Capacity planning

- **Capacity** is the maximum output rate of a production or service facility.
- **Capacity planning** is the process of establishing the output rate that may be needed at a facility:
  - Capacity is usually purchased in “chunks”
  - Strategic issues: how much and when to spend capital for additional facility & equipment
  - Tactical issues: workforce & inventory levels, & day-to-day use of equipment
Measuring Capacity Examples

- There is no one best way to measure capacity
  - **Output measures** like kegs per day are easier to understand
  - **With multiple products**, **inputs measures** work better

<table>
<thead>
<tr>
<th>Type of Business</th>
<th>Input Measures of Capacity</th>
<th>Output Measures of Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car manufacturer</td>
<td>Labor hours</td>
<td>Cars per shift</td>
</tr>
<tr>
<td>Hospital</td>
<td>Available beds</td>
<td>Patients per month</td>
</tr>
<tr>
<td>Pizza parlor</td>
<td>Labor hours</td>
<td>Pizzas per day</td>
</tr>
<tr>
<td>Retail store</td>
<td>Floor space in square feet</td>
<td>Revenue per foot</td>
</tr>
</tbody>
</table>
Capacity Information Needed

- **Design capacity:**
  - Maximum output rate under ideal conditions
  - A bakery can make 30 custom cakes per day when pushed at holiday time

- **Effective capacity:**
  - Maximum output rate under normal (realistic) conditions
  - On the average this bakery can make 20 custom cakes per day
Calculating Capacity Utilization

Measures how much of the available capacity is actually being used:

\[
\text{Utilization} = \frac{\text{actual output rate}}{\text{capacity}} \times (100\%)
\]

- Measures effectiveness
- Use either effective or design capacity in denominator
Example of Computing Capacity Utilization: In the bakery example the design capacity is 30 custom cakes per day. Currently the bakery is producing 28 cakes per day. What is the bakery’s capacity utilization relative to both design and effective capacity?

\[
\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}} (100\%) = \frac{28}{20} (100\%) = 140\%
\]

\[
\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}} (100\%) = \frac{28}{30} (100\%) = 93\%
\]

- The current utilization is only slightly below its design capacity and considerably above its effective capacity
- The bakery can only operate at this level for a short period of time
How Much Capacity Is Best?

The **Best Operating Level** is the output than results in the lowest average unit cost

**Economies of Scale:**
- Where the cost per unit of output drops as volume of output increases
- Spread the fixed costs of buildings & equipment over multiple units, allow bulk purchasing & handling of material

**Diseconomies of Scale:**
- Where the cost per unit rises as volume increases
- Often caused by congestion (overwhelming the process with too much work-in-process) and scheduling complexity
Best Operating Level and Size

- **Alternative 1:** Purchase one large facility, requiring one large initial investment
- **Alternative 2:** Add capacity incrementally in smaller chunks as needed
Implementing Capacity Decisions

- Capacity flexibility
  - Plant, process, workers, outsourcing
- Amount of capacity cushion
  - Important in to-order and services
- Timing the capacity change
  - Leading [proactive]
  - Concurrent [neutral]
  - Lagging [reactive]
- Size of the capacity increment
Timing the Capacity Change

A. Proactive Strategy

B. Neutral Strategy

C. Reactive Strategy
Other Issues

- **Focused factories:**
  - Small, specialized facilities with limited objectives

- **Plant within a plant (PWP):**
  - Segmenting larger operations into smaller operating units with focused objectives

- **Subcontractor networks:**
  - Outsource non-core items to free up capacity for what you do well

- **Capacity cushions:**
  - Plan to underutilize capacity to provide flexibility
Making Capacity Planning Decisions

The three-step procedure for making capacity planning decisions is as follows:

- Step 1: Identify Capacity Requirements
- Step 2: Develop Capacity Alternatives
- Step 3: Evaluate Capacity Alternatives
Evaluating Capacity Alternatives

- Could do nothing, or expand large now, or expand small now with option to add later

- Use Decision Trees analysis tool:
  - A modeling tool for evaluating sequential decisions
  - Identify the alternatives at each point in time (decision points), estimate probable consequences of each decision (chance events) & the ultimate outcomes (e.g.: profit or loss)
  - (Refer to example 9.2 in textbook)
Facility Location

Three most important factors in real estate:

1. Location
2. Location
3. Location

Facility location is the process of identifying the best geographic location for a service or production facility.
Location Strategy

- Infrequent decision based on:
  - Demand outgrowing existing capacity.
  - Local changes in labor productivity, exchange rates, costs, local attitudes.
  - Shifts in demographics and customer demands.

