Production & Operations Management
INFO 335-01

Capacity Planning & Facility Location

Chapter 9

Capacity Planning

- Capacity is the maximum output rate of a facility
- Capacity planning is the process of establishing the output rate that can be achieved 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, **input** measures work better

Type of Business	Input Measures of Capacity	Output Measures of Capacity
Car manufacturer	Labor hours	Cars per shift
Hospital	Available beds	Patients per month
Pizza parlor	Labor hours	Pizzas per day
Retail store	Floor space in square feet	Revenue per foot

Measuring Capacity

- Two types of information needed:

1. **Amount of available capacity**
   - Understand how much capacity the facility has
2. **Effectiveness of capacity use**
   - How effectively we are using the available capacity

Measuring Available Capacity

- **Design/Theoretical capacity:**
  - Maximum output rate under ideal conditions
  - A bakery can make 30 custom cakes per day when pushed at holiday time
- **Effective/Rated capacity:**
  - Maximum output rate under normal (realistic) conditions; usually lower than design capacity
  - On the average this bakery can make 20 custom cakes per day

Measuring Effectiveness of Capacity Use

- **Capacity Utilization**:

Measures how much of the available capacity (%) is actually being used.

$$\text{Utilization} = \frac{\text{actual output rate}}{\text{capacity}}(100\%)$$

- Measures effectiveness
- Use either **effective** (rated) or **design** (theretical) capacity in denominator

Example of Computing Capacity Utilization: A bakery's design capacity is 30 custom cakes per day, and its effective capacity is 20 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?

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%) = \boxed{28/20}(100\%) = 140\%$$

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

- 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

Capacity Considerations

- The **Best Operating Level** is the output that 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

Decision Trees

Diagramming technique

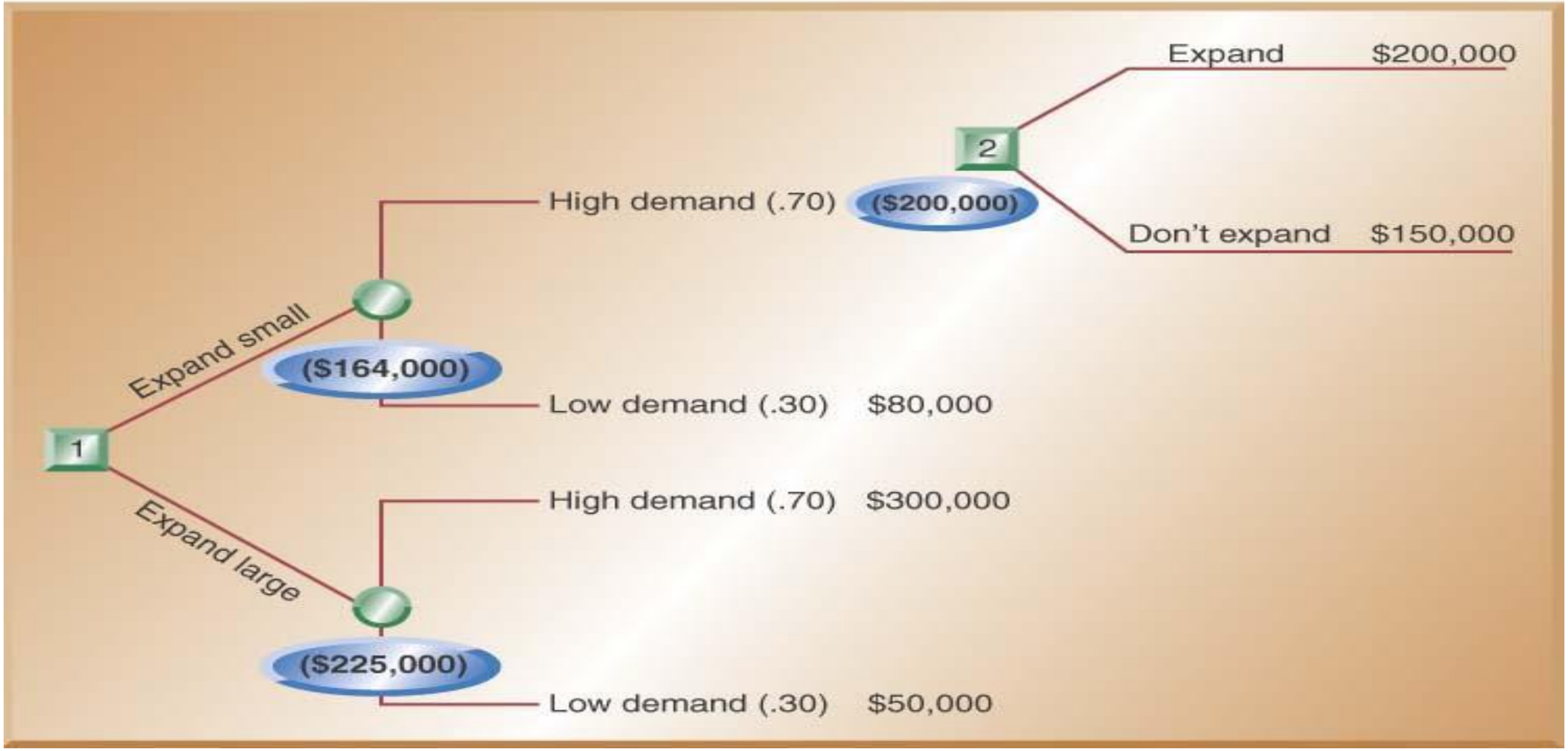
- Decision points – points in time when decisions are made, squares called nodes
- Decision alternatives – branches or arrows leaving a decision point (nodes)
- Chance events – events that could affect a decision, branches or arrows leaving circular chance nodes
- Outcomes – each possible alternative listed

