4-25-2019

An Engineered Approach to Site Selection: Determining where Facilities Should be Located

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April 25, 2019

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TODAY'S PRESENTER

Dr. Kerry Melton

Instructor – M.S. in Operations Management

- Dr. Kerry Melton earned his Ph.D. in Industrial Engineering and Management from Oklahoma State University in 2012, with a concentration in supply chain management and logistics.
- Since then, he's taught Operations Management, Transportation Strategies, Advanced Forecasting and Inventory Management, Engineering and Business Statistics, and Goods and Services at the undergraduate and graduate levels at the University of Arkansas.
- He's been teaching online since 2015, and joined the Arkansas faculty as an adjunct professor in 2013.
- He has industry experience working at J.B. Hunt Transport for 12 years and at Walmart for 6 years. He currently works for J.B. Hunt Transport in Engineering and Technology in Lowell, Arkansas.

Brief Bio

Current:

- Adjunct Professor- University of Arkansas
- J.B. Hunt Transport

Past:

- Walmart Logistics
- FM Corporation

Education:

- Ph.D. Industrial Engineering, Oklahoma State University
- Master's/Bachelor's Industrial Engineering, University of Arkansas

An Engineered Approach to Site Selection: Determining Where Facilities Should Be Located

By

Kerry Melton

Outline

- The Strategic Importance of Location
- Factors That Affect Location Decisions
- Methods for Evaluating Location Alternatives

The Strategic Importance of Location

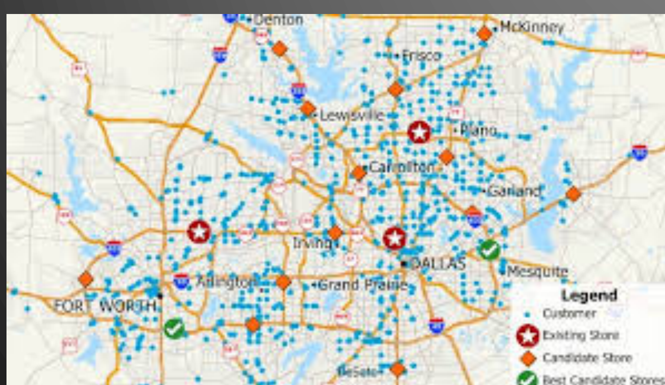
- One of the most important decisions a firm makes
- Increasingly global in nature
- Significant impact on fixed and variable costs
- Decisions made relatively infrequently
- Long-term decisions
- Once committed to a location, many resource and cost issues are difficult to change

The Strategic Importance of Location

The key objective of location strategy is to maximize the benefit of location to the firm

Options include-

1. Expanding existing facilities
2. Maintain existing and adding sites
3. Closing existing and relocating



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The Strategic Importance of Location

- Location decisions based on low cost require careful consideration
- Once in place, location-related costs are fixed in place and difficult to reduce
- Determining optimal facility location is a good investment
  - Requires good customer demand planning and forecasting
  - Real estate experts must weigh in
  - Cost factors are critical- land, building, etc.

Factors That Affect Location Decisions

Factors That Affect Location Decisions

Globalization adds to complexity

- Market economics
- Communication and systems
- Rapid, reliable transportation
- Ease of capital flow
- Differing labor costs

Identify key success factors (KSFs)

- Country, region, site

Factors That Affect Location Decisions

Country Decision

Key Success Factors

1. Political risks, government rules, **incentives**
2. Cultural and economic issues
3. Location of markets
4. Labor talent, attitudes, **productivity**, labor turnover/absenteeism culture
5. Availability of supplies, communications, energy
6. Exchange rates and currency risks

Factors That Affect Location Decisions

Region/ Community Decision

Key Success Factors

1. Corporate desires
2. Attractiveness of region
3. Labor availability and wage costs
4. Utilities cost and availability
5. Environmental regulations
6. State government incentives, taxes
7. Proximity to raw materials and customers (i.e. perishable goods, JIT, transportation costs)
8. Land/construction costs

Factors That Affect Location Decisions

Site Decision

Key Success Factors

1. Site size and cost
2. Air, rail, highway, and waterway systems
3. Zoning restrictions
4. Proximity of services/ supplies needed
5. Environmental impact issues, pollution, ethics
6. Life quality (i.e. crime, cost)
7. Public transportation
8. Education

