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INDUSTRIAL PLANTS

Chapter five:

Location of industrial plants and choice of the land

DOUBLE MASTER DEGREE IN

“PRODUCTION ENGINEERING AND MANAGEMENT”

CAMPUS OF PORDENONE

UNIVERSITY OF TRIESTE

Generality

The location where to build the establishment is chosen at two different times and often in later times:

- **choice of the territory in which the factory will be built**

  Is made taking into account the economic-policy guidelines (programming) employed on national or regional basis;

- **choice (and purchase) of land needed**

  It can be done only when the project of the new establishment is developed, at least in principle, and thus is known the form and extent of the area required.

Locational factors for territory characterization

A **selection criterion for the selection of the land** is tied to national or regional planning, which often are accompanied by tax breaks, government grants, loans at subsidized interest rates etc. Include:

a) **construction costs**

They vary depending on the land and climatic conditions, and the choice localization of the establishment should take account of such differences;

b) **market to which it is addressed**

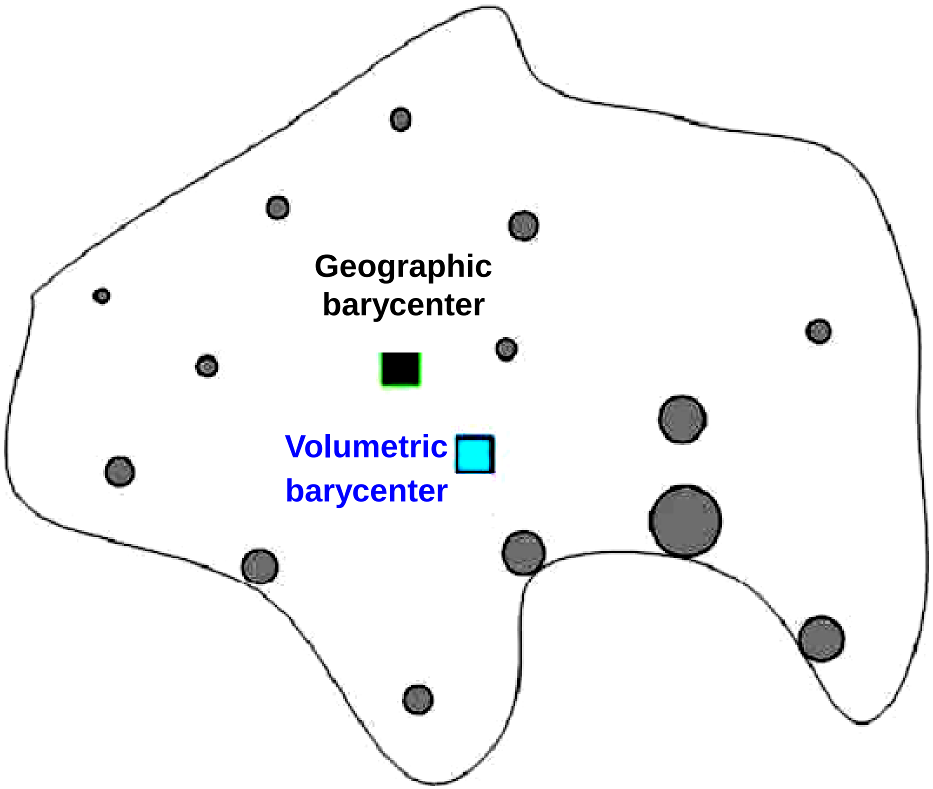
If the market is concentrated is convenient to realize the industrial plant in the vicinity of the same. If the market is distributed, the choice is less constrained, and then a policy could be to achieve the establishment within the geographical center of gravity, ponderal or volumetric, of the various markets (lower distribution costs)

Locational factors for territory characterization

Selection criterion for the choice of the territory

b) market to which it is addressed

Finding the barycenter of a market made up of more centers of consumption: we have identified two centers of gravity, **geographic** and **volumetric**



Selection criterion for the choice of the territory

b) market to which it is addressed

Suppose you calculate optimal location of the following assumptions:

- we assume a single establishment;
- demand concentrated in the "poles market";
- distances equal to segments that connect establishment and markets.

You should consider:

- coordinates of the establishment and of each market;
- distance between the establishment and each market;
- total distance traveled for supply the markets.

