Facility Layout Planning

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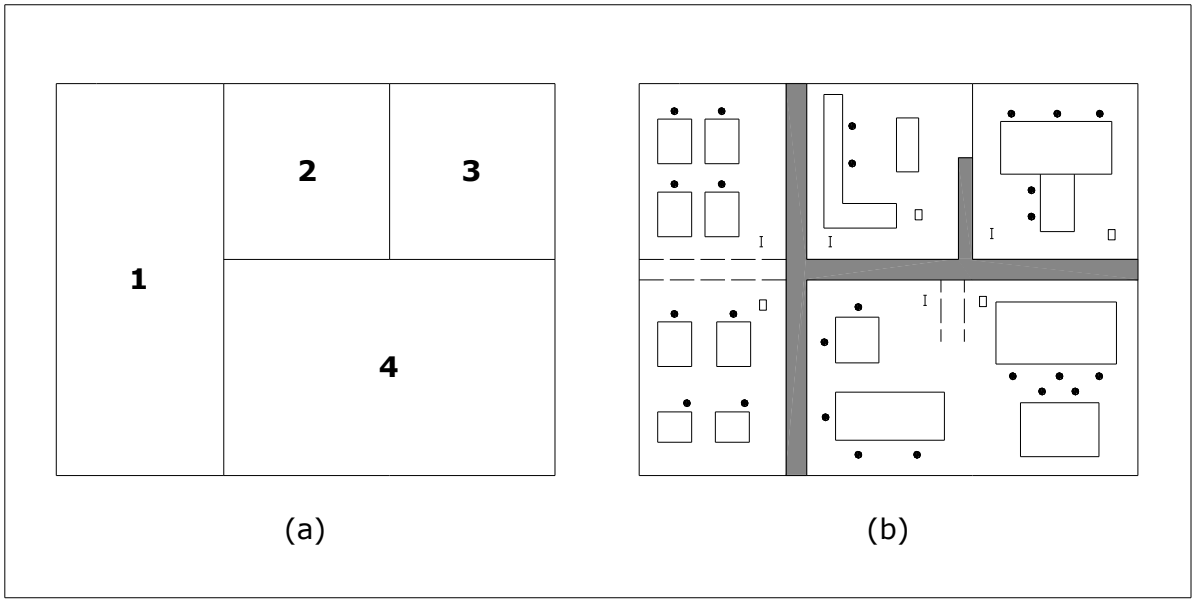
Factory Layout Planning (FLP)

- **FLP consists in the definition of the physical organization of the factory**
  - **FLP concerns the search of the most efficient location of the shops (i.e. areas of activities) within a given building or area available in a building**
  - **Shops might have needs of space very different one from the other**
  - **The objective is the minimization of costs of «relation» between the shops, respecting plant constraints (facility physical structural constraints, building constraints, floor maximum load allowed, service infrastructures)**
- **Results of FLP: CAD drawing of the factory layout**

Factory Layout Planning (FLP)

General layout, with identification of location of each shop.



The drawing of the detailed layout in which the following elements are identified: exact position of the shops, structure of corridors/passages, exit and entry points, position of machine and workstations within the shops

Objectives of the FLP problem

One of the traditional objective is to optimize the efficiency of material flows and the relation between productive areas (and non-productive areas).

The FLP problem is multi-objective!

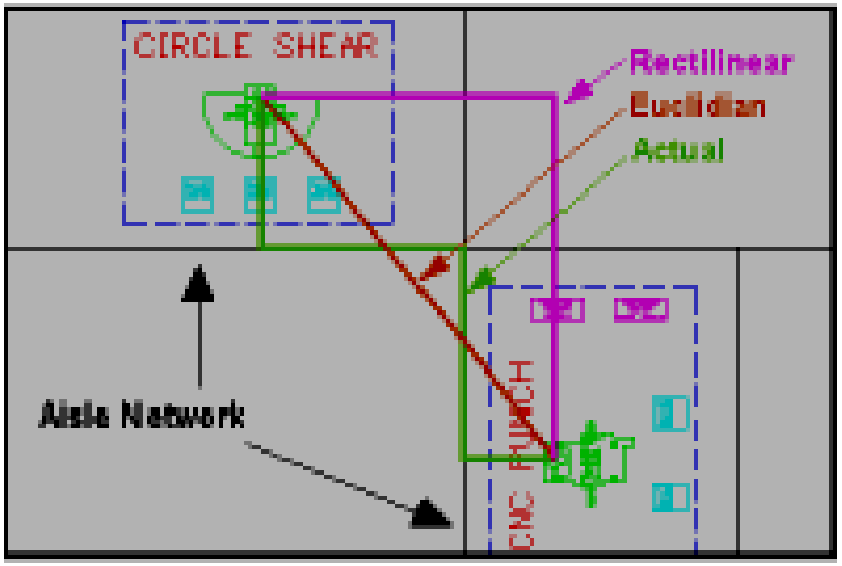
Objective Function:

$$\min \alpha \cdot \sum_i \sum_j (f_{ij} \cdot c_{ij}) \cdot d_{ij} - (1-\alpha) \cdot \sum_i \sum_j r_{ij} \cdot x_{ij}$$

- $f_{i,j}$ = material flow between two areas/shops i,j
- $c_{i,j}$ = cost per unit of movements between two areas/shops i,j
- $d_{i,j}$ = distance between two areas/shops i,j

Models for FLP analysis

Formulate the problem as objective functions with given constraints (linear programming models).



Objective function

$$\min \quad \sum_i \sum_j (f_{ij} \cdot c_{ij}) \cdot d_{ij}$$

- Rectilinear distance
- Euclidean distance
- Actual distance

Models for FLP analysis

Formulate the problem as objective functions with given constraints (linear programming models)

Constraints (Example)

$l_i \leq x_i \leq L - l_i \quad \forall i$

$w_i \leq y_i \leq W - w_i \quad \forall i$

$lb_i \leq 2l_i \leq ub_i \quad \forall i$

$lb_i \leq 2w_i \leq ub_i \quad \forall i$

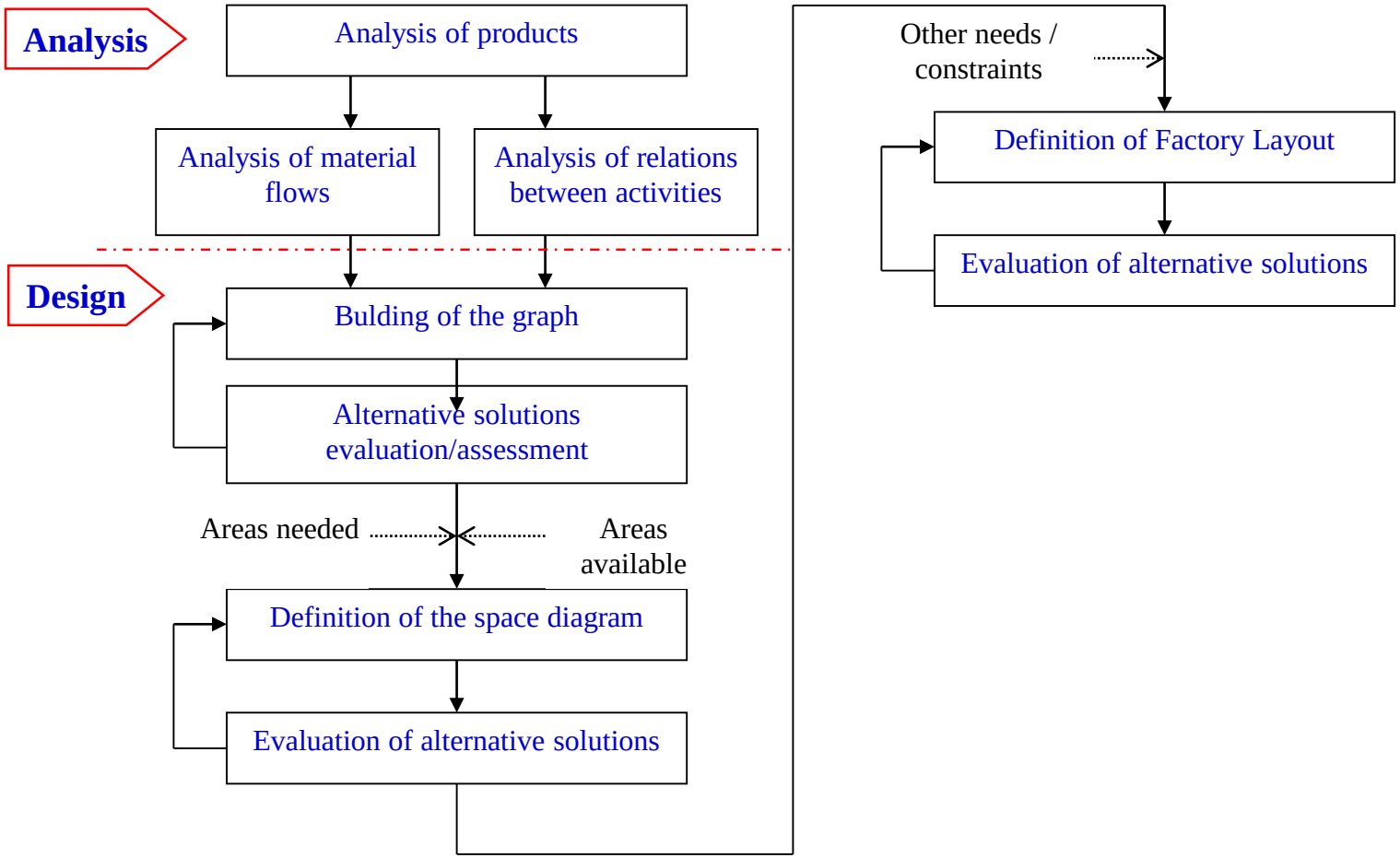
...