Factors That Affect Location Decisions

Labor productivity example

- Wage rates are not the only cost
- Lower productivity may increase total cost

$$\frac{\text{Labor cost per day}}{\text{Productivity (units per day)}} = \text{Cost per unit}$$

South Carolina

$$\frac{\$70}{60 \text{ units}} = \$1.17 \text{ per unit}$$

Mexico

$$\frac{\$25}{20 \text{ units}} = \$1.25 \text{ per unit}$$

Methods for Evaluating Location Alternatives

- Factor-Rating Method
- Locational Cost-Volume Analysis
- Center-of-Gravity
- Load Distance Method
- Transportation Model (Linear Program)
- Mixed Integer Quadratic Program

Factor-Rating Method

- Popular because a wide variety of factors can be included in the analysis (subjective/qualitative)
- Six steps in the method
  1. Develop a list of key success factors
  2. Assign a weight to each key success factor
  3. Develop a scale for each key success factor
  4. Score each location for each key success factor
  5. Multiply score by weights for each key success factor for each location and then sum the weights for each location
  6. Make a recommendation based on the highest point score or lowest score (i.e. if cost related, risk related)

Factor-Rating Example

The goal is to determine the best location (China or Sweden) for locating a plant facility based on maximizing the weighted score given the key success factors.

		Scores out of 100		Weighted Scores	
Key Success Factor	**Weight**	**China**	**Sweden**	**China**	**Sweden**
Labor availability	30%	65	75	(.30)(65) = 19.5	(.30)(75) = 22.5
Incentives	25%	70	60	(.25)(70) = 17.5	(.25)(60) = 15
Labor wages	20%	80	85	(.20)(80) = 16	(.20)(85) = 17
Education	15%	60	50	(.15)(60) = 9	(.15)(50) = 7.5
Taxes	10%	80	55	(.10)(80) = 8	(.10)(55) = 5.5
Totals	**100%**			**70**	**67.5**

Highest score is the best, so China is the best location option based on this method.

Subjective: Weights, Scoring, Key Success Factors

Locational Cost-Volume Analysis

- An economic comparison of location alternatives
- Three steps in the method
  1. Determine fixed and variable costs for each location
  2. Plot the cost for each location based on production volume
  3. Select location with lowest total cost for expected production volume

Locational Cost-Volume Analysis Example

Three locations: Clinton, MS; Akron, OH; Oakland, CA

Expected volume = 2,000 units

Which city would be the best location?

City	Fixed Cost	Variable Cost	Total Cost
Clinton, MS	$30,000	$75	$180,000
Akron, OH	$60,000	$45	$150,000
Oakland, CA	$110,000	$25	$160,000

Total Cost = Fixed Cost + (Variable Cost x Volume)

