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INDUSTRIAL PLANTS

Chapter seven:

Study of plant layout – first part

DOUBLE DEGREE MASTER IN

“PRODUCTION ENGINEERING AND MANAGEMENT”

CAMPUS OF PORDENONE

UNIVERSITY OF TRIESTE

Generality

The **study of plant layout** is the process that leads to the ***design of the accommodation plano-altimetric of an industrial plant***. This project is therefore the disposal of machinery, equipment, operators and materials.

Study is required:

- **at the beginning of the production of a new product;**
- **if the change in market demand is significant;**
- **in case of obsolescence of existing plants;**
- **to improve safety and/or working conditions.**

You can use several solutions:

- **design a new plant;**
- **rearrange the existing machines in the area available;**
- **introduce improvements located in correspondence of certain operations.**

Generality

The objectives of a study of the plant layout are:

- **the best use of the space available;**
- **minimize the costs associated with the internal transport of materials;**
- **make possible future extensions through an overall plan and rational;**
- **ensure satisfactory working conditions and safety;**
- **contain, as possible, the investment capital.**

The study can be done in three phases:

a) collection and data analysis starting;
b) search of possible solutions;
c) choose the best solution.

Study phases of plant layout

The **collection phase and analysis of the initial data** provides the elements needed in the study of plant layout:

- determine what will be produced;
- determine the quantity to be produced;
- determine which components will be made internally and which externally;
- determine the necessary operations;
- determine the sequences of operations (cycles);
- establish the standard times for operations.

At this stage the most important moments are:

- the analysis of the production process;
- the analysis of the current layout of the plant (if any).

Study phases of plant layout

In the **search phase of the study of possible solutions** to plant layout, is seek workable solutions taking account of:

- types of machining operations;
- possible internal handling systems;
- workplace.

Collection and analysis of the production process

In all industrial plants can always identify a schematization of the unfolding ideal ordered subsequent operations or phases, which in their entirety achieve the purpose for which the plant is intended.

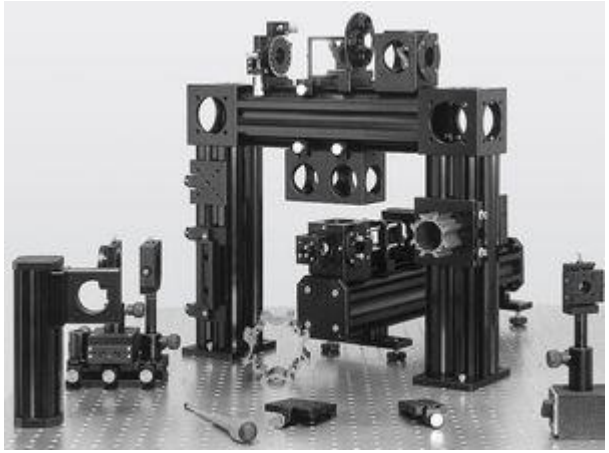
Is identified with ***processing*** the procedure which, starting from a certain material, it subsequently changes the shape, with or without changes in volume, and sometimes alters the substance up to obtain the finished product.

It intends to ***extension*** also those operations consisting in simple movements, which do not alter the starting material, such as, for example, in a silo for storage of grain, in a refrigerator for storage of foodstuffs, etc.

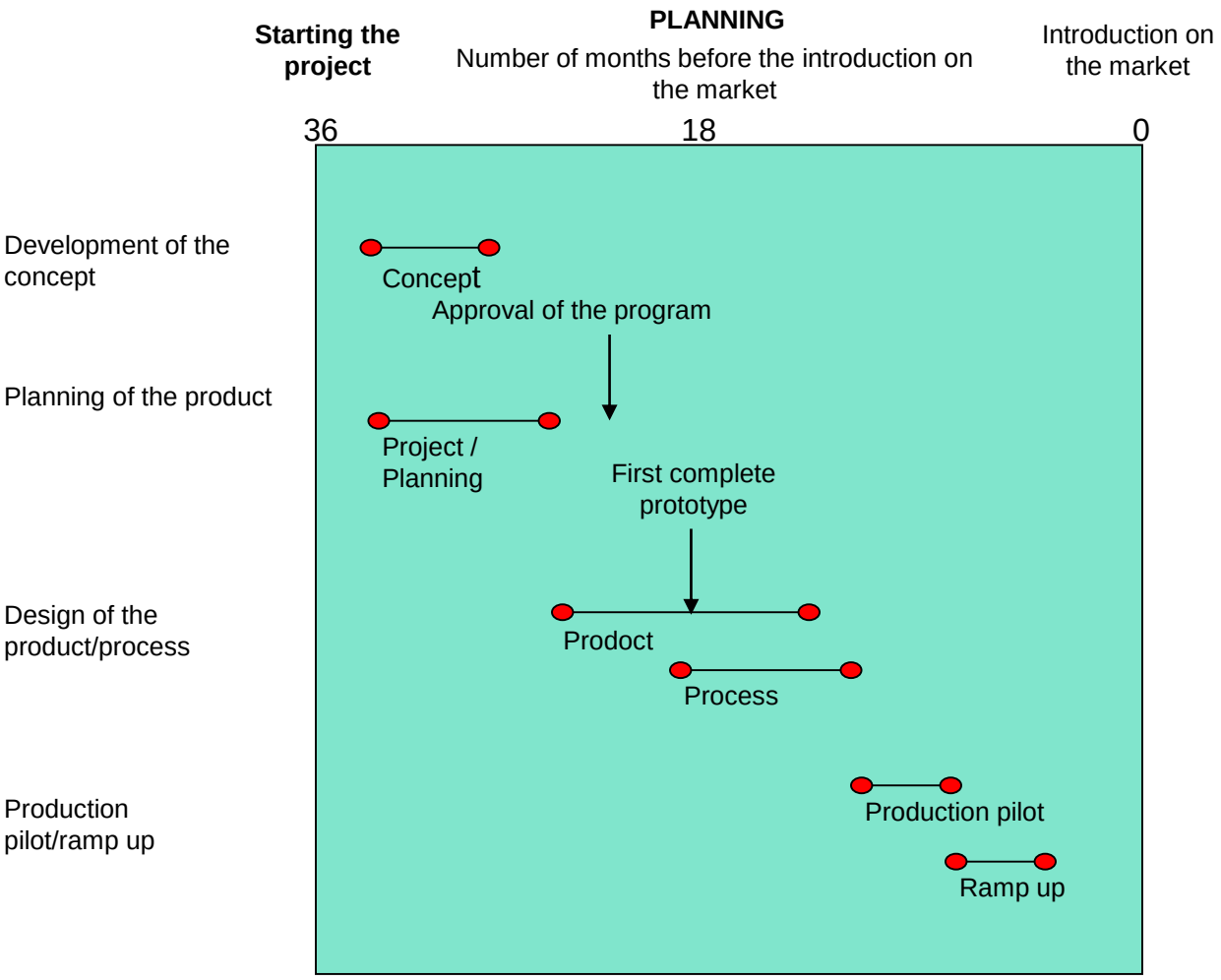
Decided **what to produce** (**product design**), you must define **how to produce**, first examining the possible procedures for the production you want to implement.

Collection and analysis of the production process

For new products is need to experimentally verify the suitability of the production cycle, making ***small batches experimental*** and using possibly, the construction of specific ***pilot plants***, taking into account also the changes that will occur through the production on an industrial scale.