If the establishment has coordinates (x, y) and the i-th market has coordinates (x_i, y_i), the distance will be considered:

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2}$$

Selection criterion for the choice of the territory

b) market to which it is addressed

If the number of trips required to supply the generic polo i-th is equal to s_i, you will find that the total distance traveled in the time period (at example the year) will be:

$$\sum_i (s_i \cdot d_i) = \sum_i \left(s_i \cdot \sqrt{(x - x_i)^2 + (y - y_i)^2} \right)$$

The most convenient location will be the one that minimizes this value.

Example:

You should evaluate the location of a warehouse that must supply 4 customers with the following characteristics:

Customer	Coordinate x (km)	Coordinate y (km)	Shipping/year
1	5	10	200
2	10	5	150
3	0	12	200
4	12	0	300

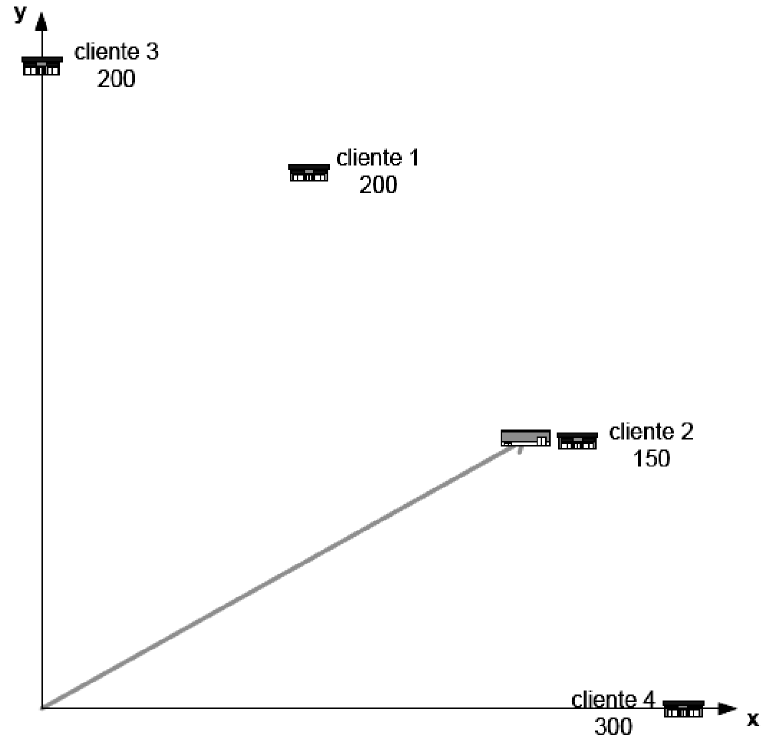
Locational factors for territory characterization

Selection criterion for the choice of the territory

b) market to which it is addressed

The solution is that which provides for the presence of the stock near the customer 2. In summary, we show the values of the four conditions in which the stock moves to a position of:

customer 1: 58.000, customer 2: 48.500, customer 3: 114.550, customer 4:102.400 (values in km/year)



Selection criterion for the choice of the territory

c) type of raw materials that employ

This factor is partly influenced by transport costs, for some companies should be placed close to sources of supply of rough materials or raw materials.

- if the company uses a single raw material, without loss of weight along the process, the new establishment can be located or from the power source of the material or at the market to buy or at an intermediate point;
- if the starting raw material is still one, but along the manufacturing process will have decreases in weight and volume, the new establishment is located at the power source of the material;
- if raw materials are available everywhere, prevails evidently the influence of the market.

Locational factors for territory characterization

Selection criterion for the choice of the territory

d) transport outside the production plant

You need to choose the location of the new establishment that corresponds to the minimum total unit cost of raw materials from the market and purchase the product that reaches the market sales.

In the case consider the location of a establishment for the processing of minerals (plant agglomeration):

- case of the installation of agglomeration of the mineral at the mineral where the ore is extracted (ad example siderite):

  C_m = purchase cost of the mineral;

  C_l = cost of production of iron ore;

  C_t = cost of transporting iron ore agglomeration at the steel plant;

  L = distance between the plant of agglomeration and utilization plant of the agglomerated;

  t = mineral content in the material purchased.