Locational Cost-Volume Analysis Example

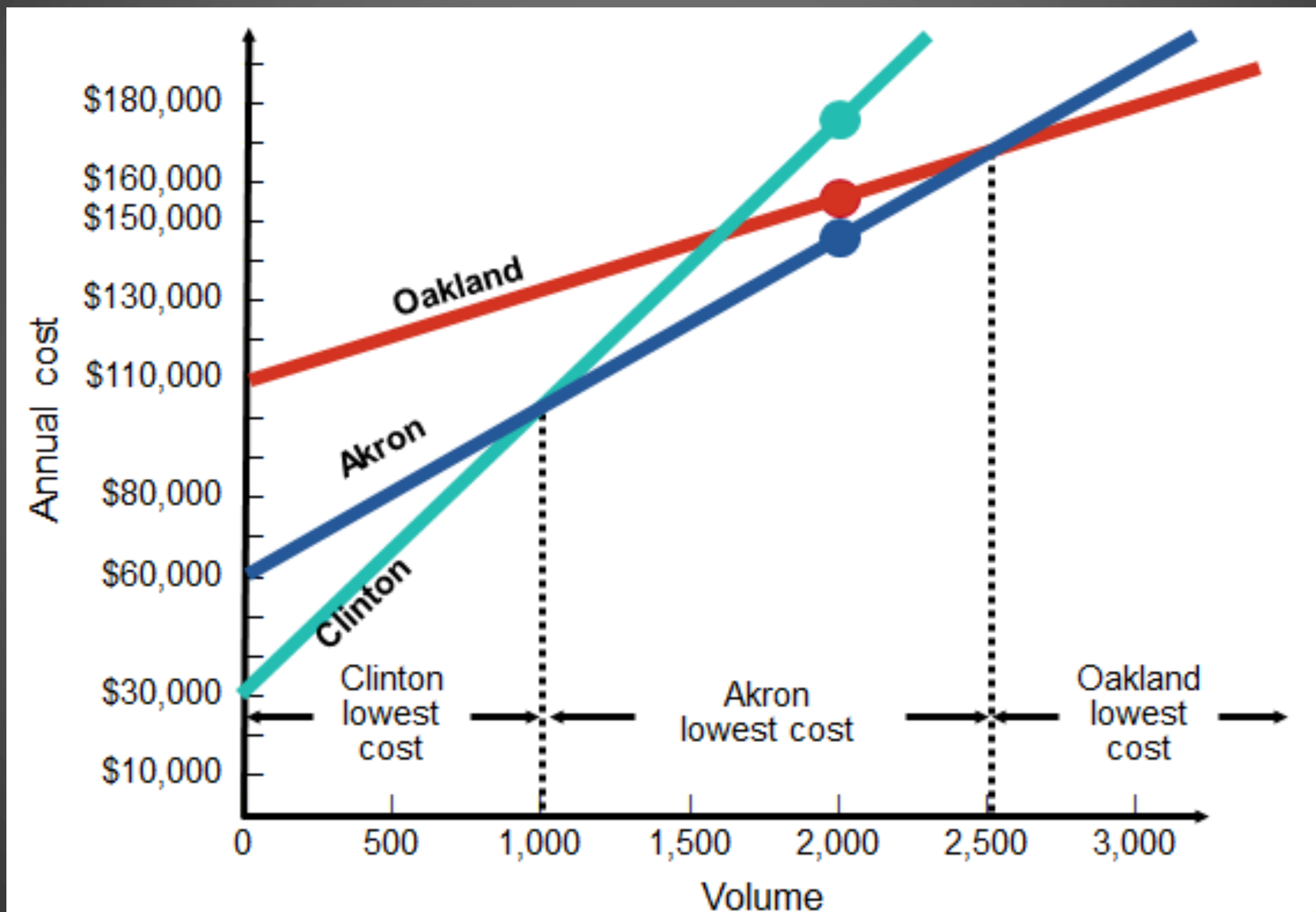


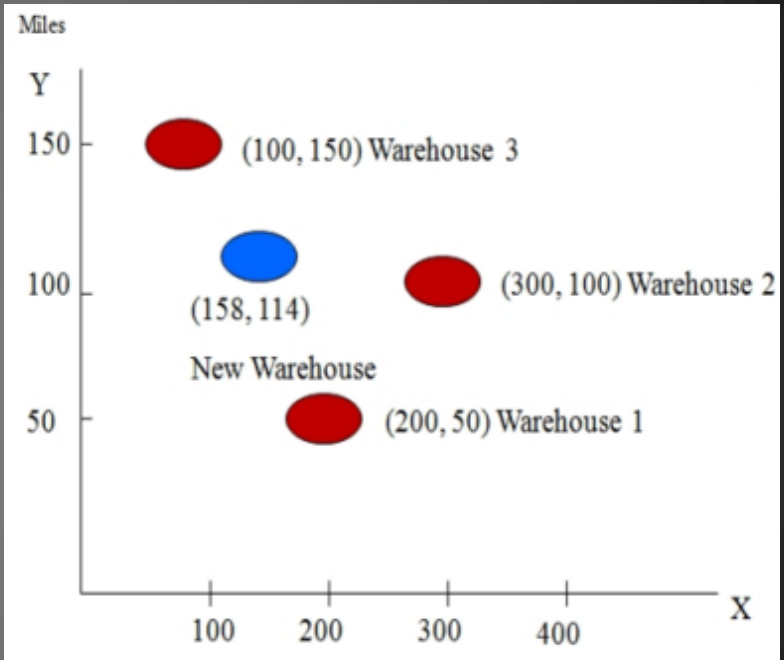
Figure 1. Cost-Volume graph [1]

Center-of-Gravity Method

- Finds the facility location that minimizes distribution costs
- Does not consider topography or direction
- Considers
  - Location of markets
  - Volume of goods shipped to those markets
  - Shipping cost or distance
- 2 methods:
  - Method 1 excludes transportation rates
  - Method 2 includes transportation rates

