Process selection refers to the way an organization chooses to produce its goods or services.

Process is a series of actions or operations that transforms inputs into outputs.

Components of Process Selection:
- Capacity Planning
- Process Selection
- Facilities/Equipment
- Work Design
- Forecast
- Product and/or Service Design
- Technology
Lesson 07 – Process Selection & Capacity Planning

Factors In Process Selection Decisions

- Make vs Buy - utilize internal capacity, subcontract, purchase sub-components based on
  - cost
  - available capacity
  - expertise
  - quality considerations
  - nature of the demand (e.g. high or low, short or long range)
  - speed
  - reliability
- Capital Intensity - the mix of equipment and labor
- Process flexibility

Types of Processes

Continuous - a system that produces highly uniform products (e.g. chemicals, paper, photographic film, steel)

Repetitive - a semi-continuous system which produces output that may be similar but not identical (e.g. electronics, automobiles, computers)

Intermittent - usually lower volume output with greater variety in both product and processing
  - batch processing - produces moderate volumes of similar items (e.g. ice cream manufacturing - strawberry then vanilla)
  - job shop - produces a unit or small volumes of units to meet customer specifications (e.g. machine shop)

Projects - non-routine jobs

Product Process Matrix

<table>
<thead>
<tr>
<th>Product Process Matrix</th>
<th>Product Variety &amp; Equipment Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Low Volume</td>
<td></td>
</tr>
<tr>
<td>Moderate Volume</td>
<td></td>
</tr>
<tr>
<td>High Volume</td>
<td></td>
</tr>
<tr>
<td>Very High Volume</td>
<td></td>
</tr>
</tbody>
</table>

Commercial Printer
Heavy Equipment
Assembly
Batch
Continuous Flow
Repetitive Assembly
Job Shop
Automation

Automation refers to machinery that has the ability to sense and control devices that enable it to operate automatically (e.g. CAM, numerically controlled (N/C) machines, robots, Computer Integrated Manufacturing (CIM)).

Capacity Planning

Capacity is the upper limit or ceiling on the load that an operating unit can handle. There are many questions that must be answered and the detail required to answer each will depend on whether the demand is short, intermediate or long range.

- What kind of capacity is needed? - depends on the products/services that management intends to produce or provide
- How much is needed?
- When is it needed? – depends on the stage of completion of a product/service

<table>
<thead>
<tr>
<th>6 Month Forecast</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast Demand</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Production Plan</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Inventory</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Capacity Decisions

Capacity decisions
- have a real impact on the ability of an organization to meet future demands for products/services
- affect operating costs - too much can sometimes be as bad as too little
- are usually a major determinant of initial cost
- involve long term commitment of both financial and human resources - once implemented, it may be very costly to modify capacity decisions without major costs
- can affect competitiveness - the ability to quickly add or utilize unproductive capacity may serve as a competitive advantage
Lesson 07 – Process Selection & Capacity Planning

Capacity Concepts

- **Design Capacity**: refers to the maximum output that can possibly be attained.
- **Effective Capacity**: refers to the maximum output given product mix, scheduling difficulties, quality factors, and other doses of reality.
- **Actual Output**: refers to the rate of output actually achieved (can not exceed the Effective Capacity).

Measures of Capacity Effectiveness

- **Utilization** = \( \frac{\text{Actual Output}}{\text{Design Capacity}} \)
- **Efficiency** = \( \frac{\text{Actual Output}}{\text{Effective Capacity}} \)

Improving Utilization

Utilization can be improved by improving effective capacity. Some of the factors which influence effective capacity are:

- **facilities**: design, location, layout, environment
- **products/services**: design, product/service mix
- **processes**: quantity and quality capabilities
- **human considerations**: job content, job design, training and experience, motivation, learning rates, absenteeism, turnover
- **operations**: scheduling, materials management, quality assurance, maintenance policies, equipment breakdowns
- **external forces**: product standards, safety regulations, unions, pollution control standards
Forecasts -- are necessary to determine demand. They can identify trends and seasonality. Statistical analysis of historical forecast accuracy can be very useful in identifying demand variability and establishing upper and lower bounds for capacity requirements.

Mathematical/Computer models and simulations (based on probability distributions describing variability in demand) can be developed to analyze capacity requirements. For example:

- How many elevators are needed in a new building?
- How many tellers are needed at a bank?
- How can you evaluate a railroad's throughput?

Developing Capacity Alternatives

When developing capacity alternatives you should:

1. Design "flexibility" into systems - provision for future expansion in original designs can be cost effective at the time the increases are necessary (e.g. a plan for 9 hole golf course may include systems big enough to handle a future 18 hole course)
2. "Big picture" approach - consideration for other issues affected by capacity increases/decreases (e.g. extra parking space, extra staff, impact on suppliers, etc.)
3. Attempt to "smooth" capacity requirements - look for complimentary demand patterns (e.g. one up while another down) and consider "trade-off" alternatives (e.g. overtime, "make ahead", etc.)

