Logistics Management
Location Strategy

Özgür Kabak, Ph.D.
Location Strategy

- **What's located?**
  - Sourcing points
    - Plants
    - Vendors
    - Ports
  - Intermediate points
    - Warehouses
    - Terminals
    - Public facilities (fire, police, and ambulance stations)
    - Service centers
  - Sink points
    - Retail outlets
    - Customers/Users
Location Strategy

Key Questions
- How many facilities should there be?
- Where should they be located?
- What size should they be?

Why Location is Important?
- Gives structure to the network
- Significantly affects inventory and transportation costs
- Impacts on the level of customer service to be achieved
Location Decisions

- Single Facility Location
- Multiple Facility Location
- Retail/service Location
Nature of Location Analysis

- **Manufacturing (plants & warehouses)**
  - Decisions are driven by **economics**. Relevant costs such as transportation, inventory carrying, labor, and taxes are traded off against each other to find good locations.

- **Retail**
  - Decisions are driven by **revenue**. Traffic flow and resulting revenue are primary location factors, cost is considered after revenue.

- **Service**
  - Decisions are driven by **service factors**. Response time, accessibility, and availability are key dimensions for locating in the service industry.
Single Facility Location

- Locating a single plant, terminal, warehouse, or retail or service point.

- Center-of-Gravity (COG) method
  - A continuous location method
  - Locates on the basis of transportation costs alone

- The COG method involves
  - Determining the volumes by source and destination point
  - Determining the transportation costs based on $/unit/mi.
  - Overlaying a grid to determine the coordinates of source and/or destination points
  - Finding the weighted center of gravity for the graph
COG Method

\[ \text{Min } TC = \sum_i V_i R_i d_i \]

- \( TC \) = total transportation cost
- \( V_i \) = volume at point \( i \)
- \( R_i \) = transportation rate to point \( i \)
- \( d_i \) = distance to point \( i \) from the facility to be located

The facility Location:

\[ \bar{X} = \frac{\sum_i V_i R_i X_i}{\sum_i V_i R_i}, \quad \bar{Y} = \frac{\sum_i V_i R_i Y_i}{\sum_i V_i R_i}, \]

- \( X_i, Y_i \) = coordinate points for point \( i \)
- \( \bar{X}, \bar{Y} \) = coordinate points for facility to be located
Suppose a regional medical warehouse is to be established to serve several Veterans Administration hospitals throughout the country. The supplies originate at $S_1$ and $S_2$ and are destined for hospitals at $H_1$ through $H_4$. The relative locations are shown on the map grid. Other data are:

<table>
<thead>
<tr>
<th>Point i</th>
<th>Products</th>
<th>Location</th>
<th>Annual Volume, cwt.</th>
<th>Rate $/cwt/mi.</th>
<th>$X_i$</th>
<th>$Y_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 $S_1$</td>
<td>A</td>
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<td>0.02</td>
<td>0.6</td>
<td>7.3</td>
</tr>
<tr>
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<td>B</td>
<td>Atlanta</td>
<td>10,000</td>
<td>0.02</td>
<td>8.6</td>
<td>3.0</td>
</tr>
<tr>
<td>3 $H_1$</td>
<td>A&amp;B</td>
<td>Los Angeles</td>
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<td>0.05</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
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<td>A&amp;B</td>
<td>Dallas</td>
<td>3,000</td>
<td>0.05</td>
<td>5.5</td>
<td>2.4</td>
</tr>
<tr>
<td>5 $H_3$</td>
<td>A&amp;B</td>
<td>Chigago</td>
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<td>7.9</td>
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</tr>
<tr>
<td>6 $H_4$</td>
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<td>5.2</td>
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</tbody>
</table>
COG Method
Example

Map scaling factor, \( K \)