Center-of-Gravity Method

- Place existing locations on a coordinate grid
  - Latitude and longitude coordinates are often used
  - An arbitrary grid can be used
- Calculate (latitude, longitude) or other (x,y) coordinates for the center of gravity location



Center-of-Gravity Method

Method 1:

latitude coordinate of the center of gravity $= \dfrac{\sum_i d_{ix} Q_i}{\sum_i Q_i}$

longitude coordinate of the center of gravity $= \dfrac{\sum_i d_{iy} Q_i}{\sum_i Q_i}$

where

d_{ix} = latitude coordinate of location i

d_{iy} = longitude coordinate of location i

Q_i = Quantity of goods moved to or from location i

Center-of-Gravity Method

Method 1:

Example- Determine where a warehouse should be located to support 4 large stores located in the Dallas metro-plex. Information about each of the 4 locations is given below. The warehouse will provide same day service so it should be located strategically.

Store Location	Latitude	Longitude	Annual Loads	Latitude Weight		Longitude Weight		
Fort Worth, TX	32.82	- 97.35	1,200	9.38	32.82*1200/4200	-27.81	-97.35*1200/4200	
Tyler, TX	32.35	- 95.30	1,100	8.47	32.35*1100/4200	-24.96	-95.30*1100/4200	
Plano, TX	33.02	- 96.68	900	7.08	33.02*900/4200	-20.72	-96.68*900/4200	
Denton, TX	32.25	- 99.53	1,000	7.68	32.25*1000/4200	-23.70	-99.53*1000/4200	
		Total	**4,200**	**32.60**		**- 97.19**		

Warehouse should be located at latitude 32.60 & longitude -97.19

Use http://www.latlong.net/Show-Latitude-Longitude.html to find the actual city/state

(32.60, -97.19) is Mansfield, TX

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Center-of-Gravity Method

Method 2:

Includes transportation rates

X coordinate: $$\frac{\Sigma (r_i W_i d_{iX})}{\Sigma (r_i W_i)}$$

Y coordinate: $$\frac{\Sigma (r_i W_i d_{iY})}{\Sigma (r_i W_i)}$$

r_i ~ shipping rate ($ per unit distance) for location i

W_i ~ weight (or volume) shipped for location i

d_{iX} ~ x-coordinate for location i

d_{iY} ~ y-coordinate for location i

Center-of-Gravity Method

Method 2:
Where should the DC be located to minimize transportation costs?

Source / Market	Rate ($/ton-mile)	Tons
Buffalo	$ 0.90	500
Memphis	$ 0.95	300
St. Louis	$ 0.85	700
Atlanta	$ 1.50	225
Boston	$ 1.50	150
Jacksonville	$ 1.50	250
Philadelphia	$ 1.50	175
New York	$ 1.50	300