- x_i, y_i = coordinate of barycentre of the shop i
- L, W = geometric dimensions of the building
- l_i and w_i = geometric dimensions of shop i
- ub_i and lb_i = max geometric dimension of shop i (orientation of the shop)

...

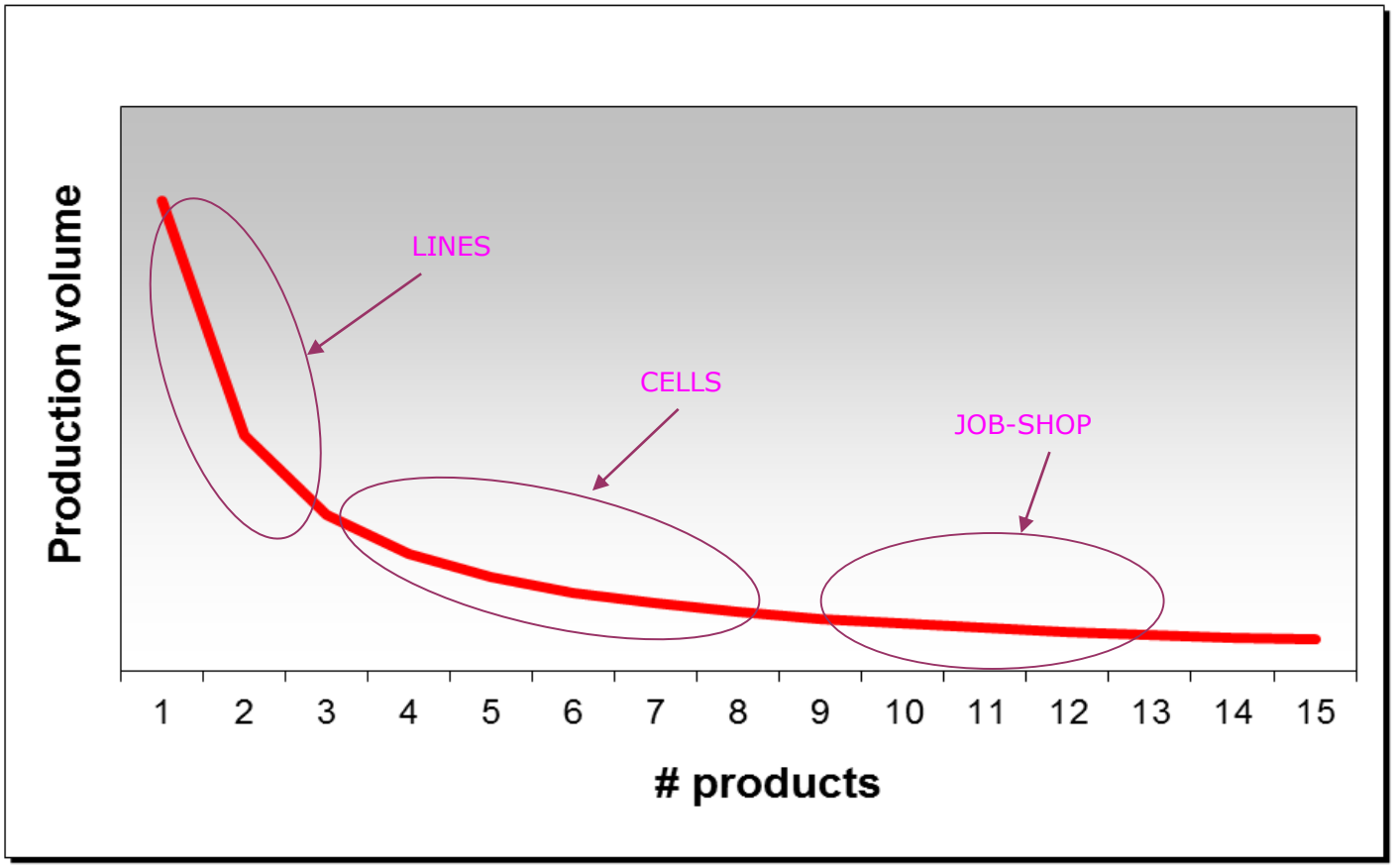
FLP Methodology: phases of the project

- **Systematic Layout Planning Methodology (Richard Muther)**



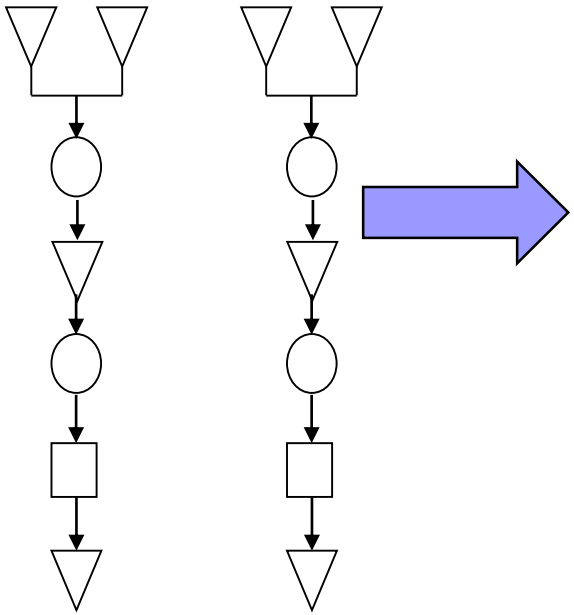
Product analysis

- **ABC analysis on products supports strategic definition of factory layout ⇒ layout product oriented vs. layout process oriented**



Material flow analysis

- **The flow diagram allows to identify the requirements for movement between shops ⇒ from technology diagram (of families of) of products to origin/destination matrix of flows**

