Chapter 12: Learning Outcomes

When you complete this chapter you should be able to:

• Define the term “JIT”
• Explain the main elements in JIT
• Discuss advantages and disadvantages of JIT
• Describe the Kanban system and explain how it works
• Distinguish between Push and Pull system
Overview

• The Just-in-Time Manufacturing Philosophy
• Prerequisites for JIT Manufacturing
• Elements of JIT Manufacturing
• Benefits of JIT Manufacturing
• Success and JIT Manufacturing
• JIT in Services
• Wrap-Up: What World-Class Companies Do

APICS Definition of JIT

“A philosophy of manufacturing based on planned elimination of waste and continuous improvement of productivity ….”

(American Production and Inventory Control Society)
JIT/Lean Production

- *Just-in-time*: Repetitive production system in which processing and movement of materials and goods occur just as they are needed, usually in small batches.
- JIT is characteristic of lean production systems.
- JIT operates with very little “fat”.

JIT Goals

- Eliminate disruptions.
- Make system flexible by reduce setup and lead times.
- Eliminate waste, especially excess inventory.
APICS Definition of JIT

“The primary elements of Just-in-Time are:
– to have only the required inventory when needed;
– to improve quality to zero defects;
– to reduce lead times by reducing setup times, queue lengths, and lot sizes;
– to incrementally revise the operations themselves;
– and to accomplish these things at minimum cost”.

JIT Synonyms

- IBM - Continuous Flow Manufacturing
- HP - Stockless Production
  - Repetitive Manufacturing System
- GE - Management by Sight
- Motorola - Short Cycle Manufacturing
- Japanese - The Toyota System
- Boeing - Lean Manufacturing
APICS Definition of Lean Manufacturing

“A philosophy of production that emphasizes the minimization of the amount of all the resources (including time) used in the various activities of the enterprise. It involves:
– … identifying and eliminating non-value-adding activities,
– … employing teams of multi-skilled workers,
– … using highly flexible, automated machines”

Time-Based Competition

• It is no longer good enough for firms to be high-quality and low-cost producers.
• To succeed today, they must also be first in getting products and services to the customer fast.
• To compete in this new environment, the order-to-delivery cycle must be drastically reduced.
• JIT is the weapon of choice today in reducing the elapsed time of this cycle.
Traditional View of Manufacturing

- A key objective was to fully utilize production capacity so that more products were produced with fewer workers and machines.
- This thinking led to large queues of in-process inventory waiting at work centers.
- Large queues meant workers and machines never had to wait for product to work on, so capacity utilization was high and production costs were low.
- This resulted in products spending most of their time in manufacturing just waiting, an arrangement that is unacceptable in today’s time-based competition.
JIT Manufacturing Philosophy

- The main objective of JIT manufacturing is to reduce manufacturing lead times.
- This is primarily achieved by drastic reductions in work-in-process (WIP).
- 100% capacity utilization is not the predominant objective.
- The result is a smooth, uninterrupted flow of small lots of products throughout production.

Capacity Utilization

![Graph showing comparison between Traditional Manufacturing and JIT Manufacturing]
### Capacity Utilization

**Increasing Production Capacity Reduces Manufacturing Lead Times**

- Only slight increases in production capacities can lead to:
  - Significant reduction of manufacturing lead times
  - Significant reduction of work-in-process inventory
- Queuing theory can be used to analyze waiting-line production problems

### Necessary Production Capacity

- We know from queuing theory (Chapter 9) that the average time in the system (manufacturing lead time) is:

  \[ \bar{t}_s = \frac{1}{(\mu - \lambda)} \]

- If we have an average lead time in mind, we can solve for the required production rate:

  \[ \mu = \frac{1}{\bar{t}_s} + \lambda \]
Work-in-Process Inventory

We also know from queuing theory that the average number of jobs in the system (work-in-process inventory) is:

\[ \bar{n}_s = \frac{\lambda}{(\mu - \lambda)} \]

Example: Necessary Production Capacity

A production manager believes reducing the firm’s manufacturing lead time will give the firm a significant competitive advantage. Two days is the lead time goal.

Currently, jobs are arriving at the rate of 6 per day and the operation can process an average of 6.125 jobs per day.