Collection and analysis of the production process



Collection and analysis of the production process

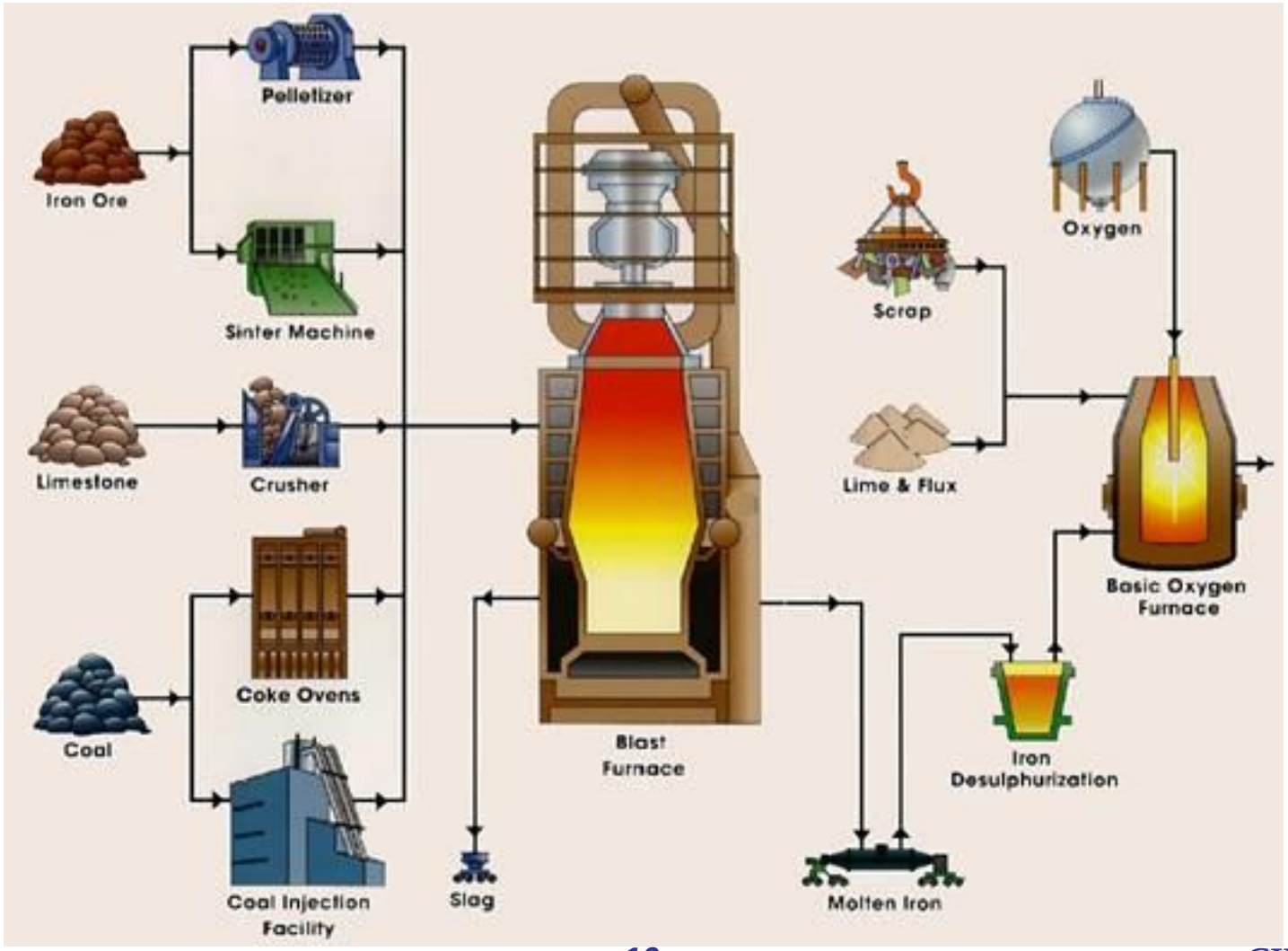
Qualitative diagram

The graphical representation schematized of a processing is called **qualitative diagram of working** or **technological scheme**.

One may use a purely indicative representation of the subsequent operations (such as block diagrams) or a graphic form in which neatly it shows the schematic representation of means that realize the operation. The qualitative diagram can be completed with other indications, such as temperatures, pressures, notes on the movement of materials, etc.

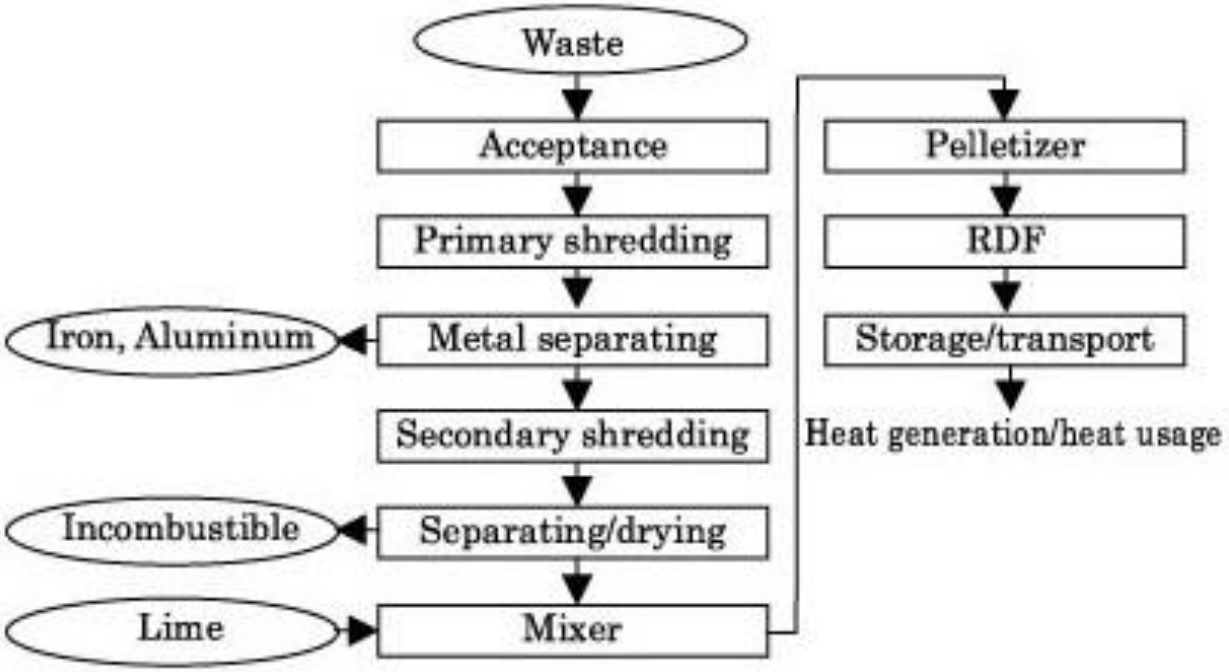
Collection and analysis of the production process

Qualitative diagram



Collection and analysis of the production process

Qualitative diagram



RDF manufacturing flow

Quantitative diagram

The **quantitative diagram** is obtained from the previous qualitative diagram overlaying each operation the corresponding **quantities** of materials required or otherwise inherent in the operation.

The quantitative diagram may be drawn with reference to the potentiality of the plant that is studied or as a **percentage**, all referring to an amount, selected appropriately, set equal to 100, for example, the most important raw material or part of them, the complex of starting materials, the most important product, etc.

