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MANAGEMENT OF INVENTORY SYSTEMS

JIT-based Approaches for Materials Management

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Sub Topics

1. Concepts and Issues, Push versus Pull Systems
2. Kanban System, Working of a Kanban System, Rules for Operating a Kanban system, Determination of Number of Kanbans
3. Numerical Examples, Determination of Number of Kanbans
4. Numerical Examples, How to Achieve the JIT Goal of Batch Size of One
5. Signal Kanban, Other Types of Kanbans, Different Types of Pull Systems, Benefits of JIT-based Production and Inventory Control System, Barriers to JIT Implementation

JIT-based Approaches for Materials Management

- ✓ **Concepts and Issues**
- ✓ **Push versus Pull System**

Concepts and Issues

- **A just-in-time (JIT) production system is a production system where only the necessary products at the necessary time in the necessary quantity are manufactured, and stock-on-hand is held to a minimum.**

- JIT-based manufacturing systems emphasize the importance of developing an inventory system that ensures smooth flow of materials within the production systems at the plants.

- JIT-based inventory system primarily controls raw materials and WIP inventory levels for dependent demand items.

Concepts and Issues

- It attempts to control and minimize the waiting times or queuing times and achieve an ideal lot size of one unit.
- JIT-based system is based on a philosophy of production where inventory is considered undesirable.
- JIT-based manufacturing system was developed by Toyota Motor Company, and one of the key areas of Toyota Production System (TPS).

Concepts and Issues

- **The objectives of TPS are as follows**:

i. Reducing costs by eliminating all kinds of wastes.

ii. Making it easier to achieve and assure product quality.

iii. Attempting to create work sites that respond quickly to change.

iv. Organizing work sites based on human dignity, mutual trust and support, and allowing workers to realize their potential fully.

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Concepts and Issues

- **TPS covers a number of areas**: **process design, job design and job standardization**; **economic lot sizes and accelerated setup times**; **just-in-time production**; **autonomation**; **kanban**; **Jidoka/andon**; and **Yo-i-don**.

- **The most distinctive and dominant** among these areas is the **Just-in-time production system**.

- **One of the key elements of JIT production system is the kanban system,** the application of which ensures a smooth flow of materials among production stages with minimum level of raw materials and WIP inventory even under highly fluctuating demand condition.

Concepts and Issues

- A pull type production system is used to respond effectively toward a fluctuating demand situation.

- JIT-based production system is capable of minimizing or eliminating different types of wastes. These wastes are grouped under three categories: Muda (waste), Mura (unevenness), and Muri (overburden).

- **In a typical production system, wastes are classified in seven types: correction, overproduction, unnecessary processing, conveyance or material handling, unnecessary movements, waiting, and inventory.**

Concepts and Issues

- **Among all these wastes, inventory may be considered the most critical as it is considered a 'necessary evil'**.

- Implementation of JIT production philosophy helps eliminate uncertainties so that inventory can be reduced to the minimum necessary amount.

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Concepts and Issues

- The goals of JIT production systems are manifold. They are to be achieved simultaneously. These goals are: **(i) zero inventory, (ii) zero defects, (iii) zero handling, (iv) zero assembly, (v) zero waiting, (vi) zero setup, and (vii) batch size of one.**

- There are specific tools and techniques we use to achieve the goal of zero inventory by following the **principle of continuous improvement (kaizen).**

Concepts and Issues

- Under JIT-based system, inventory management at the shopfloor is an important issue.
- Details of the important tools and techniques for shopfloor inventory management are to be known for their implementation.
- The main advantage of implementing JIT-based inventory management are three-fold: minimum cost, maximum quality, and minimum throughput time.
- **As far as production and inventory control system is concerned, there are two types of systems: MRP system and JIT system**.
- **Whereas MRP system is known as push system, JIT system is a pull system**.

Push versus Pull System

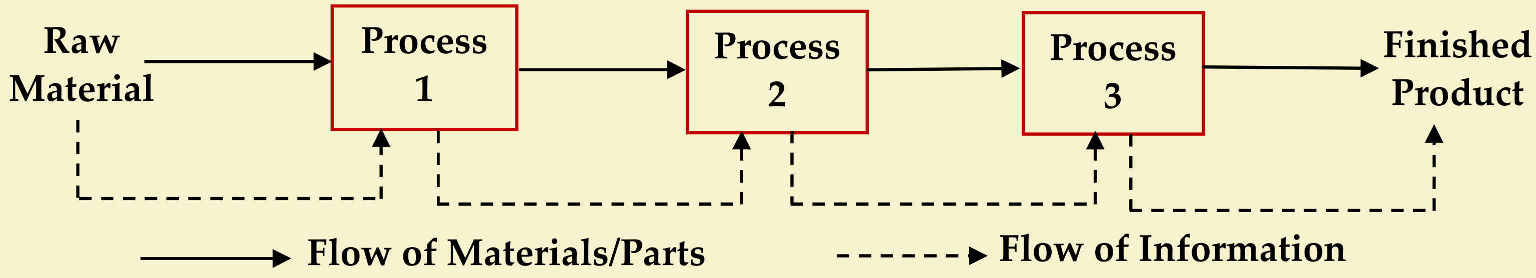
- A Push system is essentially an MRP-based production planning and inventory control system. In this system, the main objective is to produce to capacity, assuming a steady demand situation.

