IENG/MANE112

Facility Location and Layout

1. Facility: a separate unit of production or service. It interacts with other facilities and/or companies.

Examples:

1. Complete production unit,
2. Warehouse,
3. Distribution center. Factories (e.g. shoe, shirt, suit) of a brand → distribution center → retailers

This is a possible structure of a supply chain.

2. Layout: positioning units and/or machines internal the facility

3. Facility management: decision on the location of the facility and its layout.

4. Selection on the location of the facility.

The decision is twofold: territory/state/country and site

4.1 Decision No. 1: territory

Important factors

Nearness of markets	Water	Local regulations
Nearness of raw material	Available labor	Climate
Available transportation options: highway, train, airport, ship	Taxation and financial support	Fire and police protection
Electric power	Labor laws	Community attitude

Example. Steel factory needs :

1. Iron ore.
2. Coal.
3. Water.

Iron and coal is huge quantity bulk. Their cheapest transportation is ship.

Factors which must be present: labor, energy supply, water, and protection.

Cost effecting factors: nearness of market and raw material, transportation options, taxation and financial support, and labor.

Business environment: labor laws, local regulations, stability of taxation, and community attitude.

Fixed cost: investment (building and technology) and initial support (e.g. area)

Variable cost: transportation and labor.

Most frequent objective function: minimization of transportation cost.

Other objective functions. Fixed cost and variable cost must be connected by discounting factor.

5. Evaluation of potential facilities with Transportation Problem (TP)

5.1 The Transportation Problem

One typical application of the transportation problem is transporting stone from mines to road constructions. Even asphalt roads in general and particularly the asphalt itself are produced mainly from stone. In the original form of the transportation problem it is assumed that the total quantity offered by the mines equals the total quantity required by the road constructions. It is also assumed that there is no difference between the qualities of the different mines. In that situation the most economic way to organize the transportation is to minimize the total transportation cost. The variables (unknowns) of the model are the quantities transported from a particular mine to a particular road construction. The total transportation cost is the objective function of the optimization problem. It is supposed to be linear, i.e. the transportation cost from any mine to any road construction is proportional to the transported quantity. There are two sets of linear constraints. For all mines it must be true that the total quantity transported from the mine must be equal to the quantity offered by the mine. Similarly for all road construction it must be true that the total quantity which is transported to it must be equal to its demand. Finally all variables must be nonnegative. A negative value means that the stone is transported from the road construction to the mine what has no sense.

The key properties of stone are the followings. It is a single product produced and consumed on several places. Stone is produced and used in quantities which are significantly larger than the capacity of any kind of transportation device. It can be divided arbitrarily, i.e. it is bulk. If a product has these properties then its transportation can be optimized by the transportation problem.

Example. *Two stone mines supply three road constructions with stone. The production of the mine in million tons is 7 and 12. The quantities required by the road constructions are 5, 6 and 8. The unit costs of the transportation are the followings:*

3	*4*	*5*
7	*6*	*8*

Give the linear programming model of the problem.

Denote by x_{ij} the quantity which is transported from mine i to road construction j ($i=1,2$, $j=1,2,3$). As the total offered quantity (7+12=19) equals the total demand (5+6+8=19), everything must be transported from the mines:

$$x_{11}+ x_{12}+ x_{13} = 7$$

$$x_{21}+ x_{22}+ x_{23} = 12.$$

Similarly, the demands of the road constructions must be satisfied, i.e.

$x_{11} + x_{21} = 5$

$x_{12} + x_{22} = 6$

$x_{13} + x_{23} = 8.$

The transported quantities are nonnegative:

$x_{ij} \geq 0 \quad i=1,2, j=1,2,3.$

The transportation cost is proportional to the transported quantity in each relation. Hence the total transportation cost which is the objective function of the problem is

min($3x_{11} + 4x_{12} + 5x_{13} + 7x_{21} + 6x_{22} + 8x_{23}$).

Example:

Production facilities: Tulsa, Tempe. Distribution centers: San Francisco, Lincoln, Cleveland, Phoenix, and Washington DC. Potential new facilities: Youngstown, and Sparta. Transportation and production costs:

	Washington DC	**Cleveland**	**Lincoln**	**San Francisco**	**Phoenix**	**Weekly capacity**	**Pr. cost**
Tulsa	5.00	3.00	2.00	3.00	2.00	7,000	$75
Tempe	6.50	5.00	3.50	1.50	0.20	5,500	$70
Youngstown	1.50	0.50	1.80	6.50	5.00	12,500	$70
Sparta	3.80	5.00	8.00	7.50	8.00	12,500	$67
Weekly Demand	5,000	6,000	4,000	7,000	3,000		

Evaluation of Youngstown with the "cheapest cost assignment" heuristics of TP.

	Washington DC	**Cleveland**	**Lincoln**	**San Francisco**	**Phoenix**	**Weekly capacity**
Tulsa	80.00	78.00	77.00 6 2,500	78.00 7 4,500	77.00	7,000
Tempe	76.50	75.00	73.50	71.50 3 2,500	70.20 1 3,000	5,500
Youngstown	71.50 4 5,000	70.50 2 6,000	71.80 5 1,500	76.50	75.00	12,500
Weekly demand	5,000	6,000	4,000	7,000	3,000	

5.2 Measuring distances

Textbook solution: - long distance: Euclidean distance (l_2) $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$

-short distance: rectilinear (Manhattan, l_1) $|x_1 - x_2| + |y_1 - y_2|$

Real solution: - exact distance based on map

-measured time

-transportation tariff

5.3 The location of a single facility in a city having rectangular street system

STEP 1. Order the "x" coordinates. Determine the interval where no more than half of the transportations is left and right.

STEP 2. Order the "y" coordinates. Determine the interval where no more than half of the transportations is left and right.

5.4 Public sector location problems

Emergency services: maximal distance is to be minimized. E.g. first aid must reach all accidents within 15 minutes.

Example.

x	y	transp.	x	y	transp.	x	y	transp.
22.5	5.5	10	29.0	25.0	3	32.5	25.0	1
26.5	9.5	10	30.0	25.0	1	33.0	25.0	1
29.5	14.0	5	29.5	24.5	1	32.5	24.5	1
28.5	24.0	3	32.0	24.5	3	16.0	36.5	5
28.5	24.5	1	32.0	25.0	1	18.0	37.5	4

5.5 Multi-facility location

Constraints:

1. Assignment of demands to facilities
2. Facility capacity constraint
3. Technical constraints
4. Objective function: weighted sum of the transportation cost and invested amount.