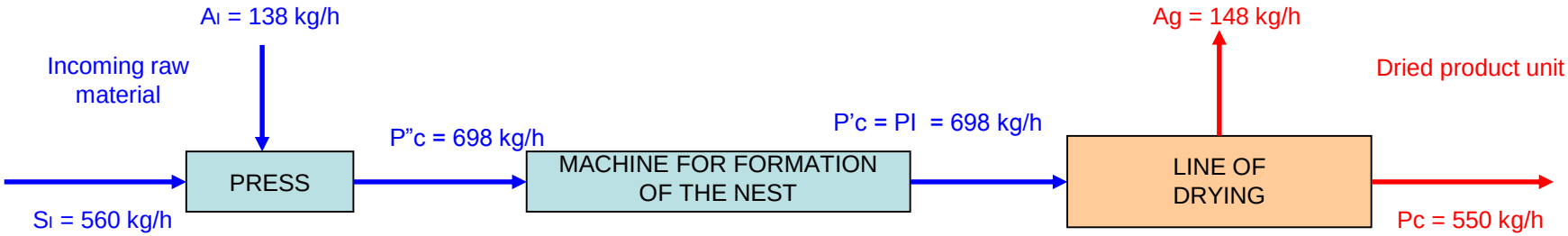
This diagram should not only indicate the amount of the initial materials and final products, but also, in stages, the amount of materials, waste, scrap, reductions, additions and everything can still change the quantity in evolution.

Collection and analysis of the production process

Quantitative diagram

The simplest is into superimpose the individual phases of the qualitative diagram the corresponding quantities related to an suitable unit of time, obtaining the so called **qualitative-quantitative diagram**.

The quantitative diagram relating to a production line of the pasta nest.



The production line is composed of the following sections: 1) preparation of dough, 2) forming the product (pressing and formation of the nest), 3) heat treatment (drying and pasteurization) and 4) packaging.

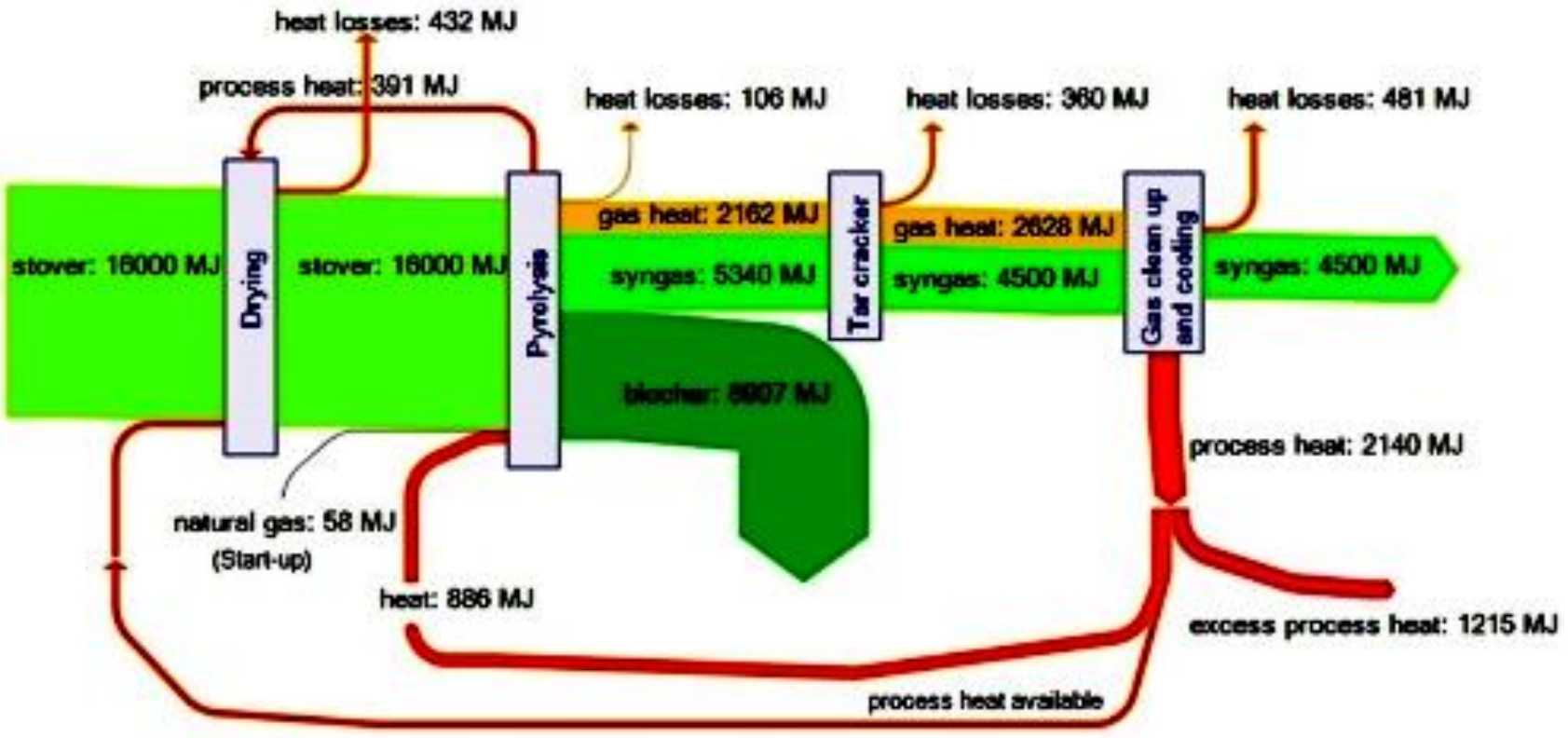
Quantitative diagram

One of the most suitable representations in many cases is suggested by **Sankey**, widely used for thermal plants, foundries, paper mills, textile factories and the like. The **Sankey diagram** is a particular type of flow chart, in which the width of the arrows is indicated in proportion to the amount of flow. They are typically used to display the energy or materials or the cost of transfers between processes.

Collection and analysis of the production process

Quantitative diagram

The diagram of Sankey relative to a Blochar Slow Pyrolysis Process



Collection and analysis of the production process

Flow process diagram

The **flow process diagram** is the clear and concise sequence of production operations, transport, testing, inventory and storages for each particular product.

	DESCRIPTION OF CYCLE	OPERATION	MOVE	CONTROL	TE.STORAGE	FIN.STORAGE	N.WORKERS	DISTANCE (m)	TIME (min)
1.	STEEL BAR RECEPTION							5	
2.	STACKING RAW MATERIAL								
3.	AT THE FORGING							9	
4.	HOT FORGING								
5.	BARELLS TO CLEANING							9	
6.	DEBURRING								
7.	THE UPPER FLOOR							24	
8.	IN WAITING								
9.	TURNING								

Collection and analysis of the production process

Flow process diagram

The collection of data on the characteristics of the machines and the requirement for services are employed in a table.