What is the current average lead time for a job? What is the necessary production rate to achieve the two-day lead time goal?
Example: Necessary Production Capacity

- Current Lead Time
  \[
  \bar{L} = \frac{1}{(\mu - \lambda)} = \frac{1}{(6.125 - 6.0)} = \frac{1}{0.125} = 8 \text{ days}
  \]

Necessary Production Rate
  \[
  \mu = \frac{1}{\lambda} = \frac{1}{2} + 6.0 = 6.5 \text{ jobs per day}
  \]

Conclusion
  A 6% increase in the production rate (from 6.125 to 6.5) results in a 75% reduction in manufacturing lead time (from 8 to 2).

Example: Reduction in WIP

In the preceding example, the production rate was increased from 6.125 jobs per day to 6.5. This 6% increase in the production rate yielded a 75% reduction in manufacturing lead time!

How much of a reduction in WIP will result from the 6% production rate increase?
Example: Reduction in WIP

- **WIP before** production rate increase

  \[ \text{old } \bar{\pi} = \frac{\lambda}{(\mu - \lambda)} = \frac{6}{(6.125 - 6)} = 48 \text{ jobs} \]

- **WIP after** production rate increase

  \[ \text{new } \bar{\pi} = \frac{\lambda}{(\mu - \lambda)} = \frac{6}{(6.500 - 6)} = 12 \text{ jobs} \]

- **Conclusion**
  
  A 6% increase in the production rate (from 6.125 to 6.5) results in a 75% reduction in work-in-process (from 48 to 12).

Successful JIT Applications

- Most successful JIT applications have been in repetitive manufacturing, operations where batches of standard products are produced at high speeds and in high volumes.
- 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 operations have been changed so that they behave somewhat like repetitive manufacturing.
Changes Required for JIT

- JIT requires certain changes to the factory and the way it is managed:
  - Stabilize production schedules
  - Increase work center capacities
  - Improve product quality
  - Cross-train workers
  - Reduce equipment breakdowns
  - Develop long-term supplier relations

Elements of JIT Manufacturing

- Eliminating waste
- Enforced problem solving and continuous improvement
- People make JIT work
- Total Quality Management (TQM)
- Parallel processing
- Kanban production control
- JIT purchasing
- Reducing inventories
- Working toward repetitive manufacturing
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Eliminating Waste in Manufacturing

- Make only what is needed now.
- Reduce waiting by coordinating flows and balancing loads.
- Reduce or eliminate material handling and shipping.
- Eliminate all unneeded production steps.
- Reduce setup times and increase production rates.
- Eliminate unnecessary human motions.
- Eliminate defects and inspection.

Problem Solving and Continuous Improvement

- JIT is a system of enforced problem solving.
- One approach is to lower inventory gradually to expose problems and force their solution.
- With no buffer inventories to rely on in times of production interruptions, problems are highly visible and cannot be ignored.
- The job of eliminating production problems is never finished.
- Continuous improvement - a practice the Japanese call kaizen - is central to the philosophy of JIT.
Uncovering Production Problems

Water level must be lowered

- Machine Breakdowns
- Workload Imbalances
- Out-of-Spec Materials
- Material Shortages
- Quality Problems
- Worker Absenteeism

People Make JIT Work

- JIT has a strong element of training and involvement of workers.
- A culture of mutual trust and teamwork must be developed.
- An attitude of loyalty to the team and self-discipline must be developed.
- Another crucial element of JIT is empowerment of workers, giving them the authority to solve production problems.
TQM and JIT

- Long-term relationships with suppliers
  - Certified suppliers eliminate incoming inspection
  - Share design process for new products
- Simplify design/processes
  - Poka-yoke
  - Process capable of meeting tolerances
  - Operators responsible for quality of own work

Parallel Processing

- Operations performed in series:
  - Cycle Time for Each Operation = 1 Hour
  - Total Product Cycle Time = 1 x 8 = 8 Hours
- Operations performed in parallel:
  - Cycle Time for Each Operation = 1 Hour
  - Total Product Cycle Time = 1 x 5 = 5 Hours
  - Operations 2 and 4 start the same time as Operation 1
In a push system of production planning and control, such as an MRP system, we look at the schedule to determine what to produce next.

