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LINEAR PROGRAMMING APPROACH FOR IDENTIFICATION OF INDUSTRIAL LOCATION

Manish Dwivedi, Sanjeev Verma & Jyoti Prakash Pathak
Research Scholar, Singhania University, Pacheri bari , Jhunjhunu, Rajasthan, India

ABSTRACT
Given the spatial distribution of the inputs and output markets, the owners of the factory will have to take the decision about the place where the factory should be located. All potential location for the factory will not be equally economical. Only one of them is to be chosen which will be the most economical. A large number of technical, economic and institutional factors, which exert pull and pressure on location of the factory in varying magnitude, are to be considered. In identifying the appropriate location for any kind of industry some of the factors are of apex importance for eg. Cost of Labour, transportation cost, cost of supply, cost of raw material etc., we can find a number of approaches and models based on these factors, like one given by Alfred Weber, in the form of theory of industrial location. Alfred Weber had taken the reference of 'Launhardt location Triangle', given by W. Launhardt a German Economist. But we can also imagine of a situation where more than one plant is needed to meet the demand of respective customers as in the case of sugar mills. In this paper we will discuss this situation and will try to answer the above question with the help of a model based on the mixed problem of linear programming.

Key words: Industrial location, linear programming, transportation model, constraints, mixed LP problem.

INTRODUCTION

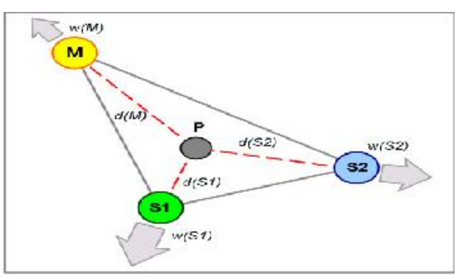
Given the spatial distribution of the inputs and output markets, the owners of the factory will have to take the decision about the place where the factory should be located. All potential location for the factory will not be equally economical. Only one of them is to be chosen which will be the most economical. A large number of technical, economic and institutional factors, which exert pull and pressure on location of the factory in varying magnitude, are to be considered. Some of the factors can be listed as follows:

Table: 1 List of factors affecting the choice of Location

Critical Factors	**Explanation of Critical Factor**
Transportation	Pipeline facilities. Airway facilities. Highway facilities. Railroad facilities. Trucking services. Waterway transportation. Shipping cost of raw material. Cost of finished goods transportation. Availability of postal services. Warehousing and storage facilities. Availability of wholesale outlets.
Labor	Low cost labor. Attitude of workers. Managerial labor. Skilled labor. Wage rates. Unskilled labor. Unions. Educational level of labor. Dependability of labor. Availability of male labor. Availability of female labor. Cost of living. Worker stability.
Raw Materials	Proximity to supplies. Availability of raw materials. Nearness to component parts. Availability of storage facilities for raw materials and components. Location of suppliers. Freight cost.
Markets	Existing consumer market. Existing producer market. Potential consumer market. Anticipation of growth of markets. Shipping costs to market areas. Marketing services. Favorable competitive position. Income trends. Population trends. Consumer characteristics. Location of competitors. Future expansion opportunities. Size of market. Nearness to related industries
Industrial Site	Accessibility of land. Cost of industrial land. Developed industrial park. Space for future

	expansion. Insurance rates. Availability of lending institutions. Closeness to other industries. community industrial development projects. Attitude of financing agents.
Utilities	Attitude of utility agents. Water supply, cost and quality. Disposable facilities of industrial waste. Availability of fuels. Cost of fuels. Availability of electric power. Cost of electric power. Availability of gas. Adequacy of sewage facilities. Availability of coal and nuclear facilities.
Government Attitude	Building ordinances. Zoning codes. Compensation laws. Insurance laws. Safety inspections. Nuisance and stream pollution laws.
Tax Structure	Tax assessment basis. Industrial property tax rates. State corporate tax structure. Tax free operations. State sales tax
International Location Factors	
Political Situation of Foreign Country	Relations with the west. History of country. Stability of regime. Protection against expropriation. Treaties and pacts. Attitude in the United Nations. Type of military alliances. Attitude toward foreign capital.
Global Competition and Survival	Material and labor. Market opportunities. Availability of capital. Proximity to international markets.
Government Regulation	Clarity of corporate investment laws. Regulations concerning joint ventures and mergers. regulations on transfer of earnings out of country. Taxation of foreign owned companies. Foreign ownership laws. Requirements on what percentage of employees may be foreign. Prevalence bureaucratic red tape. Regulations concerning price controls. Requirements for setting up local corporations.
Economic Factors	Standard of living. Per capita income. Strength of currency against US dollar. Balance of payment status. Government aids.