POS.	NAME	MANUFACTURER	DIMENSIONS m	MOTOR kW	AIR ϕ	WATER ϕ	OIL ELMULSIFIED ϕ
1	LATHE AT TURRET	DI PALO	4,00 x 1,20 x 1,50	50	3/8"	–	EMULSION 3/8"
2	LATHE AUTOMATIC	MINGANTI	5,50 x 1,30 x 2,00	60	1/2"	3/8"	OIL 1/2"
3	MILLING	MINGANTI	1,60 x 2,50 x 1,80	20	3/8"	–	EMULSION [illegible]
4	GEAR	CIMA	3,20 x 1,10 x 1,80	25	3/8"	3/8"	OIL [illegible]
5	BORRING	CERUTTI	5,00 x 4,00 x 3,50	35	3/8"	–	EMULSION [illegible]
6	GRINDING	BERCO	5,50 x 1,40 x 2,10	20	1/2"	3/8"	EMULSION 1/2"
7	PLANNING	CERUTTI	12,00 x 2,50 x 2,80	30	1/2"	–	–

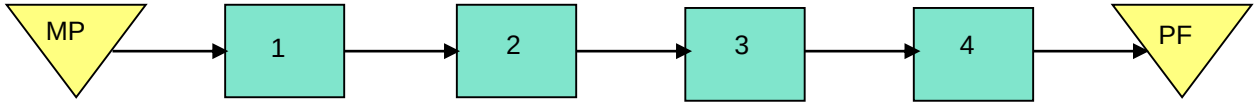
Search of possible solutions

A first indication on the provision of work centers (CdL) is provided by the choice of:

- ***machining in series* (or in-line);**
- ***machining at batch***.

Often in a plant are presented both situations.

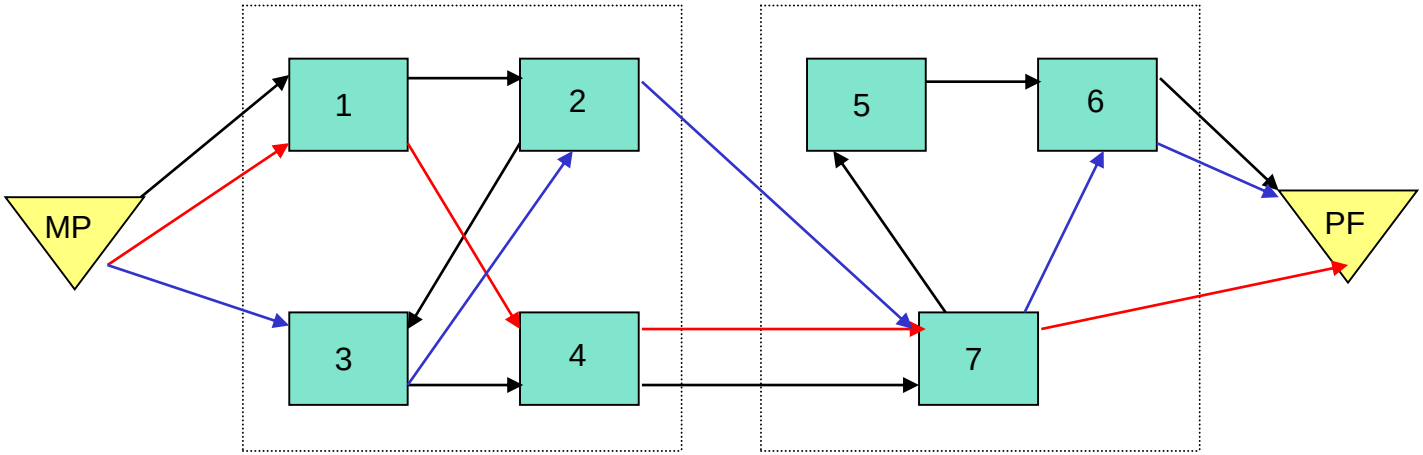
The ***in-line arrangement*** reproduces the sequence of operations of the production cycle.



The movements between the CdL is reduced, but the sequence of the same is stiff. The machine tools are often specialized and automated handling equipment. These aspects make this provision effective if output volumes are high.

Search of possible solutions

The arrangement in **machining at batch** implement a working concentration of specialized in departments.



This arrangement provides greater flexibility to the production plant, as it relates to the mix and quantities of products, but also reduced vulnerability at stop.

Search of possible solutions

The **internal handling systems** (**material handling**) include:
- the means of containment (pallets, crates, boxes etc.);
- the means of internal transportation.

The material handling have then direct influence both on the mode of loading and unloading ships that on storage.

As regards the **place of work**, one must take into account, in the design of the solution of layout, the principles of economy of motion for:
- as easy as possible all the operator-machine connections;
- reduce the physical effort needed for manual labor.

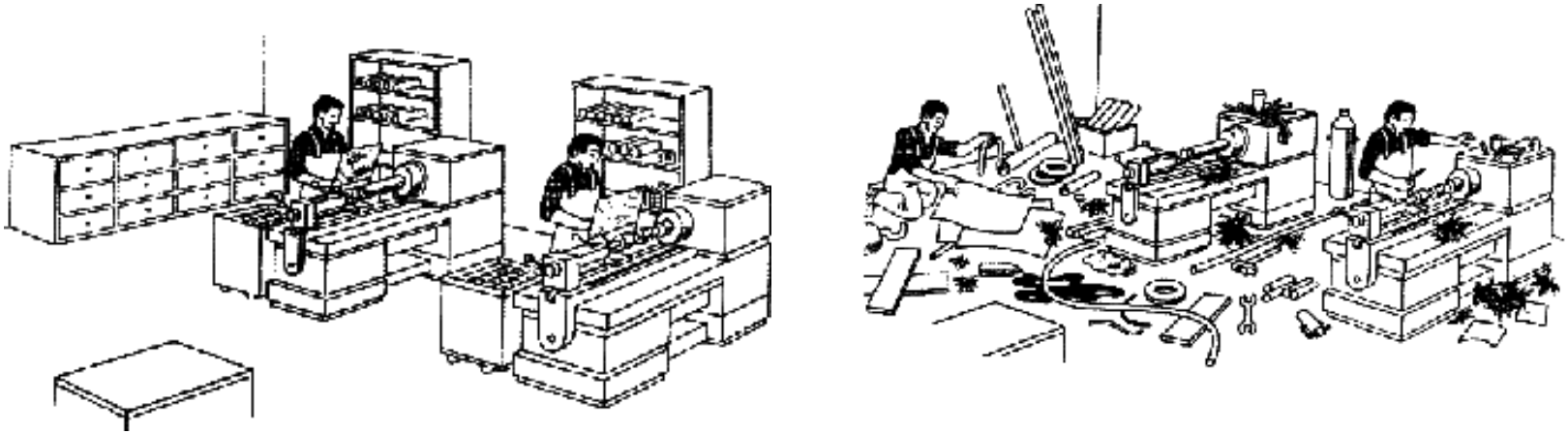
Search of possible solutions

In conducting the study of the movements you must observe some important variables:

a) **frequency of operations**

b) **length of movements**

c) **disposition of material**



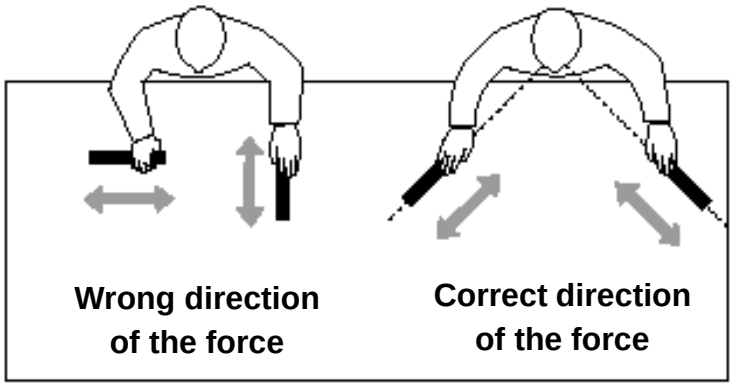
Workplace in order and workplace messy

Search of possible solutions

In conducting the study of the movements you must observe some important variables:

d) **work bimanual**

e) **direction of movement**

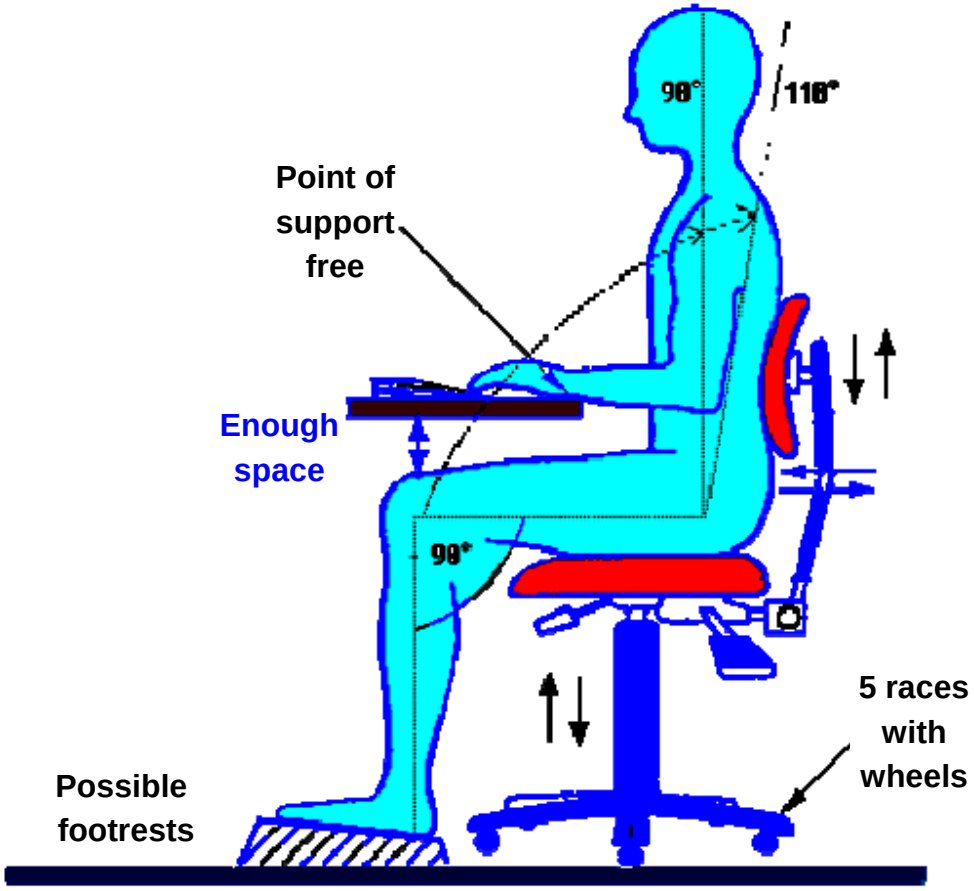


The best directions are those ranging from the point of application of the force axis of the body

Search of possible solutions

In conducting the study of the movements you must observe some important variables:

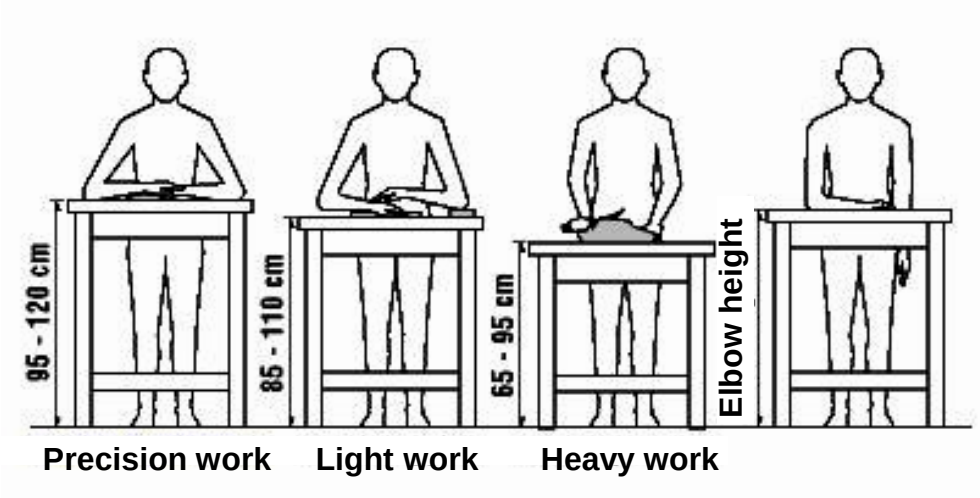
f) **posture**

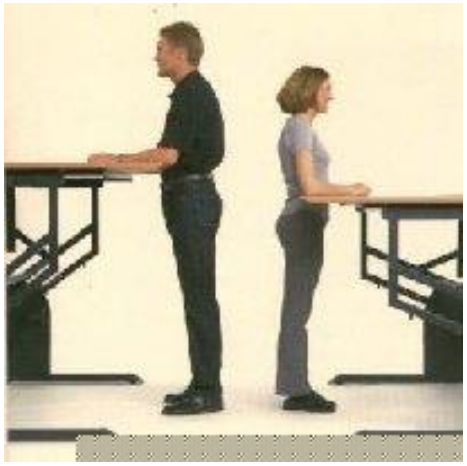


Search of possible solutions

In conducting the study of the movements you must observe some important variables:

g) **height of the work plan**

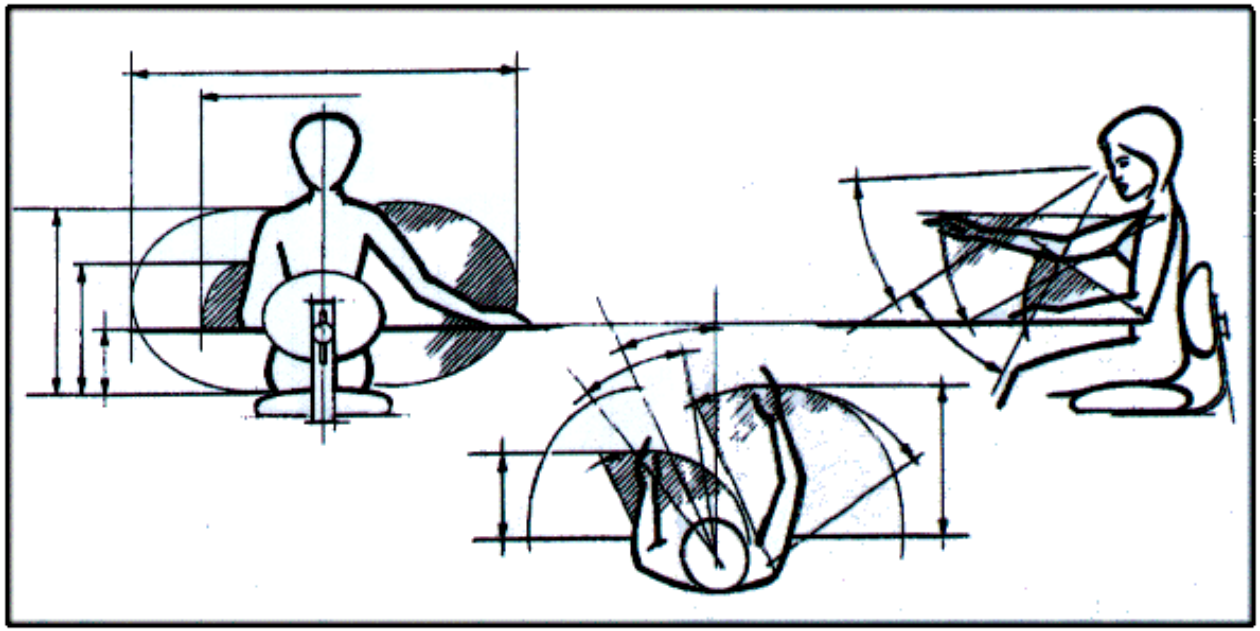




Search of possible solutions

In conducting the study of the movements you must observe some important variables:

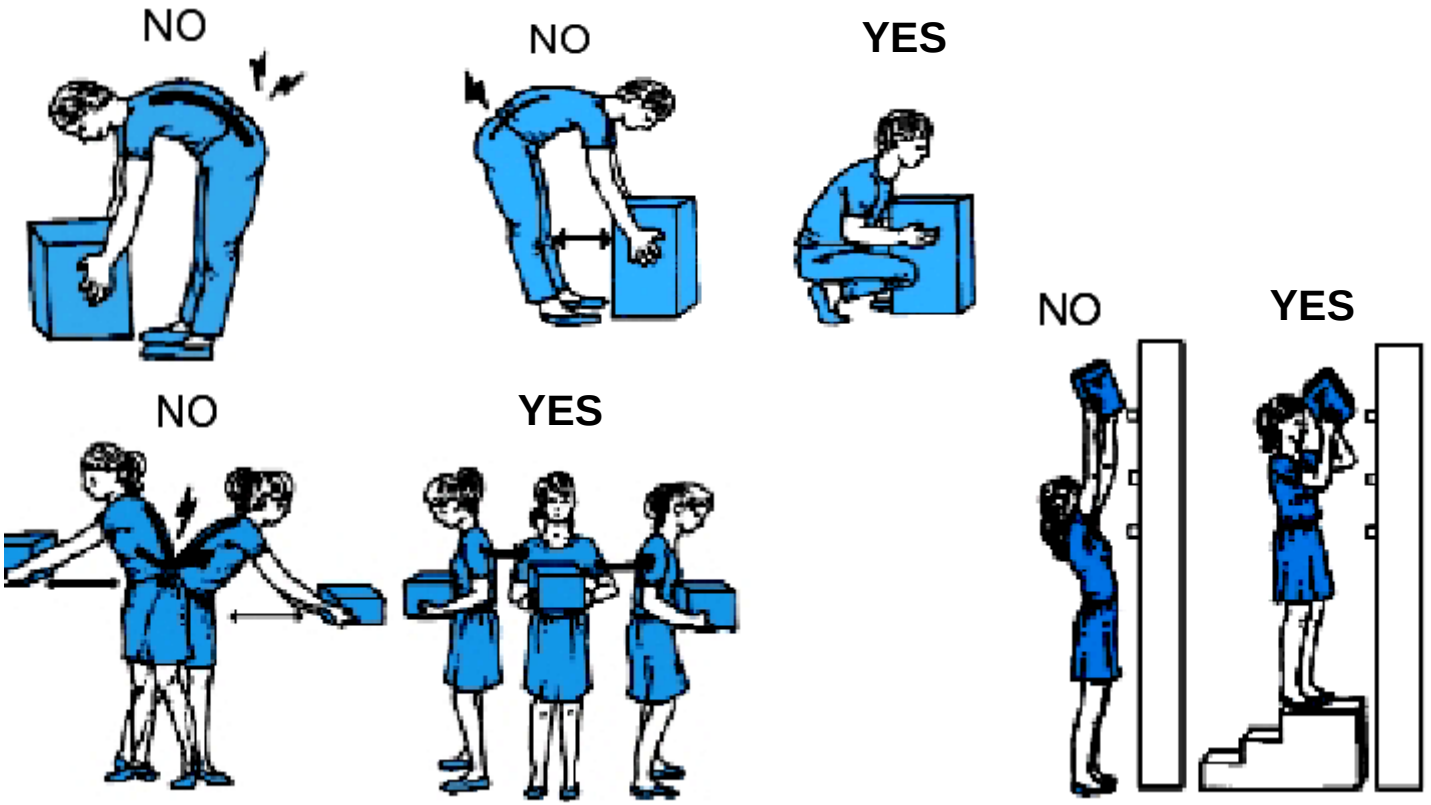
h) **normal and maximum work area**



Search of possible solutions

In conducting the study of the movements you must observe some important variables:

i) **lifting techniques**



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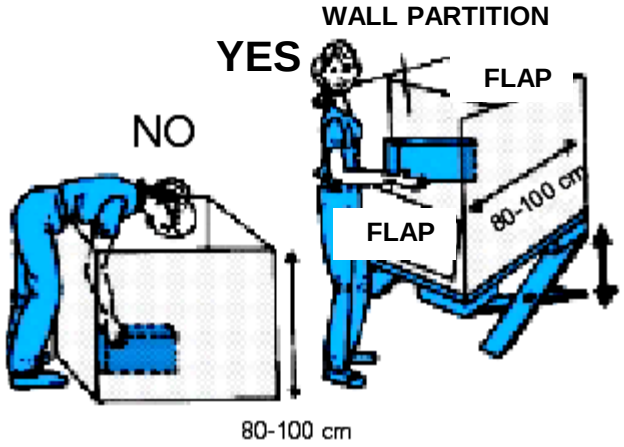