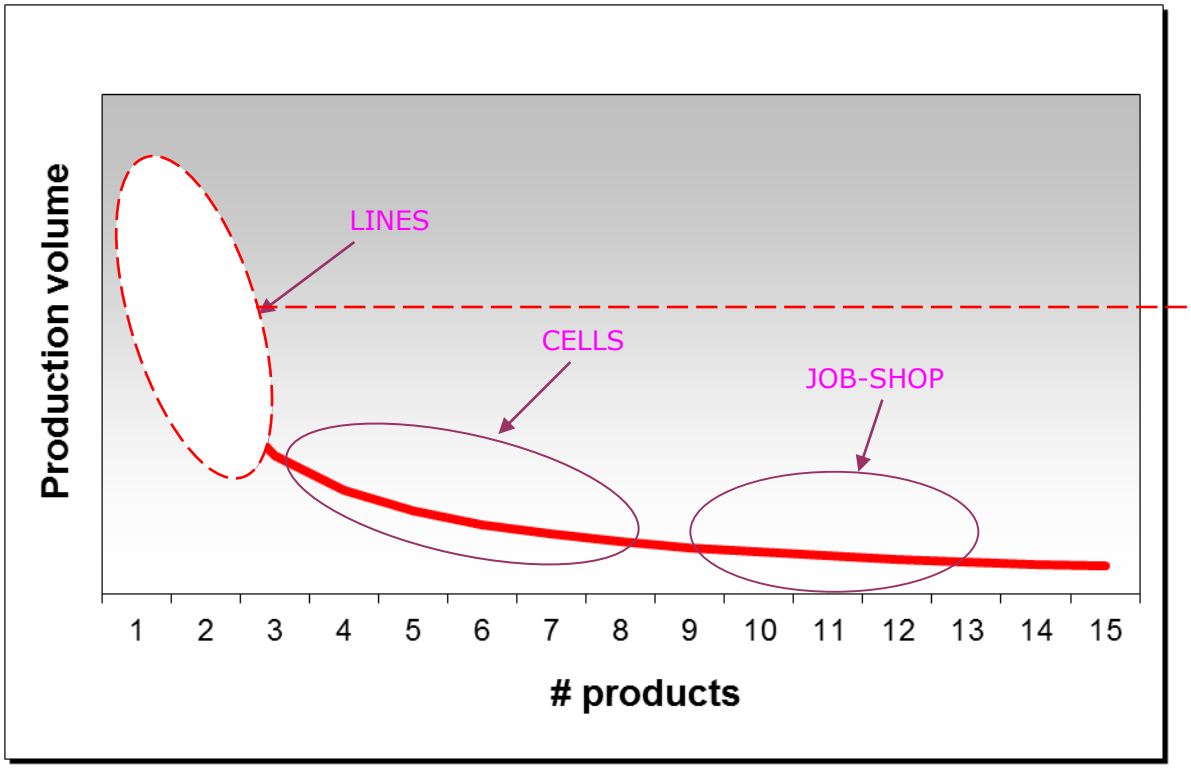


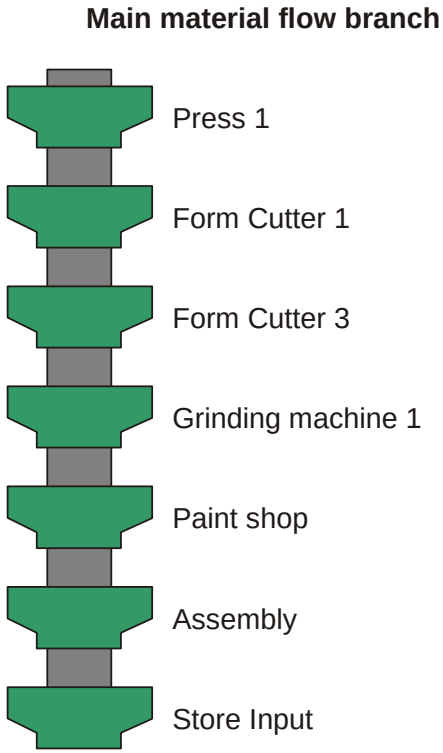
From to	Shop A	Shop B	Shop C	,,,	Sjhop Z
Shop A			20		
Shop B	100		50		300
Shop C	200	150			
,,,					
Shop Z			180		