- If demand changes quite frequently (an erratic demand pattern), a push system does not work efficiently resulting mainly in under-utilization of resources with its serious implication on financial performance.

- However, in produce-to-stock strategy with guaranteed demand of consumer items regularly used, the push system may be a desired alternative.

Push versus Pull System

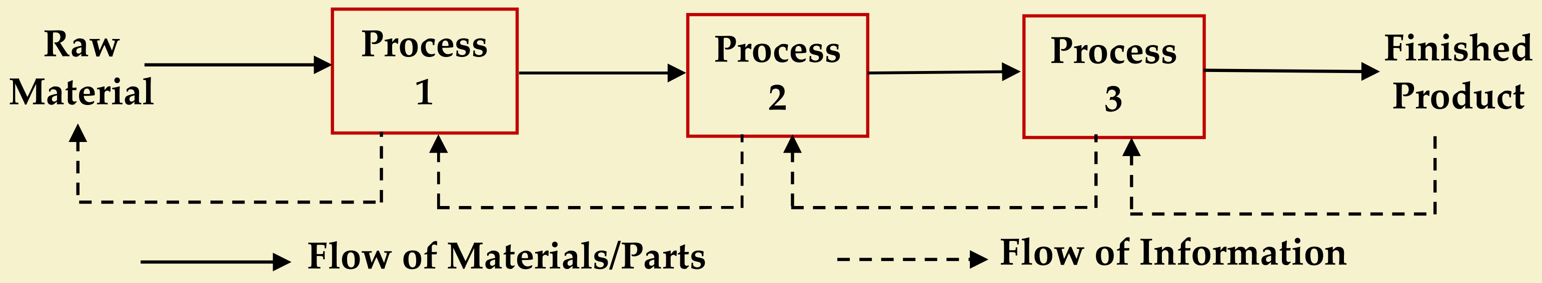
- The material and information flow process in a push system is given as



- A pull system is essentially a JIT-based production and inventory control system. In this system, the main objective is to produce as per the demand assuming a highly fluctuating and erratic demand pattern.

Push versus Pull System

- In today's context, many companies face a highly competitive situation wherein a steady demand of products may not be assured even if the company's product is well-known and the company is known for its core competency in the product concerned.
- A pull system performs very efficiently under erratic demand situations.
- The materials and information flow process in a pull system is given as



Push versus Pull System

- In a pull system, items at each stage are produced as per the demand of the next downstream stage in a given period of time (short term). Requirements of certain items at a stage are pulled from the previous upstream stage.

- **At each stage, manufacturing or production technology employed should be such that production of varying amounts or quantities is cost effective.**

- Japanese companies use kanban system to control production and inventory following JIT principles using pull system.

JIT-based Approaches for Materials Management

- ✓ **Kanban System**
- ✓ **Working of a Kanban System**
- ✓ **Rules for Operating a Kanban system,**
- ✓ **Determination of Number of Kanbans**

Kanban System

- Kanban is a Japanese word meaning 'visible record'.
- Toyota developed the kanban system. In this system, a set of cards travel between preceding and succeeding processes/production stages communicating what parts are needed at what quantities at the subsequent processes.
- It is used to move materials driven by the usage of parts and to control WIP, production, and inventory flow.