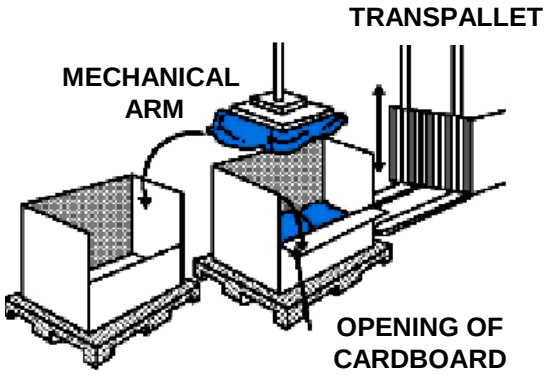

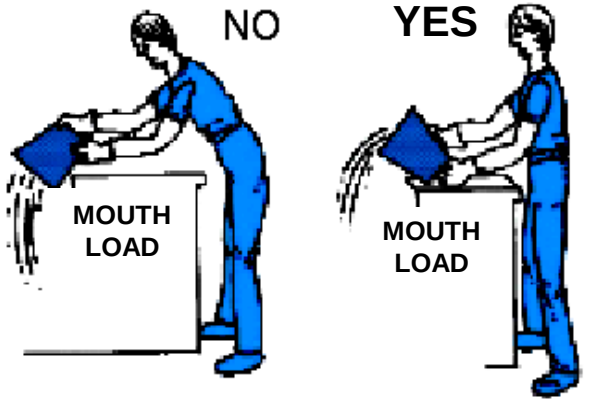

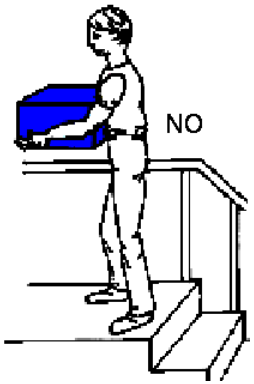

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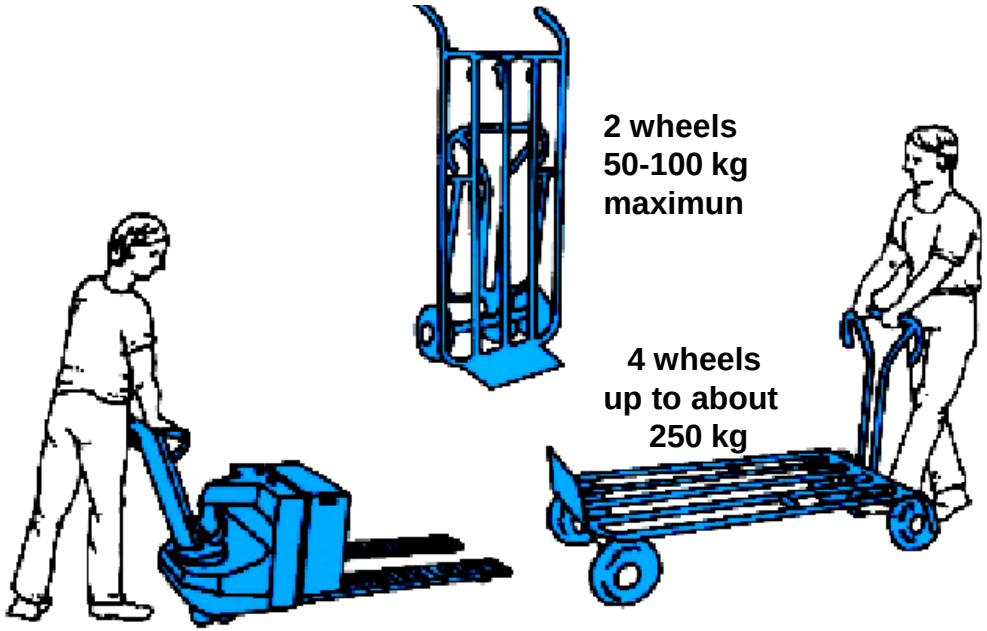


Search of possible solutions

Important for the choice of layout is the analysis of production volumes and varieties produced through:

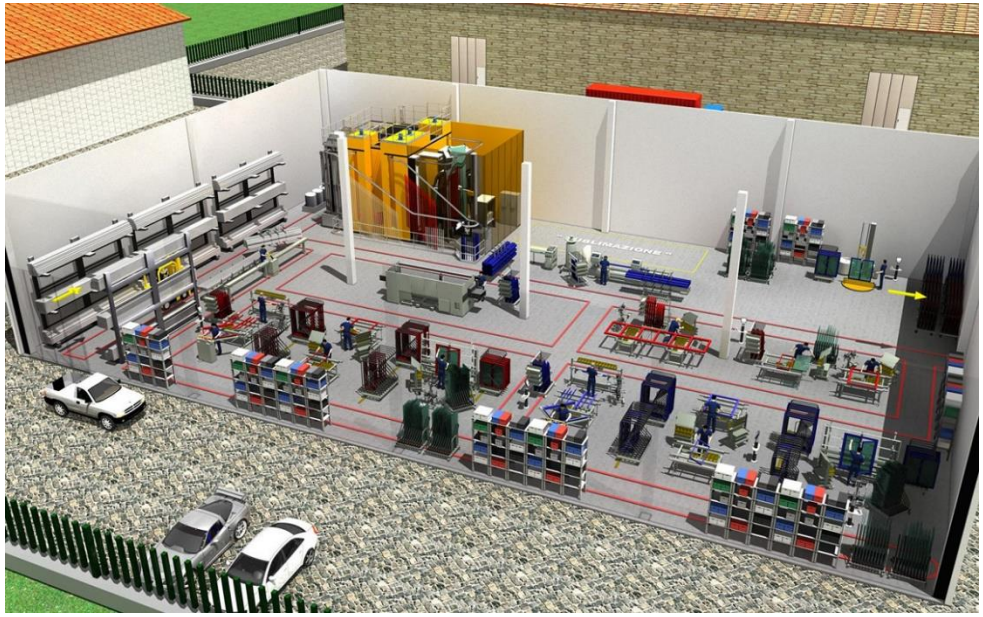
- **subdivision and/or grouping of different products or models examined in groups or families;**
- **calculation of the quantity to be produced for each subdivision or group and for each product, model or varieties within each group.**

To a large quantity and for a few types of product may have provisions for **layout for the product** (operations of the technological cycle of the product), while for small amounts and many types of product you may have available of **layout at fixed position** (operations installation) or **layout of process** (processing and treatment are carried out in departments).

Search of possible solutions

The advantages achieved with the **layout of process** are:

- less duplication of machines, plants etc. and therefore less investment;
- greater flexibility in production;
- control and supervision of specialized highly effective;
- greater incentives for individual employees to increase productivity;
- increased opportunity to remedy defects and failures of machines, plants etc.



Search of possible solutions

The advantages achieved with the **layout for the product** are:

- lower total cost of transportation of material;
- lower total production time;
- reduced inventories of production;
- greater incentives for the various departments and increase productivity;
- lower surface of establishment request per unit of product;
- simplification of the production control.

Search of possible solutions

The advantages achieved with the **layout at fixed point** are:

- opportunities to develop skills of employees or to obtain an extension or upgrading of job;
- minimal capital investment.

Criteria of the study of solutions of plant layout

The **study of plant layout** should make it clear:

- the arrangement of the various departments, plants, general services and auxiliary services;
- the development of the plant in one or more buildings;
- the possibility of future expansion.

In the case of **processes in line**, attention can focus immediately on the disposal of machinery and the study of the workplaces.
In the case of **processes at batch**, you must first develop the study of the different departments.

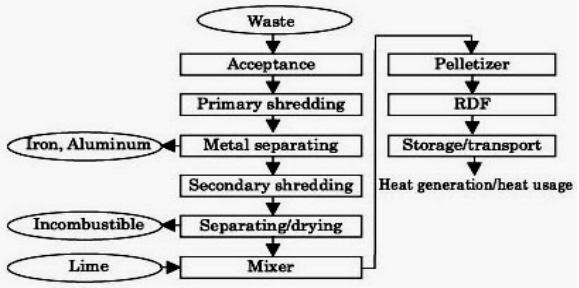
The methods, that will be presented below, are supported:

- the arrangement of machines in a department;
- the mutual disposal of the various departments.

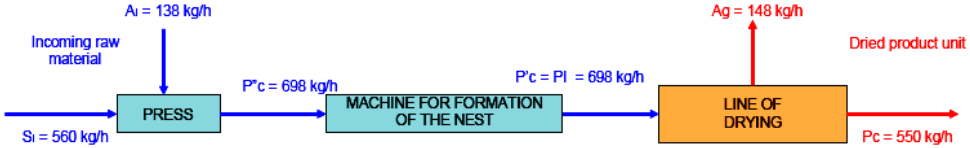
Criteria of the study of solutions of plant layout

Development of the project of layout follows the implementation of:

- qualitative diagrams;



- quantitative diagrams;



relative to cycles and to flows of production.

The general projects, both in the case of machining operations in line, both in the machining for departments, are distinguished by different systems of transport of the materials.

