LO1 Explain the four principles of lean operating systems.
LO2 Describe the basic lean tools and approaches.
LO3 Explain how lean principles are used in manufacturing and service organizations.
LO4 Describe the concepts and philosophy of just-in-time operating systems.
Where’s our pizza?” Rachel asked. “I don’t know,” said her dad, “but I think I have an idea. . . .” Peering back across the next table into the kitchen, Steve sees mass confusion. The kitchen is crammed with workers running in all directions. Some workers are rushing about madly while others stand by idly, unsure of what to do. Other workers are cleaning up discarded pieces of dough and excess toppings from the floor. Several assistant managers are directing every step of the pizza-making process. Next to each workstation are piles of unfinished pizzas waiting for the addition of sauce, toppings, or cheese. Between the oven and the packaging table are piles of pizzas that have been set aside because they were made incorrectly. In one corner of the kitchen are stacked boxes of dough, meats, and cheeses from suppliers, none of which has been checked or properly stored. “Be patient, Rachel,” Steve sighed, “we’ll get it eventually. . . .”

What do you think? Can you cite any personal experiences in your work or around your school where you have observed similar inefficiencies as in the pizza kitchen?
**Lean enterprise** refers to approaches that focus on the elimination of waste in all forms, and smooth, efficient flow of materials and information throughout the value chain to obtain faster customer response, higher quality, and lower costs.

Manufacturing and service operations that apply these principles are often called **lean operating systems**.

Lean concepts were initially developed and implemented by the Toyota Motor Corporation.
Four Basic Lean Principles

1. **Elimination of Waste:** Eliminate any activities that do not add value in an organization. Includes overproduction, waiting time, processing, inventory, and motion.

2. **Increased Speed and Response:** Better process designs allow efficient responses to customers’ needs and the competitive environment.

3. **Improved Quality:** Poor quality creates waste, so improving quality is essential to the lean environment.

4. **Reduced Cost:** Simplifying processes and improving efficiency translates to reduced costs.
**Exhibit 17.1 Common Examples of Waste in Organizations**

<table>
<thead>
<tr>
<th>Excess capacity</th>
<th>Produce too early</th>
<th>Too much space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inaccurate information</td>
<td>Long distance traveled</td>
<td>Unnecessary movement of materials, people, and information</td>
</tr>
<tr>
<td>Excess inventory</td>
<td>Retraining and relearning time and expense</td>
<td>Equipment breakdowns</td>
</tr>
<tr>
<td>Long changeover and setup times</td>
<td>Scrap</td>
<td>Knowledge bottlenecks</td>
</tr>
<tr>
<td>Spoilage</td>
<td>Rework and repair</td>
<td>Non-value-added process steps</td>
</tr>
<tr>
<td>Clutter</td>
<td>Long unproductive meetings</td>
<td>Misrouting jobs</td>
</tr>
<tr>
<td>Planned product obsolescence</td>
<td>Poor communication</td>
<td></td>
</tr>
<tr>
<td>Excessive material handling</td>
<td>Waiting time</td>
<td></td>
</tr>
<tr>
<td>Overproduction</td>
<td>Accidents</td>
<td></td>
</tr>
</tbody>
</table>
A Water-Level Analogy of Waste

- Rework
- Supplier Problems
- Defects, Mistakes, Errors
- Equipment Breakdowns
Lean Tools and Approaches

The 5S principles are as follows:

1. **Sort**: each item is in the proper place.
2. **Set in order**: arrange materials so that they are easy to find and use.
3. **Shine**: clean work area.
4. **Standardize**: formalize procedures and practices.
5. **Sustain**: keep the process going.
Lean Tools and Approaches

The 5Ss

- 5S Principles are used to create a clean and well-organized work environment.

- Messy and disorganized workplaces waste time, energy, and resources.
Lean Tools and Approaches

Visual Controls

- **Visual controls** are indicators for operating activities that are placed in plain sight of all employees so that everyone can quickly and easily understand the status and performance of the work system.

- **Examples:** electronic scoreboards in production processes, painted areas on the floor where certain boxes and pallets should be placed, employee pull cords to stop production, signal lights on machines, and even Kanban cards.
Lean Tools and Approaches

Single Minute Exchange of Dies (SMED)

• **SMED** refers to quick setup or changeover of tooling and fixtures in processes so that multiple products in smaller batches can be run on the same equipment.

• Reducing setup time frees up capacity that can be producing output, and therefore, generating revenue.

• Example: Yammar Diesel reduced a machine setup from 9.3 hours to 9 minutes!
Lean Tools and Approaches

Small Batch and Single-Piece Flow

• **Batching** is the process of producing large quantities of items as a group before being transferred to the next operation.

• Lean operating systems seek to reduce batch sizes using *single-piece flow*.
Lean Tools and Approaches

Small Batch and Single-Piece Flow

• *Single-piece flow* is the concept of ideally using batch sizes of one.

• It allows companies to better match production to customer demand, avoid large inventory buildups, and ensure uninterrupted movement of WIP through the production system.