Kanban System

- **Two types of Kanbans are commonly used:**

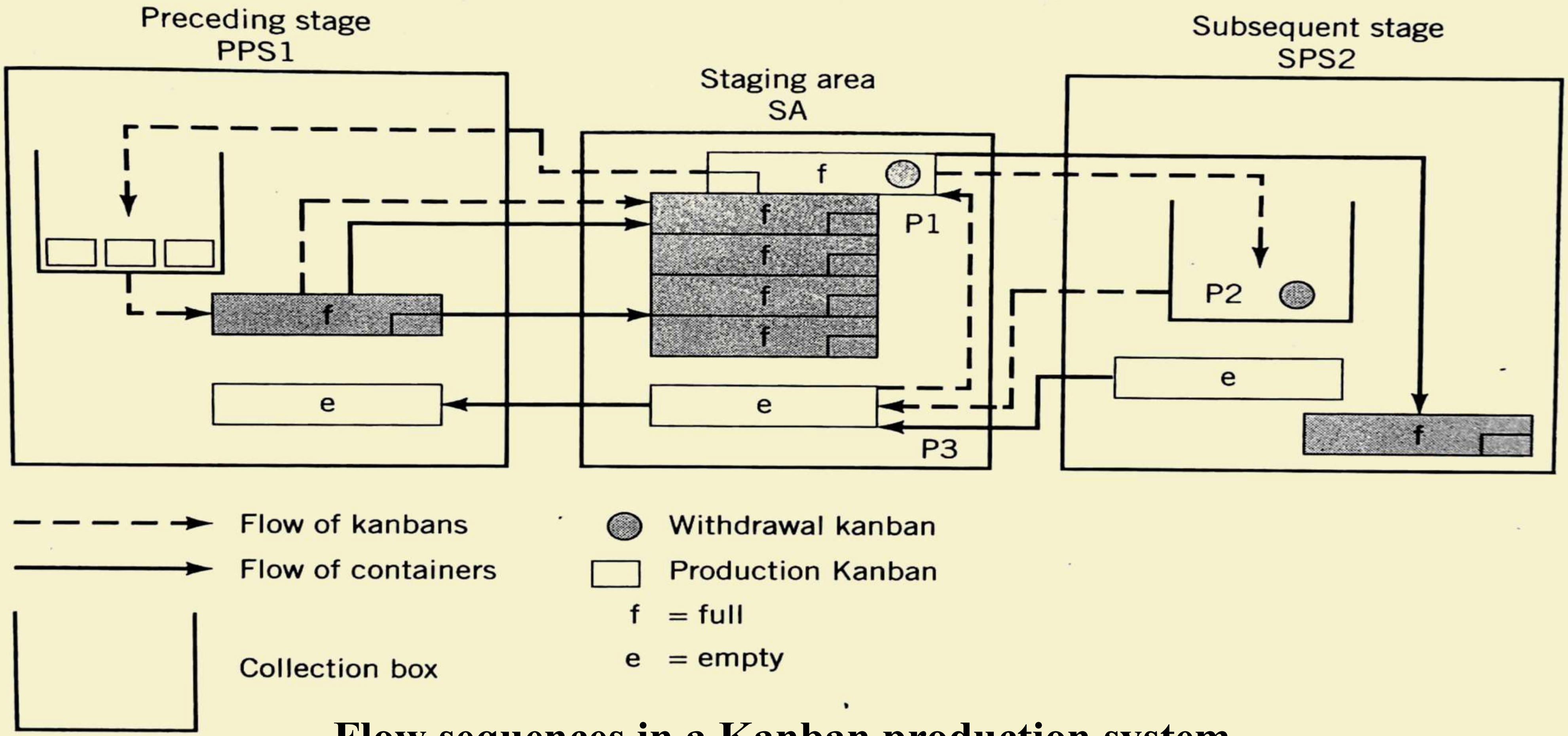
i. **Withdrawal (or conveyance) kanban**
ii. **Production kanban**

- The **primary function of a withdrawal kanban** is to pass the authorization of movement of parts from one centre to another.

- The **primary function of production kanban** is to release an order to the preceding process/stage to produce parts equal to the lot size specified on the card.

Working of a Kanban System

- In JIT system, control of materials and WIP inventory at the shopfloor is an important consideration. The shopfloor control is done by kanban system.
- The kanban system needs to be explained in respect of two successive production stages, viz. preceding production stage, PPS1 and subsequent production stage, SPS2, with a stacking area (intermediate stage), SA in between.
- The sequence of movements of kanbans (withdrawal and production) and containers between processing stages and the stacking area is presented in the Figure. The flow sequences explain the working of a typical kanban system. **The kanban card is attached with a container of a specified capacity, in terms of number of parts (in a given state) it can contain**.



Flow sequences in a Kanban production system

Rules for operating a Kanban system

- Certain set of rules is to be followed in a kanban system so that its working achieves the purpose for which it is designed and implemented.

- **These rules are as follows**:

i. No withdrawal of parts without a kanban.

ii. Subsequent process comes to withdraw parts/items only when they are needed (pull system logic).

iii. Defective parts should not be sent to the subsequent process.

Rules for operating a Kanban system

iv. **Preceding process should produce only the exact quantity of parts withdrawn by the subsequent process (the container in subsequent process comes to the preceding process to withdraw the necessary parts in necessary quantities at the necessary time).**

v. If the withdrawals fluctuate in quantity or time, the peak demand decides the inventory levels, equipment and workers, and hence, it is important to smooth (or minimize the fluctuation of) production.

iv. It is necessary to fine tune production using kanban (stopping process when demand decreases or increasing production rate when demand increases).

Determination of Number of Kanbans

- In a kanban system, the number of kanbans in use may represent the amount of WIP inventory on an average. The number of kanbans, after its determination considering a number of factors, usually remains fixed.