In identifying the appropriate location for any kind of industry the above mentioned factors are considered at a priority, in these factors some of the factors are of apex importance for eg. Cost of Labour, transportation cost, cost of supply, cost of raw material etc., we can find a number of approaches and models based on these factors, like one given by Alfred Weber, in the form of theory of industrial location.



Alfred Weber had taken the reference of 'Launhardt location Triangle', given by W. Launhardt a German Economist.

Weber uses the **location triangle** within which the optimal is always located. The above figure illustrates the issue of minimizing transport costs. Considering a product of w(M) tons to be offered at market M, w(S1) and w(S2) tons of materials coming respectively from S1 and S2 are necessary. The problem resides in finding an optimal factory location P located at the respective distances of d(M), d(S1) and d(S2).

But we can also imagine of a situation where more than one plant is needed to meet the demand of respective customers as in the case of sugar mills. In this paper we will discuss this situation and will try to answer the above with the help of a model based on the mixed problem of linear programming

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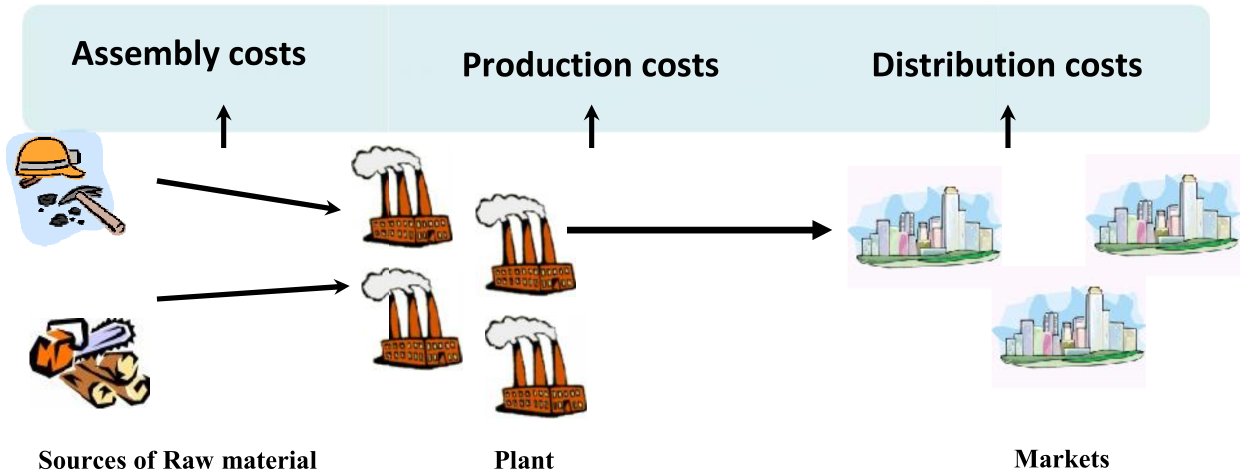

The Model (mixed linear programming)

As we know that the transportation problem is an example of linear programming with continuous variables. The problem of location discussed in this paper is an example of mixed programming. It is the task of linear programming where its variables are continuous.

ASSUMPTIONS OF THE MODEL

1- productivity of the plant is fixed.
2- productivity of the plant is fixed.
3- Demand generated in a given period of time is known.
4- More than one plant is to be installed.
5- The construction cost of the plant or plants is fixed

MATHEMATICAL FORMULATION

There are m industrial plants, which produce goods for n customers with demand for dj units, j = 1, 2, ..., n. The plant construction involves necessary costs for realisation the territorial investment ci (ci = 0) and its productivity pi (pi = 0). Unitary transportation cost of a unit of a product from a plant i to a customer j is aij. We want to select such a plant and its location so that the total cost is minimal and the demand dj is met. If yij denotes the size of freight from the production plant i to a customer j then the following data is needed -

m- the no. of prospective sites for plant location
n- the no. of potential customers
d_j- the no. of units required at destination j, j=1,2,3-------n
A_{ij}- the transportation cost per unit of a product from production plant i to a customer j
p_i- productivity of the i^{th} production plant, i=1,2,3,-----m (p_i=0)
y_{ij}- amount transported from from production plant I to a customer j.
c_i- the construction cost of the i^{th} production plant, i=1,2,3,----m

$$z = \sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij} y_{ij} + \sum_{i=1}^{m} c_i$$