Decision Tree Diagrams

Decision trees developed by

- Drawing from left to right
- Use squares to indicate decision points
- Use circles to indicate chance events
- Write the probability of each chance by the chance (sum of associated chances = 100%)
- Write each alternative outcome in the right margin

Example Using Decision Trees: A restaurant owner has determined that she needs to expand her facility. Alternatives are to expand large now and risk smaller demand, or expand on a smaller scale now, knowing that she might need to expand again in three years. Which alternative would be most attractive?



Evaluating the Decision Tree

- Utilizes Expected Value (EV) analysis
- EV is a weighted average of chance events
  - Probability of occurrence * chance event outcome
- Refer to previous slide
  - At decision point 2, choose to expand to maximize profits **($200,000 > $150,000)**
  - Calculate **EV** of small expansion:
    - $EV_{small} = 0.30(\$80{,}000) + 0.70(\$200{,}000) = \$164{,}000$

Evaluating the Decision Tree - cont'd

- Calculate **EV** of large expansion:
  - $\boldsymbol{EV_{\text{large}}}$ **= 0.30($50,000) + 0.70($300,000) = $225,000**
- At decision point 1, compare alternatives & **choose the large expansion** to maximize the expected profit:
  - **$225,000 > $164,000**
- **Choose large expansion** despite the fact that there is a 30% chance it's the worst decision:

Take the calculated risk!

Location Analysis

- Three most important factors in real estate: Location, Location, Location
- **Facility location** is the process of identifying the best geographic location for a service or production facility
- Long term commitment
- Sizable financial investment and impact

Factors Affecting Location Decisions

- **Proximity to source of supply:**
  - Reduce transportation costs of perishable or bulky raw materials
- **Proximity to customers:**
  - High population areas, close to JIT partners
- **Proximity to labor:**
  - Local wage rates, attitude toward unions, availability of special skills (Silicon Valley)

More Location Factors

- **Community considerations:**
  - Local community's attitude toward the facility (prisons, utility plants, etc.)
- **Site considerations:**
  - Local zoning & taxes, access to utilities, etc.
- **Quality-of-life issues:**
  - Climate, cultural attractions, commuting time, etc.
- **Other considerations:**
  - Options for future expansion, local competition, transportation access and congestion, etc.

Making Location Decisions

- **Analysis should follow 3 step process:**
  1. Identify dominant location factors
  2. Develop location alternatives
  3. Evaluate locations alternatives
- **Procedures/tools for evaluating location alternatives include**
  - **Factor rating method**
  - **Load-distance model**
  - **Center of gravity approach**
  - **Break-even analysis**
  - **Transportation method**

Factor Rating (with example)

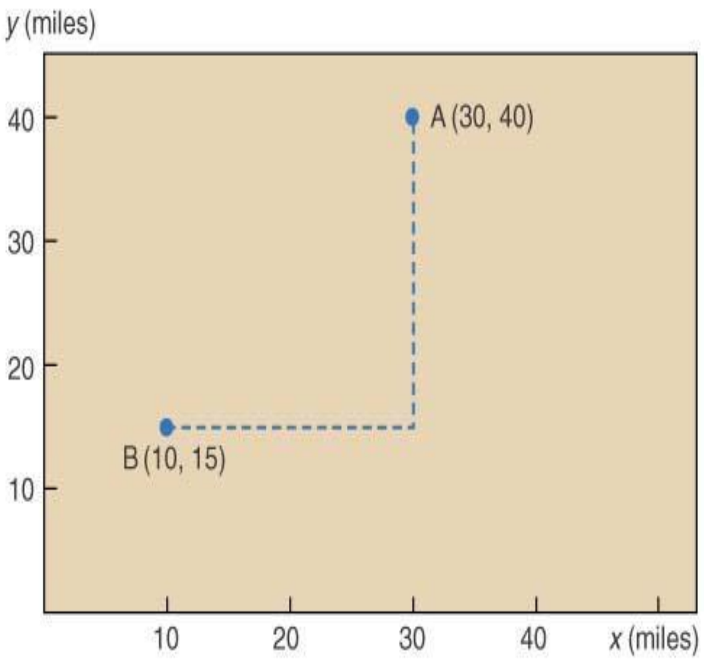
A procedure to evaluate multiple alternative locations based on a number of selected factors.

