies due to high inventory, scrap, rework, production bottlenecks, etc. Harley-Davidson adopted JIT as a revitalisation strategy. The company called its JIT programme -"MAN" i.e., Material as Needed. The programme encompassed reduction of setups inventories and lead time; flow processing and schedule stabilisation : use of preventive maintenance, statistical process control and quality circles; employee involvement and vendor programmes. The salient features of JIT application are:

Company	:	Harley Davidson
Product category	:	Mptorcycles
Productivity improvement	:	Vehicles per employee up-32% Revenue per employee up-100%
Setup time reduction	:	Overall setup reduction by 75% (many operations-combined)
Inventory reduction	:	WIP and RM reduction by 50%
Quality improvement	:	35% decrease in warranty 50% decrease in scrap rework, Manufacturing errors down by two-third defects per unit down by 70%
Space savings	:	35% reduction in warehouse 15% reduction in manufacturing
Lead times	:	All Suppliers within 200 miles weekly or daily delivery

3) JIT in an Auto Components Company

A UK based Auto components company adopted JIT as a strategy to contend with the Japanese competition. The company employed 600 people and fabricated automotive components. The change to JIT had the following objectives-reduction in through put time from average 10 days to under 1 working day, reduction of WIP to minimum necessary, doubling of sales per employee, and reduction in scrap rates and rework. The salient features of JIT application are:

Company	:	Tokai Rika
Product Category	:	Automotive parts
Productivity improvement	:	(Indexed) 100 to 145, equivalent to 317 people.
Set up Time Reduction	:	Die cast : 40 to 2 min. 90 min. to 20 sec.
Inventory Reduction	:	(Indexed) 100 in 1975 to 35 in 1976. 17 days in 1975 to 6 days in 1976.
Quality Improvement	:	Significant
Space Savings	:	Significant, elimination of warehouses.
Lead Time Reduction	:	Significant

4) JIT in Automobile Company

The salient features of JIT application are :

Company	:	Toyo Kagyo
Product Category	:	Automobiles.
Productivity Improvement	:	70 to 80% gain from elimination of waste.
Set up Time Reduction	:	Ring gear cutter.30 min. in 1976 to 13 min. in 1980
Inventory Reduction	:	(Indexed) 100 in 1973 to 31 in 1981.
Quality Improvement	:	Significant, Machine down time reduced to 50 to 60 hours/month.
Space Savings	:	Significant
Lead Time Reduction	:	Significant

JIT in Electronics, Computers, Telecommunication and Instrumentation

1) JIT at Hewlett Packard

The computer systems division of Hewlett Packard Inc.; USA had experienced a number of problems in manufacturing. The standard lead times for a lot of single in-house made

PCB was as much as 11-15 workdays and 10-45 days for subcontracted assemblies. The schedules in the Random Access Memory circuit testing were not linked with MRP, causing late deliveries. JIT systems were introduced to achieve; small lot, continuous flow manufacturing. Kanban control areas were developed for material flow regulation, at various segments of manufacturing flow. The salient features of JIT application are:

Company	:	Hewlett Packard
Product Category	:	Computers and Test Systems
Productivity Improvement	:	87 to 39 stanard hours
Set up Time Reduction	:	30% to 45% reduction in manual setup
Inventory Reduction	:	Significant ($2 million inventory eliminated)
Quality Improvement	:	First to improvement JIT/TQC.
Space Savings	:	PC assembly : 8500 to 5750 sq.ft.
Lead Times	:	PC assembly: 15 to 1.5 days

2) JIT as a basic for the world claw manufacturing (WCM) at Calcomp

JIT strategy was used as a basic to achieve World Class Manufacturing (WCM) at Display Products Division of Calcomp Inc.- a Lockhead company. The division produced computer graphics in a number of models and options. To began with, a simple keyboard unit. Streamlined layout, mixed model progressive value adding assembly concept, use of Kanban squares for control of the production flow and worker centered inspection were features of the successful pilot implementation. Similar methods were then implemented in a major final assembly area containing hundreds of parts. The salient features of JIT application are:

Company	:	WCM.
Product Category	:	Computer graphics.
Productivity Improvement	:	41% increase in yields.
Setup Time Reduction	:	Decrease in mfg.cycle time from 12 weeks to 4 weeks.
Inventory Reduction	:	60% decrease in average inventory.
Quality Improvement	:	67% decrease in annual scrap and rework.
Space Savings	:	75000 sq.ft. reduction in floor space.
Lead Times	:	53% improvement in supplier on time delivery.