... prepare for capacity "chunks" - capacity is often increased in large increments even though demand changes steadily (e.g. a machine produces 40/hr; when demand is 35 you have 5 excess; when demand goes to 45 capacity goes to 80/hr and you have 35 excess which could create excess costs)

. Identify the "optimal" operating level - may vary by size of plant

Optimal Rate of Output for Minimum Cost

- Graph showing the optimal rate of output for minimum cost.

- Chart showing the relationship between rate of output and average cost per unit.
Example 2: A department works one 8-hour shift, 250 days per year. The following products are all made on the same machine. How many machines will be needed to meet the demand?

\[
\text{Number of machines} = \frac{5800}{2000} = 2.9 \text{ or 3 machines.}
\]

<table>
<thead>
<tr>
<th>Product</th>
<th>Annual Demand</th>
<th>Standard Processing Time/Unit (hr)</th>
<th>Annual Processing Time (hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>400</td>
<td>5.0</td>
<td>2000</td>
</tr>
<tr>
<td>B</td>
<td>300</td>
<td>8.0</td>
<td>2400</td>
</tr>
<tr>
<td>C</td>
<td>700</td>
<td>2.0</td>
<td>1400</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>5800</td>
</tr>
</tbody>
</table>

Total annual processing time needed = 5800

Number of hours in a manufacturing year = 8*250 = 2000

Number of machines = 5800/2000 = 2.9 or 3 machines.

Cost Volume Analysis

Accounting Standards have been established to ensure that businesses classify cost appropriately. Generally these costs are described by:

- **Fixed Costs** - those which do not vary with the volume of units produced (e.g. building rent, property taxes, management salaries)
- **Variable Costs** - those costs that are directly related to the volume of units produced (e.g. raw materials, direct/indirect labor, packaging materials)
- **Step Fixed Costs** - when production units increase beyond a certain point additional fixed expenses may occur (e.g. capacity chunks, another building, more equipment, etc.)

Cost Symbols & Relationships

\[
\begin{align*}
FC &= \text{Fixed Costs} \\
Q &= \text{Quantity Produced} \\
VC &= \text{Variable Cost per unit} \\
TVC &= \text{Total Variable Cost} = VC \cdot Q \\
R &= \text{Revenue per unit} \\
TR &= \text{Total Revenue} = R \cdot Q \\
TC &= \text{Total Costs} = FC + VC \cdot Q \\
P &= \text{Profit} = TR - TC = R \cdot Q - (FC + VC \cdot Q) = Q (R - VC) - FC
\end{align*}
\]

Note: various other formulas can be generated by using these mathematical relationships.
Lesson 07 – Process Selection & Capacity Planning

Bakery - Fixed Costs

Example 3: A bakery makes pies with the following monthly costs. FC = Fixed Costs = $6,000, VC = Variable Cost per pie = $2, R = Revenue per pie = $7. Plot the problem on a graph.

First, plot the fixed costs on the graph.

Bakery – Total Variable Costs (TVC)

Example 3: A bakery makes pies with the following monthly costs. FC = Fixed Costs = $6,000, VC = Variable Cost per pie = $2, R = Revenue per pie = $7. Plot the problem on a graph.

Next, plot the total variable costs on the graph.

Bakery – Total Costs (TC)

Example 3: A bakery makes pies with the following monthly costs. FC = Fixed Costs = $6,000, VC = Variable Cost per pie = $2, R = Revenue per pie = $7. Plot the problem on a graph.

Next, plot the total costs on the graph.
Bakery – Total Revenue (TR)

Example 3: A bakery makes pies with the following monthly costs. FC = Fixed Costs = $6,000, VC = Variable Cost per pie = $2, R = Revenue per pie = $7. Plot the problem on a graph.

Next, plot the total revenue on the graph.

Bakery – Profit & Loss

Example 3: A bakery makes pies with the following monthly costs. FC = Fixed Costs = $6,000, VC = Variable Cost per pie = $2, R = Revenue per pie = $7. Plot the problem on a graph.

The Break Even Point (BEP) is the quantity where Total Revenue (TR) and Total Costs (TC) are the same. We can use the relationships to solve for the quantity where TR and TC are the same.

\[
TR = TC \\
R*Q = FC + VC*Q \\
Q_BEP = \frac{FC}{R - VC}
\]
Example 3: A bakery makes pies with the following monthly costs. FC = Fixed Costs = $6,000, VC = Variable Cost per pie = $2, R = Revenue per pie = $7.

Break Even Point (BEP) = FC/(R-VC) = 6000/(7-2) = 1,200 pies

Calculate the break even point.
How much profit or loss will the bakery have if it sells 1000 pies?

\[ P = Q(b-VC) - FC = 1000(7-2) - 6000 = -1000 \]

Breakeven Analysis

How many pies will the bakery have to sell to make a profit of $10,000.

\[ P = Q(b-VC) - FC = 10000 = Q(7-2) - 6000 \]

\[ Q = \frac{10000 + 6000}{5} = 3200 \text{ pies} \]

How many pies will the bakery have to sell to achieve a revenue of $60,000.

\[ \text{See if you can figure out the formula.} \]
Example 4: A manager has the option of purchasing 1, 2 or 3 machines. Fixed costs and potential volumes, variable costs and revenue per unit produced are shown below. \( VC = 10 \), \( R = 40 \). Draw a graph showing the total costs and revenue over each range.

