# Lecture #33

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Service Processes & Systems
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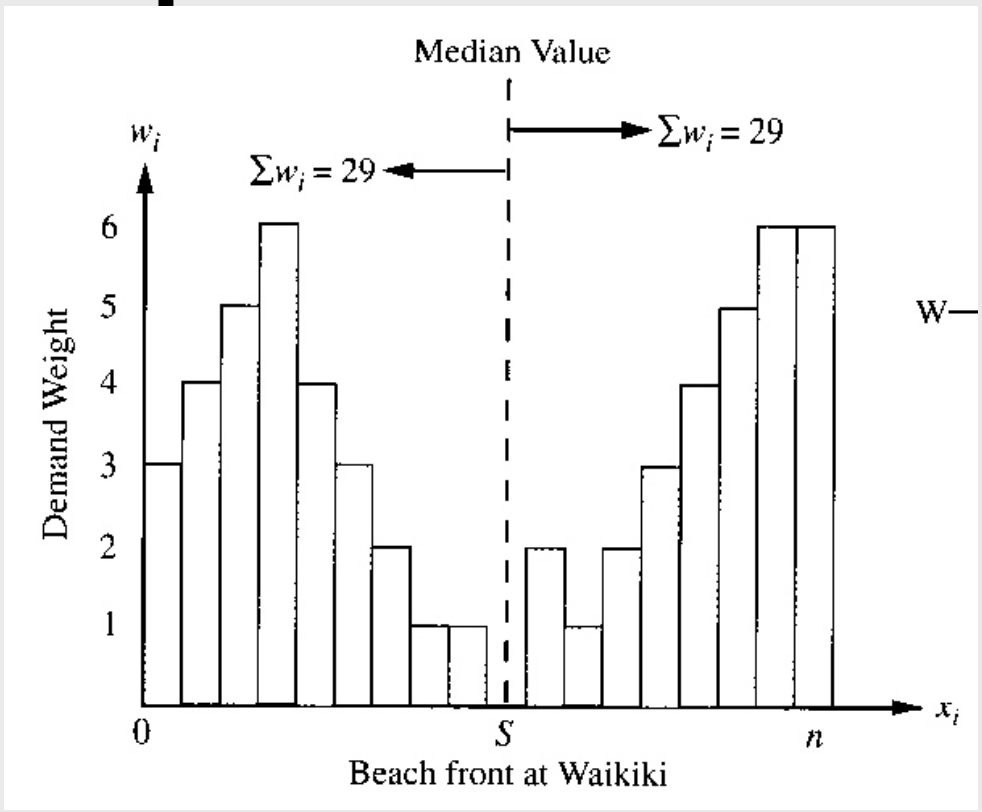
# Facility Location Techniques

- **Locating a single facility on a line**
  - Consider the problem of locating a beach mat concession along Waikiki beach front.
  - You wish to find a location that would minimize the average walk to your concession from anywhere on the beach.
  - Further, suppose you have data showing the density of bathers along the beachfront, which is related to the size and location of hotels.

# Example

$$Z = \sum_{i=0}^{n} \left| x_i - x_{loc} \right|$$




- **The objective is**
  - **Minimize** $Z = \sum_{i=0}^{s} w_i (x_s - x_i) + \sum_{i=s}^{n} w_i (x_i - x_s)$

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# Example

- **where:**
  - $w_i$ = relative weight of demand attached to the ith location on the beach
  - $x_i$ = location of the ith demand point on the beach in feet from the origin, in this case taken to be the west end of the beach
  - s = position in the series of data that corresponds to site of the beach mat concession.

# Example

- The objective function Z is differentiated with respect to $x_s$ and set equal to zero.
- This yields
  - $dZ/ds = \sum_{i=0}^{s} w_i - \sum_{i=s}^{n} w_i = 0$ or $\sum_{i=0}^{s} w_i = \sum_{i=s}^{n} w_i$
- Weight sums are equal if s corresponds to median



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# Example

- Result suggests that site should be located at the median with respect to the density distribution of bathers. Locate site so that 50% of the potential demand is to each side (i.e., 29 in figure).
- Result for locating a site along a line can be generalized for locating a site on a plane if we use the metropolitan metric. Total travel distance will be minimized if the coordinates of the site correspond to the intersection of the x and y medians for their respective density distributions.