- **There are two models, deterministic and probabilistic, used to determine the number of kanbans.**

Determination of Number of kanbans

Deterministic Model

- Toyota has proposed and used this model.
- The formula used to determine the number of kanbans is as follows:

$$\text{Number of kanbans, } y \geq \frac{D\left(T_w+T_p\right)(1+\alpha)}{a}$$

Determination of Number of kanbans

where,

y = number of kanbans

D = demand per unit time

T_w = waiting time of kanban

T_p = processing time

$T_w + T_p$ = lead time

α = a policy variable, indicative of level of external disturbances as assessed subjectively ($1+\alpha$ is the safety factor)

a = container capacity (usually not more than 10% of daily requirement)

Determination of Number of Kanbans

- In order to control WIP inventory, once determined the number of kanbans becomes a constant. If the demand increases, the lead time needs to be decreased by taking effective steps.

- If is also desirable to reduce the value of $\alpha$to zero so that safety factor is 1.

- For improving the performance of kanban system (minimum WIP), reduction in the values of a, α, and lead time $(\mathrm{T_w} + \mathrm{T_p})$ is essential.

JIT-based Approaches for Materials Management

- ✓ **Numerical Examples**
- ✓ **Determination of Number of Kanbans**

Numerical Example-1

Consider the production of a certain item manufactured in XYZ company. Its requirements are 10,000 units per month. Suppose the company has just started implementing the JIT system. Accordingly, the policy variable is set at $\alpha = 0.40$. the container capacity is fixed at 50 items and the production lead time is 0.50 days.

1. Determine the number of production kanbans.

2. Suppose the company has stable production environment and the policy variable can be fixed at $\alpha = 0.00$. Determine the number of kanbans and the resulting impact on work-in-process inventory.

Numerical Example-1

3. What happens if the lead time is increased to 1 day because of labour shortages and failure of machines?

4. What happens if the lead time is reduced to 0.25 days because of process improvements? The value of α is 0.30 as a result of these process improvements.

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Solution

1. We now know that number of kanbans is given by the following formula:

$$\text{Number of kanbans} = \frac{(\text{Daily demand})(\text{lead time})(\text{safety factor})}{\text{container capacity}}$$

Assuming 20 work days in a month, the daily demand is 10,000/20 = 500 parts. Accordingly,

$$\text{Number of kanbans} = \frac{(500)(0.50)(1.40)}{50} = 7$$

Solution

2. If α = 0.00, then the safety factor is 1.00. Accordingly,

$$\text{Number of kanbans} = \frac{(500)(0.50)(1.00)}{50} = 5$$

3. $$\text{Number of kanbans} = \frac{(500)(1.00)(1.00)}{50} = 14$$

   The implication if this change in the system operation is that the average inventory increases by 350 units [(7)(50) = 350] compared with case 1. this is because extra containers are available as safety stock.