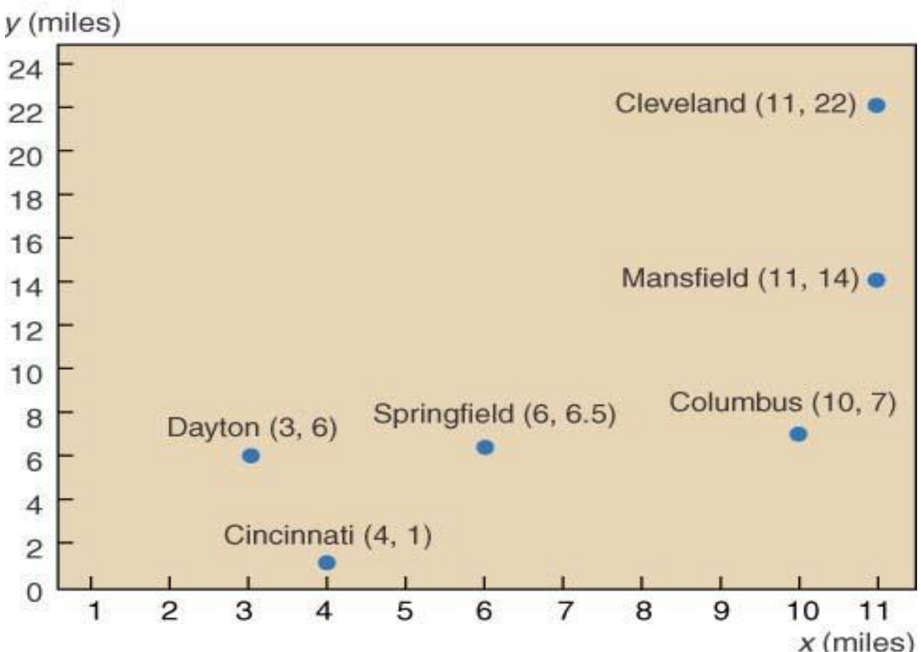
Factor	Factor Weight	Factor Score		Weighted Score	
		Location 1	Location 2	Location 1	Location 2
Cost of living	10	5	2	50	20
Proximity to family	20	4	2	80	40
Climate	30	2	5	60	150
Transportation system	10	5	3	50	30
Quality of life	30	3	5	90	150
TOTAL	100			330	390

A Load-Distance Model Example: Matrix Manufacturing is considering where to locate its warehouse 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.

A procedure for evaluating location alternatives based on distance.

- Calculate the rectilinear distance: $d_{AB} = |30 - 10| + |40 - 15| = 45 \text{ miles}$





- Multiply by the number of loads between each site and four cities

Calculating Load-Distance Score: Springfield vs. Mansfield

Computing the Load-Distance Score for Springfield				
City	Load	Distance	ld	
Cleveland	15	20.5	307.5	
Columbus	10	4.5	45	
Cincinnati	12	7.5	90	
Dayton	4	3.5	14	
Total		Load-Distance Score(456.5)		

Computing the Load-Distance Score for Mansfield				
City	Load	Distance	ld	
Cleveland	15	8	120	
Columbus	10	8	80	
Cincinnati	12	20	240	
Dayton	4	16	64	
Total		Load-Distance Score(504)		

The load-distance score for Mansfield is higher than for Springfield. The warehouse should be located in **Springfield**.

The Center of Gravity Approach

Requires the analyst to find the center of gravity of the geographic area being considered for an alternative site.

Computing the Center of Gravity				
	Coordinates	Load		
Location	(X,Y)	(l_i)	l_iX_i	l_iY_i
Cleveland	(11,22)	15	165	330
Columbus	(10,7)	10	100	70
Cincinnati	(4,1)	12	48	12
Dayton	(3,6)	4	12	24
Total		41	325	436

- Computing the Center of Gravity for Matrix Manufacturing

$$X_{c.g.} = \frac{\sum l_i X_i}{\sum l_i} = \frac{325}{41} = 7.9 \;;\; Y_{c.g.} = \frac{\sum l_i Y_i}{\sum l_i} = \frac{436}{41} = 10.6$$

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