Facility Layout Planning (Aldep-Craft)

Marco Macchi-Laura Cattaneo

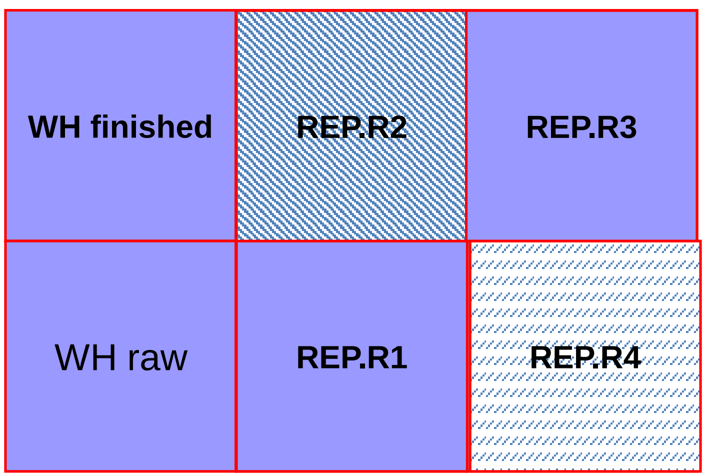
Computerized Layout Technique

- 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.

Methods and criteria for FLP planning

Heuristic CRAFT (Computerized Relative Allocation of Facilities Technique)

- Starting with an existing layout
- Matrix to exchange position of shops
- Evaluation of cost of the exchange of position (difference of objective function)



Matrix

	WH raw	R1	R2	R3	R4	WH fin
WH raw	0	Diff. F.o.	Diff. F.o.	Diff. F.o.	Diff. F.o.	Diff. F.o.
R1		0	Diff. F.o.	Diff. F.o.	Diff. F.o.	Diff. F.o.
R2			0	Diff. F.o.	Diff. F.o.	Diff. F.o.
R3				0	Diff. F.o.	Diff. F.o.
R4					0	Diff. F.o.
WH fin						0