<table>
<thead>
<tr>
<th>Number of Machines</th>
<th>Annual Total (FC)</th>
<th>Range of Output (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$9,600</td>
<td>0 to 300</td>
</tr>
<tr>
<td>2</td>
<td>$15,000</td>
<td>301 to 600</td>
</tr>
<tr>
<td>3</td>
<td>$20,000</td>
<td>601 to 900</td>
</tr>
</tbody>
</table>
You should verify that you understand this concept by manually graphing the example on a piece of graph paper.

Example: A manager has the option of purchasing 1, 2 or 3 machines. Fixed costs and potential volumes, variable costs and revenue per unit produced are shown below. $\text{VC} = $10, $\text{R} = $40.

Use the graph on the previous page to visually estimate the breakeven point over each range.

Mathematically determine the actual Break Even Point for each range.

<table>
<thead>
<tr>
<th>Number of Machines</th>
<th>Annual Total (FC)</th>
<th>Range of Output (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$9,600</td>
<td>0 to 300</td>
</tr>
<tr>
<td>2</td>
<td>$15,000</td>
<td>301 to 600</td>
</tr>
<tr>
<td>3</td>
<td>$20,000</td>
<td>601 to 900</td>
</tr>
</tbody>
</table>

$\text{BEP} = \frac{\text{FC}}{\text{R} - \text{VC}}$

Example: A manager has the option of purchasing 1, 2 or 3 machines. Fixed costs and potential volumes, variable costs and revenue per unit produced are shown below. $\text{VC} = $10, $\text{R} = $40. If the projected annual volume is between 580 and 660 units, how many machines should the manager buy?

Let's look at this problem visually.

<table>
<thead>
<tr>
<th>Number of Machines</th>
<th>Annual Total (FC)</th>
<th>Range of Output (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$9,600</td>
<td>0 to 300</td>
</tr>
<tr>
<td>2</td>
<td>$15,000</td>
<td>301 to 600</td>
</tr>
<tr>
<td>3</td>
<td>$20,000</td>
<td>601 to 900</td>
</tr>
</tbody>
</table>
Lesson 07 – Process Selection & Capacity Planning

**BEP w/ Step Fixed Costs - Example**

Conclusion: Since annual demand is between 580 and 660 the manager should purchase 2 machines. If 3 machines are purchased all demand will be met, but the company will lose money.

Does it appear the manager will make a profit when demand is 580 units?

Does it appear the manager will make a profit when demand is 660 units?

You should verify that you understand this concept by manually calculating the revenue, total cost, and profit at each volume level to verify your visual results.

Copyright – Harland E. Hodges, Ph.D
For the previous example, note how the data is entered. Breakeven Points are automatically calculated for each range.

For a demand analysis situation, enter the low and high demand quantities.

You should verify the calculations manually to ensure that you understand all the information this template provides with respect to revenue, costs, and profit.

What is the profit if low demand materializes?

What is the profit if high demand materializes?

Loss of $200

Profit of $2,400

For the same example, suppose you want to make a profit of at least $2,500 per week. How many machines should you buy?

To get a profit of $2,500 requires a volume shown here. Therefore, since the demand is between 580 and 660, the manager should buy 2 machines.
Evaluating Multiple Alternatives

Solved Problem 1: A firm’s manager must decide whether to make or buy a certain item used in the production of vending machines. Making the item would involve annual lease costs of $150,000. Cost estimates for the two alternatives are shown below. Answer the following questions.

<table>
<thead>
<tr>
<th>Options</th>
<th>Fixed Cost</th>
<th>VC/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make</td>
<td>$150,000</td>
<td></td>
</tr>
<tr>
<td>Buy</td>
<td>0</td>
<td>$80</td>
</tr>
</tbody>
</table>

Can you visually determine what the cost is for buying 12,000 units?
Can you visually determine what the cost is for making 12,000 units?
Lesson 07 – Process Selection & Capacity Planning

Over what range should the manager choose each option? (i.e. Which one has the least cost over what range?)

Buy: Volume < 7,500 Make: Volume > 7,500

Note: there are no equal signs in the answer. Why?

At what volume is the manager indifferent to whether he chooses make or buy?

7,500 units

What is the cost of each alternative at the point of indifference?

$600,000

The template can also be used to analyze profitability scenarios by entering a revenue per unit.

Notice when the revenue per unit and a volume are entered, profits are displayed rather than costs.
What is the profit for each alternative if the volume is 12,000 units and the revenue per unit is $100?

Make: $330,000  Buy: $240,000

What is the profit at the point of indifference?

$150,000

Cash flow analysis - refers to the difference between the cash received from sales and other sources (e.g. sale of old equipment) and the cash outflow for labor, materials, overhead, taxes, etc.

Present Value - expresses in current terms the sum of all future cash flows of an investment proposal.

The three most commonly used methods of financial analysis are

- payback
- present value
- internal rate of return

Homework

Read and understand all material in the chapter.

Discussion and Review Questions

Recreate and understand all classroom examples

Exercises on chapter web page