$f_{ij} * c_{ij}$
$f_{ij} * w_{ij}$
f_{ij}

Product and material flow analysis

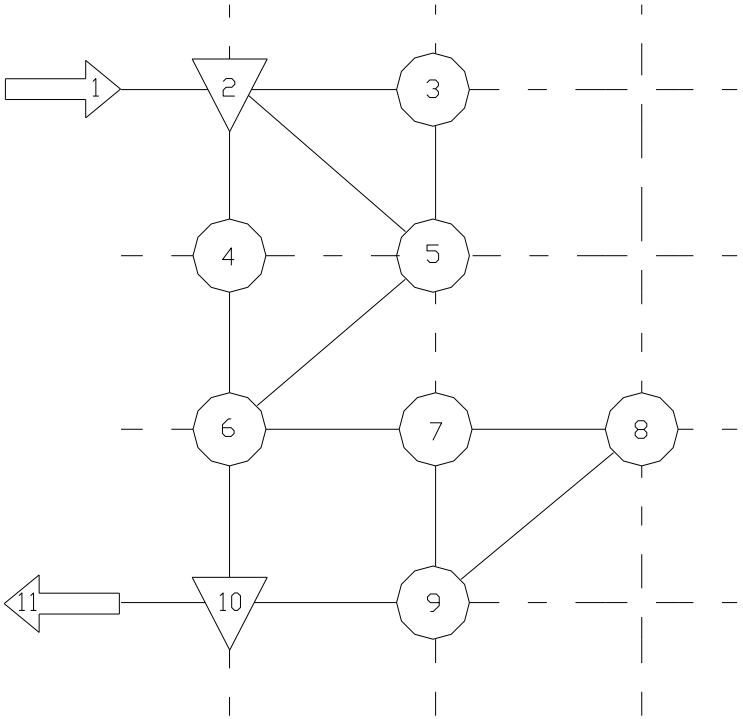
- **Example for high volumes products**



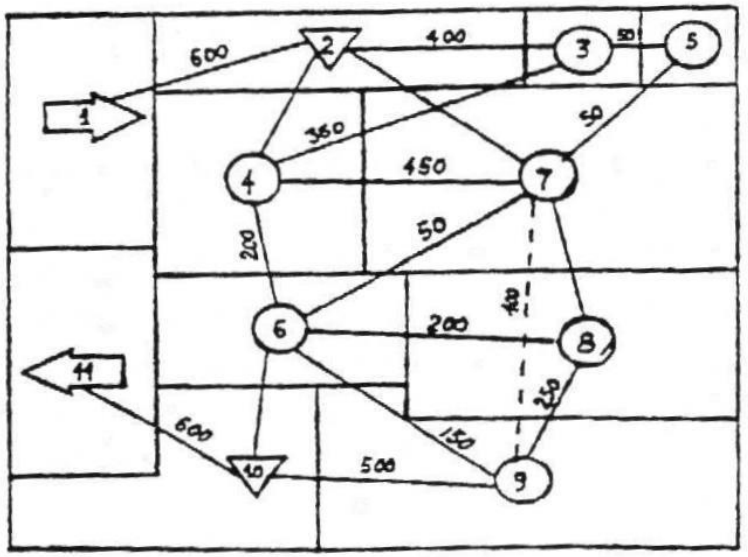


Graph and space diagram

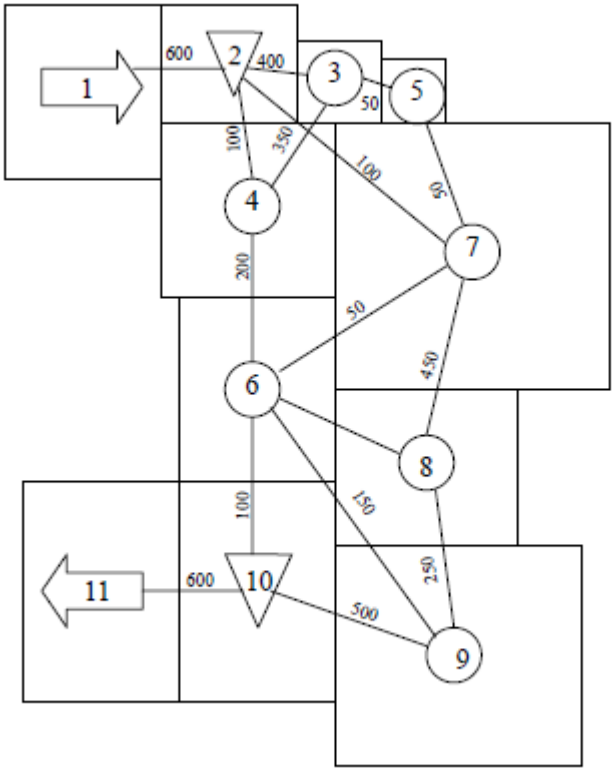
Graph method

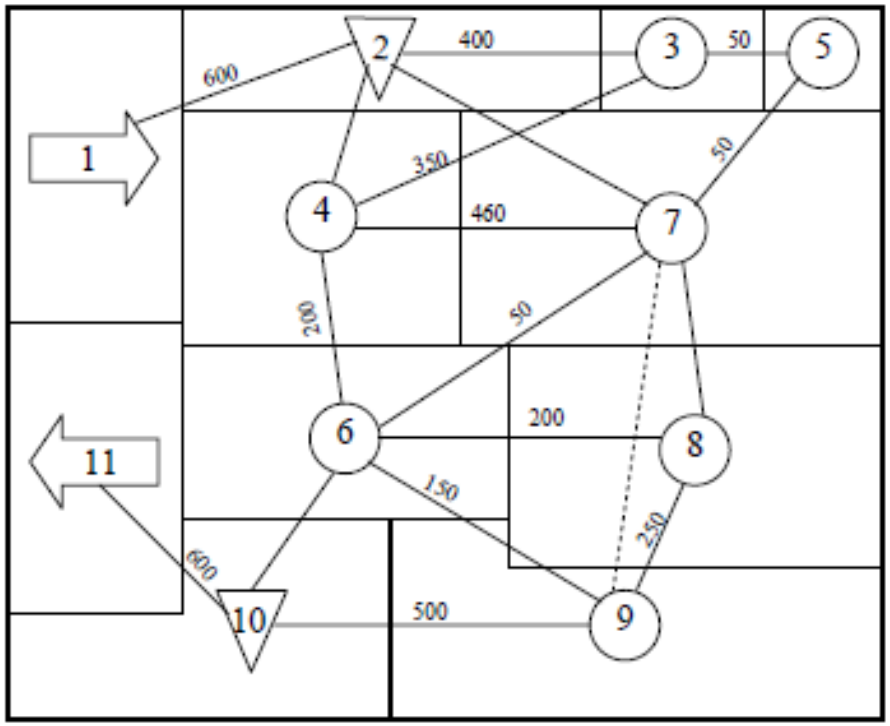


Space diagram method



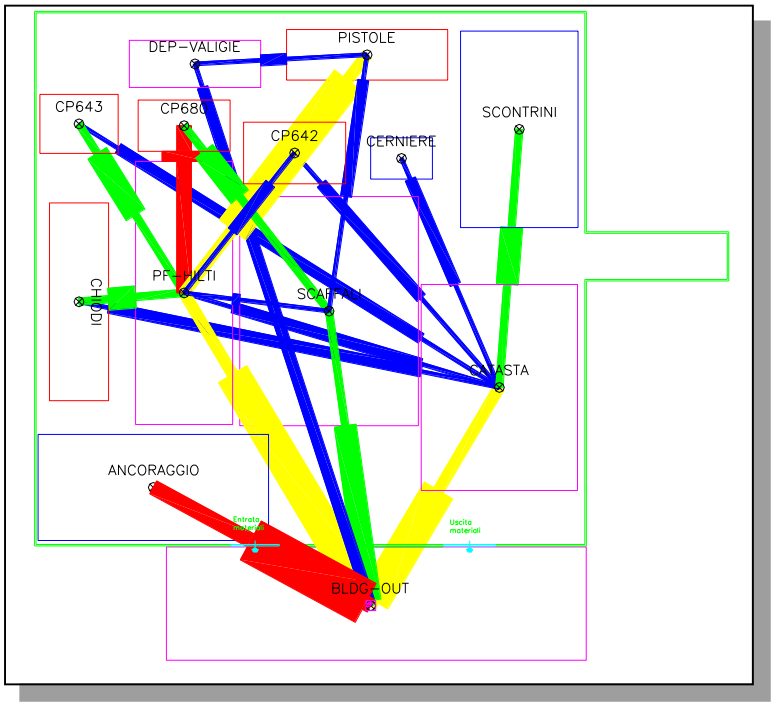
Graph and space diagram

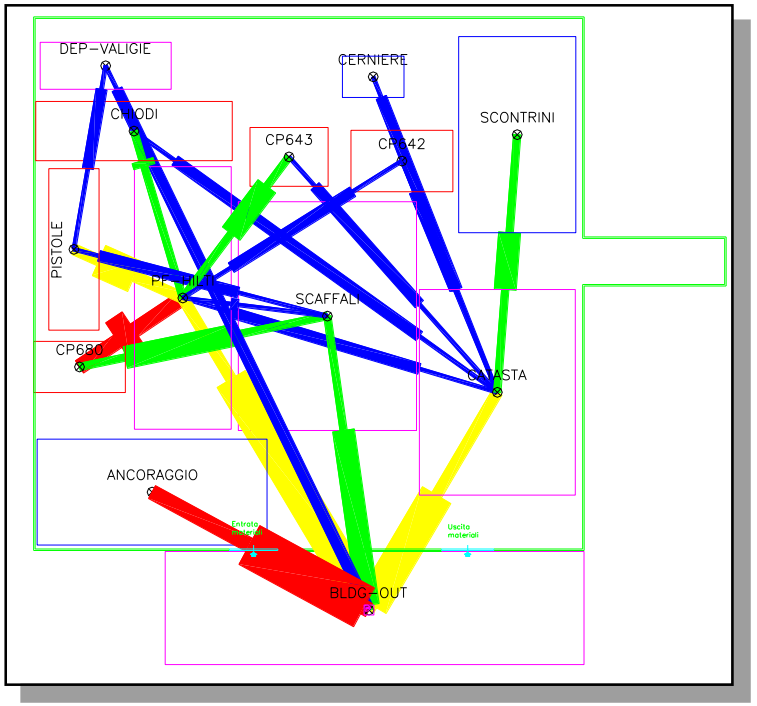




Factory layout drawing

Example of CAD factory layout with identification of shops with high density of flows