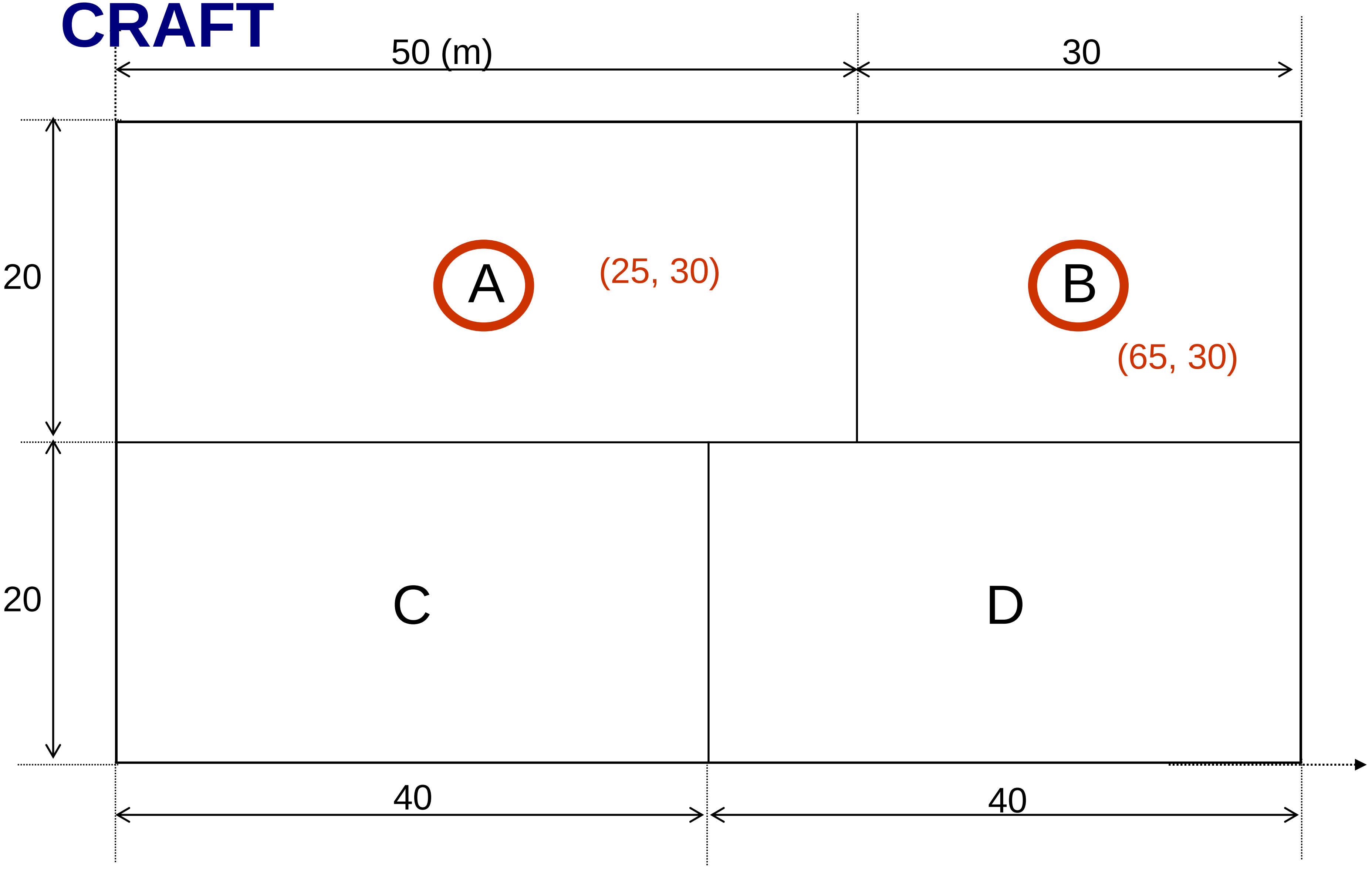
CRAFT

- **CRAFT is one of the first heuristic models (Computerised Relative Allocation of Facilities Technique)**
- **It is based on the minimization of moving cost among the shops**
- **It needs a starting layout**

CRAFT

- **Input**
  - **Initial Layout**
  - **From-to table (origin/destination matrix of flows)**
  - **Cost of the movements**
  - **Number of shops to be allocated and their constrains**

CRAFT



CRAFT

Centroid-based distances

$$d_{AB} = |x_A - x_B| + |y_A - y_B| = |25 - 65| + |30 - 30| = 40$$

From-to table (f_{ij} = trips/day)

	A	B	C	D
A		2	4	4
B	1		1	3
C	2	1		2
D	4	1	0	

From-to table for single movement (meters/trip))

	A	B	C	D
A		40	25	55
B	40		65	25
C	25	65		40
D	55	25	40	

CRAFT

From-to table for movement costs (€/meter)

	A	B	C	D
A		1	1	1
B	1		1	1
C	1	1		1
D	1	1	1	

1 €/metro

From-to table for the total costs (€)

	A	B	C	D	Tot
A		80	100	220	**400**
B	40		65	75	**180**
C	50	65		80	**195**
D	220	25	0		**245**
Tot	**310**	**170**	**165**	**375**	**1020**

CRAFT

- Given a layout, CRAFT first finds the total distance traveled and, then, the total cost, as illustrated on the previous slides
- CRAFT then attempts to improve the layout by pair-wise interchanges
  - If some interchange results some savings in the total distance traveled / total cost, the interchange that saves the most (total distance traveled / total cost) is selected
  - While searching for the most savings, exact savings are not computed. At the search stage, savings are computed assuming when shops are interchanged, centroids are interchanged too. This assumption does not give the exact savings, but approximate savings only
- Interchanges can be done on 1 way, with shops of that are next to themselves (one side at least should be connected)