In a pull system, such as JIT, we look only at the next stage of production and determine what is needed there, and then we produce only that.

As Robert Hall states, “You don’t never make nothin’ and send it no place. Somebody has got to come and get it”.

**Pull/Push Systems**

- **Pull system**: System for moving work where a workstation pulls output from the preceding station as needed. (e.g. Kanban)
- **Pull system**: material is *pulled* to a workstation just as it is needed
- **Push system**: material is *pushed* into downstream workstations regardless of whether resources are available
- **Push system**: System for moving work where output is pushed to the next station as it is completed
From a «push» to a «pull» System

Work is pushed to the next station as it is completed.

A workstation pulls output as needed.
A pull system uses signals to request production and delivery from upstream stations.
Upstream stations only produce when signaled.
System is used within the immediate production process and with suppliers.

By pulling material in small lots, inventory cushions are removed, exposing problems and emphasizing continual improvement.
Manufacturing cycle time is reduced.
Push systems dump orders on the downstream stations regardless of the need.
Kanban Production Control

- At the core of JIT manufacturing at Toyota is Kanban, an amazingly simple system of planning and controlling production.
- Kanban, in Japanese, means card or marquee.
- Kanban is the means of signaling to the upstream workstation that the downstream workstation is ready for the upstream workstation to produce another batch of parts.

Kanbans and Other Signals

- There are two types of Kanban cards:
  - a conveyance card (C-Kanban)
  - a production card (P-Kanban)
- Signals come in many forms other than cards, including:
  - an empty crate
  - an empty designated location on the floor
### Kanban Cards

#### Conveyance Kanban Card

- **Part number to produce:** M471-36
- **Part description:** Valve Housing
- **Lot size needed:** 40
- **Container type:** RED Crate
- **Card number:** 2 of 5
- **Retrieval storage location:** NW53D
- **From work center:** 22
- **To work center:** 35

#### Production Kanban Card

- **Part number to produce:** M471-36
- **Part description:** Valve Housing
- **Lot size needed:** 40
- **Container type:** RED crate
- **Card number:** 4 of 5
- **Completed storage location:** NW53D
- **From work center:** 22
- **To work center:** 35
- **Materials required:**
  - **Material no.:** 744B
    - **Storage location:** NW48C
  - **Part no.:** B238-5
    - **Storage location:** NW47B
How Kanban Operates?

When a worker at downstream Work Center #2 needs a container of parts, he does the following:
- He takes the C-Kanban from the container he just emptied.
- He finds a full container of the needed part in storage.
- He places the C-Kanban in the full container and removes the P-Kanban from the full container and places it on a post at Work Center #1.
- He takes the full container of parts with its C-Kanban back to Work Center #2.

Flow of Kanban Cards and Containers

Upstream Work Center #1

<table>
<thead>
<tr>
<th>P-Kanban and empty container</th>
<th>Full container and P-Kanban</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-Kanban and empty container</td>
<td>Full container and C-Kanban</td>
</tr>
</tbody>
</table>

In-process storage

Downstream Work Center #2

Parts Flow
Containers in a Kanban System

- Kanban is based on the simple idea of replacement of containers of parts, one at a time.
- Containers are reserved for specific parts, are purposely kept small, and always contain the same standard number of parts for each part number.
- At Toyota the containers must not hold more than about 10% of a day’s requirements.
- There is a minimum of two containers for each part number, one at the upstream “producing” work center and one at the downstream “using” work center.

Calculating the Number of Containers between Work Centers

\[ N = \frac{UT(1+P)}{C} \]

- \( N \) = Total number of containers between 2 stations
- \( U \) = Usage rate of downstream operation
- \( T \) = Average elapsed time for container to make entire cycle
- \( P \) = Policy variable indicating efficiency... 0 - 1
- \( C \) = Capacity (number of parts) of standard container
There are two adjacent work centers, one of which is fed parts from the other. The production rate of the using work center is 165 parts per hour. Each standard Kanban container holds 24 parts.

It takes an average of 0.6 hour for a container to make the entire cycle from the time it leaves the upstream center until it is returned, filled with production, and leaves again. The efficiency of the system is observed to be 0.2.