Selection criterion for the choice of the territory

d) transport outside the production plant

The unit cost of iron ore agglomerated at destination is:

$$C_1 = \frac{C_m + C_l}{t} + C_t \cdot L$$

- case of the location of the mineral agglomerated plant at the integrated steel plant cycle:

C_m = purchase cost of the mineral;

C_l' = cost of production of iron ore;

C_t' = cost of transporting iron ore containing t of ore of steel plant;

L = distance between the plant of agglomeration and utilization plant of the agglomerated.

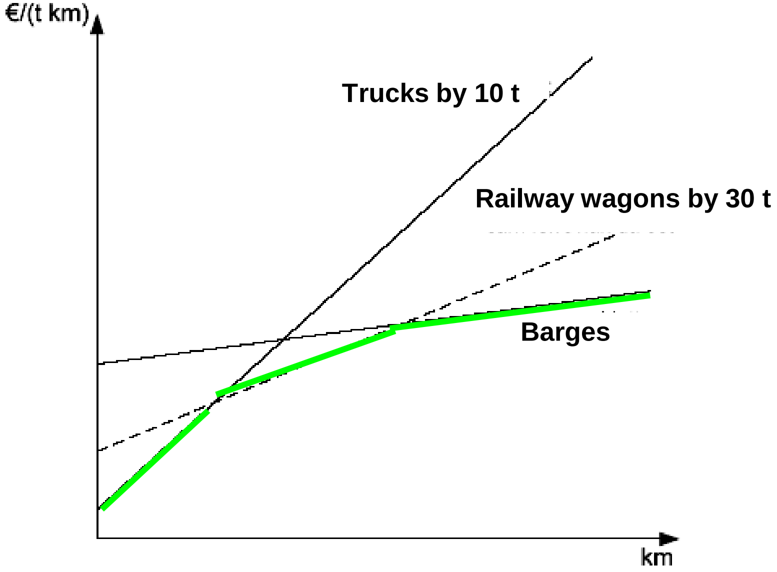
The unit cost of iron ore agglomerate at the destination is:

$$C_2 = \frac{C_m + C_l^{'} + C_t^{'} \cdot L}{t}$$

Selection criterion for the choice of the territory

d) transport outside the production plant

Not considering other constraints (technological and environmental regulations), you would choose the cheapest option between two alternatives. Interesting is the change in the unit costs of travel in relation to the means of transport used as a function of the distances to be traveled, even if in these cases one must also consider the constraint of the presence of appropriate infrastructure to reach the market of purchase or sale of the product.



Selection criterion for the choice of the territory

e) energy supply

In addition to electricity, which is necessary in almost all factories, both for power supply the production systems, both for lighting, it can take other forms of energy: gas, coal, fuel oil etc.

The available energy of an area should be carefully examined, not neglecting to ensure continuity of supply, cost etc.

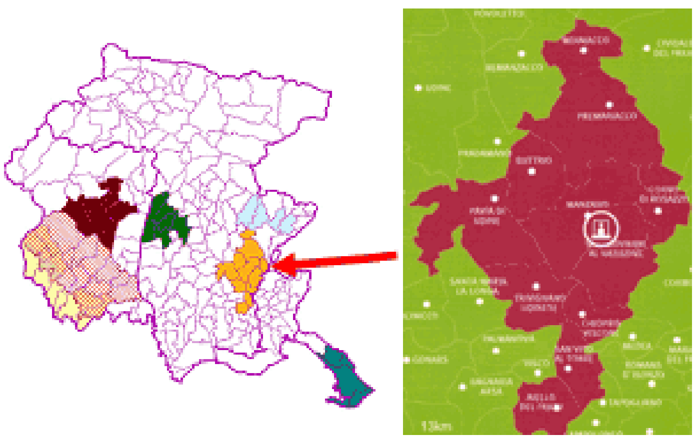
Selection criterion for the choice of the territory

f) presence of manpower

The territory must be present labor required to the production needs of the new establishment.

The chances of finding enough skilled workers are greater in magnitude in the vicinity of large industrial centers.

In some cases, the skilled manpower is more than in the large industrial cities, in areas with a long tradition of working in a specific activity (*industrial districts*).



Industrial District of Chair

Choice of land

The main factors that may affect the choice of land are:

a) analysis of the plan regulator

The choice of location of a establishment must take into account the *requirements of applicable legislation*.

You should not build establishments whose works *prove dangerous, noisy or produce fumes harmful to health*, in the vicinity of civilian homes or areas constrained by special requirements (landscape protection etc.).