3) JIT at Sundstrand Data Control

Sundstrand Data Control's Instrument System Division began its JIT programme with its Q-Flex Accelerometer, a high volume milked - model production line. It implemented JIT on a phased basis, over a period of two years. To do this, it formed a steering committee of top level managers and an operating committee of personnel from relevant areas. The other features of JIT included: i) Training workshop for all employees, ii) Setting up Key bench mark for WIP, cycle time and quality levels, iii) Use of balanced assembly line, iv) Movement of stock room close to the line, v) Pull system of production, and vi) Worker centered quality control The salient features of JIT application are:

Company	:	SUNDRAND
Product Category	:	Q-flex accelerometer
Productivity Improvement	:	20% improvement in total capacity.
Setup Time Reduction	:	Cycle time reduced to 90% per unit.
Inventory Reduction	:	Reduction by 80%
Quality Improvement	:	Up by 50%; Rework reduced by 66% Scrap costs cut by 60%
Space Savings	:	Significant
Lead Times	:	100 days to 2.5 days

4) JIT at Apple Computers

The salient features of JIT application are :

Company	:	Apple Computers
Product Category	:	Micro computers
Productivity Improvement	:	i) Inspection labour from 25 to 9.
		ii) Assembly Labour from 22 to 4
Setup Time Reduction	:	Estimate to 30% (lines mostly dedicated, started JIT)
Inventory Reduction	:	Estimate of 90% in WIP and raw material.
Quality Improvement	:	Scrap and rework reduced by 10%, incoming material quality up by 20%
Space Savings	:	No need for warehouse; material delivered to point of use
Lead Times	:	All computers less than two days. Daily schedule.

JIT in Process Type Industry

1) JIT in Hand Blown Glass Manufacture

An application of JIT in a hand blown glass manufacturing plant has been reported by Byrd and Carter. The JIT production system was introduced in 1986. The objective was to reduce the inventories. The overall impact of the project was :

- Over $ 750,000 in cost saving manufacturing
- Reduction in manufacturing cycle time of the glass from three weeks to 4 hours.
- Reduction in material flow through the plant by 81 %.
- Release of over 1000 sq. ft. of floor space for better use.
- Reduction in material handling by 7 moves in one product line and 4 moves in another product line.

2) JIT Manufacturing at Avon Cosmetics

Avon Product Inc. is amongst the biggest producer of cosmetics in the world. It is a direct selling enterprise and its high quality products include cosmetics and fashion jewellery. Avon adopted JIT in 1982. A trend prognosis system was setup for improving accuracy of the sales forecasts.

JIT oriented material disposition and purchasing were brought about using long term contracts; frequent deliveries, approved vendors and vendor rating schemes. Introduction of Quality and Productivity Improvement Programme (QPIP) worldwide resulted in many quantity and productivity improvement system. Results obtained over a 5 years period (1982-87) were as follows:

- Reduction in inventory of finished goods by 25%, Components (53%), raw ingredients (52%).
- Reduction in warehousing and handling cost (25%), reduction in average run size (18%) and improvement in readiness to deliver (5.7).
- Quality improvement in materials (6.2%), production (1.3).

3) JIT in Food Processing Industry

In the food industry, the adoption of JIT principles has been largely due to the increasing demands from key customers for a better package of services and product options. The key challenges facing food industry are : improving order performance, improving responsiveness on pack deliveries, enhanced product duality and freshness, and providing greater pack option variety.

A limited shelf life food-producer in UK in response to many of these pressures, responded effectively to the challenge through several `innovations to enable JIT operation. The application produced the following results:

-- Initial reduction in clean down time (45%)

-- Reduction in setup time (65%)

- Reduction in process losses related to changeovers (60%)
- Reduction in type outer cartons for packaging from 20 to 2, and
- Increasing the weekly deliveries to key retailers to thrice a week.

Other non-quantified benefits were : enhanced customer service, elimination of out of code returns, reduction in capital charges, lower material handling and quality costs, much reduced chill store requirement and simplified planning and logistic systems.

4) JIT at Asia Securities Printing

The new production system application at Asia Securities Printing (ASP) is an illustration of JIT in the printing and publishing industry. ASP adopted JIT, on becoming a number of NPSRA of Japan. It specialised in printing securities-a high value added product. The important requirements in this industry are:

i) Short lead time from order -receipt to delivery,

ii) Error free printing, and

iii) Flexibility to print different types of documents.