Scale: 1 = 500 mi.
## COG Method Example

<table>
<thead>
<tr>
<th>i</th>
<th>$X_i$</th>
<th>$Y_i$</th>
<th>$V_i$</th>
<th>$R_i$</th>
<th>$V_iR_i$</th>
<th>$V_iR_iX_i$</th>
<th>$V_iR_iY_i$</th>
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<td>3</td>
<td>10000</td>
<td>0.02</td>
<td>200</td>
<td>1720</td>
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<td>2</td>
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<tr>
<td><strong>Total</strong></td>
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<td></td>
<td></td>
<td></td>
<td><strong>1260</strong></td>
<td><strong>7901</strong></td>
<td><strong>5538</strong></td>
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</table>

\[
\bar{X} = \frac{7,901}{1,260} = 6.27 \\
\bar{Y} = \frac{5,538}{1,260} = 4.40
\]
COG Method
Example

Scale: 1 = 500 mi.
**COG Method**

**Example**

- The total cost for this location is found by:

\[ TC = \sum_i V_i R_i K \sqrt{(X_i - \bar{X})^2 + (Y_i - \bar{Y})^2} \]

- \( K \) is the map scaling factor to convert coordinates into miles.

<table>
<thead>
<tr>
<th>( i )</th>
<th>( X_i )</th>
<th>( Y_i )</th>
<th>( V_i )</th>
<th>( R_i )</th>
<th>( TC )</th>
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<tr>
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<td>271,526</td>
</tr>
<tr>
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<td>2</td>
<td>3</td>
<td>5000</td>
<td>0.05</td>
<td>561,597</td>
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<td>2.4</td>
<td>3000</td>
<td>0.05</td>
<td>160,417</td>
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<td>7.9</td>
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<td>4000</td>
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<td>196,859</td>
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<td>6</td>
<td>10.6</td>
<td>5.2</td>
<td>6000</td>
<td>0.05</td>
<td>660,529</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,360,633</strong></td>
</tr>
</tbody>
</table>
Multiple Location Methods

- A more complex problem that most firms have.
- It involves trading off the following costs:
  - Transportation inbound to and outbound from the facilities
  - Storage and handling costs
  - Inventory carrying costs
  - Production/purchase costs
  - Facility fixed costs
- Subject to:
  - Customer service constraints
  - Facility capacity restrictions
- Mathematical methods are popular for this type of problem that
  - Search for the best combination of facilities to minimize costs
  - Do so within a reasonable computational time
  - Do not require enormous amounts of data for the analysis
Location Cost Trade-Offs

- Total cost
- Warehouse fixed
- Inventory carrying and warehousing
- Production/purchase and order processing
- Inbound and outbound transportation

Number of warehouses vs. Cost
Examples of Practical COG Model Use

- Location of truck maintenance terminals

- Location of public facilities such as offices, and police and fire stations

- Location of medical facilities

- Location of most any facility where transportation cost (rather than inventory carrying cost and facility fixed cost) is the driving factor in location

- As a suggestor of sites for further evaluation
Multiple COG

- Formulated as basic COG model
- Can search for the best locations for a selected number of sites.
- Fixed costs and inventory consolidation effects are handled outside of the model.

A multiple COG procedure

- Rank demand points from highest to lowest volume
- Use the M largest as initial facility locations and assign remaining demand centers to these locations
- Compute the COG of the M locations
- Reassign all demand centers to the M COGs on the basis of proximity
- Recompute the COGs and repeat the demand center assignments, stopping this iterative process when there is no further change in the assignments or COGs
Multiple COG Example

- Warehouse Cost = $800,000\sqrt{N}$
- For $N = 1$
- Total cost = Transportation cost + Warehouse Cost
  
  
  $2,360,633 + 800,000 = 3,160,633$

<table>
<thead>
<tr>
<th></th>
<th>$X_i$</th>
<th>$Y_i$</th>
<th>$V_i$</th>
<th>$R_i$</th>
<th>TC</th>
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<td>0.02</td>
<td>509,706</td>
</tr>
<tr>
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<td>0.05</td>
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<tr>
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<td>10.6</td>
<td>5.2</td>
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<td>0.05</td>
<td>660,529</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,360,633</strong></td>
</tr>
</tbody>
</table>
Multiple COG Example

- For N = 2
- Determine initial locations
  - \( w_1(8.6, 3) \) -- \( w_2(0.6, 7.3) \)

- Compute the distance of each point from initial locations
- Determine the cluster of each point