# Copying Service Example

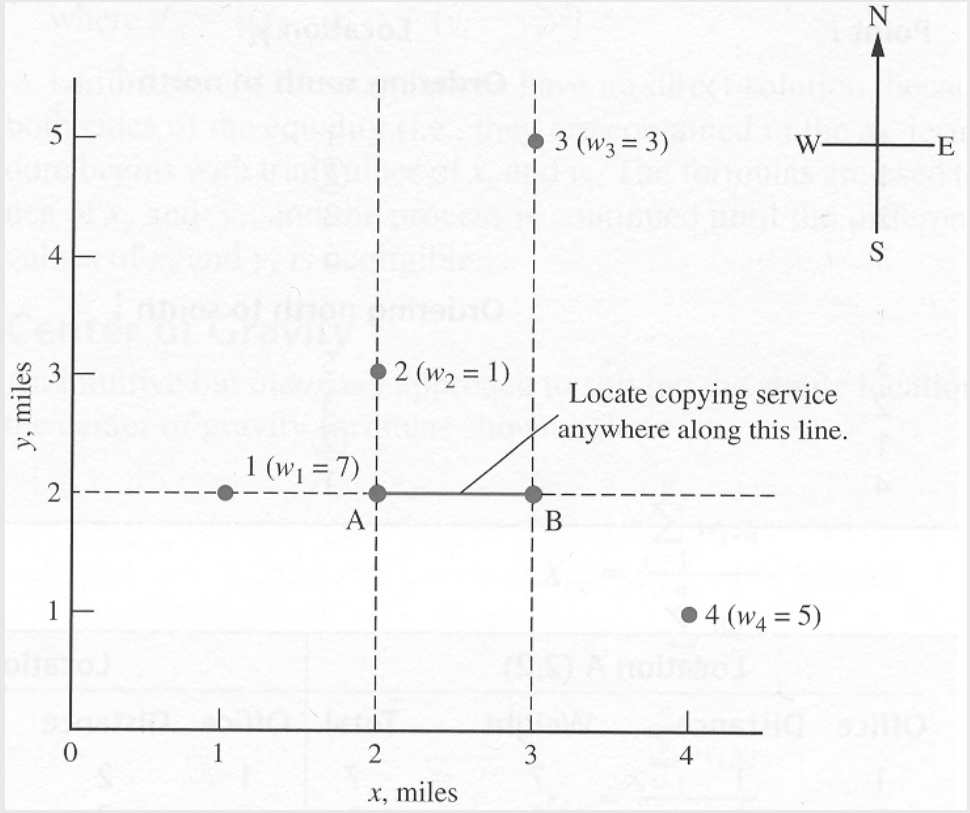
- Copying service has decided to open office in a city. Four office buildings that will generate a major portion of its business have been identified.
- Figure shows location of these demand points on an X-Y coordinate system.
- Weights are attached to each point and represent potential demand per month in hundreds of orders. The manager would like to determine a central location that will minimize the total distance per month that customers travel to the copying service.

# Copying Service Example

- Because of the urban location, a metropolitan metric is appropriate.
- Locate site using cross-median approach
- First, the median is calculated:

  - Median = $\sum_{i=1}^{n} w_i / 2$

# Copying Service Example




- Median = (7+1+3+5)/2=8
- To identify the x-coordinate median for $x_s$, we sum the values of $w_i$ in the x direction both west to east and east to west.