ASP faced problems like large paper inventory and a number of non-value adding operations like stacking and unstacking etc., prior to JIT. The switch to JIT had the following results:

- daily delivery of paper,
- debottlenecking the printing process to reduce lead time, and
- use of stockless based on production smoothing and staggered deliveries to customer, as needed, to reduce customer inventory.

JIT enabled ASP to develop a full service business in printing all kinds of documents, and expand its customer base by 50-60 customers per year. Its sales were targeted to rise at least 25% per year. Moreover, it helped the customer to reduce his inventory.

JIT in Seasonal Demand Industry

1) The World Company

The fashion garment industry is example of a high seasonal industry. Fashion garments are highly style and fashion sensitive and get out-dated quickly. Thus, discount sales and financial losses are not uncommon. World company is a leading producer of fashion garments in Japan. It is a member of NPSRA. Prior to JTT, world used mass production system, which made it suffer from over-production, and excessive inventory.

As part of its JIT strategy, world dispensed with the mass production machinery. It adopted "slow speed" machines to achieve balanced, synchronised garment production. `Multitask' production was adopted, where in each worker operated not one but several machines which performed different tasks, in a well defined cycle. With transition to JIT, world reduced the lead time from one month to two hours, enabling it to produce to orders, eliminate inventories and discounting:

2) Use of Kanban in a Job Environment

A manufacturer in Canada operated a job shop to manufacture to orders, high quality outdoor clothing used for camping, hunting, canoeing, skiing and so on. Both summer and winter clothes were produced. The manufacturer faced problems resulting in out of phase production. Traditionally the orders were grouped in to a production run that included all the sizes and colours required. This resulted in high WIP and long lead times.

After implementing KANBAN and JIT, following improvements were observered : improved quality due to small lots, less WIP, lower congestion in packing and shipping areas, increase in throughput capacity, quicker availability of finished products, and release of 40-50% of space.

Other Manufacturing Industries

1) JIT Implementation in Lucas Industries, UK

JIT implementation was brought about in 18 months. The steps involved:

-- Training for all levels of management
– Factory redesign on a cellular basis
– Job redesign and reclassification to suit cellular organisation .
– Reduction in the machine and process change-over times
– Use of Kanban system.

Introduction of JIT resulted in reduction of lead time from 14 days to 1 day. Productivity increased by 25%. The final assembly operated with only 15 hrs. of stock. Stock levels were reduced by 7.5 million pounds. The staff strength was reduced by 300. Business turnover ratio increased from 7 to 15 times.

2) JIT at Kawasaki Electricals

ET was implemented at Kawasaki Electric of Japan, a member of NPSRA, as a way to over come the near bankruptcy condition of the company in 1982. Kawasaki operated in the electrical switch board industry. Kawasaki began JIT with a focus on orderlines and organisation leading to a plant clean up campaign. The benefits derived were as follows :

– Space saving of 53,000 sq.ft.
– Overall workforce decreased by 157 over a four a four year period.

3) JIT at Misawa Homes

A unique example of application of JIT in prefabricated housing industry is provided by Miswa Homes of Japan. Miswa was the leader in this industry in Japan. It was however facing difficulties due to poor sales and profit, on account of an industry recession. Miswa's inventory of unsold homes was mounting. It then adopted JIT and developed seven new design for the homes to match seven stages of a person's life cycle. Thus there were 49 combinations of design and life cycle stages. The strategy called for high diversified, small volume production, often customised, but at no additional costs. The results observed were:

-- Capital investment per year reduced from $4 million/year to $1.2 million/year.
-- Manufacturing lead time decreased from 2 months to 1 day.
-- Inventory went down to $ 2.8 million.
-- Productivity went up 2-3 times.
-- Vast amount of space released.

JIT in Service and Administration Operations

JIT philosophy has already demonstrated its usefulness in service and administrative operations. The various case applications are :

1) JIT at Skylark Restaurant Chain

Prior to JIT Skylark owned a chain of 300 restaurant in Japan. To service these, it prepared food, using mass production equipment, in its centralised kitchen facility. This, coupled with the need to cater a large variety resulted in large quantities of each variety. A large refrigeration facility was used to preserve the prepared foods. These practices led to large amount of wastage, enormous cost and very low capital turnover.

Transition to ET was achieved by dismantling much of the mass production equipment in favour of the single item production methods. Kanban method was used in production and in production and in keeping the restaurant clean. The switch to ET produced impressive results. Free space was released. The inventory was cut to half in just 3 months of JIT introduction. JIT enabled Skylark to switch to custom production in a highly cost effective manner.