<table>
<thead>
<tr>
<th></th>
<th>( X )</th>
<th>( Y )</th>
<th>( d_1 )</th>
<th>( d_2 )</th>
<th>Cluster #</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<td>0.00</td>
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<td>6</td>
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<td>2.97</td>
<td>10.22</td>
<td>1</td>
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</table>
Multiple COG Example

- COG for the first Cluster

<table>
<thead>
<tr>
<th>i</th>
<th>$X_i$</th>
<th>$Y_i$</th>
<th>$V_i$</th>
<th>$R_i$</th>
<th>$V_i R_i$</th>
<th>$V_i X_i$</th>
<th>$V_i Y_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8.6</td>
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<td>10000</td>
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<td>1720</td>
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<td>5.5</td>
<td>2.4</td>
<td>3000</td>
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<td>150</td>
<td>825</td>
<td>360</td>
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<td>5</td>
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<td>6000</td>
<td>0.05</td>
<td>300</td>
<td>3180</td>
<td>1560</td>
</tr>
</tbody>
</table>

$w_1 = \left(\frac{7305}{850};\frac{3520}{850}\right) = (8.59, 4.26)$

- COG for the second Cluster

<table>
<thead>
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<th>$V_i$</th>
<th>$R_i$</th>
<th>$V_i R_i$</th>
<th>$V_i X_i$</th>
<th>$V_i Y_i$</th>
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<td>1</td>
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<td>160</td>
<td>96</td>
<td>1168</td>
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<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>5000</td>
<td>0.05</td>
<td>250</td>
<td>500</td>
<td>750</td>
</tr>
</tbody>
</table>

$w_2 = \left(\frac{596}{410};\frac{1918}{410}\right) = (1.45, 4.68)$
Multiple COG Example

- For $w_1(8.59, 4.26) - w_2(1.45, 4.68)$
- Compute the distance of each point from locations
- Determine new clusters of each point

<table>
<thead>
<tr>
<th>i</th>
<th>$X_i$</th>
<th>$Y_i$</th>
<th>$d_1$</th>
<th>$d_2$</th>
<th>Cluster #</th>
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<td>2</td>
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<td>1</td>
</tr>
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</table>

- Clusters do not change, stop procedure!
## Multiple COG Example

- **Calculate Transportation cost for N = 2**

<table>
<thead>
<tr>
<th>i</th>
<th>Xi</th>
<th>Yi</th>
<th>Vi</th>
<th>Rj</th>
<th>wx</th>
<th>wy</th>
<th>Distance</th>
<th>Transportation Cost</th>
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</table>

<table>
<thead>
<tr>
<th><strong>Total Cost (N=2)</strong></th>
<th><strong>2,443,722</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Cost (N=1)</strong></td>
<td><strong>3,160,633</strong></td>
</tr>
</tbody>
</table>

\[ \text{Total Cost (N=2)} = 1,312,351 + 800.000\sqrt{2} = 2,443,722 \]

\[ \text{Total Cost (N=1)} = 2,360,633 + 800,000 = 3,160,633 \]
**Multiple COG Example**

- **Minimum cost at N = 3;**

<table>
<thead>
<tr>
<th>i</th>
<th>Xi</th>
<th>Yi</th>
<th>Vi</th>
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<th>wy</th>
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</table>

**Total Cost (N=3) = 934,807 + 800.000\sqrt{3} = 2,320,447**

**Total Cost (N=2) = 1,312,351 + 800.000\sqrt{2}= 2,443,722**

**Total Cost (N=1) = 2,360,633 + 800,000 = 3,160,633**
Multifacility Location Models
Places are Already Known

- Conventional Network
Consider the following distribution system:

- Single product
- Two plants $p_1$, $p_2$
- Plant $p_2$ has an annual capacity of 60,000 units
- The two plants have the same production costs
- Two existing warehouses, referred to as warehouse $w_1$ and warehouse $w_2$ have identical warehouse handling costs
- Three markets, $c_1$, $c_2$, $c_3$ with demands of 50,000, 100,000 and 50,000 respectively

<table>
<thead>
<tr>
<th>Facility Warehouse</th>
<th>$p_1$</th>
<th>$p_2$</th>
<th>$c_1$</th>
<th>$c_2$</th>
<th>$c_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_1$</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>$w_2$</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Multifacility Location Models
Places are Already Known

Plant $P_1$
Production = $4/cwt.$
Capacity = 60,000 cwt.

