Layout design IV.

Chapter 6

Layout generation

- CORELAP
- ALDEP
- MULTIPLE

Algorithm classification

Construction algorithm	Improvement algorithm
Graph-based method ALDEP CORELAP PLANET	Pairwise exchange method CRAFT MCCRAFT MULTIPLE
BLOCPLAN LOGIC Mixed integer programming	

CORELAP: Computerized Relationship Layout Planning

- Developed for main frame computers
- Construction type
- Adjacency-based method
  - CORELAP uses A=4, E=3, I=2, O=1, U=0 and X=-1 values
- Selection of the departments to enter the layout is based on Total Closeness Rating
  - **Total Closeness Rating (TCR**) for a department is the sum of the numerical values assigned to the closeness relationships between the department and all other departments.

$$TCR = \sum_{j=1, i \neq j}^{m} w_{ij}$$

CORELAP

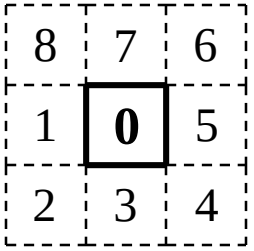
Department selection

1. The first department placed in the layout is the one with the greatest TCR value. If there is a tie, then choose the one with more A's (E's, etc.).
2. If a department has an X relationship with the first one, it is placed last in the layout and not considered. If a tie exists, choose the one with the smallest TCR value.
3. The second department is the one with an A (or E, I, etc.). relationship with the first one. If a tie exists, choose the one with the greatest TCR value.
4. If a department has an X relationship with the second one, it is placed next-to-the-last or last in the layout. If a tie exists, choose the one with the smallest TCR value.
5. The next department is the one with an A (E, I, etc.) relationship **with the already placed departments**. If a tie exists, choose the one with the greatest TCR value.
6. The procedure continues until all departments have been placed. ➔ **Placement sequence**

CORELAP

Department placement

- ***Department neighbors***
  - **Adjacent** (in position 1, 3, 5 or 7) with department 0
  - **Touching** (in position 2, 4, 6 or 8) department 0



- ***Placing rating (PR)*** is the sum of the weighted closeness ratings between the department to enter the layout and its neighbors.

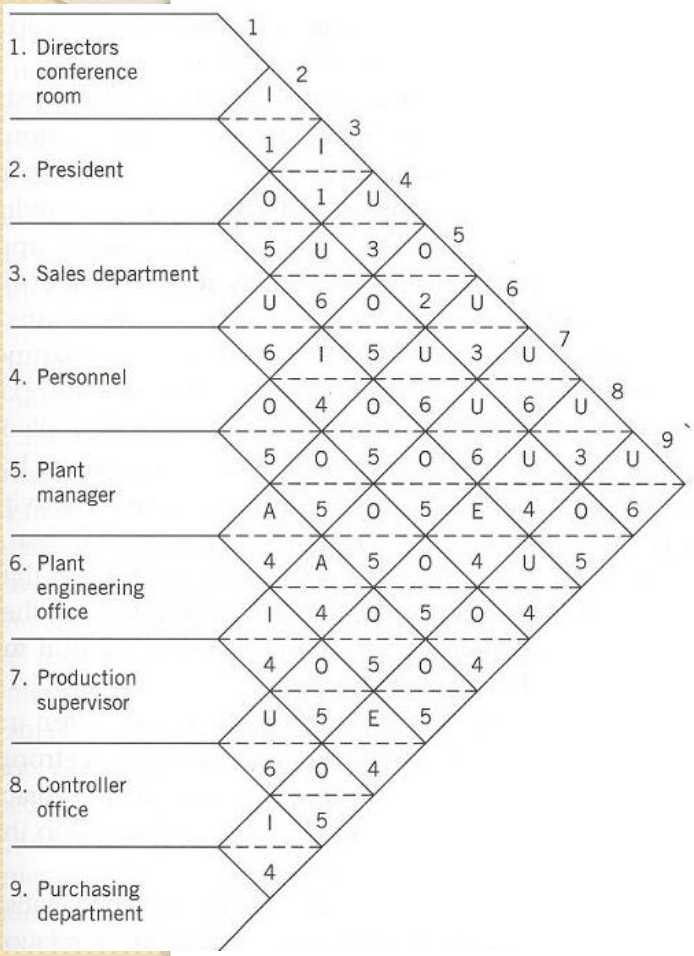
$$PR = \sum_{k} w_{ik} \text{ where } k = \{\text{departments already placed}\}$$

- The placement of departments is based on the following steps:

1. The first department selected is placed in the middle.
2. The placement of a department is determined by evaluating PR for all possible locations around the current layout in counterclockwise order beginning at the "western edge".
3. The new department is located based on the greatest PR value.