CRAFT

- **Let's change A with B**
  - **New distances**

d	A	B	C	D
A		40	65	25
B	40		25	55
C	65	25		40
D	25	55	40	

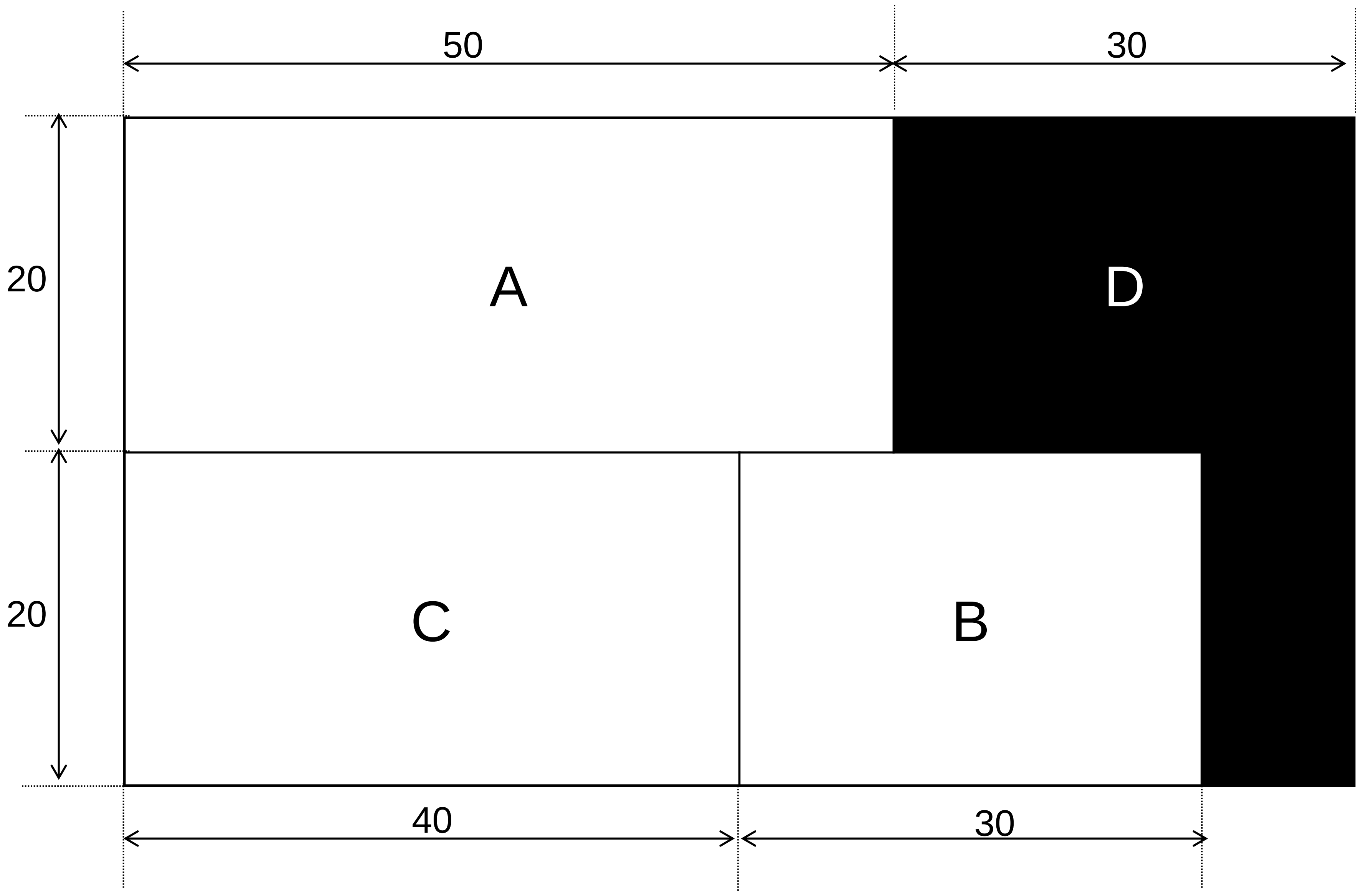
New total cost (€)

	A	B	C	D	Tot
A		80	260	100	440
B	40		25	165	230
C	130	25		80	235
D	100	55	0		155
Tot	270	160	285	345	1060

CRAFT

Possibile exchanges in the initial layout	**New total layout cost**
A with B	1.060
A with C	955
A with D	1.095
B with C	This is not possibile, since B is not next to C in the original layout
B with D	**945**
C with D	1.040

CRAFT



CRAFT

- Sometimes, an interchange may result in a peculiar shape of a shop; a shape that is composed of some rectangular pieces
- It is an improvement procedure, not a construction procedure
- Estimated cost reduction may not be obtained after interchange

ALDEP - Automated Layout Design Program

- While CRAFT is an improvement procedure, ALDEP is a construction procedure
- CRAFT requires an initial layout, which is improved by CRAFT
- ALDEP does not need any initial layout
- ALDEP constructs a layout when there is none

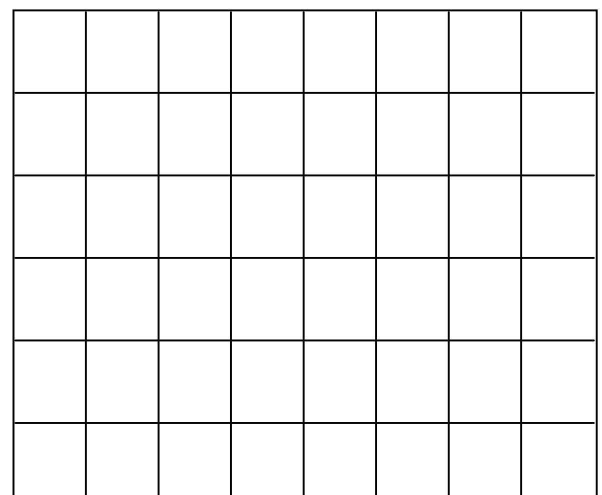
ALDEP

- **Given:**
  - **Size of the facility**
  - **The shops/areas of activities**
  - **Size of the shops/areas of activities**
  - **Proximity relationships (activity relationship chart)**
  - **A sweep width (defined later)**