Plant $P_2$
Production = $4/cwt.$
Capacity = 60,000 cwt.

Warehouse $W_1$
Handling = $0/cwt.$
Capacity = Unrestricted
Fixed = $100,000
Inventory carrying cost = $100(Throughput)^{0.7}$

Warehouse $W_2$
Handling = $2/cwt.$
Capacity = Unrestricted
Fixed = $400,000

Customer $C_1$
50,000 cwt.

Customer $C_2$
100,000 cwt.

Customer $C_3$
50,000 cwt.
Multifacility Location Models Heuristics

- **Heuristic 1**
  - For each market we choose the cheapest warehouse to source demand.
    - $c_1, c_2, c_3$ would be supplied by $w_2$.
    - For this warehouse choose the cheapest plant;
      - 60,000 units from $p_2$
      - the remaining 140,000 from $p_1$.
    - Total cost $= 2 \times 50,000 + 1 \times 100,000 + 2 \times 50,000 + 2 \times 60,000 + 5 \times 140,000 = 1,120,000$
Heuristics

- **Heuristic 2**
  - For each market area, choose the warehouse where the total delivery costs to and from the warehouse are the lowest; that is, consider inbound and outbound distribution costs.
  - Thus for market area $c_1$, consider the paths $p_1-w_1-c_1$, $p_1-w_2-c_1$, $p_2-w_1-c_1$, $p_2-w_2-c_1$.
  - The cheapest is $p_1-w_1-c_1$, so choose $w_1$ for $c_1$.
  - Using a similar analysis, we choose $w_2$ for $c_2$ and $w_2$ for $c_3$.
  - This implies that warehouse $w_1$ delivers a total of 50,000 units while warehouse $w_2$ delivers a total of 150,000 units.
  - The best inbound flow pattern is to supply 50,000 from plant $p_1$ to warehouse $w_1$, supply 60,000 units from plant $p_2$ to warehouse $w_2$, and supply 90,000 from plant $p_1$ to warehouse $w_2$.
  - The total cost for this strategy is 920,000.
Multifacility Location Models Optimization Model

- Places are already known
- Minimize total transportation cost
  \[
  0X(p_1,w_1) + 5X(p_1,w_2) + 4X(p_2,w_1) + 2X(p_2,w_2) + 3X(w_1,c_1) + 4X(w_1,c_2) + 5X(w_1,c_3) + 2X(w_2,c_1) + 1X(w_2,c_2) + 2X(w_2,c_3)
  \]
- s.t.
  - \( X(p_2,w_1) + X(p_2,w_2) \leq 60,000 \)  \( \) Plant 2 capacity
  - \( X(p_1,w_1) + X(p_2,w_1) = X(w_1,c_1) + X(w_1,c_2) + X(w_1,c_3) \)  \( \) Whs.1 input/output
  - \( X(p_1,w_2) + X(p_2,w_2) = X(w_2,c_1) + X(w_2,c_2) + X(w_2,c_3) \)  \( \) Whs.2 input/output
  - \( X(w_1,c_1) + X(w_2,c_1) = 50,000 \)  \( \) Customer 1 demand
  - \( X(w_1,c_2) + X(w_2,c_2) = 100,000 \)  \( \) Customer 2 demand
  - \( X(w_1,c_3) + X(w_2,c_3) = 50,000 \)  \( \) Customer 3 demand
Multifacility Location Models
Optimization Model

- EXCEL Solver
Multifacility Location Models Optimization Model

- Result
- Total Cost: $740,000

<table>
<thead>
<tr>
<th>w_1</th>
<th>w_2</th>
<th>c_1</th>
<th>c_2</th>
<th>c_3</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_1</td>
<td>140000</td>
<td>0</td>
<td>50000</td>
<td>40000</td>
</tr>
<tr>
<td>w_1</td>
<td>w_2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p_2</td>
<td>0</td>
<td>60000</td>
<td>0</td>
<td>60000</td>
</tr>
</tbody>
</table>
Retail Location