How many containers are needed?

\[
N = \frac{UT(1 + P)}{C}
\]

\[
N = \frac{165 \times 0.6 \times (1 + 0.2)}{24}
\]

\[
N = \frac{99 \times 1.2}{24}
\]

\[
N = \frac{118.8}{24}
\]

\[
N = 4.95 \text{ or } 5 \text{ containers}
\]
Essential Elements of JIT Purchasing

- Cooperative and long-term relationship between customer and supplier.
- Supplier selection based not only on price, but also delivery schedules, product quality, and mutual trust.
- Suppliers are usually located near the buyer's factory.
- Shipments are delivered directly to the customer's production line.
- Parts are delivered in small, standard-size containers with a minimum of paperwork and in exact quantities.
- Delivered material is of near-perfect quality.

E-Commerce and JIT Purchasing

- Internet-based information systems allow firms to quickly place orders for materials with their suppliers.
- This is an efficient and effective purchasing process
  - Saves the time of paperwork
  - Avoids errors associated with paperwork
  - Reduces procurement lead time
  - Reduces labor costs
  - ... and Kanbans can be sent to suppliers
Reducing Inventories through Setup Time Reduction

- Central to JIT is the reduction of production lot sizes so that inventory levels are reduced.
- Smaller lot sizes result in more machine setups
- More machine setups, if they are lengthy, result in:
  - Increased production costs
  - Lost capacity (idle machines during setup)
- The answer is: REDUCE MACHINE SETUP TIMES

Setup Time Required for an EOQ

- The economic production lot size (EOQ) model (detailed in Chapter 14) is:

\[
EOQ = \sqrt{\frac{2DS}{C - \frac{p}{p-d}}} \]

where:
D = annual demand rate
d = daily demand rate
p = daily production rate
C = carrying cost per unit per year
S = cost per setup

... more
Setup Time Required for an EOQ

- The setup cost required for a given lot size can be derived from the EOQ model as:

\[ S = \frac{C(EOQ)^2}{2D} \left(\frac{p-d}{p}\right) \]

- The setup time can be derived from the setup cost, \( S \):

\[ \text{Setup Time} = \frac{S}{\text{Labor rate}} \]

Example: Setup Time Required

A firm wants to determine what the length of the setup time of an operation should be in order to make an production lot size (EOQ) of 50 economical. An analyst has made the following estimates:

- \( D = 16,800 \) units (annual demand)
- \( d = 84 \) units (daily demand rate @ 200 days/yr)
- \( p = 140 \) units (daily production rate)
- \( C = $20 \) (carrying cost per unit per year)
- Labor rate = $25.00/hour
Example: Setup Time Required

- Setup Cost Required for EOQ = 50

\[ S = \frac{C(EOQ)^2}{2D} \cdot \frac{p-d}{p} \]

\[ = \frac{42(50)^2}{2(16,800)} \left( \frac{140 - 84}{140} \right) = 1.25 \]

Setup Time = \( \frac{S}{\text{Labor rate}} = \frac{1.25}{15.00/\text{hr}} = 0.833 \text{ hours} \)

\(.0833 \text{ hours} = 5.0 \text{ minutes}\)
Working Toward Repetitive Manufacturing

• Reduce setup times and lot sizes to reduce inventories
• Change factory layout to allow streamlined flows
• Convert process-focused layout to cellular manufacturing (CM) centers
• Install flexible manufacturing systems (FMS)
  • .....more

Working Toward Repetitive Manufacturing

• Standardize parts designs
• Train workers for several jobs
• Implement preventive maintenance (PM) programs
• Install effective quality control programs
• Develop an effective subcontractor network
Benefits of JIT

- Inventory levels are drastically reduced:
  - frees up working capital for other projects
  - less space is needed
  - customer responsiveness increases
- Total product cycle time drops
- Product quality is improved
- Scrap and rework costs go down
- Forces managers to fix problems and eliminate waste .... or it won’t work!

Wrap-Up: World-Class Practice

- Focus on time-based competition to capture market share
- JIT method to reduce order-to-delivery cycle
- Prerequisites must be present to successfully implement JIT
  - behave like repetitive manufacturing
  - stable schedules
End of Chapter 12