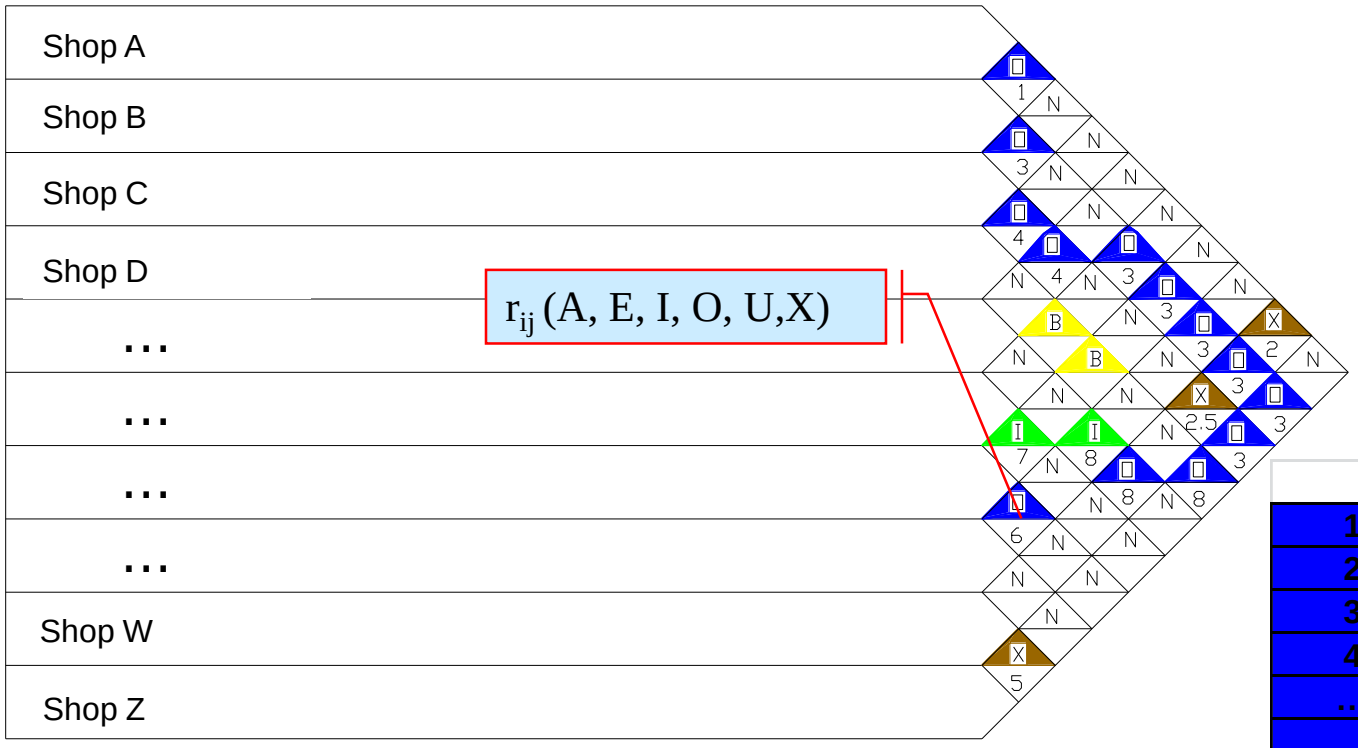


Tip: shops with high density of flows should be put one close to the other

FLP Methodology: Relationship analysis

The method of “Relationship Chart” identifies the requirements of relation between shops (i.e. areas of activity) (between shop i and shop j)

⇒ causes and importance of relations are identified by dedicated codes

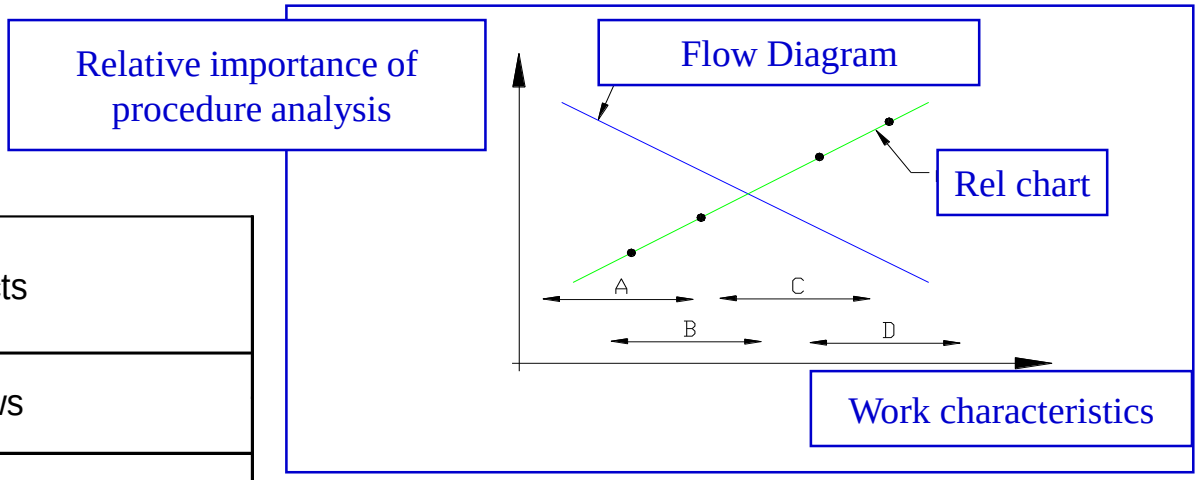


Scale	
A	100
E	50
I	20
O	10
U	0
X	-50

Code	
1	Supervision
2	Sharing of tools
3	Division
4	Vibration
...	
...	

Flow analysis vs Relationship analysis

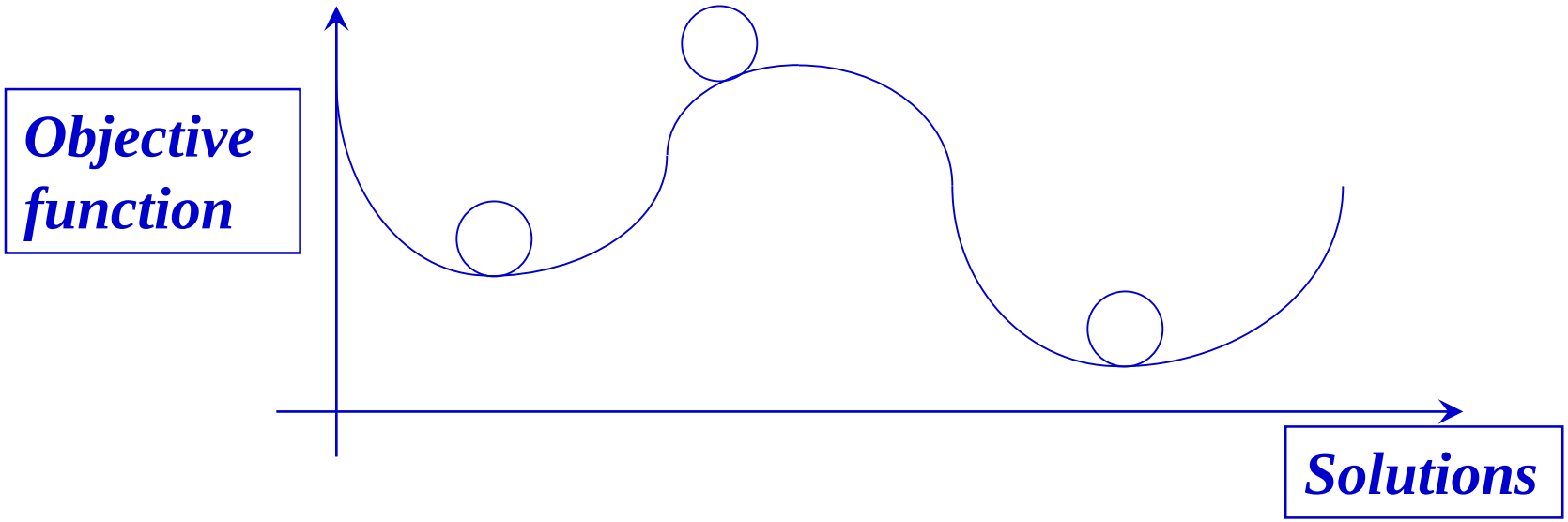
A	Large volumes and/or big products
B	Defined and well established flows
C	Shops or offices with high diversity of product (repairing shops, etc.)
D	Office layout



$$\min \alpha \cdot \sum_i \sum_j (f_{ij} \cdot c_{ij}) \cdot d_{ij} - (1-\alpha) \cdot \sum_i \sum_j r_{ij} \cdot x_{ij}$$

Methods and criteria for FLP planning

- **Heuristic techniques for the solution search**
  - **Search of a «good» solution**
  - **Automation of the search vs. interactive search**



Heuristic

- In computer science, artificial intelligence, and mathematical optimization, a heuristic is a technique designed for solving a problem more quickly when classic methods are too slow, or for finding an approximate solution when classic methods fail to find any exact solution. This is achieved by trading optimality, completeness, accuracy, or precision for speed. In a way, it can be considered a shortcut.
- The objective of a heuristic is to produce a solution in a reasonable time frame that is good enough for solving the problem at hand. This solution may not be the best of all the actual solutions to this problem, or it may simply approximate the exact solution. But it is still valuable because finding it does not require a prohibitively long time.
- Heuristics may produce results by themselves, or they may be used in conjunction with optimization algorithms to improve their efficiency (e.g., they may be used to generate good seed values).