Criteria of the study of solutions of plant layout - Generality on methods

The basic idea of many methods is to closer together the work centers (CdL) characterized by a greater number of exchange relationships (flow of materials and information).
Other criteria that can push to closer or farther away of the CdL are processual, ergonomics and safety.

An important aspect that should be considered for the study of methods for the search of the solution of the plant layout are the **transports.**
The total cost of transport between two CdL (i, j) in a given unit of time (hour, day, year etc.) depends on:

- amount of material to be moved between CdL;
- distances between the two CdL.

Criteria of the study of solutions of plant layout - Generality on methods

Generally we can consider the **cost of transport of the unit of material** as directly proportional to the distance traveled.

The cost of transport in the unit time is the sum of the products of the transported quantities (weights) between i and j (p_{ij}) for the cost of transporting the unit of material (for example kg) referred to the unit of distance traveled (c_{ij}) and for the distance between i and j (d_{ij}).

The value that is obtained consider in the first place the **flow** between the two CdL.

The flow measure indicate the **level of interaction** between pairs of CdL.

In general, a measure of flow is provided by the frequency of shifts (of vehicles, persons etc.) between two CdL.

Criteria of the study of solutions of plant layout - Generality on methods

Are used generally two types of matrices:

a) ***origin-destination matrices* (O/D)**

The matrices contain the number of movements by CdL of origin (O) to that destination (D)

	CdL 1	CdL 2	CdL 3	CdL 4	CdL 5	CdL 6
CdL 1	-	12	3	3		
CdL 2	21	-				
CdL 3	4	5	-	8	8	8
CdL 4				-	4	4
CdL 5	1	2	2	15	-	19
CdL 6	4	9		7	19	-

Criteria of the study of solutions of plant layout - Generality on methods

Are used generally two types of matrices:

b) **matrices of frequency of trips**

The matrices contain the number of total trips (independent of the direction) between two CdL

	CdL 1	CdL 2	CdL 3	CdL 4	CdL 5	CdL 6
CdL 1	-	33	7	3	1	4
CdL 2	33	-	5		2	9
CdL 3	7	5	-	8	10	8
CdL 4	3		8	-	19	11
CdL 5	1	2	10	19	-	38
CdL 6	4	9	8	11	38	-

Criteria of the study of solutions of plant layout - Generality on methods

If we consider the amount of materials that are exchanged between two CdL, **regardless of the mode**, there is an evaluation of the intensity of trade. In this case it is useful already the second matrix.

If you proceed at the quantitative evaluation of the costs of moving, it will be necessary to consider the **manner in which the materials are transported**.

In general, neither the distance nor the shipping cost per unit are equal for to the direction i $\rightarrow$ j and for that j $\rightarrow$ i.

To the O/D matrix can be combined with a matrix having in correspondence of each pair ij the cost c_{ij}.

The product for the generic pair ij will be:

$$p_{ij} \cdot c_{ij}$$

that provides the cost of transport between the CdL i and j per unit of distance and time, being p_{ij} the weight of the flow of materials in transit between i and j.

Criteria of the study of solutions of plant layout - Generality on methods

If d_{ij} measure the distance between the barycentres of the CdL i and j, the cost of transportation will be:

$$C_{ij} = p_{ij} \cdot c_{ij} \cdot d_{ij}$$

If you want to estimate the total cost for all CdL involved in the project layout is considered:

$$C = \sum_i \sum_j C_{ij} = \sum_i \sum_j p_{ij} \cdot c_{ij} \cdot d_{ij}$$

If we consider the **criterion of approaching**, we seek the disposal that gives the lowest total cost, that is that minimizes the relationship described above.

Note that, if the CdL are departments, the report of the total cost for all concerned CdL provides the cost related to the barycenter of departments.

Criteria of the study of solutions of plant layout - Generality on methods

As regards the determination of the distance measurements can be considered:

a) **euclidean distance**

Considered:

- x_i, coordinate x of the barycentre of the i-th CdL;
- y_i, coordinate y of the barycentre of the i-th CdL;
- d_{ij}, distance between the barycenters of the CdL i-th and j-th, the euclidean distance is:

$$d_{ij} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}$$

This measure is used more often for problems of location

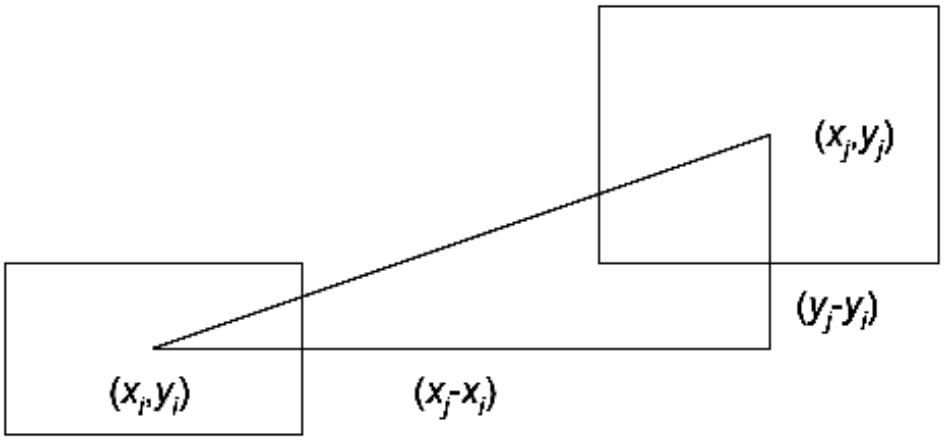
Criteria of the study of solutions of plant layout - Generality on methods

As regards the determination of the distance measurements can be considered:

b) **rectilinear distance**

It is equal to the sum of the length the horizontal and vertical between barycenters of the CdL i-th and j-th:

$$d_{ij} = \left|x_i - x_j\right| + \left|y_i - y_j\right|$$

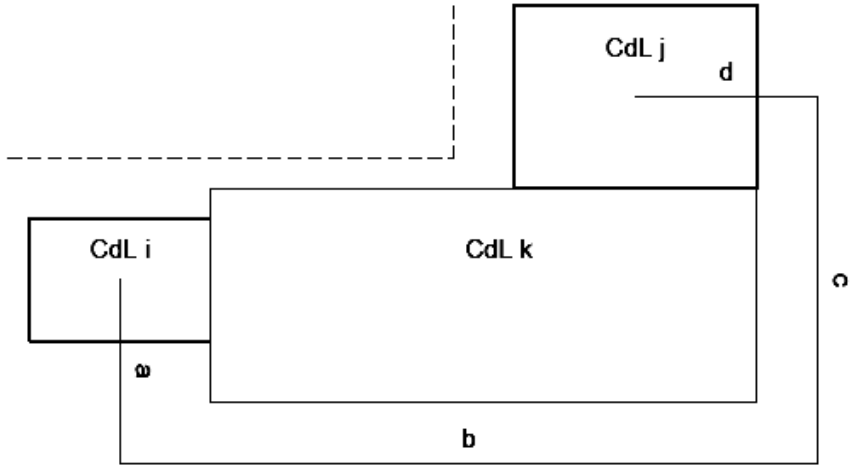


Criteria of the study of solutions of plant layout - Generality on methods

As regards the determination of the distance measurements can be considered:

c) **distance on the actual path**

This is the actual distance that a means of transport, which moves along lanes, must travel to get from CdL i-th to j-th CdL (in the figure is equal to: a + b + c + d)



The actual path is not generally known in the initial stages, this distance is therefore used in the subsequent stages of planning and evaluation.