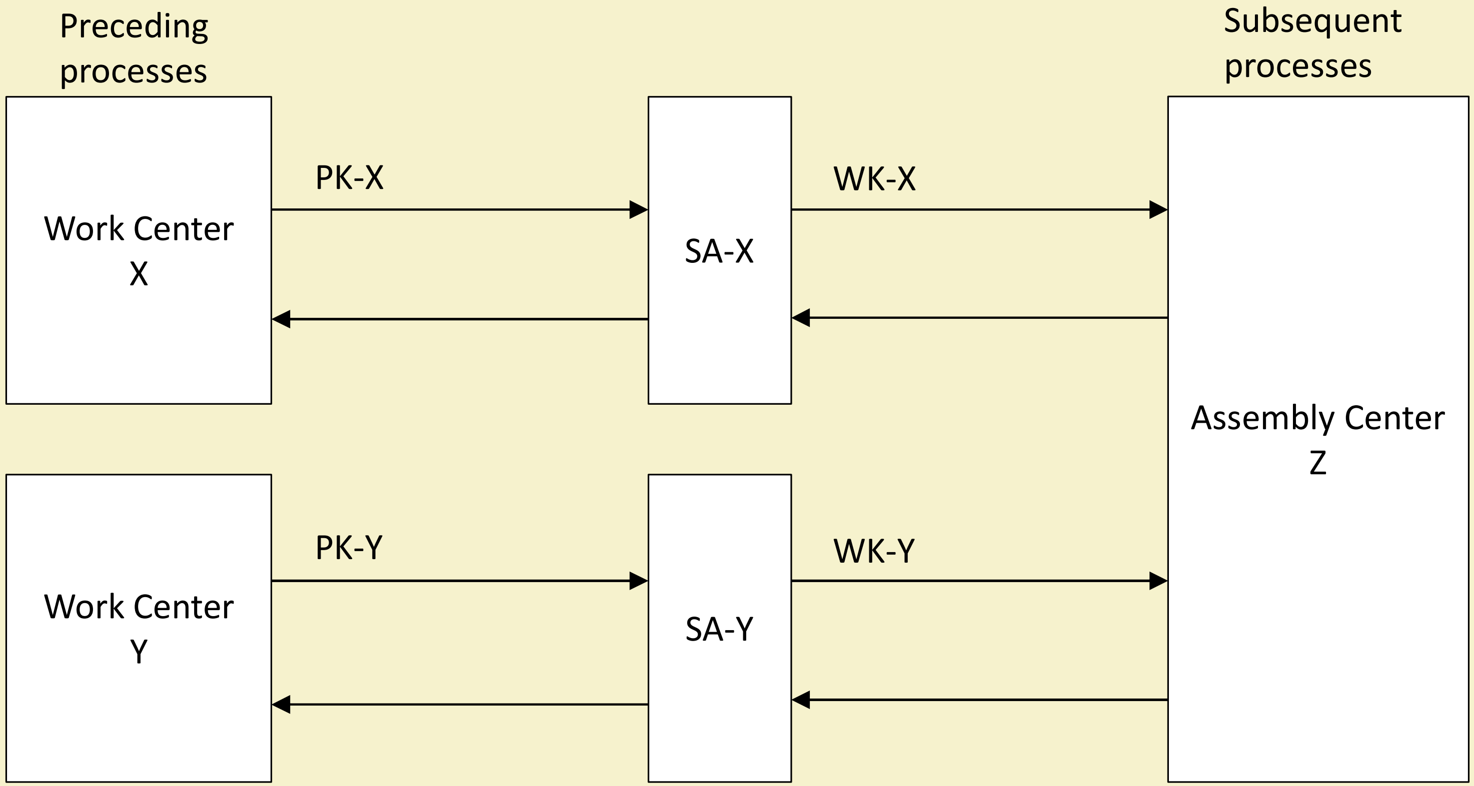
4. $$\text{Number of kanbans} = \frac{(500)(0.25)(1.30)}{50} = 3.25$$

Numerical Example-2

Consider the manufacturing of product Z in a company. Product Z is assembled from two parts, X and Y, that are manufactured in the company. A schematic layout depicting preceding stage, staging area, subsequent stage, and the flow of production and withdrawal kanbans is given in the Figure. The data given in Table are available.

1. Determine the number of withdrawal and production kanbans.
2. Now suppose the assembly process is shifted to Mexico as a part of reorganization. The lead time to travel between the new location in Mexico and the present plant location is 4 days each for parts X and Y. determine the number of withdrawal and production kanbans and the impact of this policy on work-in-process inventory.

Numerical Example-2



PK-X = production kanban for part X
PK-X = production kanban for part Y
WK-X = withdrawal kanban for part X
WK-Y = withdrawal kanban for part Y
SA-X = staging area for part X
SA-Y = staging area for part Y

Numerical Example-2

Part	Demand (Units/Day)	Lead time (Days)	α	Container capacity
Assembly Stage				
X	2000	1.00	0.00	100
Y	800	0.50	0.25	50
Manufacturing stage				
X	2000	0.50	0.20	100
Y	800	1.00	0.00	50

Solution

1. (a) X = 20, Y = 10

   (b) X = 12, Y = 16

2. Since the lead time is now 4 days, the number of withdrawal kanbans for parts X and Y are 80 and 80, respectively. The impact of this decision is that 60 containers for part X and 70 containers for part Y remain in the pipeline. There is no change in the number of production kanbans.

Determination of Number of Kanbans

Probabilistic Model

- In a JIT system, usually planning horizon is 1 month (MPS is frozen for one month) and the number of kanbans at a workcentre is determined based on average demand for the period.
- Lead time is one of the factors determining the number of kanbans. However, lead time may be a variable and hence, there may be variations in the demand during lead time.

Determination of Number of Kanbans

- For determination of number of kanbans in this context, we assume that

    i. Probability mass function (pmf) of the number of kanbans is known ($p(x)$).

    ii. Holding cost per container per unit time is known (C_h).

    iii. Shortage cost per container short per unit time is known (C_s).

Determination of Number of Kanbans

- **At any point in time, let there be n number of kanbans in the system.**
- If the actual requirement for the kanbans is x, there may be two possibilities:

Case-1: when $x<n$.

Expected holding cost = $C_h \sum_{x=0}^{n}(n-x)p(x)$

Case-2: when $x>n$.