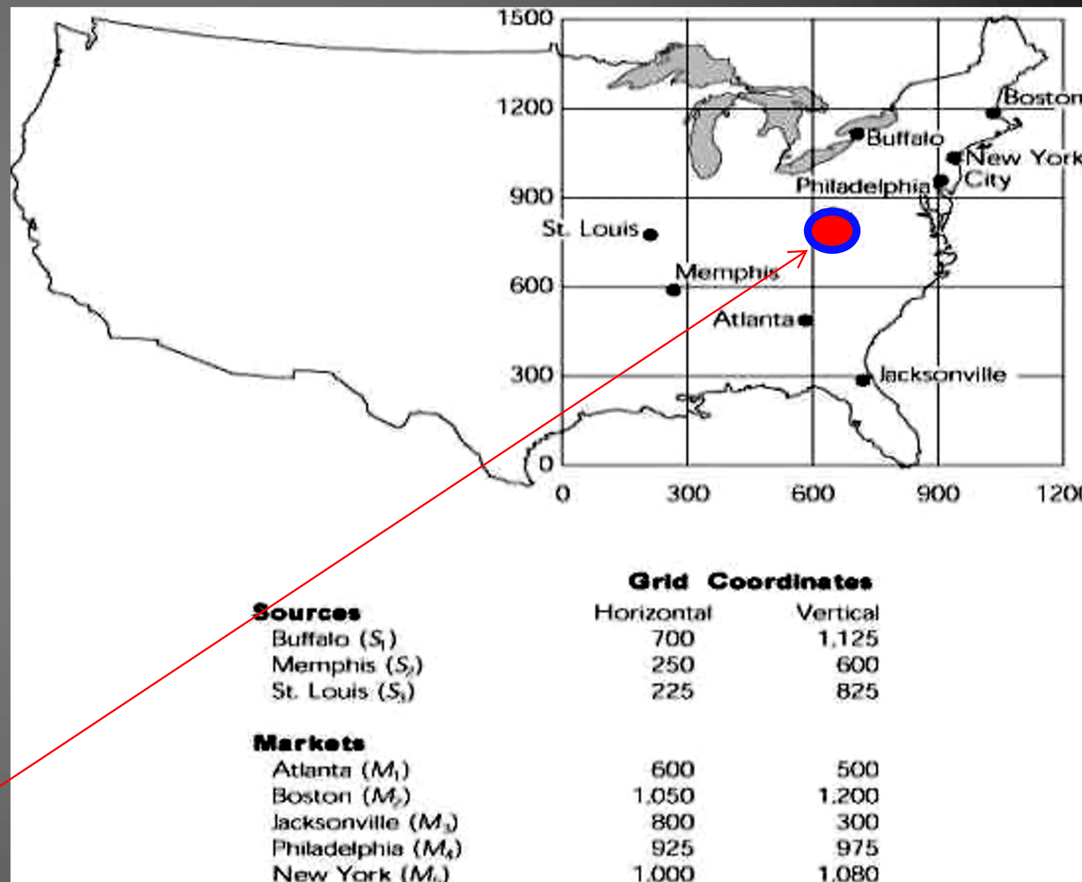


Figure 2. Center-of-Gravity illustration [2]

Best location to minimize transportation costs.

Load Distance Method

Load distance- quick method for determining a location based on volume (i.e. shipments, demand, etc.) and potential site locations and existing facilities along with distance

A Load Distance Model Steps:

- Calculate the distance between each potential site and existing facility where an existing facility can be a supplier or destination (DC, store, etc.)
- Multiply the distance by the volume between each potential site and each existing facility to obtain the load distances
- Sum the load distances for each potential site
- The potential site with the smallest (minimum) load distance is the best choice option

Load Distance Method

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.

Load Distance Method

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 (ld) score for Mansfield is higher than for Springfield. The warehouse should be located in Springfield.
- The goal is to minimize load distance

Transportation Model

- Finds amount to be shipped from several points of supply to several points of demand
- Solution will minimize total production and shipping costs
- A special class of linear programming problems

Transportation Model

Determine how many product cases to ship from each supplier to each processing plant based on the supplier and plant volume constraints with the goal of minimizing distance. Use a linear program (LP).

Transportation flow diagram:

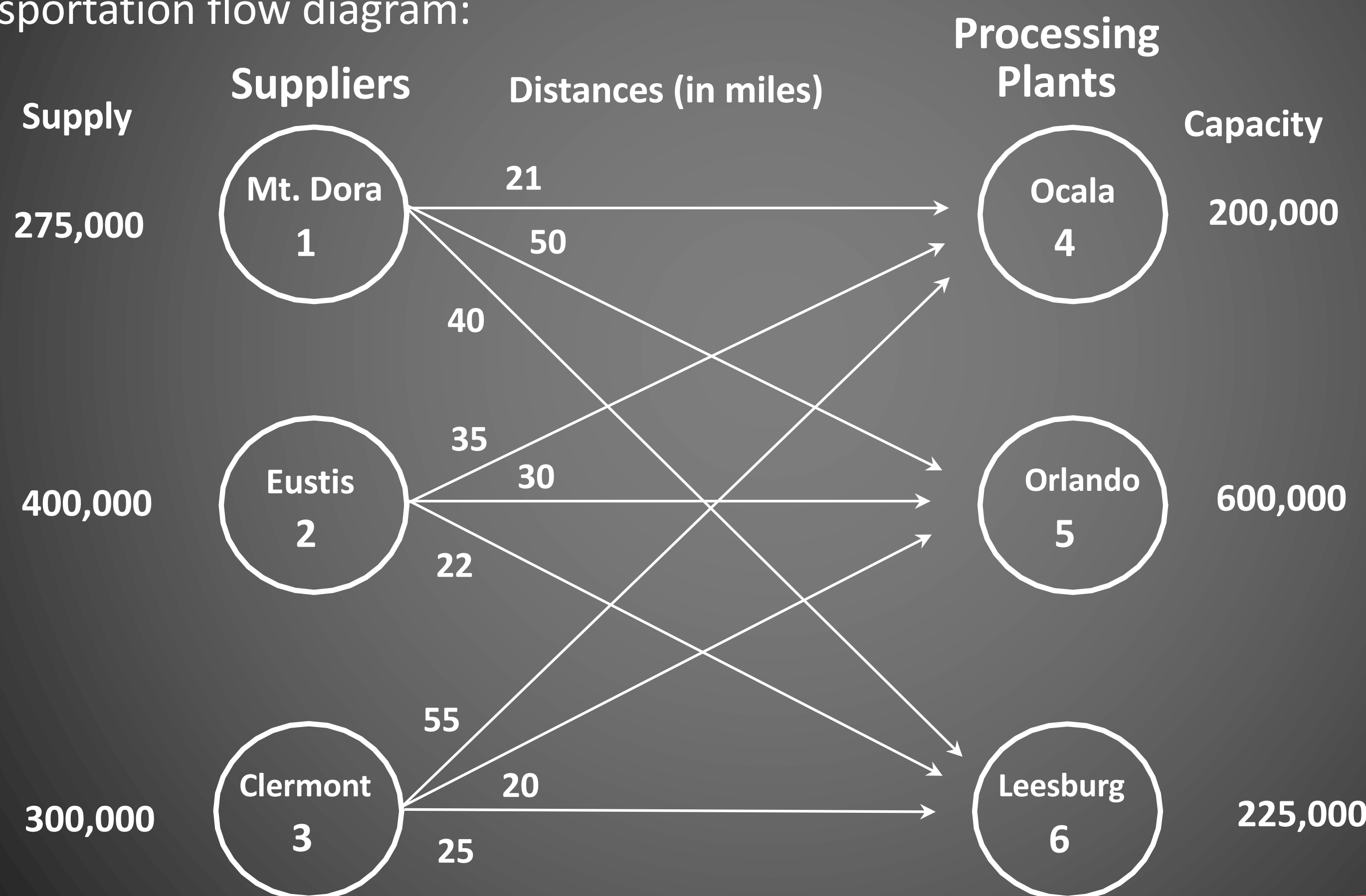


Figure 3. Transportation model illustration [2]

Transportation Model

LP Decision variables:

X_{ij} = # of cases shipped from node i to node j

Specifically, the nine decision variables are:

X_{14} = # of cases shipped from Mt. Dora (node 1) to Ocala (node 4)
X_{15} = # of cases shipped from Mt. Dora (node 1) to Orlando (node 5)
X_{16} = # of cases shipped from Mt. Dora (node 1) to Leesburg (node 6)
X_{24} = # of cases shipped from Eustis (node 2) to Ocala (node 4)
X_{25} = # of cases shipped from Eustis (node 2) to Orlando (node 5)
X_{26} = # of cases shipped from Eustis (node 2) to Leesburg (node 6)
X_{34} = # of cases shipped from Clermont (node 3) to Ocala (node 4)
X_{35} = # of cases shipped from Clermont (node 3) to Orlando (node 5)
X_{36} = # of cases shipped from Clermont (node 3) to Leesburg (node 6)

Transportation Model

LP Objective:

Minimize the total number of case miles.

$$\begin{aligned} \text{MIN: } & 21X_{14} + 50X_{15} + 40X_{16} + \\ & 35X_{24} + 30X_{25} + 22X_{26} + \\ & 55X_{34} + 20X_{35} + 25X_{36} \end{aligned}$$

Transportation Model

LP Constraints:

- Capacity constraints

  $X_{14} + X_{24} + X_{34} <= 200{,}000$ } Ocala

  $X_{15} + X_{25} + X_{35} <= 600{,}000$ } Orlando

  $X_{16} + X_{26} + X_{36} <= 225{,}000$ } Leesburg

- Supply constraints

  $X_{14} + X_{15} + X_{16} = 275{,}000$ } Mt. Dora

  $X_{24} + X_{25} + X_{26} = 400{,}000$ } Eustis

  $X_{34} + X_{35} + X_{36} = 300{,}000$ } Clermont

- Non-negativity conditions

  $X_{ij} >= 0$ for all i and j

Transportation Model

LP Solution using Microsoft Excel Solver:

LP Using Microsoft Excel Solver					
		minimize			
Decision variables		objective	24,000,000		
X14	200,000				
X15	0	constraints			
X16	75,000	200,000		≤	200,000
X24	0	550,000		≤	600,000
X25	250,000	225,000		≤	225,000
X26	150,000	275,000		=	275,000
X34	0	400,000		=	400,000
X35	300,000	300,000		=	300,000
X36	0	200,000		≥	0
		0		≥	0
		75,000		≥	0
		0		≥	0
		250,000		≥	0
		150,000		≥	0
		0		≥	0
		300,000		≥	0
		0		≥	0

X_{14} = # of cases shipped from Mt. Dora to Ocala

X_{15} = # of cases shipped from Mt. Dora to Orlando

X_{16} =# of cases shipped from Mt. Dora to Leesburg

X_{24} = # of cases shipped from Eustis to Ocala

X_{25} = # of cases shipped from Eustis to Orlando

X_{26} = # of cases shipped from Eustis to Leesburg

X_{34} = # of cases shipped from Clermont to Ocala

X_{35} = # of cases shipped from Clermont to Orlando

X_{36} = # of cases shipped from Clermont to Leesburg

Mixed Integer Quadratic Program

Mixed Integer Quadratic Program can be used to determine locations

- **Models include an objective and constraints**
- **Models are often complex and timely and computationally difficult to solve**

Mixed Integer Quadratic Program

Melton & Ingalls [3]; Method to improve driver home time:

- **Determines locations where truck drivers can relay trailer equipment to increase driver home time and to reduce driver driving distances**
  - **Location points established using mathematical programming-mixed integer quadratic program**
- **Method to improve the truckload driving job but not at the expense of the transportation carrier and customer**

Mathematical Program Includes:

1. **Driver home time**
2. **Driver turnover costs based on historical data for avg. weekly driving distances**
3. **Equipment maintenance and depreciation costs**
4. **Driver hiring charges/labor costs for areas of the country**
5. **Miles driven per week**
6. **Relay setup cost**
7. **Driver wages**

Mixed Integer Quadratic Program

Melton & Ingalls [3]; Mathematical Program

Objective:

Minimize

(1) $\sum_{(ij)\epsilon P} f^{ij} \sum_{k,l \epsilon P^{ij}:k<l} c_{kl}^{ij} d_{kl}^{ij} y_{kl}^{ij} +$
(2) $\sum_{k\epsilon N} e_k z_k +$
(3) $\tau * u * q +$
(4) $b * q$

Constraints:

(1) $\sum_{l\epsilon P^{ij}:k<l,\ d_{kl}^{ij} \leq \theta} y_{kl}^{ij} = z_k$ for all $(ij)\epsilon$ **P** and $k \epsilon P^{ij} \setminus \{i,j\}$

(2) $\sum_{l\epsilon P^{ij}:l<k,\ d_{lk}^{ij} \leq \theta} y_{lk}^{ij} = z_k$ for all $(ij)\epsilon$ **P** and $k \epsilon P^{ij} \setminus \{i,j\}$

(3) $\sum_{l \epsilon P^{ij}:l<j,\ d_{lj}^{ij} \leq \theta} y_{lj}^{ij} = 1$ for all $(ij)\epsilon$ **P**

(4) $\sum_{l \epsilon P^{ij}:i<l,\ d_{il}^{ij} \leq \theta} y_{il}^{ij} = 1$ for all $(ij)\epsilon$ **P**