(Wikipedia definition)

Methods and criteria for FLP planning

Heuristic MAT (Modular Allocation Technique) – starting from green field

Objective function

$$\min \alpha \cdot \sum_i \sum_j (f_{ij} \cdot c_{ij}) \cdot d_{ij} - (1-\alpha) \cdot \sum_i \sum_j r_{ij} \cdot x_{ij}$$

Input data

Weight of relations between shops

WH finished	POS.1	POS.3
WH raw	POS.2	POS.4

Origin/Destination matrix

	WH raw material	R1	R2	R3	R4	WH finished product
WH raw		275				
Shop - R1			225		50	
R2				200		25
R3						200
R4						50
WH finished						

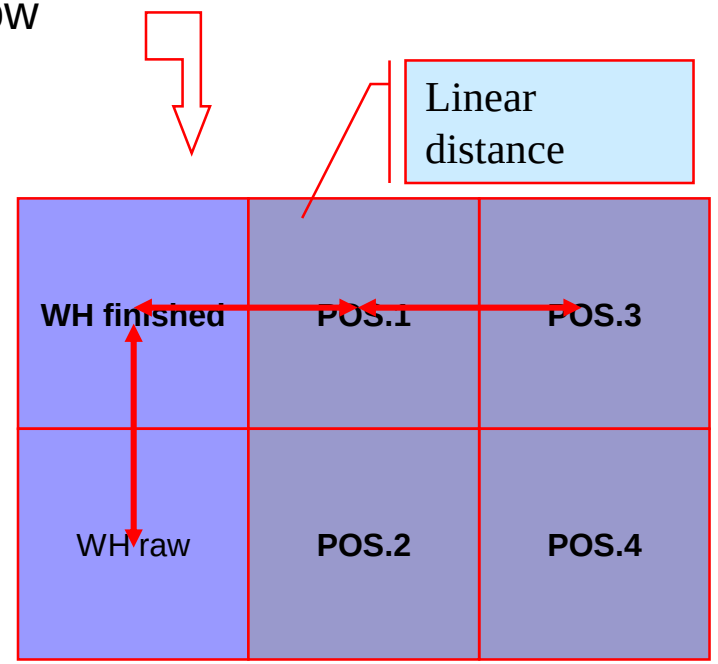
f_{ij}

Methods and criteria for FLP planning

Heuristic MAT

- Order couple of positions with growing distance
- Order couple of shops with decreasing flow

Flow order (MAT)		
WH raw	R1	275
R1	R2	225
R2	R3	200
R3	WH finished	200
R1	R4	50
R4	WH finished	50
R2	WH finished	25



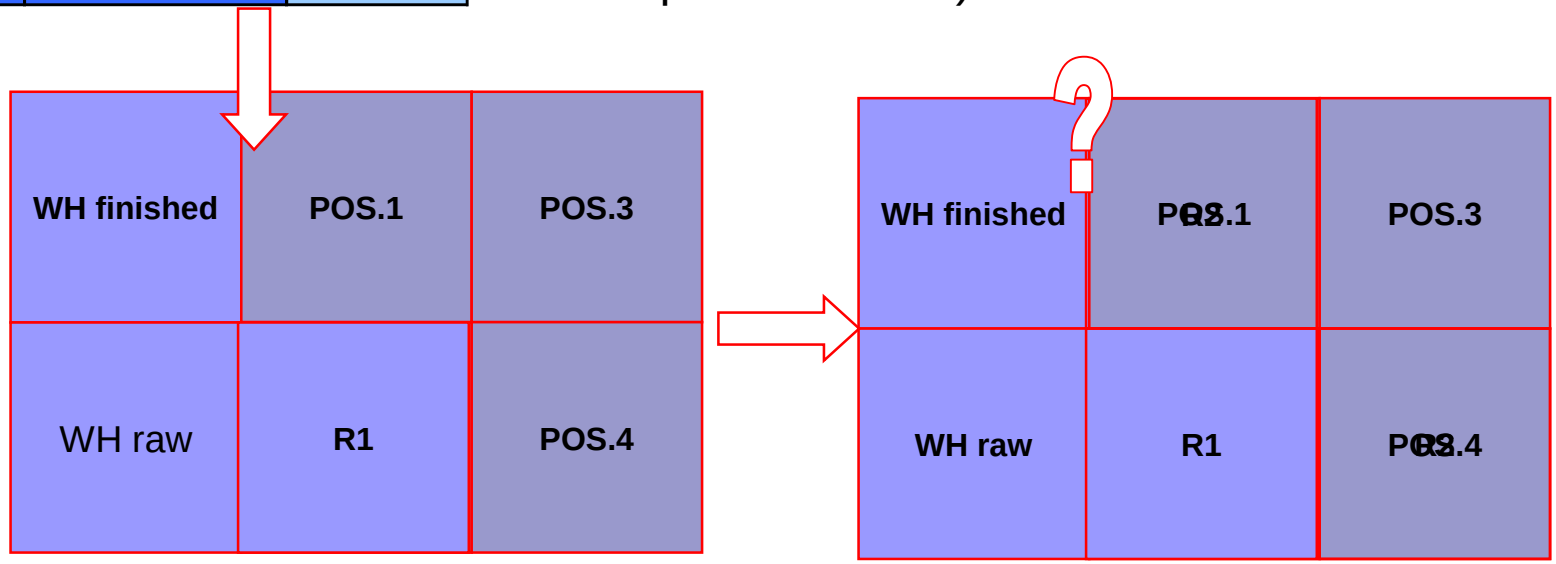
Methods and criteria for FLP planning

Heuristic MAT

Flow order (MAT)		
WH raw	R1	275
R1	R2	225
R2	R3	200
R3	WH finished	200
R1	R4	50
R4	WH finished	50
R2	WH finished	25

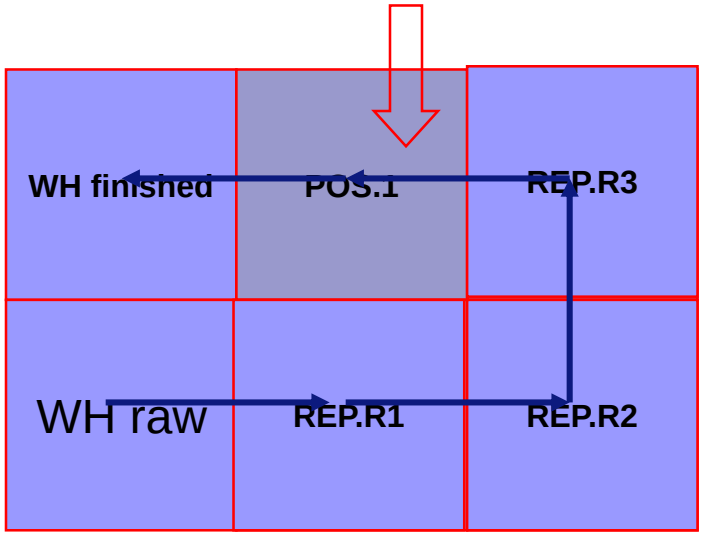
Design criteria

- Shops with larger exchanged flow should be positioned one beside the other (to minimize operative costs)