- Location options:
  - Don’t move, expand an existing facility.
  - Maintain current sites, add another facility.
  - Close an existing facility and move to another location.
Factors That Affect Location Decisions

- General factors.
- Global Region or Country decision.
- Sub-region or state decision.
- Community/site decision.
General Factors

- Globalization.
- Market (customer) proximity
  - High population areas, close to JIT partners
- Suppliers proximity
  - Transportation costs, perishability, bulk
- Labor proximity and productivity
  - Proximity—local wage rates, unions, special skills availability
  - Productivity—low cost may be linked to low productivity and vice versa)
- Competitor proximity
  - *Clustering*—due to a major resource in the area).
Global Region or Country

- **Key International Locations**
  - North America, Europe, Pacific Rim.

- **Key Considerations**
  - Political/legal concerns.
  - Cultural issues (including business).
  - Infrastructure: supplies, communication, utilities.
  - International trade issues.
    - Exchange rates.
  - Market access issues.
  - Labor availability, attitudes, productivity, costs.
  - Quality-of-life issues.
Sub-region or State

Key factors:

- Government incentives.
- Corporate desires
- Market and demographic factors.
- Proximity to raw materials and customers
- Attractiveness of region (culture, taxes, climate, etc.)
- Environmental regulations of state and town.
- Economic conditions.
- Costs of key inputs and advertising media.
- Cost and availability of utilities.
- Labor availability, costs, attitudes towards unions.
Community/Site

Factors:

- Financial incentives.
- Site size and cost.
- Transportation options and costs.
- Utility options and costs.
- Nearness of services/supplies needed.
- Legal climate and community receptiveness.
  - Zoning restrictions
- Environmental concerns.

Significant trends:

- Moving to the suburbs
- Industrial parks
- Moving closer to end user (JIT)
Location Analysis Methods

Analysis should follow 3 step process:

- Step 1: Identify dominant location factors
- Step 2: Develop location alternatives
- Step 3: Evaluate locations alternatives

- Factor rating method
- Load-distance model
- Center of gravity approach
- Break-even analysis
- Transportation method
Factor-Rating Method

Six steps:

1. Develop a list of relevant factors.
2. Assign a weight to each factor reflecting its relative importance to the firm.
3. Develop a rating scale for the factors.
4. Score each location on each factor based on the scale.
5. Multiply the scores by the weights for each factor and total the weighted scores for each location.
6. Make a recommendation based on the maximum point score, considering other [quantitative?] factors.
## Factor Rating Example

<table>
<thead>
<tr>
<th>Factor</th>
<th>Factor Weight</th>
<th>Factor Score</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Location 1</td>
<td>Location 2</td>
</tr>
<tr>
<td>Cost of living</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Proximity to family</td>
<td>20</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Climate</td>
<td>30</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Transportation system</td>
<td>10</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Quality of life</td>
<td>30</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A Load-Distance Model Example: Matrix Manufacturing is considering where to locate its warehouse in order to service its four Ohio stores located in Cleveland, Cincinnati, Columbus, Dayton. Two sites are being considered; Mansfield and Springfield, Ohio. Use the load-distance model to make the decision.