Expected holding cost = $C_s \sum_{x=n+1}^{\infty}(x-n)p(x)$

Determination of Number of Kanbans

- Total expected cost, $\mathrm{TC(n)}$ is given by

$$TC(n) = C_h \sum_{x=0}^{n} (n - x)p(x) + C_s \sum_{x=n+1}^{\infty} (x - n)p(x)$$

- For determining optimal value of n, minimum $\mathrm{TC(n)}$ satisfies the following conditions:

  i. $\Delta \mathrm{TC(n)} = \mathrm{TC(n+1)} - \mathrm{TC(n)} > 0$

  ii. $\Delta \mathrm{TC(n-1)} = \mathrm{TC(n)} - \mathrm{TC(n-1)} < 0$

Determination of Number of Kanbans

- Taking first forward difference and simplifying, we get

$$P(n) > \frac{C_s}{C_h + C_s},\; p(n) = \sum_{x=0}^{n} p(x) = \text{cdf of } x$$

- Taking first backward difference and simplifying, we get

$$P(n-1) < \frac{C_s}{C_h + C_s}$$

- Optimal number of kanbanscan be determined from the following expression:

$$\boxed{P(n-1) < \frac{C_s}{C_h + C_s} < P(n)}$$

JIT-based Approaches for Materials Management

- ✓ **Numerical Examples**
- ✓ **How to Achieve the JIT Goal of Batch Size of One**

Numerical Example-3

Suppose the probability mass function of the number of kanbans is known and is given in the following Table. Furthermore, suppose the holding and the shortage costs per container per unit time are Rs 50 and Rs 200, respectively. Determine the optimum number of kanbans to minimize the total expected cost.

Probability	0.20	0.30	0.35	0.10	0.05
Number of kanbans	1	2	3	4	5

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Solution

Using the probabilistic model, the value of $\frac{C_s}{C_h+C_s}$ is $\frac{200}{(200+5\ \ )}$ = 0.80. From the Table, the value of n that gives $P(n)$ greater than or equal to 0.80 and $P(n-1)$ less than 0.80 is 3. Therefore, from the equation $P(n-1) < \frac{C_s}{C_h+C_s} < P(n)$, the optimal number of kanbans is equal to 3.

How to Achieve the JIT Goal of Batch Size of One

- In a JIT-based manufacturing system, while the batch size of an inventory item is determined, we need to consider Economic Production Quantity (EPQ) model.

- As has already been stated, EPQ depends on production rate, P and demand or consumption rate, D for the given item (inside supply case).

- Other factors determining EPQ are: setup cost and holding cost.

- In JIT system, it is essential that batch size or EPQ is reduced to one. This condition can be achieved only when setup cost become negligible, ideally zero.

How to Achieve the JIT Goal of Batch Size of One

- Let as elaborate the concept.
- Against production order quantity of Q at a workcentre (say, a machine tool), the total variable cost, TC(Q) is given by

$$\mathrm{TC(Q)} = \frac{\mathrm{AD}}{\mathrm{Q}} + \frac{\mathrm{iCQ}}{2}\,(1 - D/P)$$