- Contrasts with plant and warehouse location.
- Factors other than costs such as parking, nearness to competitive outlets, and nearness to customers are dominant

Methods

- Weighted checklist
  - Often many of the factors that are important to retail location are not easily or inexpensively quantified
  - Judgment is an integral part of the decision
  - Good where many subjective factors are involved
  - Quantifies the comparison among alternate locations

- Spatial-Interaction Model
  - The gravity model to determining the drawing power, or overall desirability, of a site
  - The basic idea is that two competing cities attract trade from an intervening town in direct proportion to each city’s population but inverse proportion to square distance between cities and town.
A Hypothetical Weighted Factor Checklist for a Retail Location Example

<table>
<thead>
<tr>
<th>Factor Weight (1 to 10)</th>
<th>Location Factors</th>
<th>Factor Score (1 to 10)</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Proximity to competing stores</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>Space rent/lease considerations</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>Parking space</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>Proximity to complementary stores</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td>6</td>
<td>Modernity of store space</td>
<td>9</td>
<td>54</td>
</tr>
<tr>
<td>9</td>
<td>Customer accessibility</td>
<td>8</td>
<td>72</td>
</tr>
<tr>
<td>3</td>
<td>Local taxes</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Community service</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Proximity to major transportation arteries</td>
<td>7</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td><strong>Total Index</strong></td>
<td></td>
<td><strong>391</strong></td>
</tr>
</tbody>
</table>

Factor weights approaching 10 indicate great importance. Factor scores approaching 10 refer to a favored location status.
Spatial-Interaction Model
Huff's Gravity Model

- A take-off on Newton's law of gravity.
- "Mass" or retail "variety" attracts customers, and the distance from customer repels them.
- The basic model

\[ E_{ij} = P_{ij} C_i = \frac{S_j/T_{ij}^a}{\sum_j S_j/T_{ij}^a} C_i \]

- \( E_{ij} \) = expected demand from population center \( i \) that will be attracted to retail location \( j \).
- \( P_{ij} \) = probability of customers from \( i \) travelling to retail location \( j \).
- \( C_i \) = customer demand at point \( i \)
- \( S_j \) = size of retail location \( j \)
- \( T_{ij} \) = travel time between customer location \( i \) and retail location \( j \)
- \( n \) = number of retail locations \( j \)
- \( a \) = empirically estimated parameter
Huff's Gravity Model Example

- Two shopping centers ($R_A$ and $R_B$) are to attract customers from $C_1$, $C_2$, and $C_3$. Shopping center $A$ has 500,000 square feet of selling area whereas center $B$ has 1,000,000. The customer clusters have a buying potential of $10, $5, and $7 million, respectively. The parameter $a$ is estimated to be 2. What is the sales potential of each shopping center?

<table>
<thead>
<tr>
<th>Customer</th>
<th>Time from Customer $i$ to Location $j$</th>
<th>$T_{ij}^2$</th>
<th>$S_j/T_{ij}^2$</th>
<th>$P_{ij}$</th>
<th>Potential</th>
<th>$E_{ij} = P_{ij}C_{ij}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>$C_1$</td>
<td></td>
<td>30</td>
<td>56,6</td>
<td>900</td>
<td>3204</td>
<td>556</td>
</tr>
<tr>
<td>$C_2$</td>
<td></td>
<td>44,7</td>
<td>30</td>
<td>1998</td>
<td>900</td>
<td>250</td>
</tr>
<tr>
<td>$C_3$</td>
<td></td>
<td>36</td>
<td>28,3</td>
<td>1296</td>
<td>801</td>
<td>386</td>
</tr>
</tbody>
</table>
Huff's Gravity Model Example
Other Methods for Retail Location

- Regression Analysis (to forecast the revenues that a specific site can expect)
- Covering models (particularly useful for locating emergency services such as police and fire stations)
- Game Theory (suggested when competition is a key factor)
- Location-Allocation models such as goal programming and integer programming (see example at the blackboard)
Next Class

- Final Exam

- June 20, 2012
  - The exam will be in room D301 at 19:30.

- All course topics are included in the exam.

- It is strictly forbidden to use mobile phones for calculations or other purposes.
- Please provide calculator for calculations.

- No class on June 13!