- **ALDEP constructs a layout**

ALDEP

- The size of the facility and the size of the shops are expressed in terms of blocks.
- The procedure will be explained with an example. Suppose that the facility is 8 blocks (horizontal) $\times$ 6 blocks (vertical).
- The shops and the required number of blocks are:
  - Production area 14 blocks
  - Office rooms 10
  - Storage area 8
  - Dock area 8
  - Locker room 4
  - Tool room 4



ALDEP

A: absolutely necessary

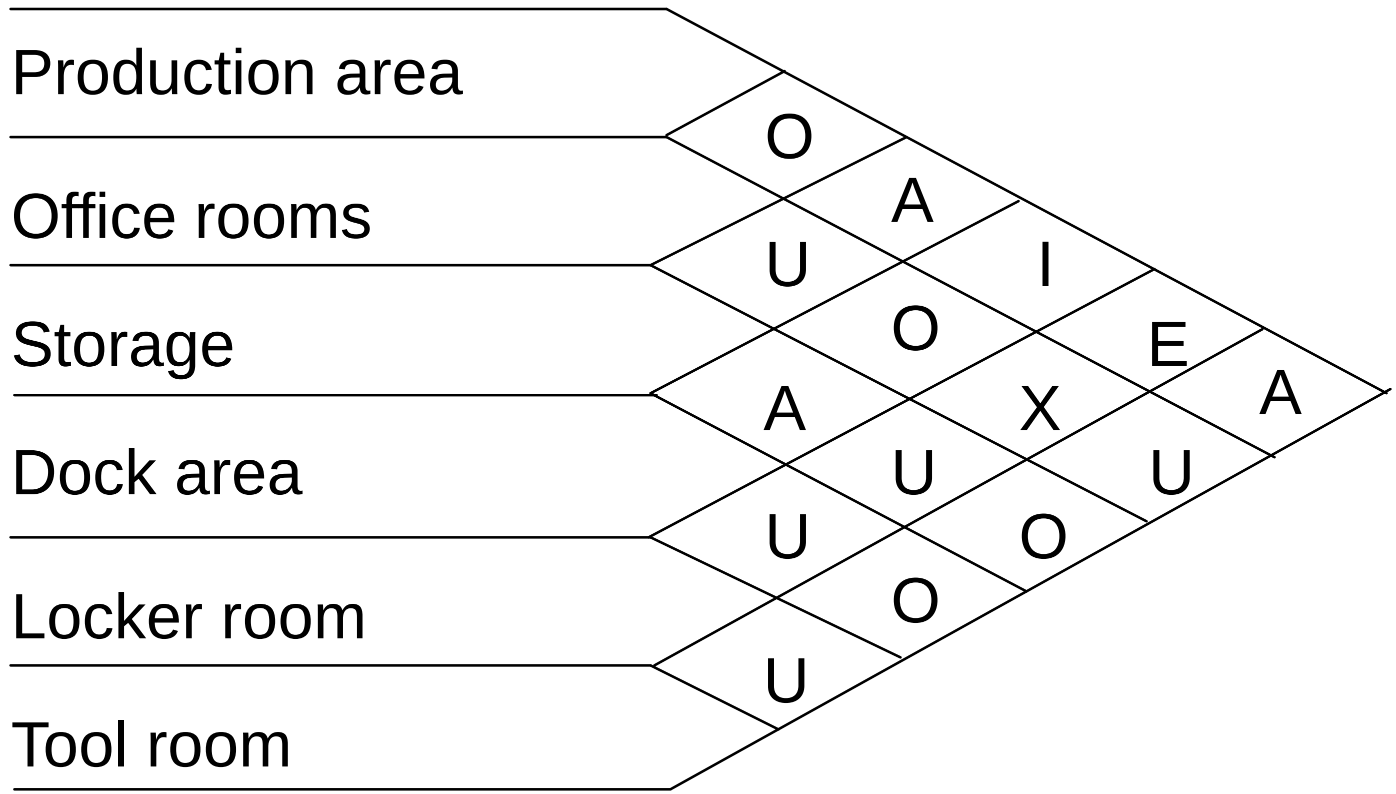
E: especially important

I: important

O: ordinarily important

U: unimportant

X: undesirable



ALDEP

- **ALDEP starts to allocate the shops from the upper left corner of the facility. The first shop is chosen at random. By starting with a different shop, ALDEP can find a different layout for the same problem.**

- ❑ Let’s start with dock rooms (D). On the upper left corner 8 blocks must be allocated for the dock area.
- ❑ The sweep width defines the width in number of blocks. Let sweep width = 2. Then, dock area will be allocated $2 \times 4 = 8$ blocks.