Choice of land

The main factors that may affect the choice of land are:

b) external transport

They influence:

- final cost of products;
- loading/unloading of finished goods, raw materials and components;
- entrances and exits (roads, etc.) provided in the new plant.

Should be preferred the soil which match the lower costs of transportation of materials received by the establishment and that they come out.

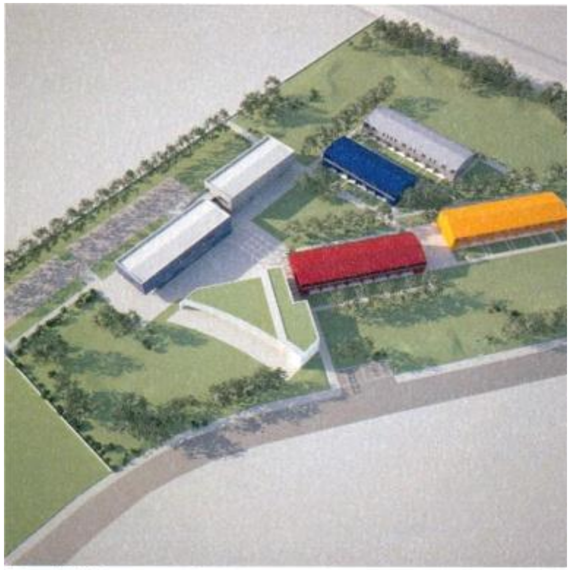
Choice of land

The main factors that may affect the choice of land are:

c) distance from place of residence of workers

It is important to consider the convenience of transportation and the time required for such transfers.

Some companies provide to purchase suitable areas in the vicinity of the factory, to provide them with appropriate infrastructure and pass them on favorable terms to their employees or contribute to the costs of housing associations made between the employees themselves.



Danieli Factory Campus

Asilo Nido Cecilia Danieli

Choice of land

The main factors that may affect the choice of land are:

d) water supply

Essential to locate the new establishment in an area that has *water availability*.

The shallow aquifer is *sufficiently deep* or require foundation work for buildings and facilities, which can be particularly onerous.

Choice of land

The main factors that may affect the choice of land are:

e) communication routes

The new plant should be constructed in the vicinity of one or more communication routes (road, rail etc.).

Choice of land

The main factors that may affect the choice of land are:

f) exposure to wind

If the plant produces *fumes, dust, odors, noise* etc. you must place it in a favorable position with respect to prevailing winds, regardless of any facility or assistance essential for reducing pollutants.

Choice of land

The main factors that may affect the choice of land are:

g) conditions of the soil

It should have good resistance to loads induced by the foundations of buildings and installations, do not be too steep or rough to avoid significant costs of leveling and should not be subject to flooding, floods, etc.

Choice of land

The main factors that may affect the choice of land are:

h) easements and restrictions or boundaries

A soil encumbered by easements, liens or from adjoining soils belonging to institutions or individuals whose work contrasts with that of the building facility, involves the *conclusion of agreements* or *compromises*, with *costs not always predictable in advance*.

If they exist, you must perform the signing of agreements or compromises between the two parties, with expenses not foreseeable in advance

Choice of land

The main factors that may affect the choice of land are:

i) extension of the soil and its cost

The soil must have the *extension* and the *form* identified by the study of the general plan of the establishment for future expansion.

Choice of land

The main factors that may affect the choice of land are:

j) refuse

Many plants produce *waste materials* in size and with characteristics such that their removal or disposal can be a *very critical problem* (think of water pollution, solid waste and muddy, the scraps etc.).

Choice of land

The main factors that may affect the choice of land are:

k) presence of complementary businesses or auxiliary

An industrial plant in need of materials, services and assistance provided by other companies (branch or subsidiary).

It 's so important to their neighborhood.

Choice of land

The main factors that may affect the choice of land are:

I) acquisition cost

The cost of soil and related works of accommodation should be minimal.

Industrial decentralization

The **place** where realize of the industrial establishment, within a predetermined area, can be chosen in *position decentralized*, *peripheral* or *close to urban centers*.

Favor the **industrial decentralization**:

a) procurement of higher tracts of soil for future expansion;

b) possibility of financial incentives or favorable credit, and advantageous organizations in the area.