Calculate the rectilinear distance:

$$d_{AB} = |30 - 10| + |40 - 15| = 45 \text{ miles}$$

- Multiply by the number of loads between each site and the four cities
Calculating the Load-Distance Score for Springfield vs. Mansfield

- The load-distance score for Mansfield is higher than for Springfield. The warehouse should be located in Springfield.
Center-of-Gravity Method

1. Place the locations to be supported on a coordinate system (like a graph).
2. Calculate the center of gravity:

\[ X_{cg} - \text{coordinate} = \frac{\sum l_i x_i}{\sum l_i} \quad Y_{cg} - \text{coordinate} = \frac{\sum l_i y_i}{\sum l_i} \]

Where:

\( x_i \) = x-coordinate of location i.
\( y_i \) = y-coordinate of location i.
\( l_i \) = quantity (load) of goods moved to/from location i.
The Center of Gravity Approach

This approach requires that the analyst find the center of gravity of the geographic area being considered.

Computing the Center of Gravity for Matrix Manufacturing

<table>
<thead>
<tr>
<th>Location</th>
<th>Coordinates (X,Y)</th>
<th>Load (l_i)</th>
<th>l_iX_i</th>
<th>l_iY_i</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleveland</td>
<td>(11,22)</td>
<td>15</td>
<td>165</td>
<td>330</td>
</tr>
<tr>
<td>Columbus</td>
<td>(10,7)</td>
<td>10</td>
<td>165</td>
<td>70</td>
</tr>
<tr>
<td>Cincinnati</td>
<td>(4,1)</td>
<td>12</td>
<td>165</td>
<td>12</td>
</tr>
<tr>
<td>Dayton</td>
<td>(3,6)</td>
<td>4</td>
<td>165</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>41</td>
<td>325</td>
<td>436</td>
</tr>
</tbody>
</table>

Computing the Center of Gravity for Matrix Manufacturing

\[ X_{c.g.} = \frac{\sum l_iX_i}{\sum l_i} = \frac{325}{41} = 7.9 \; \; ; \; Y_{c.g.} = \frac{\sum l_iY_i}{\sum l_i} = \frac{436}{41} = 10.6 \]

Is there another possible warehouse location closer to the C.G. that should be considered?? Why?
Break-Even Analysis

Break-even analysis can be used for location analysis especially when the costs of each location are known.

- **Step 1:** For each location, determine the fixed and variable costs.
- **Step 2:** Plot the total costs for each location on one graph.
- **Step 3:** Identify ranges of output for which each location has the lowest total cost.
- **Step 4:** Solve algebraically for the break-even points over the identified ranges.

Remember the break even equations used for calculation total cost of each location and for calculating the breakeven quantity $Q$.

- Total cost = $F + cQ$
- Total revenue = $pQ$
- Break-even is where Total Revenue = Total Cost
The Transportation Method

The transportation method of linear programming can be used to solve specific location problems.

- It is discussed in detail in the supplement to this text.
- It could be used to evaluate the cost impact of adding potential location sites to the network of existing facilities.
- It could also be used to evaluate adding multiple new sites or completely redesigning the network.
Service Location Strategies

Maximize the volume of business and revenue:

- Purchasing power of the customer-drawing area.
- Service and image compatibility with the customer-drawing area.
- Competition in the area.
- Quality of the competition.
- Uniqueness of the firm’s and competitor’s locations.
- Physical qualities of facilities and neighboring businesses.
- Operating policies of the firm.
- Quality of management.
Chapter 9 Highlights

- Capacity planning is deciding on the maximum output rate of a facility.
- Location analysis is deciding on the best location for a facility.
- Capacity planning and location decisions are often made at the same time because they are inter-related.
- The analysis steps for both capacity and location analysis are assessing needs, developing alternatives, and evaluating alternatives.
Chapter 9 Highlights (continued)

- To choose between capacity planning alternatives managers may use a modeling tool like decision trees.
- Key factors in location analysis include proximity to customers, transportation, source of labor, community attitude, and proximity to supplies.
- Location analysis tools include factor ratings, the load-distance model, the center of gravity approach, break-even analysis, and the transportation method.
Chapter 9 Homework Hints

- Problem 9.5: calculate utilizations based on design and effective capacities (see example 9.1). Present conclusions.
- Problem 9.14: use factor rating method to compare the possible locations (see example 9.3).
- Problem 9.15: use load-distance model to compare locations (see example 9.4).
- Problem 9.16: use center-of-gravity method. Use data from problem 15 (e.g. load between city and warehouse) to determine desired coordinates for the new warehouse.