2) JIT at a Customer Service Centre

Northern Telecom's customer service centre repaired printed circuit packs (PCPS) which become inoperable in digital switches. The labour intensive operation had four major steps: PCP modification, testing and trouble shooting, repair and shipping. The centre faced problems which caused quality errors, high WIP, long repair cycle time of one week, and an 85% customer service level. In 1987, JIT was started at the centre. Following a training programme in JIT, work cells were implemented, each of which was full responsible for the complete repair of a specified group of POPS. WIP and work flow were controlled by the use of Kanbans and remarkable : 100% customer service level, 89% improvement in quality, 75% reduction in WIP and two day repair cycle time for PCP.

3) JIT in a Mail Order Operation

A company called Semantodontics in USA adopted JIT in a mail order operation. It sold nationwide to dentists by mail order catalogue and had a major production line called personalised printed products. The large number of customer complaints on this products. The large number of customer complaints on this product mainly arose on account of information delays on the amount charged and order delivery delays. These were caused by the customer waiting times of three or more weeks and a monthly charging of customers.

A JIT like operation was achieved by the use of three order batches per day, elimination of new customer set-up processes, and faster pace of working in the order verification area. As a result, the order processing lead time went down from 4 days to 4 hours. The complaint calls went down sharply.

12.10 SUMMARY

JIT is a new approach to repetitive manufacturing, whereas MRP is suited to job shop or batch production. We have seen how parts should be produced just-in-time rather then Just-in-Case they are needed. This is accomplished by a simple visual system of production control and dedication toward constant reduction in inventories. The objective of JIT is to improve return on investment. This is done by increasing revenues, reducing costs, and reducing the investment required. It is based on philosophy of eliminating the waste and utilising the full capability of each worker. This system was originally developed in Japan and gradually picking up in Indian industries In Kanban system a faxed number of containers are provided for each plant required. When these containers full, no more parts are produced, thus limiting the inventory of each part. Improvement activities are encouraged by workers and management to reduce the number of containers, size of containers and inventory. Impleme4tation of JIT systems requires a staged progression of activities. Top management must provide leadership and support.

12.11 SELF-ASSESSMENT EXERCISES

1) Why did the JIT approach evolve in Japan and not in western countries?
2) How can lot sizes and inventories be reduced in a JIT system? Mention specific approach.
3) Why has repetitive manufacturing tended to use long runs and large lot sizes in the past?
4) Describe vendor relations both before and after installation of a JIT approach.
5) What are the effects of JIT system on workers and manager?
6) Suppose a work center has a setup plus run time of 30 minutes to make 50 parts. Also assume that it takes 10 minutes to move a standard container of 50 parts. Also assume that it takes 10 minutes to move a standard container of 50 parts to the next work center, and the demand rate is one part per minute through the day.
   a) Schedule this situation by drawing a picture of when work center. A should be producing and idle and when movements of containers take place from A to B.
   b) How many standard containers are needed for this part to calculate the picture in part a.
   c) Use the formula n = DT/ C to calculate the number of container.
7) Why is it important to study Japanese manufacturing in a production and operation and operations management course?

8) The process of making a certain component involves seven work stations. The cycle time for all of the work stations is nine minutes. The cyrrent lot size is 25 units. What would be the effect on WIP levels and process flow-through times if the lot size were reduced to :

   a) 19 units

   b) 12 units

   c) 5 units

   d) 1 units

9) What are the most critical things needed to implement JM. Compare these things to implementation of an JIT system.

10) Will the EOQ formula work in JIT environment?

11) The process for making alarm clocks involves six work stations with cycle times of four minutes per item for every work station. The single card kanban system uses 10 units in each bin. The quality circle group has found a method to eliminate one stage of production, reducing the number of work stations to five. What are the reductions in work-in-process inventories and in flow-through time?

12) Discuss how JIT reduces costs (material, labor, overhead)- not including inventory. Be specific.

13) For a particular operation, the setup time is 10 minutes at a cost of $10 in lost machine time and labor. The run time is 50 minutes to produce a standard lot of 400 parts. Assume a holding cost of $2 per part per month a production rate of 20000 parts per month. It takes 3 hours to circulate a container of parts.

   a) Calculate the EOQ for this part.

   b) How many standard containers are needed?

   c) If the setup time can be cut to 1 minute, recalculate the lot size and number of containers needed.

12.12 FURTHER READINGS

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