The **industrial decentralization** allows of:

- contain the phenomenon of urbanization;
- enhance the economic aspect in the decentralized areas;
- avoid proximity to urbanized areas of the business headquarters;
- relieve traffic in urban areas.

Negative effects of **decentralization** are:

- difficulty in finding skilled manpower;
- remoteness of the suppliers of materials required.

Methods for location choices

The **study and solution a location problem of an industrial plant** must take into account the qualitative and quantitative factors, although it is difficult combination thereof, so that the procedure is:

- determination of a solution with a quantitative analytical procedures;
- modification of the analytical solution obtained on the basis of quality factors;
- determination of the final solution.

To determine the **optimal solution**, it may take several **methods**:

- method of scoring;
- method of production costs;
- method based only on transport costs;
- method of the median;
- method of the center.

Only the first method is qualitative, while the other four are quantitative.

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

a) method of scoring

Is a method for the choice location between two or more alternatives. The method comprises:

a) list of solutions alternatives of location considered (j = 1, 2, …….., n)

b) identification and listing of the critical factors for each possible location (i = 1, 2, ……, m) definable based on the specific needs of the production cycle

c) assignment of a weight p_i, in %, to each of m critical factors, indicating its influence on the choice of location. The values derived from the importance of each factor with respect to total production costs and other considerations (those related to industrial development area, those concerning the possibility of future expansions etc.);

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

a) method of scoring

Is a method for the choice location between two or more alternatives. The method comprises:

d) assignment of a numerical evaluation V_{ij} location of each j-th on the basis of each critical factor i-th

e) calculation of the partial scores determined by the product of the weight p_i and the numerical evaluation V_{ij}

f) determining the overall score for each location j-th through the relation (con j = 1, 2, ……, n)

$$P_j = \sum_{i=1}^{m} \left(p_i \cdot V_{ij} \right)$$

g) localization choice with the highest overall score $P_{j\,max}$.

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

a) method of scoring

Suppose we analyze the example:

Factor critical location	Weight	Evaluation			Score		
		Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Energy	15	4	7	5	60	105	75
Manpower	35	8	2	6	280	70	210
Commodities	25	3	9	7	75	225	175
Market	15	4	7	6	60	105	90
Other	10	8	2	4	80	30	40
Total	100	-	-	-	555	535	590

In this example, area location 3 is preferable.

The assessment requires considerable experience, in fact, just change the assessment area for manpower location 3 from 6 to 4 and there is a score value of the location 3 equal to 520, which move the preference area location 1

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

b) method of production costs

The method consists in evaluating the costs of each element constituting the industrial plant to be realized (investment and operating costs). Do not considered the costs intangible (for example the social costs).

It performs a comparison between the two or more choices locations and do not considered the cost items equal, but only those different. It is considered as the best solution that has lower capital and operating costs per year.

If the two entries may not agree for the same solution location, you should consider the investment costs per year (for instance, examining the depreciation of machinery, buildings etc.).

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

b) method of production costs

Example

Investiment costs	Area of location		Annual costs operating	Area of location	
	1	2		1	2
Soil	100	80	Transport raw material	70	80
Buildings and facilities	750	650	Trasport finished goods	320	240
Escavations	30	45	Trasport waste to landfill	10	5
Leveling	55	50	Labor	440	385
Piling	25	32	Energy	190	185
Connection with the railroad	15	20			
Connection with the road	existent	20			
Water supply	20	43			
TOTAL	995	940	TOTAL	1030	895

It is noted that the solution is located in area 2 is analyzing the investment costs that those per year of operation

Methods for location choices

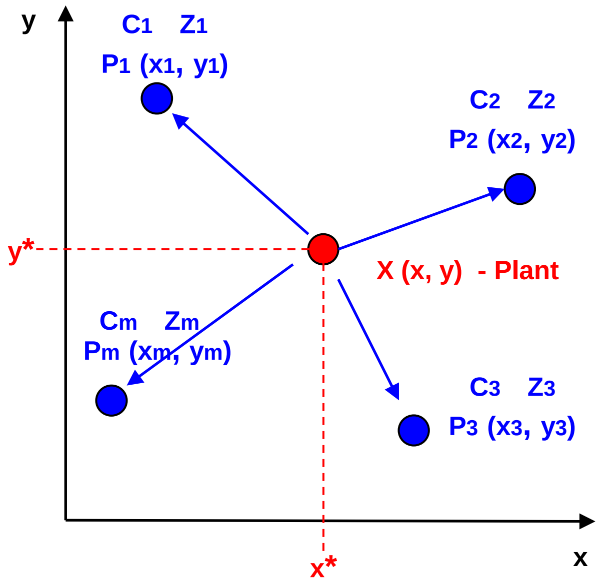
To determine the **optimal solution**, it may take several **methods**:

c) method based only on transport costs

This method tries to choose the area of the industrial location considering only one parameter of influence: the cost of transportation and fixing the others (such as points of sale in the market for finished products or raw material extraction, etc.).