With the following constraints:-

$$\sum_{i=1}^{m} y_{ij} = d_j \qquad \text{j=1,2,------, n.}$$

$$\sum_{j=1}^{n} y_{ij} \le p_i \qquad \text{i =1,2,----, m.}$$

minimum of the function.-
Where $y_{ij} \geq 0$ are continuous variable.
Now if we consider the I^{st} constraint i.e.

$$\sum_{i=1}^{m} y_{ij} = d_j \qquad \text{j=1,2,------, n.}$$

We can see that the amount supplied y_{ij} to different customers is equal to the total demand d_j if we put the available data in the format of a transportation model we can easily satisfy the given constraint.

Customer	Customer 1	Customer 2	Customer 3	-------n	Supply (n_j)
Plant					
m_1	a_{11} y_{11}	a_{12} y_{12}	a_{13} y_{13}	---a_{1n} ------y_{1n}	n_1
m_2	a_{21} y_{21}	a_{22} y_{22}	a_{23} y_{23}	---a_{2n} ------y_{2n}	n_2
m_3	a_{31} y_{31}	a_{32} y_{32}	a_{33} y_{33}	---a_{3n} ------y_{11}	| n_3
Demand (dj)	d1	d2	d3	-----dn	

The above given demand (dj) and supply (n_j) can be given in the linear programming forms follows:-
Minimize (z)= $a_{11} . y_{11} + a_{12} . y_{12} + a_{13} . y_{13}$ +------ $a_{1n} . y_{1n}$

$+ a_{21} . y_{21} + a_{22} . y_{22} + a_{23} . y_{23}$ +------ $a_{2n} . y_{2n}$
$+a_{31} . y_{31} + a_{32} . y_{32} + a_{33} . y_{33}$ +------ $a_{3n} . y_{3n}$

Subject to constraints:-

Requirement Constraint

$a_{11} . y_{11} + a_{21} . y_{21} + a_{31} . y_{31} = d_1$
$a_{12} . y_{12} + a_{22} . y_{22} + a_{32} . y_{32} = d_2$
$a_{13} . y_{13} + a_{23} . y_{23} + a_{33} . y_{33} = d_3$

Supply Constraint

$a_{11} . y_{11} + a_{12} . y_{12} + a_{13} . y_{13}$ +------ $a_{1n} . y_{1n} = n_1$
$a_{21} . y_{21} + a_{22} . y_{22} + a_{23} . y_{23}$ +------ $a_{2n} . y_{2n} = n_2$
$a_{31} . y_{31} + a_{32} . y_{32} + a_{33} . y_{33}$ +------ $a_{3n} . y_{3n} = n_3$

total demand will be equal to total supply i.e . $d_i = n_j$ and $y_{ij} \geq 0$ for all i & j.

By applying the above mentioned algorithm we can find out the location of the plant from where we can transport the maximum no. of units produced at i^{th} plant to j^{th} customer.

Now moving on to our next constraint i.e.

$$\sum_{j=1}^{n} y_{ij} \leq p_i \qquad i = 1,2,\text{----}, m.$$

As we have taken 'm' no. of sites (location) in our assumption, the no. of location may be greater than the no. of actual plant installed. Hence we can also assume that productivity (p_i) of some of the plants may be equal to zero. If we assume that all the production plants with productivity p_i (where i=0 also) are added, we will get a set of prospective location i.e. z_r where (r=1,2,3,----k) and if the sites with $p_{i=0}$ are identified (k-m) i.e. he sites with $p_{i=0}$ will not be considered in the actual permutation.

Hence,

$$k! - \frac{k!}{(k-m)!} = p_{i=1,2,3.....m}$$

After identifying the sites with p_i (i=1,2,3,-----m) where productivity of each plant is fixed then we cannot supply the product to any customer or customers, more than the productivity of a particular plant.

CONCLUSION

This model refers to the production plants i.e. sugar mills etc. where there is a considerable influence of fixed cost on plant functioning costs. This model of localization finds its application in small areas as well as in areas of medium size.

We can even carry out the simulation study of different hypothetical economic and social situation such as changes of transport charges, change in fuel cost, socio-political changes etc.

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