D	D						
D	D						
D	D						
D	D						

ALDEP

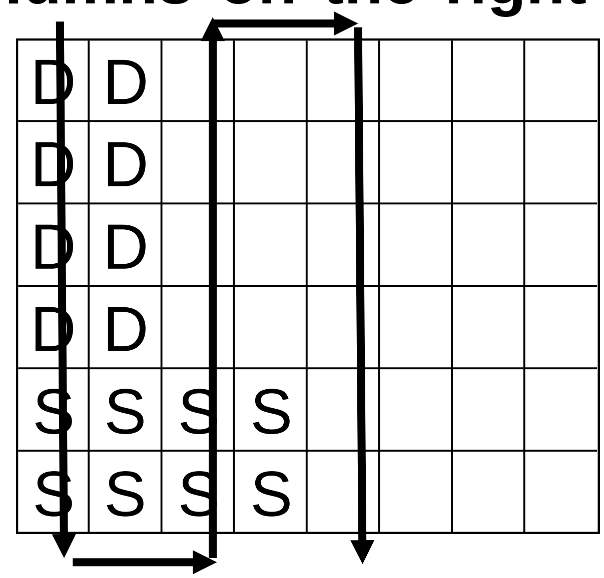
- **To find the next shop to allocate, find the shop that has the highest proximity rating with the dock area. Storage area (S) has the highest proximity rating A with the dock area.**
- **So, the storage area will be allocated next. The storage area also needs 8 blocks.**

- There are only 2×2 = 4 blocks, remaining below dock area (D). After allocating 4 blocks, the down wall is hit after which further allocation will be made on the adjacent 2 (=sweep width) columns and moving upwards.

D	D						
D	D						
D	D						
D	D						
S	S	S	S				
S	S	S	S				

ALDEP

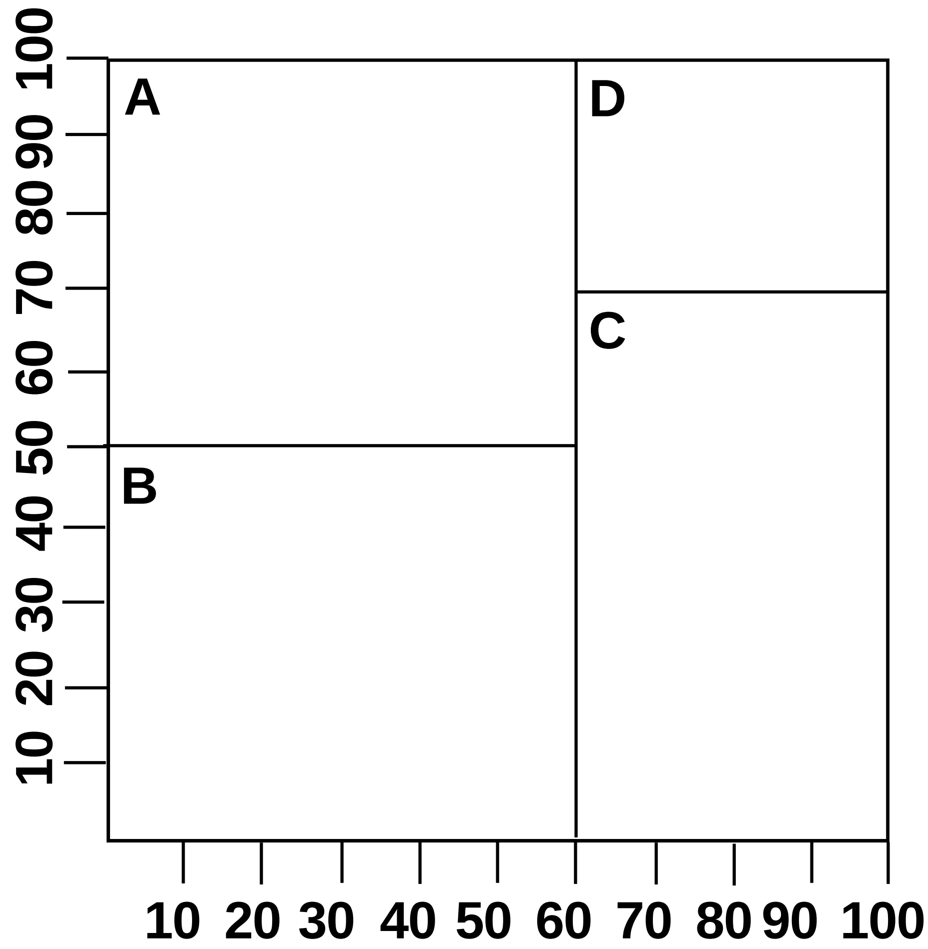
- **See carefully that the allocation started from the upper left corner and started to move downward with an width of 2 (=sweep width) blocks.**
- **After the down wall is hit, the allocation continues on the adjacent 2 (=sweep width) columns on the right side and starts moving up.**



- This zig-zag pattern will continue.
- Next time, when the top wall will be hit, the allocation will continue on the adjacent 2 (=sweep width) columns on the right side and starts moving down.