# Copying Service Example

| Point $i$ | Location $x_i$ | $\sum w_i$ |
|---|---|---|
| | Ordering west to east → | |
| 1 | 1 | 7 = 7 |
| 2 | ② | 7 + 1 = 8 |
| 3 | 3 | |
| 4 | 4 | |
| | Ordering east to west ← | |
| 4 | 4 | 5 = 5 |
| 3 | ③ | 5 + 3 = 8 |
| 2 | 2 | |
| 1 | 1 | |

- **The weights attached to each demand point are summed in descending order until the median value of 8 is reached or exceeded. That happens when the weight of location 2 is added to the weight of location 1: thus, the first x median is established at the value of 2 miles (circled).**

# Copying Service Example

- This procedure is repeated with demand points ordered from east to west as shown in table.
- The second x median is established at the value of 3 miles (circled).
- The next table shows the same procedure for identifying the y-coordinate median for ys.

| Point $i$ | Location $y_i$ | $\sum w_i$ |
|---|---|---|
| | Ordering south to north ↑ | |
| 4 | 1 | 5 = 5 |
| 1 | ② | 5 + 7 = 12 |
| 2 | 3 | |
| 3 | 5 | |
| | Ordering north to south ↓ | |
| 3 | 5 | 3 = 3 |
| 2 | 3 | 3 + 1 = 4 |
| 1 | ② | 3 + 1 + 7 = 11 |
| 4 | 1 | |

# Copying Service Example

- Note in the following table that the total weighted travel distance calculated for point A and point B is equal to 35 miles in both instances; thus, any location at either point or along the line between them will be acceptable.

| Location A (2,2) | | | | | | Location B (3,2) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Office | Distance | | Weight | | Total | Office | Distance | | Weight | | Total |
| 1 | 1 | × | 7 | = | 7 | 1 | 2 | × | 7 | = | 14 |
| 2 | 1 | × | 1 | = | 1 | 2 | 2 | × | 1 | = | 2 |
| 3 | 4 | × | 3 | = | 12 | 3 | 3 | × | 3 | = | 9 |
| 4 | 3 | × | 5 | = | 15 | 4 | 2 | × | 5 | = | 10 |
| | | | | | 35 | | | | | | 35 |

# Locating a Retail Outlet

- When locating a retail outlet such as a supermarket, the objective is to maximize profit.
- A gravity model is used to estimate consumer demand. Based on the physical analog – gravitational attraction of two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance that separates them.

# Locating a Retail Outlet

- For a service, the attractiveness of a facility may be expressed as

$$A_{ij} = \frac{S_j}{T_{ij}^{\lambda}}$$

  - where
    - $A_{ij}$ = attraction to facility j for customer i
    - $S_j$ = size of the facility j
    - $T_{ij}$ = travel time for customer i's location to facility j
    - λ = parameter estimated empirically to reflect the effect of travel time on various kinds of shopping trips (e.g., where a shopping mall may have a λ = 2, convenience stores would have a λ = 10 or larger).

# Huff Analysis

- This gravity model used to predict the benefit that a customer would have for a particular store size and location (D.L. Huff).
- Knowing that customers also would be attracted to other competing stores, he proposed the ratio $P_{ij}$. For n stores, this ratio measures the probability of a customer from a given area i traveling to a particular shopping facility j.

$$P_{ij} = \frac{A_{ij}}{\sum_{j=1}^{n} A_{ij}}$$

# Huff Analysis

- An estimate of $E_{jk}$, the total annual consumer expenditures for a product class k at a potential shopping facility j, then can be calculated as

$$E_{jk} = \sum_{j=1}^{m} \left( P_{ij} C_i B_{ik} \right)$$

  - $P_{ij}$ = Probability customers from area i travel to store j
  - $C_i$ = Number of customers in area i (e.g. census track)
  - $B_{ik}$ = Annual budget for product k for customers in area i
  - m = Number of customer areas in the market region

# Huff Analysis

- An estimate of $M_{jk}$, the market share captured by facility j of product class k sales, can be calculated as

$$M_{jk} = \frac{E_{jk}}{\sum_{i=1}^{m} (C_i B_{ik})}$$

- An exhaustive procedure is used to calculate the expected annual profit of each potential site for various possible store sizes at the site.



