Lesson 07
Process Selection & Capacity Planning

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

Process

a series of actions or operations that transforms inputs into outputs

Components of Process Selection

Forecast
Product and/or Service Design
Technology

Process Selection
Capacity Planning
Facilities/Equipment
Work Design
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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>Job Shop</td>
</tr>
<tr>
<td>Moderate Volume</td>
<td>Batch</td>
</tr>
<tr>
<td>High Volume</td>
<td>Repetitive Assembly</td>
</tr>
<tr>
<td>Very High Volume</td>
<td></td>
</tr>
</tbody>
</table>
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 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></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales 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>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

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

Determining Capacity Requirements

Developing Capacity Alternatives

When developing capacity alternatives you should:

- 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)
- "big picture" approach - consideration for other issues affected by capacity increases/decreases (e.g. extra parking space, extra staff, impact on suppliers, etc.)
- 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.)

Developing Capacity Alternatives (cont'd)

- 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
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Evaluating Capacity - Example

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?

<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></td>
<td></td>
<td></td>
<td></td>
</tr>
<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

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

Note: various other formulas can be generated by using these mathematical relationships.
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.

- **Bakery - Fixed Costs**
  - Plot the fixed costs on the graph.

- **Bakery - Total Variable Costs (TVC)**
  - Plot the total variable costs on the graph.

- **Bakery - Total Costs (TC)**
  - Plot the total costs on the graph.
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Next, plot the total revenue on the graph.

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 = FC/(R-VC)

Q_{BEP} = \frac{FC}{R - VC}
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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.

Calculate the break-even point:

\[
BEP = \frac{FC}{R-VC} = \frac{6000}{7-2} = 1,200 \text{ pies}
\]
How much profit or loss will the bakery have if it sells 1000 pies?

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

Breakeven Analysis

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

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

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

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

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>
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<td>3</td>
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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. \( VC = \$10, \ R = \$40. \)

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 Machines</th>
<th>Annual Total (FC)</th>
<th>Range of Output (Q)</th>
<th>BEP w/ Step Fixed Costs - Example</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>$9,600</td>
<td>0 to 300</td>
<td>BEP 1 Machine = 9,600/(40-10) = ( \frac{9,600}{30} ) = 320 units (not in range)</td>
</tr>
<tr>
<td>2</td>
<td>$15,000</td>
<td>301 to 600</td>
<td>BEP 2 Machines = 15,000/(40-10) = ( \frac{15,000}{30} ) = 500 units</td>
</tr>
<tr>
<td>3</td>
<td>$20,000</td>
<td>601 to 900</td>
<td>BEP 3 Machines = 20,000/(40-10) = ( \frac{20,000}{30} ) = 667 units</td>
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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.

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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. \( VC = \$10, \ R = \$40. \) 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.
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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.

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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. Why should you not buy 3 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>$0</td>
</tr>
<tr>
<td>Buy</td>
<td></td>
<td>$60</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?
Buy: $960,000  Make: $870,000

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.
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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

Evaluating Capacity – Other Quant Methods

Homework
Read and understand all material in the chapter.

Discussion and Review Questions

Recreate and understand all classroom examples

Exercises on chapter web page