CRAFT exercise

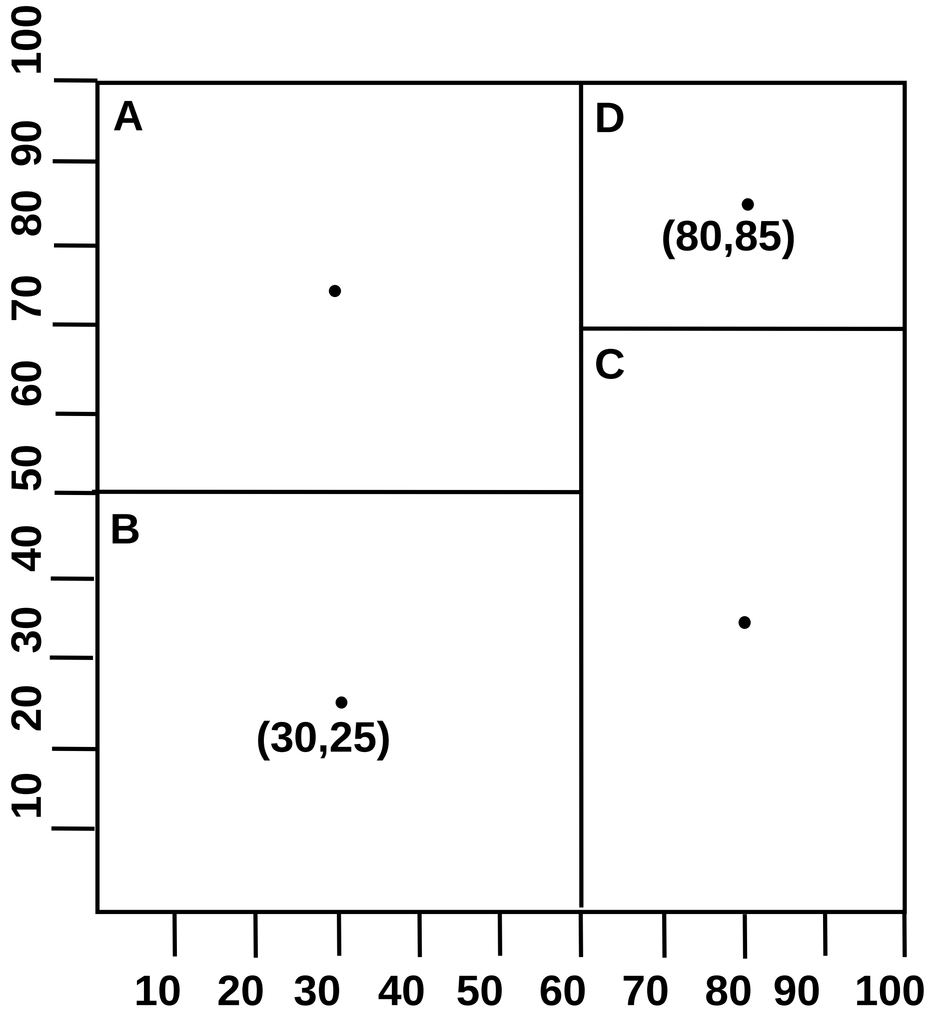
- **Following are some examples of questions addressed by CRAFT:**
  - **Is this a good layout?**
  - **If not, can it be improved?**



- **Distance Between Two Shops**
  - **Consider the problem of finding the distance between two adjacent shops, separated by a line only**
  - **People needs walking to move from one shop to another, even when the shops are adjacent**
  - **An estimate of average walking required is obtained from the distance between centroids of two shops**
  - **Centroid of a rectangle is the point where two diagonals meet**
  - **So, if a rectangle has two opposite corners** (x_1, y_1) **and** (x_2, y_2) **then the centroid is** $\left(\dfrac{x_1 + x_2}{2}, \dfrac{y_1 + y_2}{2}\right)$

- The distance between two shops is taken from the distance between their centroids
  - People walks along some rectilinear paths. An Euclidean distance between two centroids is not a true representative of the walking required. The rectilinear distance is a better approximation.
- So, Distance (A,B) = rectilinear distance between centroids of shops A and B

- Centroid of A =?
- Centroid of C =?
- Distance (A,C) =?