where, A = setup cost/setup

C = unit cost

i= inventory carrying cost

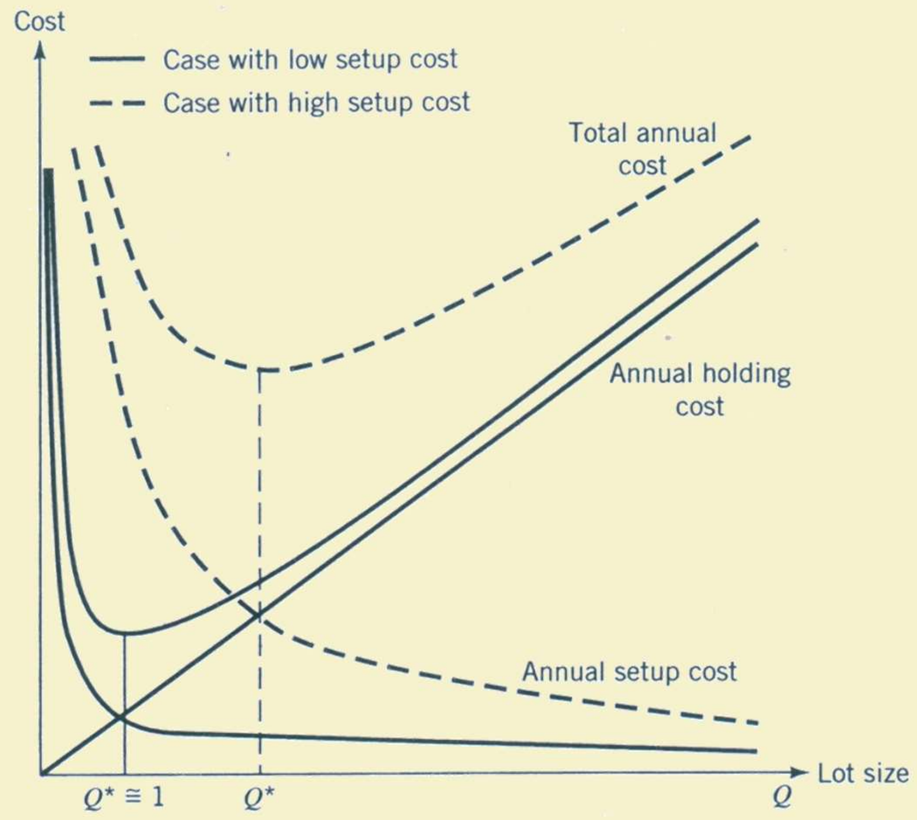
Q = EPQ

- The optimal EPQ, $\mathrm{Q}^* = \sqrt{\dfrac{2AD}{iC\left(1-\frac{D}{P}\right)}}$

How to Achieve the JIT Goal of Batch Size One

- The relationship between EPQ and setup and holding cost is given in Figure.
- With reduced setup cost, the total cost function is pulled toward the origin. You need to determine the value of setup cost, A when Q* = 1.

How to Achieve the JIT Goal of Batch Size One



Numerical Example-4

Consider a product with the following data:

Unit cost, C = Rs 100.00
Annual inventory carrying cost rate, i = 10%
Demand rate, D = 10,000 units per year
Production rate, P = 15,000 units per year

Determine the optimal lot sizes for various values of setup costs varying from Rs 400 to the lowest possible value.

Solution

The optimal Q* from equation, $Q^* = \sqrt{\frac{2AD}{iC\left(1-{}^{D}/_{P}\right)}}$.

By varying the setup cost from Rs 400.00 per setup to a very low value of setup cost say, Rs 0.00016, the results are presented below:

Case-I: Setup cost, A = Rs. 400.00

The optimal value of the economic production quantity, Q* = 1549.

Case-II: Setup cost, A = Rs. 100.00

The optimal value of the economic production quantity, Q* = 775.

Solution

Case-III: Setup cost, A = Rs. 1.00

The optimal value of the economic production quantity, Q* = 78.

Case-IV: Setup cost, A = Rs. 0.00016

The optimal value of the economic production quantity, Q* = 1.

How to achieve the JIT goal of batch size of one

- To achieve the goal of unit production quantity (EPQ = 1), the setup cost should tend to zero.

- Setup cost is directly related to setup time, and possible setup time reduction technologies are to be used and adopted.

- A few such technologies are as follows:
  i. Quick tool and die changers.
  ii. Reduction of ‘internal’ setup.
  iii. SMED (Single Minute Exchange of Dies), a Japanese technique with its application in several cases.

How to achieve the JIT goal of batch size of one

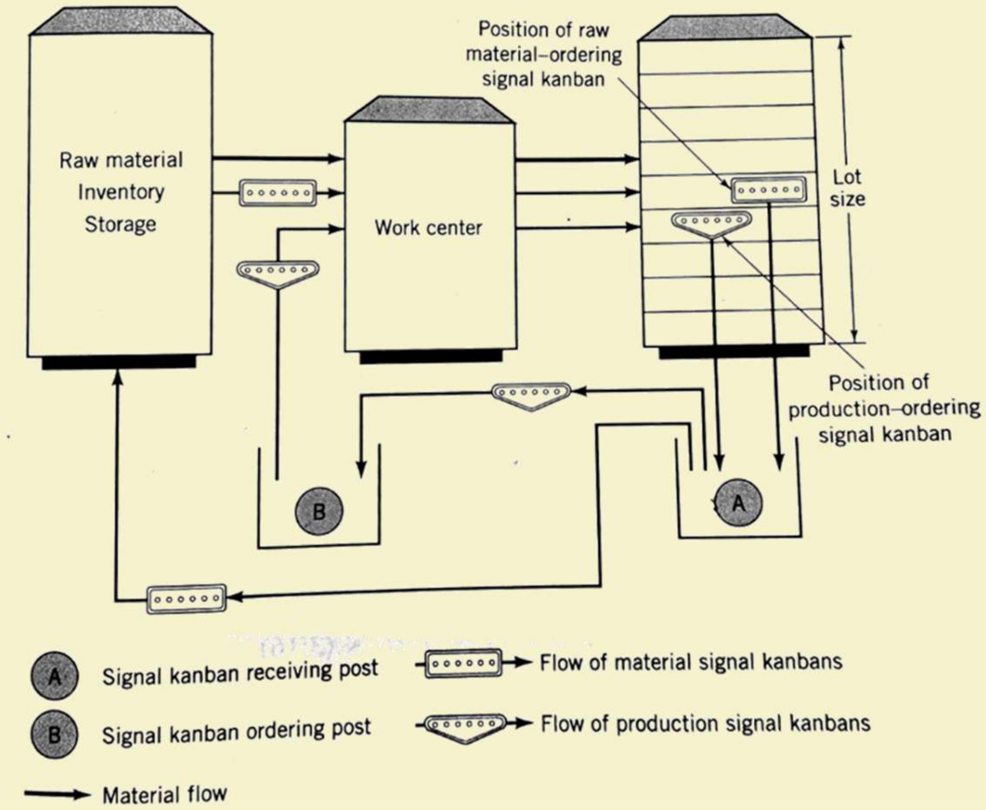
- The two-card based Kanban system is applicable in a manufacturing process where setup time is considered negligible.
- However, there are processes, like forging, die casting, and press operation, where setup time is substantial.
- In order to use the kanban system in such processes, a modified version of Kanban system is recommended. This modified version is known as **Signal Kanban System.**