The transportation cost is proportional to the distance traveled.

Denoting by X the production plant of unknown coordinates (x, y):



To determine the **optimal solution**, it may take several **methods**:

c) method based only on transport costs

- P_i (i = 1, 2, ….., m) point of purchasing of material o customer of product;
- $d(X, P_i)$ the distance between X and the generic point P_i;
- C_i the cost per unit of the transport path between X and the generic point P_i;
- Z_i the number of trips between X and the generic point P_i in a unit of time;
- W_i the product between the cost per unit of path (weight):

$$\mathbf{W_i = C_i \cdot Z_i}$$

The total annual cost of transportation CT(X) between the new industrial plant and the m points of sale or supply is determined:

$$C_T(X) = \sum_{i=1}^{m} W_i \cdot d(X, P_i)$$

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

c) method based only on transport costs

The problem finds a solution by minimizing the total annual cost of transportation CT(X), which determines the optimal location of the plant (x*, y*).

The distance d(X, Pi) can be assessed by considering:

- rectangular distance

$$d(X, P_i) = |x - a_i| + |y - b_i|$$

- euclidean distance

$$d(X, P_i) = \sqrt{(x - a_i)^2 + (y - b_i)^2}$$

- euclidean distance to square or barycenter or center of gravity

$$d(X, P_i) = (x - a_i)^2 + (y - b_i)^2$$

To determine the **optimal solution**, it may take several **methods**:

c) method based only on transport costs

Suppose you have 5 providers of a particle board, the coordinates of which, expressed in km, the locations on the Cartesian plane are respectively (0, 0), (5, 15), (10, 20), (15, 5) and (20, 0). The annual number of trips purchased panels are respectively 10, 20, 40, 40 and 30, one wonders what is the location of the industrial plant that will minimize the transport distance.

You consider the cost of transport unit independent of the path and equal to C_i = 1,00 €/km, you can assume $W_i = Z_i$ and is supposed to use a road transport with the assumption of Euclidean distances squared.

The objective function to minimize is:

$$C_T(X) = \sum_{i=1}^{m} W_i \cdot \left[(x - a_i)^2 + (y - b_i)^2 \right]$$

To determine the **optimal solution**, it may take several **methods**:

c) method based only on transport costs

from which:

$$x^* = \frac{\sum_{i=1}^{5} a_i \cdot W_i}{\sum_{i=1}^{5} W_i} = \frac{(0 \cdot 10 + 5 \cdot 20 + 10 \cdot 40 + 15 \cdot 40 + 20 \cdot 30)}{(10 + 20 + 40 + 40 + 30)} = \frac{1700}{130} = 12{,}143 \ km$$

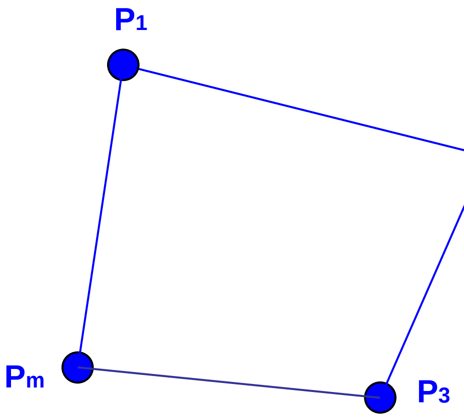
$$y^* = \frac{\sum_{i=1}^{5} b_i \cdot W_i}{\sum_{i=1}^{5} W_i} = \frac{(0 \cdot 10 + 15 \cdot 20 + 20 \cdot 40 + 5 \cdot 40 + 0 \cdot 30)}{(10 + 20 + 40 + 40 + 30)} = \frac{1300}{130} = 9{,}286 \ km$$

To determine the **optimal solution**, it may take several **methods**:

d) method of the median

The resolution involves the use of graphics non-oriented. Suppose you need to find the optimal position of the location of an industrial plant compared m points P_i (i = 1, 2, …., m) which are, for example, points of sale in the market for finished products, points extraction of raw materials etc.