- **Let**
  - **Centroid of Shop A =** $\left(x_{\mathrm{A}}, y_{\mathrm{A}}\right)$
  - **Centroid of Shop B =** $\left(x_{\mathrm{B}}, y_{\mathrm{B}}\right)$
- **Then, the distance between shops A and B, Dist(A,B)**

$$= \left|x_A - x_B\right| + \left|y_A - y_B\right|$$

- **The distance between shops A and C is the rectilinear distance between their centroids (30,75) and (80,35). Distance (A,C)**

$$= \left|x_A - x_C\right| + \left|y_A - y_C\right| = \left|30 - 80\right| + \left|75 - 35\right| = 90$$

- **If the number of trips between two shops are very high, then such shops should be placed near to each other in order to minimize the total distance travelled**
- **Distance travelled from shop A to B = Distance (A,B) × Number of trips from shop A to B**
- **Total distance travelled is obtained by computing distance travelled between every pair of shops, and then summing up the results**
- **Given a layout, CRAFT first finds the total distance travelled**

CRAFT: Total Distance Traveled

(a) Material handling trips (given)

From \ To	A	B	C	D
A		2	7	4
B	3		5	7
C	6	7		3
D	7	7	3	

(a)

CRAFT: Total Distance Traveled

(a) Material handling trips (given)

(b) Distances (given)

(a)

From \ To	A	B	C	D
A		2	7	4
B	3		5	7
C	6	7		3
D	7	7	3	

(b)

From \ To	A	B	C	D
A		50	90	60
B	50		60	110
C	90	60		50
D	60	110	50	

CRAFT: Total Distance Traveled

(a) Material handling trips (given)

(b) Distances (given)

(c) Sample computation:
distance traveled (A,B)
= trips (A,B) × dist (A,B)
=

Total distance traveled
= 100+630+240+….
= 4640

(a)

From \ To	A	B	C	D
A		2	7	4
B	3		5	7
C	6	7		3
D	7	7	3	

(b)

From \ To	A	B	C	D
A		50	90	60
B	50		60	110
C	90	60		50
D	60	110	50	

(c)

From \ To	A	B	C	D
A		100	630	240
B	150		300	770
C	540	420		150
D	420	770	150	

- **Savings are computed for all feasible pairwise interchanges. Savings are not computed for the infeasible interchanges.**
- **An interchange between two shops is feasible only if the shops have the same area or they share a common boundary:**
  - **feasible pairs are {A,B}, {A,C}, {A,D}, {B,C}, {C,D}**
  - **and an infeasible pair is {B,D}**

- To illustrate the computation of savings, we shall compute the savings from interchanging Shops C and D
- New centroids:
  - A (30,75) Unchanged
  - B (30,25) Unchanged
  - C (80,85) Previous centroid of Shop D
  - D (80,35) Previous centroid of Shop C

  - Note: If C and D are interchanged, exact centroids are C(80,65) and D(80,15). So, the centroids C(80,85) and D(80,35) are not exact, but approximate.

- The first job in the computation of savings is to reconstruct the distance matrix that would result if the interchange was made.
- The purpose of using approximate centroids will be clearer now.
  - If the exact centroids were used, we would have to re-compute distances between every pair of departments that would include one or both of C and D.
  - However, since we assume that centroids of C and D will be interchanged, the new distance matrix can be obtained just by rearranging some rows and columns of the original distance matrix. This will now be shown.

- The matrix on the left is the previous matrix, before interchange. The matrix on the right is after.
- Dist (A,B) and (C,D) does not change.
- New dist (A,C) = Previous dist (A,D)
- New dist (A,D) = Previous dist (A,C)
- New dist (B,C) = Previous dist (B,D)
- New dist (B,D) = Previous dist (A,C)

Interchange C,D

From \ To	A	B	C	D
A		50	90	60
B	50		60	110
C	90	60		50
D	60	110	50	

From \ To	A	B	C	D
A		50	60	90
B	50		110	60
C	60	110		50
D	90	60	50	

(a) Material handling trips (given)

To / From	A	B	C	D
A		2	7	4
B	3		5	7
C	6	7		3
D	7	7	3	

(a)

(a) Material handling trips (given)

(b) Distances (rearranged)

From \ To	A	B	C	D
A		2	7	4
B	3		5	7
C	6	7		3
D	7	7	3	

(a)

From \ To	A	B	C	D
A		50	60	90
B	50		110	60
C	60	110		50
D	90	60	50	

(b)

(a) Material handling trips (given)