• To utilize single-piece flow, a company must be able to change between products quickly and inexpensively by reducing setup times.
Lean Tools and Value Stream Mapping

• Value Stream Mapping was introduced in Chapter 7.

• The difference between value stream mapping (VSM) and traditional flowcharting analysis and service blueprinting is that VSM tries to highlight value-added and non-value-added work activities, that is, the economics of process flow.
Lean Tools and Quality Approaches

Six Sigma and Lean concepts and methods are often combined into **Lean Six Sigma**.

- Both are driven by customer requirements.
- Both try to eliminate waste, reduce costs, speed things up, and improve quality.
- Both focus on real dollar savings.
- Both rely on a systematic methodology.
Lean Tools and Approaches

Total Productive Maintenance (TPM)

• **TPM** is focused on ensuring that operating systems will perform their intended function reliably.

• TPM works to prevent equipment failures and downtime, maximizing equipment effectiveness and uptime.

• TPM tries to predict equipment failure rates and perform maintenance before a problem arises.

• The principles of TPM also include employee “ownership” of the equipment.
Lean Tools and Approaches

Manufactured Good Recovery

• In an effort to reduce costs, many companies are actively recovering and recycling parts.

• Options include repairing, refurbishing, remanufacturing, cannibalizing, and recycling.

• This can occur as various points of the supply chain, as shown in the following slide.
Exhibit 17.2

Integrated Manufactured Good Recovery Value Chain

- Raw Materials
- Parts Fabrication
- Module Assembly
- Manufactured Good Assembly
- Distribution
- Customers/Users

Service Parts

1. Direct Reuse
   1. Direct reuse/resale

Waste Management
   7. Incineration
   9. Landfill

Manufactured Good
   2. Repair
   3. Refurbishing
   4. Remanufacturing
   5. Cannibalization
   6. Recycling

6. Recycling
5. Cannibalization
4. Remanufacturing
3. Refurbishing
2. Repair
1. Direct Reuse/resale

7 and 8
Lean Manufacturing Tours

- **Timken Company** is a leading manufacturer of highly engineered bearings and alloy steels and related products.
- Lean tools that Timken utilized are as follows:
  - Eliminate waste: eliminate non-value-added steps from processes.
  - Increase speed and response: radically reduce cycle time for new product development with integrated supply chain.
  - Improve quality: utilizing Six Sigma process variation tools and ISO 9000 quality standards.
  - Reduce cost: using technology to reduce costs.
Timken’s DMAIC Toolkit for Lean Six Sigma

**Define**
- Lean Tools: Value Stream Mapping, Performance metrics
- Six Sigma: Process Map, Data Collection, Sampling, Capability studies

**Measure**
- Value Stream Mapping
- Statistical Analysis
- 7 Tools

**Analyze**
- Eliminate Waste
- Advanced Statistical Analysis

**Improve**
- 5S, Standard Work
- Setup Time Reduction, One-piece Flow, Reduce Variation
- Design of Experiments
- Failure Analysis

**Control**
- Statistical Process Control, Visual Aids
- SPC, Control Plans
Lean Service Tours

Southwest Airlines is clearly a lean airline:

• Eliminate waste: Southwest minimizes idle time by fast airplane turnaround.

• Increase speed and response: standardized the type of aircraft used (Boeing 737).

• Improve quality: simplified processes to reduce variability in flight schedules.

• Reduce cost: Short setup and turnaround times translate to higher asset utilization and lower costs.
Push Production/Distribution Systems

- A **push system** produces finished goods inventory in advance of customer demand using a forecast of sales.

- Parts and subassemblies are “pushed” through the operating system based on a predefined schedule that is independent of actual customer demand.

- A traditional automobile factory and distribution system is a good example of a push system.
Just-in-Time Systems (JIT)

• *In a pull system*, employees at a given operation (work station) go to the source of the required parts, such as machining or subassembly, and withdraw the units as they need them (see also Chapter 9).

• By pulling parts from each preceding workstation, the entire manufacturing process is synchronized to the final-assembly schedule.

• Finished goods are made to coincide with the actual rate of customer demand, resulting in minimal inventories and maximum responsiveness.
Just-in-Time Systems (JIT)

• JIT systems are sometimes called a Kanban system.

• A Kanban is a flag or a piece of paper that contains all relevant information for an order.

• Slips, called Kanban cards, are circulated within the system to initiate withdrawal and production items through the production process.

• The Kanban cards are simple visual controls.
Just-in-Time Systems (JIT)

• The withdraw Kanban authorizes the material handler to transfer empty containers to the storage area. Next, a production Kanban triggers production of parts. Finally, the full container is delivered to the material handler.