JIT-based Approaches for Materials Management

- ✓ Signal Kanban
- ✓ Other Types of Kanbans
- ✓ Different Types of Pull Systems
- ✓ Benefits of JIT-based Production and Inventory Control System
- ✓ Barriers to JIT Implementation

SIGNAL KANBAN

A typical signal Kanban system is shown in Figure



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SIGNAL KANBAN

- **There are three importance parameters of this system**:

i. Lot size: minimum lot size per setup
ii. Position of production-ordering kanban
iii. Position of material-ordering kanban

- When data pertaining to available production time, machine utilization, average setup time per part/product, kanban cycle time, average demand, safety factor and container capacity are made available, the values of the above-stated parameters can be computed.

Other Types of Kanbans

- In specific situations, kanbans of special types can be designed and used.
- The following specific type kanbans are used:

i. **Express Kanban**: When shortage of parts occur.

ii. **Emergency Kanban**: When there are defective units, machine failure, or fluctuation in production quantities.

iii. **Through Kanban**: When two or more workunits are located very close to each other.

Different Types of Pull Systems

- As JIT system is built on pull system, it is designed as per the pull systems used. There may be different types of pull system:

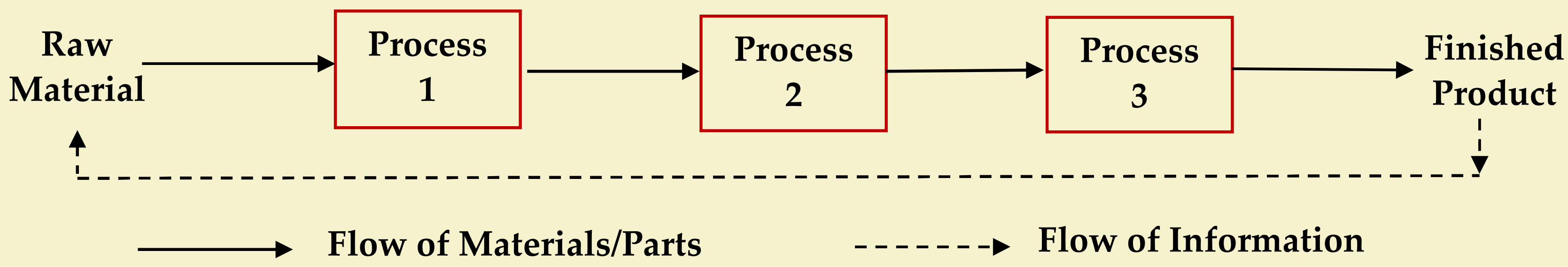
i. **Periodic pull system**: Based on on-line computerized information processing resulting in better system performance with reduced lead time and inventory, and faster response.

ii. **Constant WIP (CONWIP) system**: When production Kanbans are assigned to the production line, if there are a large number of parts and Kanban system is considered impractical.

iii. **Long Pull system**: It is basically a combined push-pull system.

Different Types of Pull Systems

- The flow of parts and information in such a system is shown in figure below:



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Benefits of JIT-based Production and Inventory Control System

- There are many benefits a company may have if JIT-based system is implemented. The main benefits are as follows:

i. Increased productivity
ii. Reduced lead time
iii. Reduced setup
iv. Less scrap and rework, and hence reduced requirements for raw materials and machine capacity
v. Less WIP
vi. Increased worker and equipment efficiency
vii. Improved quality

Barriers to JIT Implementation

- Implementation of JIT system may be difficult in many situations. A total systems approach is needed and hence, implementation depends on the level of integration and teamwork needed.

- A few problems in this context is worth mentioning:

i. Difficulty in knowing exact demand of an item at particular stage in a given time period.

ii. Equipment failures may become uncontrollable.

iii. Frequent changes in production plans.

- However, even if these problems come across, with concerted effort and following principles of JIT implementation, there have been several instances where JIT-based systems implemented in several functional areas, such as manufacturing, engineering, purchasing, marketing, quality control and assembly.

- The equivalent European system, called Lean Engineering, can also be implemented.

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Thank You!!