(b) Distances (rearranged)

(c) Sample computation:
distance traveled (A,B)
= trips (A,B) × dist (A,B)
=

Total distance traveled
= 100+420+360+…
= 4480

Savings

(a)

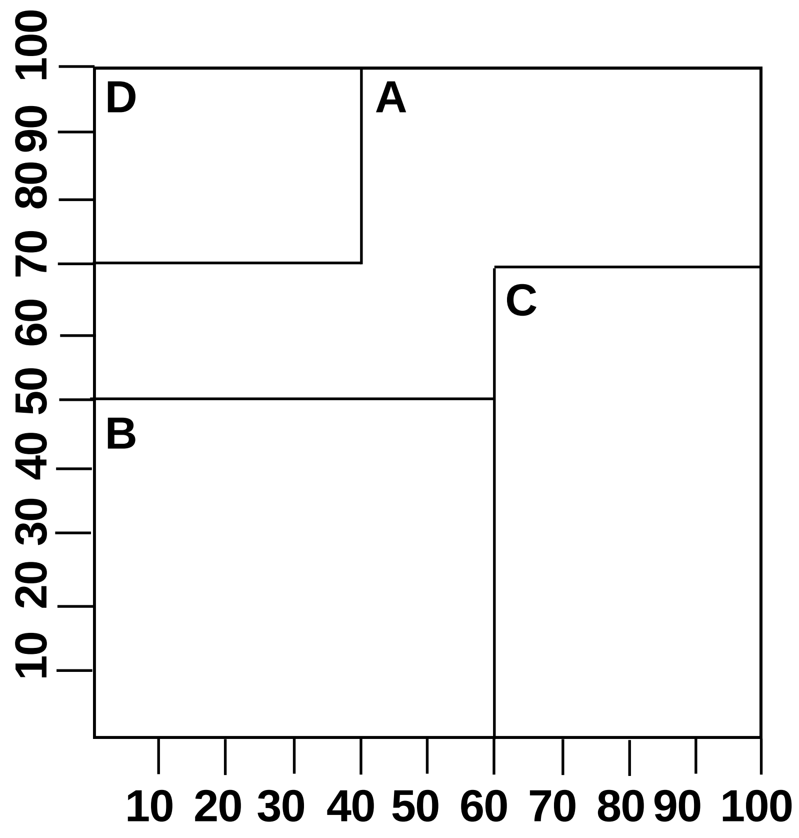
From \ To	A	B	C	D
A		2	7	4
B	3		5	7
C	6	7		3
D	7	7	3	

(b)

From \ To	A	B	C	D
A		50	60	90
B	50		110	60
C	60	110		50
D	90	60	50	

(c)

From \ To	A	B	C	D
A		100	420	360
B	150		550	420
C	360	770		150
D	630	420	150	



D
A
C
B
100
90
80
70
60
50
40
30
20
10
10 20 30 40 50 60 70 80 90 100

- To complete the exercise
  - Compute savings from all the feasible interchanges. If there is no (positive) savings, stop
  - If any interchange gives some (positive) savings, choose the interchange that gives the maximum savings
  - If an interchange is chosen, then for every shop find an exact centroid after the interchange is implemented
  - Repeat the above 3 steps as long as Step 1 finds an interchange with some (positive) savings.

ALDEP – exercize

The layout consists of 5 department with the following required blocks and relation ship

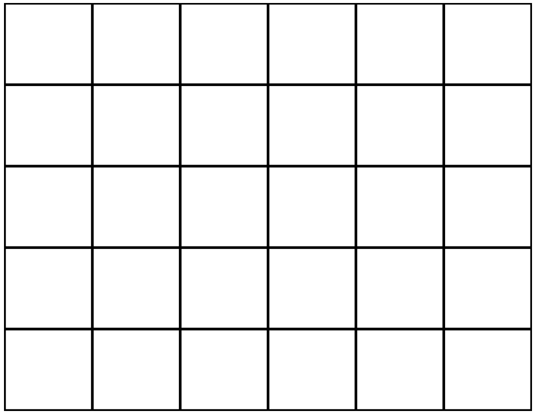
Department	Name	Blocks
A	Receiving	6
B	Milling	4
C	Press	6
D	Drilling	4
E	Assembly	8

	A	B	C	D	E
A		E	O	I	O
B			U	E	I
C				U	U
D					I
E					

A: absolutely necessary
E: especially important
I: important
O: ordinarily important
U: unimportant
X: undesirable

ALDEP - exercize

The specified sweep width is equal to 2 blocks. The space available in the layout is described in solution section. Start to build the solution from department A. Then repeat the exercise starting the solution from department D.



Available Space