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# Copying Service Example

- Assume x=2, y=2
- Also assume that each customer order represents an expenditure of approximately $10. Because convenience would be an important customer criterion, assume that $\lambda = 2$.
- If we wish to open a new store at location (x=3,y=2) but with twice the capacity for the existing copying center, how much market share would we expect to capture?

# Copying Service Example

- Using the travel distances shown on the next table as input to the Huff model, the calculations on the following 3 tables are obtained

TABLE 9.5
Travel Distance in Miles ($T_{ij}$) (Using Metropolitan Metric)

| Site ($j$) | Customer Location ($i$) | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Proposed (3, 2) | 2 | 2 | 3 | 2 |
| Existing (2, 2) | 1 | 1 | 4 | 3 |

# Copying Service Example

TABLE 9.6
Attraction ($A_{ij}$)

| Site ($j$) | Customer Location ($i$) 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Proposed ($S_1 = 2$) | 0.5 | 0.5 | 0.2222 | 0.500 |
| Existing ($S_2 = 1$) | 1.0 | 1.0 | 0.0625 | 0.111 |
| Total attraction | 1.5 | 1.5 | 0.2847 | 0.611 |

TABLE 9.7
Probability ($P_{ij}$)

| Site ($j$) | Customer Location ($i$) 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Proposed | .33 | .33 | .78 | .82 |
| Existing | .67 | .67 | .22 | .18 |

TABLE 9.8
Monthly Expenditures ($E_{jk}$) and Market Share ($M_{jk}$)

| Site ($j$) | Customer Expenditures 1 | 2 | 3 | 4 | Monthly Total | Market Share % |
|---|---|---|---|---|---|---|
| Proposed | $2,333 | $ 333 | $2,340 | $4,100 | $ 9,106 | 0.57 |
| Existing | 4,667 | 667 | 660 | 900 | 6,894 | 0.43 |
| Totals | $7,000 | $1,000 | $3,000 | $5,000 | $16,000 | 1.00 |

# Site Selection Considerations

1. Access:
   - Convenient to freeway exit and parking
   - entrance ramps
   - Served by public transportation
2. Visibility:
   - Set back from street
   - Surrounding clutter
   - Sign placement
3. Traffic:
   - Traffic volume on street that may
   - Indicate potential impulse buying
   - Traffic congestion that could be a hindrance (e.g.., fire stations)
4. Parking:
   - Adequate off-street
5. Expansion:
   - Room for expansion
6. Environment:
   - Immediate surroundings should complement the service
7. Competition:
   - Location of competitors
8. Government:
   - Zoning restrictions
   - Taxes

# Breaking the Rules

- Competitive Clustering (Among Competitors)
  - (e.g. Auto Dealers, Motels)
- Saturation Marketing (Same Firm)
  - (e.g. Au Bon Pain, Ice Cream Vendors)
- Marketing Intermediaries
  - (e.g. Credit Cards, HMO)
- Substitute Electronic Media for Travel
  - (e.g. telecommuting, e-Commerce)
- Impact of the Internet on Service Location
  - (e.g. Amazon, eBay, FedEx)

# Strategic Location Considerations

| | Front Office | Back Office |
|---|---|---|
| **External Customer (consumer)** | Is travel out to customer or customer travel to site?<br>Can electronic media substitute for physical travel?<br>Is location a barrier to entry? | Is service performed on person or property?<br>Is co-location necessary?<br>How is communication accomplished? |
| **Internal Customer (employee)** | Availability of labor?<br>Are self-service kiosks an alternative? | Are economies of scale possible?<br>Can employees work from home?<br>Is offshoring an option? |

# Geographic Information System

- GIS – originally limited to scientists and cartographers.
- Now some companies use GIS tools (e.g., ArcView) for business applications
- GIS can be used for tasks such as mapping customer databases, determining site locations, analyzing demand, and improving delivery services.