Each vertex of the graph represents the position of one of the m points P_i.



To determine the **optimal solution**, it may take several **methods**:

d) method of the median

Each element of the graph connects two points on the graph itself. It indicates:

- $d(P_i, P_j)$ the distance between two vertices for each pair (P_i, P_j);
- $W(P_i)$ the weight of the vertex P_i;
- $d(X, Y)$ the distance between two generic points of the graph.

We define the median of G any point x of G which minimizes the function:

$$F(x) = \frac{1}{[P]} \cdot \sum_{i=1}^{m} d(X, P_i) \cdot W_i$$

In a connected undirected graph G there exists at least one vertex P which is also the median (Hakimi's theorem).

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

d) method of the median

To determine the median applies the following algorithm:

- determining the matrix $D(G) = [d(P_i,P_j)]$ of the distances between each pair of vertices;
- multiply each j-th column for the weight $W(P_i)$, in this way we obtain the matrix D'(G);
- summing the elements of each row D'(G);
- choose the g-th row corresponds to the minimum amount. The summit P_g is the median of G.

To determine the **optimal solution**, it may take several **methods**:

d) method of the median

Example: Consider the matrix of distances between 5 suppliers

Point	1	2	3	4	5
1	0	20	30	40	30
2	20	0	20	30	10
3	25	20	0	10	5
4	40	30	10	0	20
5	30	10	5	20	0

The weight of each individual market is assigned according to the number of trips alleged between the industrial plant and the suppliers. It carries the product of distances to the respective weights and summing the terms in each row we have:

Point	1	Weight	2	Point	3	Point	4	Point	5	Point	Sum row	
1	0	2	20	1	25	3	40	1	30	2	195	
2	20	2	0	1	20	3	30	1	10	2	150	
3	25	2	20	1	0	3	10	1	5	2	90	Median
4	40	2	30	1	10	3	0	1	20	2	180	
5	30	2	10	1	5	3	20	1	0	2	105	

The vertex indicated by point 3 represents the median of G.

Methods for location choices

To determine the **optimal solution**, it may take several **methods**:

e) method of the center

Suppose we know an undirected graph and connected with a archs of arbitrary length and vertices with arbitrary weights, both positive quantities, we define eccentricity of a point X the quantity

$$E(X) = \max\left[d(X, P_i) \cdot W(P_i)\right]$$

that represents the distance weighing of the generic point X from the vertex farther. Each point with minimum eccentricity is called the absolute center, while the vertex with minimum eccentricity is called the center of vertex.

To determine the **optimal solution**, it may take several **methods**:

e) method of the center

This method minimizes the distance between the generic point (suppliers or buyers market) P_i and the industrial plant at the farthest point (worst case). You can apply the following algorithm:

- determining the matrix D(G) = [d_{ij}] of the distances between each pair of vertex(P_i, P_j);
- multiply each j-th column for the weight W(P_i);
- determine the maximum on each line to obtain:

$$E(X) = \max\left[d(X, P_i) \cdot W(P_i)\right]$$

- choose the minimum value among all E(P_i) that corresponds to the center of the vertex X.

To determine the **optimal solution**, it may take several **methods**:

e) method of the center

Example: Consider as an example the matrix of distances between 5 suppliers

Punt	1	2	3	4	5
1	0	20	25	40	30
2	20	0	20	30	10
3	25	20	0	10	5
4	40	30	10	0	20
5	30	10	5	20	0

The weight of each individual market is assigned according to the number of trips between the alleged industrial plant and suppliers. It performs the product of the distances to the respective weights and it is considered for each row the maximum value (eccentricity)

Point	1	Weight	2	Weight	3	Weight	4	Weight	5	Weight	Max value	
1	0	2	20	1	25	3	40	1	30	2	75	
2	20	2	0	1	20	3	30	1	10	2	60	
3	25	2	20	1	0	3	10	1	5	2	50	center
4	40	2	30	1	10	3	0	1	20	2	80	
5	30	2	10	1	5	3	20	1	0	2	60	

The vertex indicated by point 3 represents the center of G