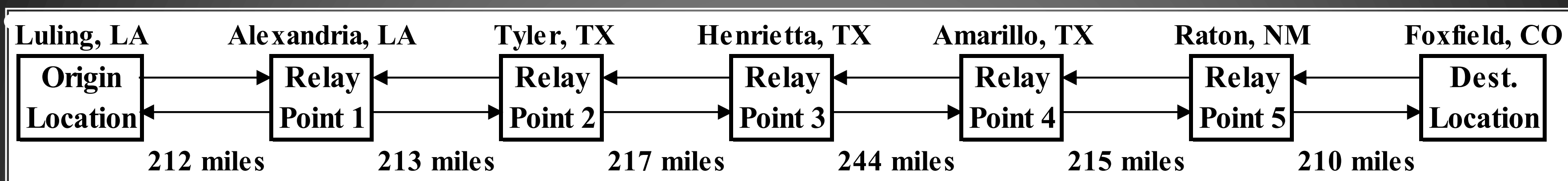
(5) $\sum_{d=0}^{r} \lambda_d m_d = (1/[2\sum_{(ij)\epsilon P} f^{ij} d_{ij}^{ij}]) * \sum_{(ij)\epsilon P} [(2\sum_{k,l \epsilon P^{ij}:k<l} y_{kl}^{ij} d_{kl}^{ij} f^{ij}/(\rho_{kl}^{ij} * w * h)) +$
$(2{*}f^{ij}/(w * h)) + (\sum_{(ij)\epsilon P} f^{ij} \sum_{k\epsilon P^{ij}} e_k z_k \psi \,/\, (w * h))]$

(6) $\sum_{i=0}^{r} \lambda_i = 1, \lambda_i \geq 0, i = 0, \dots, r$
(7) $\sum_{i=1}^{r} \delta_i = 1, \delta_i \epsilon \{0,1\}, i = 0, \dots, r$
(8) $\lambda_0 \leq \delta_1$
(9) $\lambda_i \leq \delta_i + \delta_{i+1}, i = 1, \dots, r-1$
(10) $\lambda_r \leq \delta_r$
(11) $\tau = \sum_{i=0}^{r} \lambda_i t_i$
(12) $q = \sum_{(ij)\epsilon P} [(2\sum_{k,l \epsilon P^{ij}:k<l} y_{kl}^{ij} d_{kl}^{ij} f^{ij}/(\rho_{kl}^{ij} * w * h)) + (2{*}f^{ij}/(w * h)) +$
$(\sum_{(ij)\epsilon P} f^{ij} \sum_{k\epsilon P^{ij}} e_k z_k \psi \,/\, (w * h))]$
(13) $y_{kl}^{ij} \epsilon \{0,1\}$ for all $k,l \epsilon P^{ij}$ and for all $(ij)\epsilon$ **P**
(14) $z_k \epsilon \{0,1\}$ for all k; $k \epsilon N$

Mixed Integer Quadratic Program

Melton & Ingalls [3]- Driver route using relay points

- Luling, LA to Foxfield, CO path
- Relay points picked in: Alexandria, LA; Tyler, TX; Henrietta, TX; Amarillo, TX; Raton, NM (each driving loop ranges from 210 miles to 244 miles)



Site Selection Location Tools Used in Industry

- LLamasoft Supply Chain Guru
- Maptitude
- Accruent
- Microsoft Excel

Comments

- Site selection software- few options in the market
- Site selection location is important for long-term solutions (e.g. new DC needed in 5 years based on projected customer demand growth)
- Locations are often locked in for a period of years and are not mobile
  - Once a 3M square feet DC is built for $60M, the company is locked to the location and cost.
  - Long-term building leases can be costly to terminate

References

[1] Heizer, J., Render, B., Munson, C. *Operations Management: Sustainability and Supply Chain Management*. 12th ed., Pearson, 2017.

[2] Ragsdale, Cliff. *Spreadsheet Modeling & Decision Analysis: A Practical Introduction to Business Analytics*. 7th ed., Cengage Learning, 2015.

[3] Melton, K. D., Ingalls, R. "Utilizing Relay Points to Improve the Truckload Driving Job." *International Journal of Supply Chain* 1 3 (2012): 1-10.

M.S. in Operations Management At a Glance:

- Online and Live Course Options
- 30 Credit Hours (10 Graduate Courses)
  - With up to 4 pre-requisite classes
- Five 8-week Sessions Per Year
- No GRE/GMAT required with 3.0 Bachelor's GPA
- Total Program Cost is $12,000 to $15,000 (depending on pre-reqs needed)
- Can be completed in one year, but you have up to six years to complete

PROJECT MANAGEMENT GRADUATE CERTIFICATE AT A GLANCE:

- Online and Live Course Options
- 12 Credit Hours (4 Graduate Courses)
- 8-week sessions
- Five Enrollment Periods: Aug, Oct, Jan, Mar, May
- Entire Program Cost: Approximately $5,000
- 2.5 GPA with a Bachelor's Degree required for admission
- Certificate courses can also count toward MSOM degree