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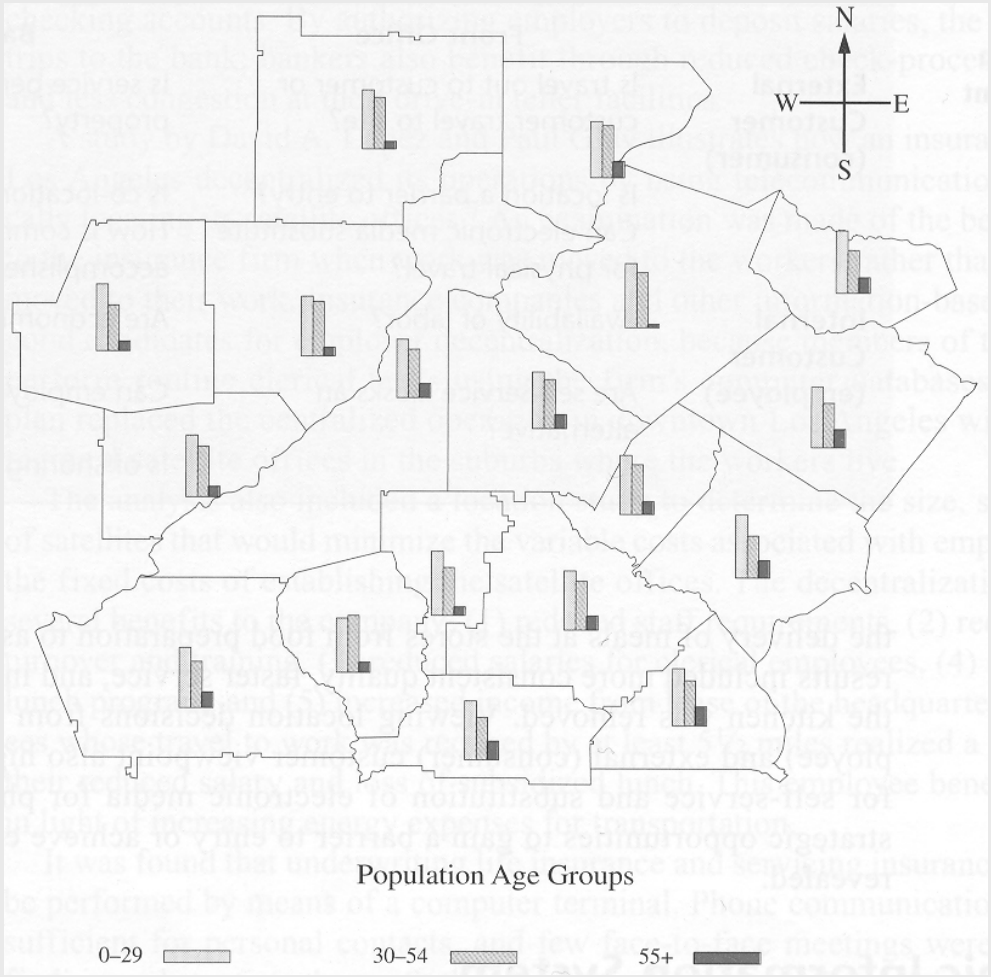
# Geographic Information System

- ArcView translates data, such as demographic info into a map.
  - e.g., a table that lists street addresses and median home values. It may be possible to discern a pattern in the list, if the data are for a community of 150 people in central Montana
  - If the data are for whole city of Denver, may be difficult to discern a useful pattern for locating a new high-end specialty shop.
  - ArcView transfers the data to a map base and color-codes the median home values according to different zip codes.

# GIS Example

- Suppose a state agency wants to establish a warehouse to store surplus foods for Meals on Wheels organizations in an 18-county area.
- Most Meals on Wheels clients are elderly and homebound, so the agency commissioner wants to identify a location that will be most convenient for the MoW units that have the highest demand.
- One solution is to use ArcView to look at the distribution of the population by age groups

# GIS Example




- Counties on the eastern perimeter of the area tend to have larger populations in the 55+ age group.
- Based on this info, the warehouse could be located to serve these counties more conveniently.