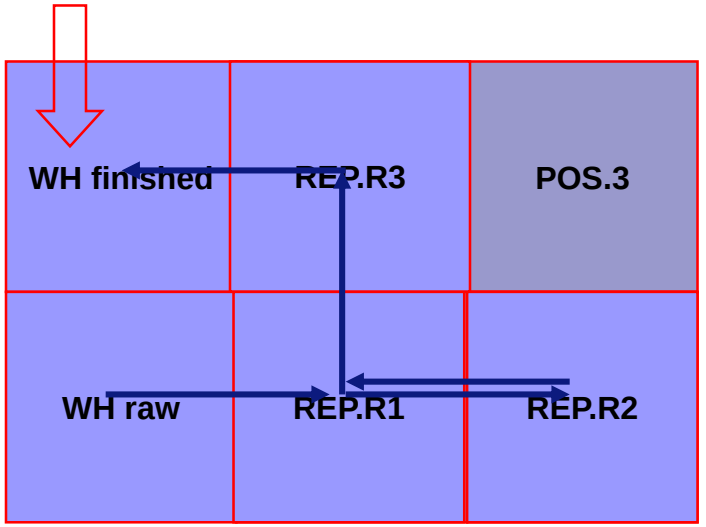


Methods and criteria for FLP planning

U layout



«Linear» layout



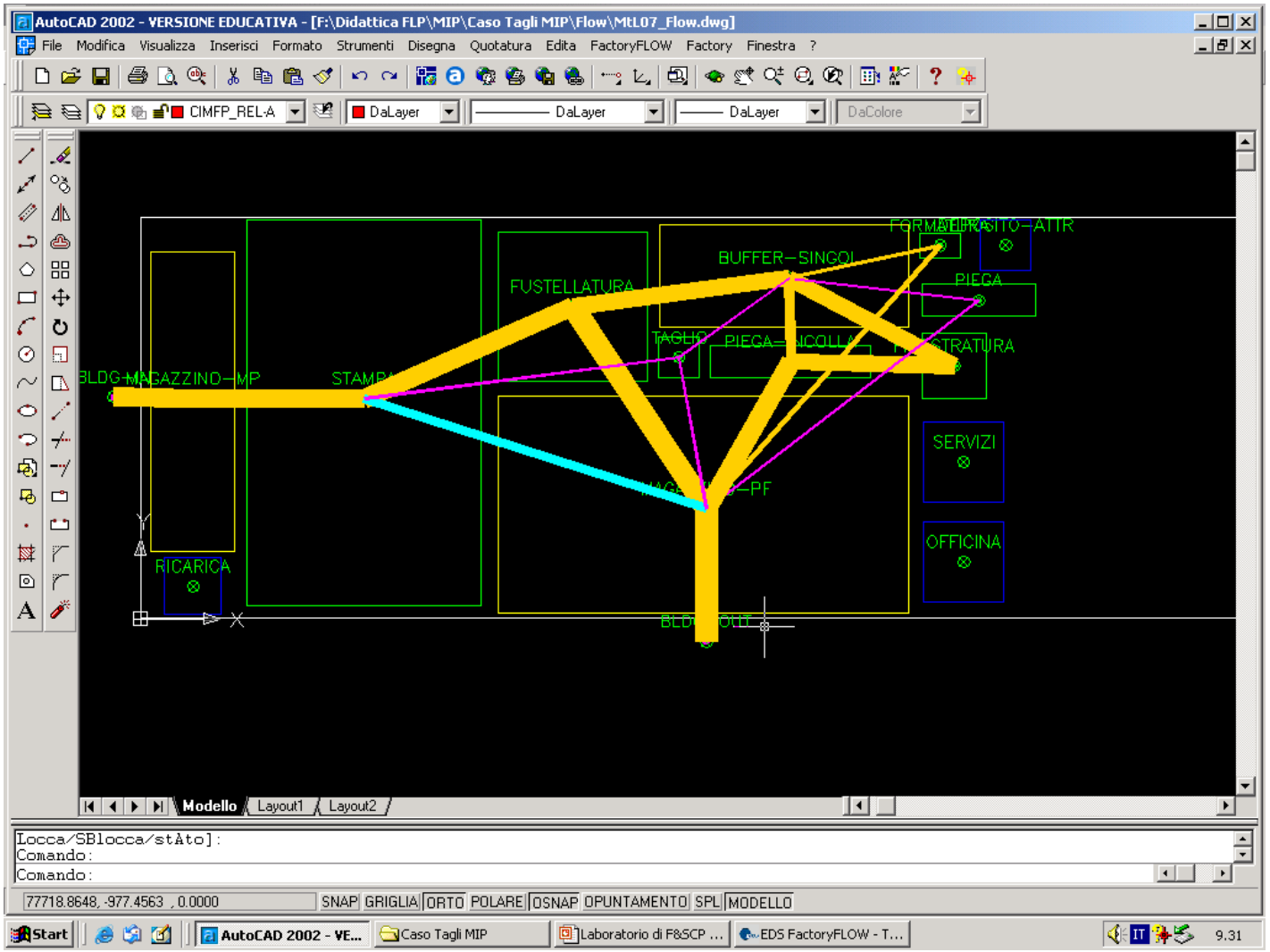
Reflect on a different method and perspective (different from the heuristic MAT)

Computerized Layout Technique

- **Suppose that we are given some space for some shops (i.e. areas of activities). How shall we arrange the shops within the given space?**
- **We shall assume that the given space is rectangular shaped and every shop is either rectangular shaped or composed of rectangular pieces.**
- **We shall discuss:**
  - **a layout improvement procedure, CRAFT, that attempts to find a better layout by pair-wise interchanges when a layout is given and**
  - **a layout construction procedure, ALDEP, that constructs a layout when there is no layout given.**