• See Exhibit 17.3 for how a two-card Kanban System works.
Exhibit 17.3
A Two-Card Kanban JIT Operating System

[Diagram of a two-card Kanban JIT operating system showing steps 1 to 4 and associated processes and rates.]
Number of Kanban Cards Required:

\[ K = \frac{d(p + w)(1+ \alpha)}{C} \]  \[17.1\]

where

- \( K \) = the number of Kanban cards in the operating system.
- \( d \) = the average daily production rate as determined from the master production schedule.
- \( w \) = the waiting time of Kanban cards in decimal fractions of a day (that is, the waiting time of a part).
- \( p \) = the processing time per part, in decimal fractions of a day.
- \( C \) = the capacity of a standard container in the proper units of measure (parts, items, etc.).
- \( \alpha \) = a policy variable determined by the efficiency of the process and its workstations and the uncertainty of the workplace, and therefore, a form of safety stock usually ranging from 0 to 1. However, technically there is no upper limit on the value of \( \alpha \).
Kanban System

The number of Kanban cards is directly proportional to the amount of work-in-process inventory.

Managers and employees strive to reduce the number of cards in the system through reduced lead times ($p$ or $h$), lower $\alpha$ values, or other improvements.

WIP inventories are similar to the water level in a lake. High levels hide critical inefficiencies. By reducing inventories, inefficiencies are exposed and must be solved using a JIT system.
Solved Problem

Bracket Manufacturing uses a Kanban system for a component part. The daily demand is 800 brackets. Each container has a combined waiting and processing time of 0.34 days. The container size is 50 brackets and safety factor (α) is 9 percent.

a) How many Kanban card sets should be authorized?
b) What is the maximum inventory of brackets in the system of brackets?
c) What are the answers to (a) and (b) if waiting and processing time are reduced by 25%?
d) If we assume one-half the containers are empty and one-half full at any given time, what is the average inventory in the system for the original problem?
Solved Problem – Solution

Using Equation 17.1:

\[ K = \frac{d(p + w)(1 + \alpha)}{C} = \frac{(800 \text{ units})(0.34)(1 + 0.09)}{50} = 5.93 \approx 6 \]

Thus, 6 containers and 6 Kanban card sets are necessary to fulfill daily demand.

b) The maximum authorized inventory is \( K \times C = 6 \times 50 = 300 \) brackets.

c) \[ K = \frac{d(p + w)(1 + \alpha)}{C} = \frac{(800 \text{ units})(0.255)(1 + 0.09)}{50} = 4.45 \approx 5 \]

Thus, 5 containers and 5 Kanban card sets are necessary to fulfill daily demand. The maximum authorized inventory is now \( K \times C = 5 \times 50 = 250 \) brackets.
Solved Problem - Solution

d) The average inventory under this assumption is $300/2 = 150$ brackets.

Many variables in the JIT system determine whether this assumption is valid or not. For example, for a given combination of daily demand, processing and waiting times, and other process inefficiencies and uncertainties, it is possible for more or less containers to be empty (full).
JIT in Service Organizations

- JIT implementations can impact service organizations by increasing service levels at lower costs, thus improving profits.

- In implementing a JIT system, the entire value chain synchronizes its activities and speeds up.

- For information-intensive organizations, the Internet is the enabler (see Chapter 5 on Technology).
Designing Effective JIT Systems

• In implementing a JIT system, the entire value chain must synchronize its activities.

• JIT is an integrative operating system that demands the best ideas, methods, and management practices.
### Exhibit 17.4

**Example JIT Characteristics and Best Practices**

<table>
<thead>
<tr>
<th>JIT Characteristics</th>
<th>Best Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup/changeover time minimized</td>
<td>Small repetitive order/lot sizes</td>
</tr>
<tr>
<td>Excellent preventive maintenance</td>
<td>Minimize the number of parts/items</td>
</tr>
<tr>
<td>Mistake-proof job and process design</td>
<td>Minimize the number of bill-of-material levels</td>
</tr>
<tr>
<td>Stable, level, repetitive master production schedule</td>
<td>Facility layout that supports continuous or</td>
</tr>
<tr>
<td>Phantom bill of materials with zero lead time</td>
<td>single-piece flow</td>
</tr>
<tr>
<td>Fast processing times</td>
<td>Minimize distance traveled and handling</td>
</tr>
<tr>
<td>Clean and uncluttered workspaces</td>
<td>Clearly defined performance metrics</td>
</tr>
<tr>
<td>Very little inventory to hide problems and inefficiencies</td>
<td>Minimize the number of production, inventory,</td>
</tr>
<tr>
<td>Use production cells with no wasted motion</td>
<td>and accounting transactions</td>
</tr>
<tr>
<td>May freeze the master production schedule</td>
<td>Good calibration of all gauges and testing</td>
</tr>
<tr>
<td>Use reusable containers</td>
<td>equipment</td>
</tr>
<tr>
<td>Outstanding communication and information sharing</td>
<td>Employees trained in quality management concepts and tools</td>
</tr>
<tr>
<td>Keep it simple and use visual controls</td>
<td>Excellent employee recognition and reward</td>
</tr>
<tr>
<td>High quality approaching zero defects</td>
<td>systems</td>
</tr>
<tr>
<td></td>
<td>Employee cross-training and multiple skills</td>
</tr>
<tr>
<td></td>
<td>Empowered and disciplined employees</td>
</tr>
</tbody>
</table>