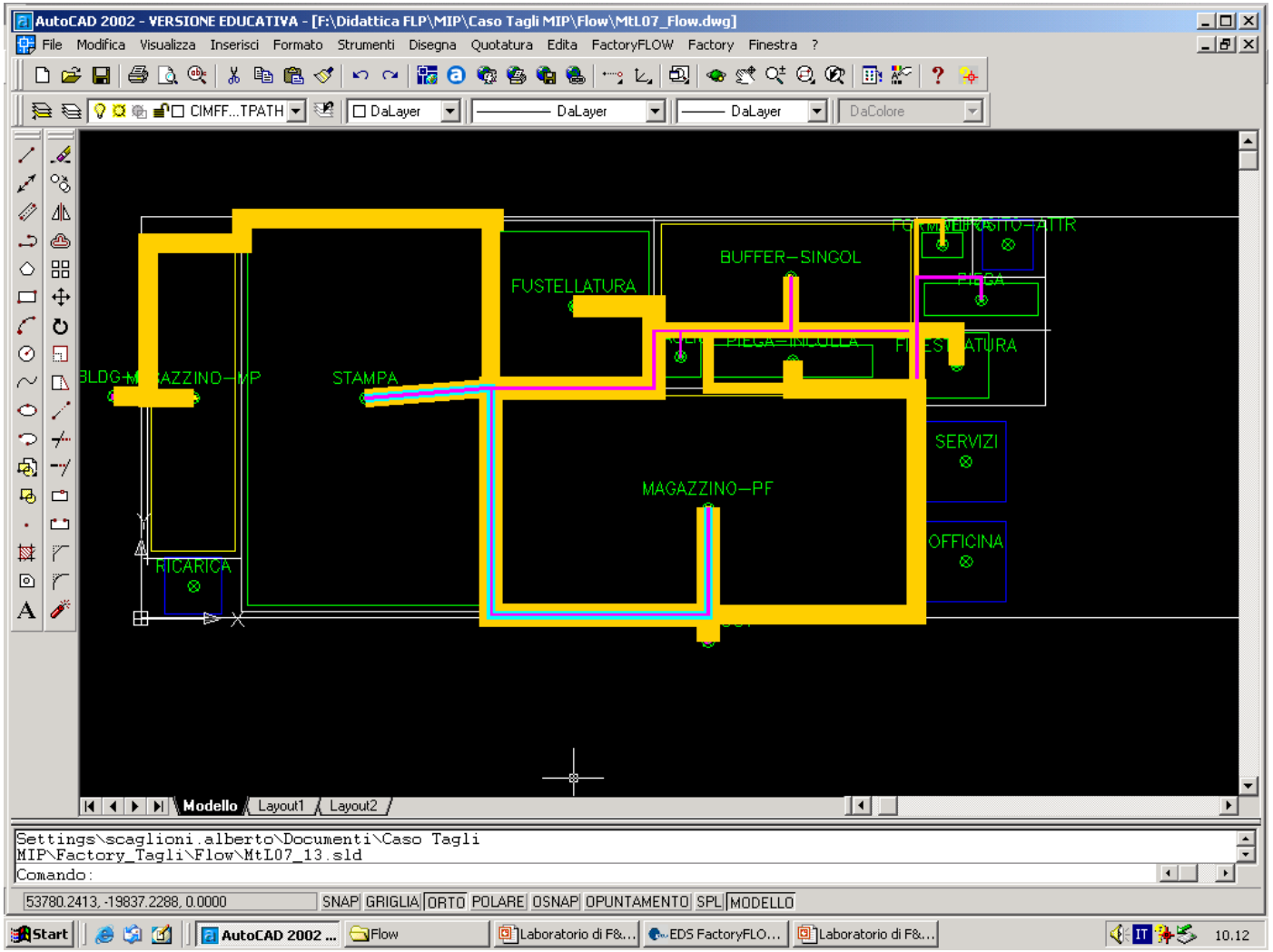
Computer-assisted layout using CAD

Centroid-based distances

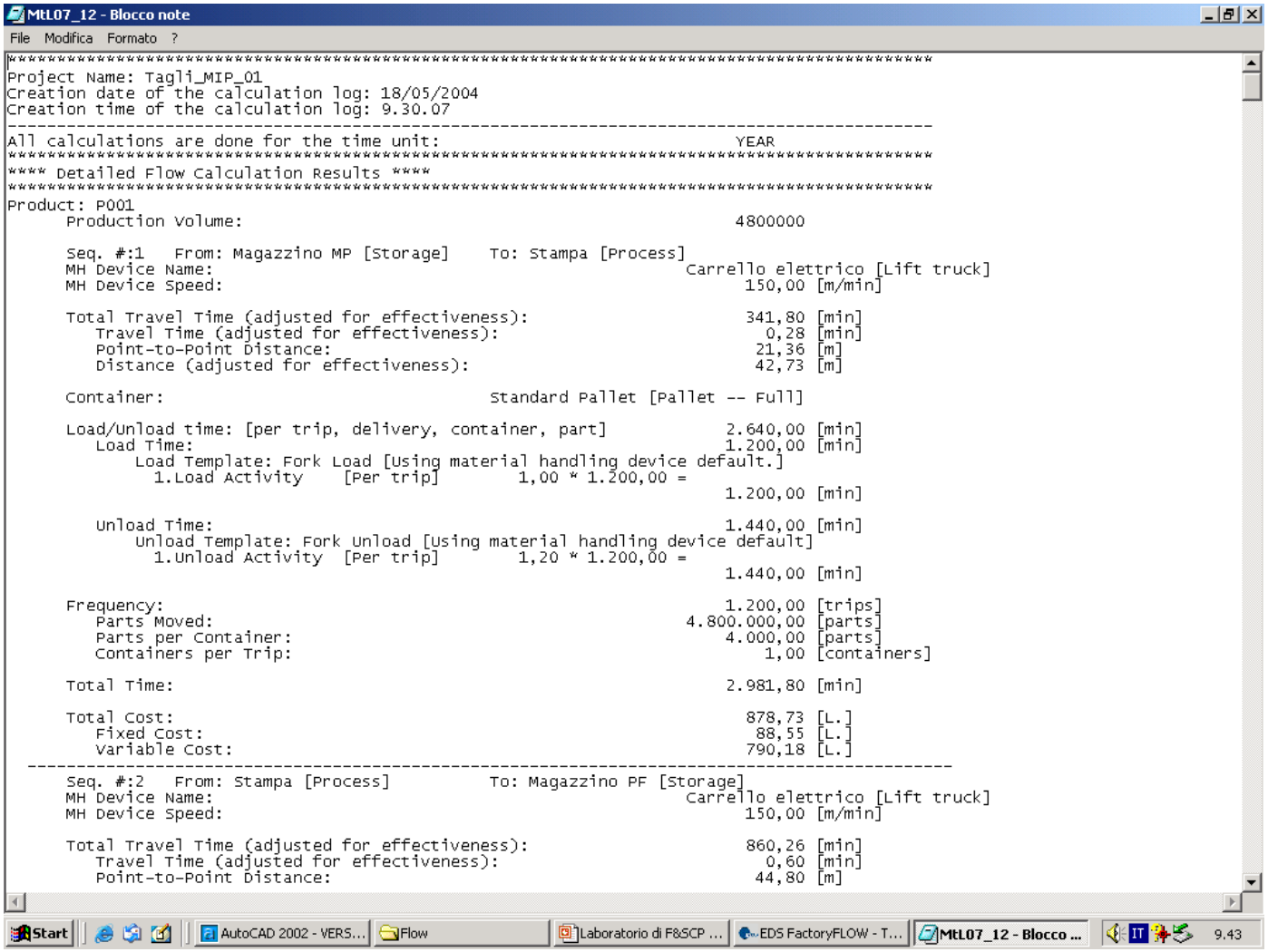


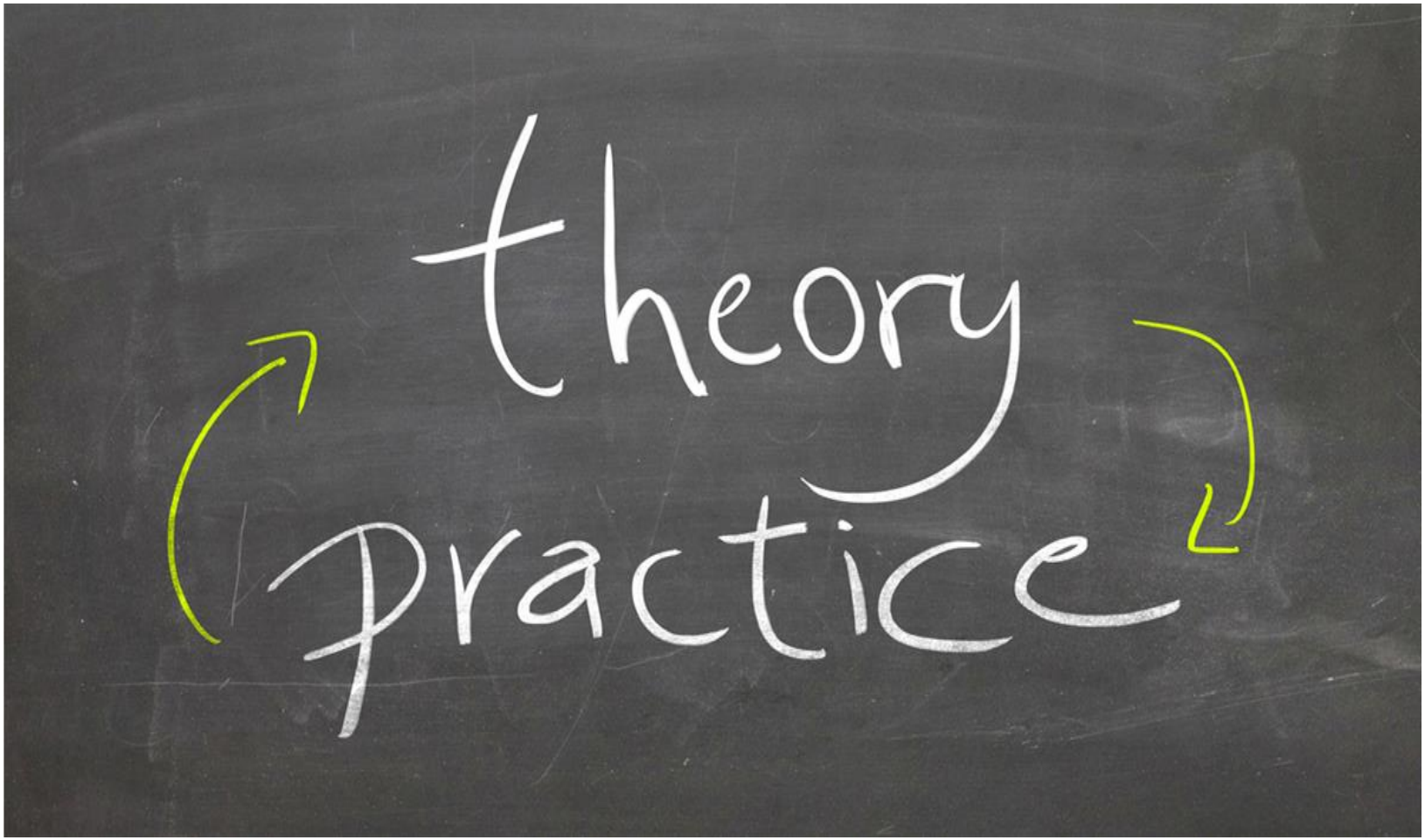
Computer-assisted layout using CAD

Corridors-based distances



Computer-assisted layout using CAD




theory
practice