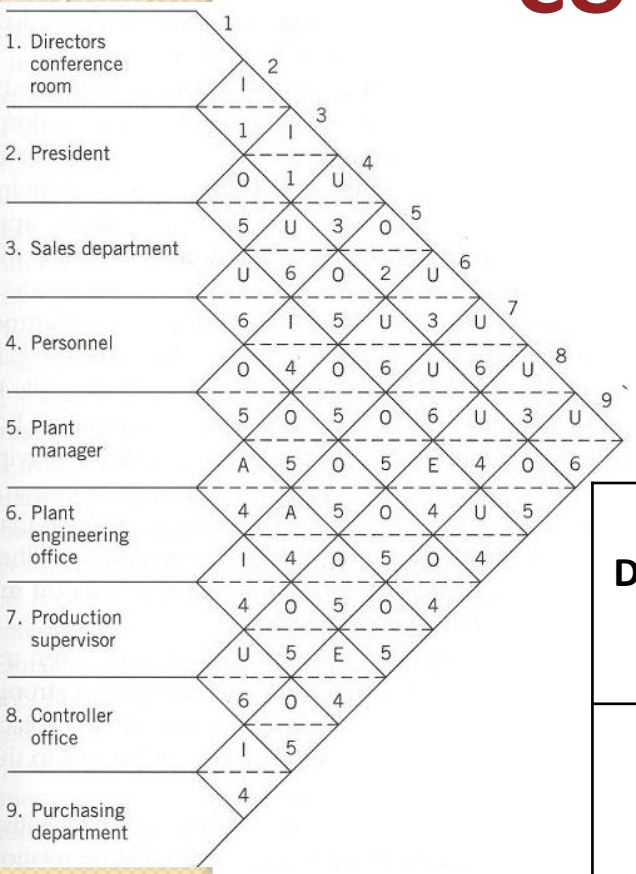
CORELAP – Example 1

- Given the relationship chart and the departmental dimensions below determine the sequence of the placement of the departments in the layout based on the CORELAP algorithm. Place the departments in the layout while evaluating each placement.



Department Sizes	Sq.ft.	Num of Grids
1. Conf Room	100	2
2. President	200	4
3. Sales	300	6
4. Personnel	500	10
5. Plant Mng.	100	2
6. Plant Eng	500	10
7. P. Supervisor	100	2
8. Controller Office	50	1
9. Purchasing Dept	300	6

CORELAP – Example 1



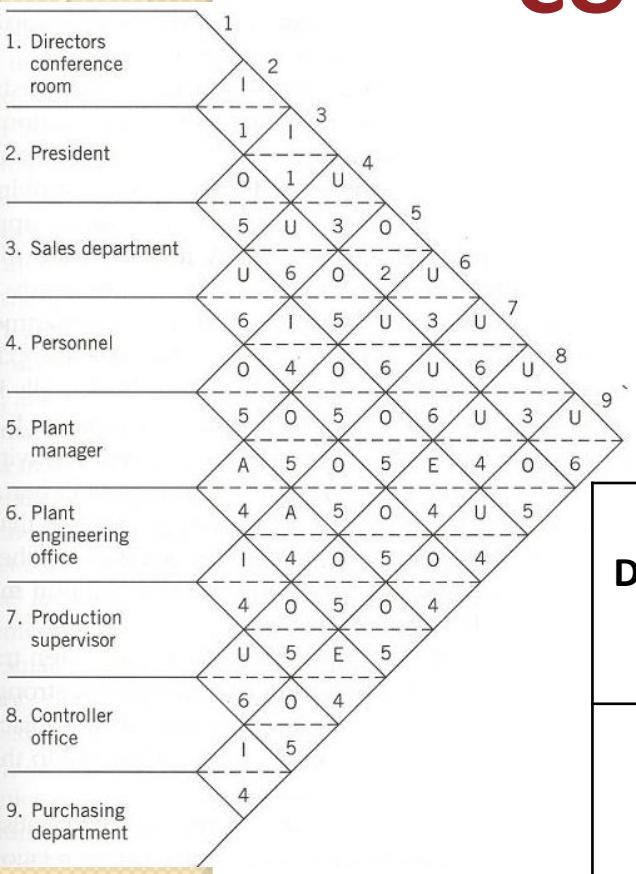
A=4, E=3, I=2, O=1, U=0, X=-1

The first department placed in the layout is the one with the greatest TCR value. If there is a tie, then choose the one with more A's (E's, etc.). Any X relationships?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	

The placement sequence: **5**

CORELAP – Example 1



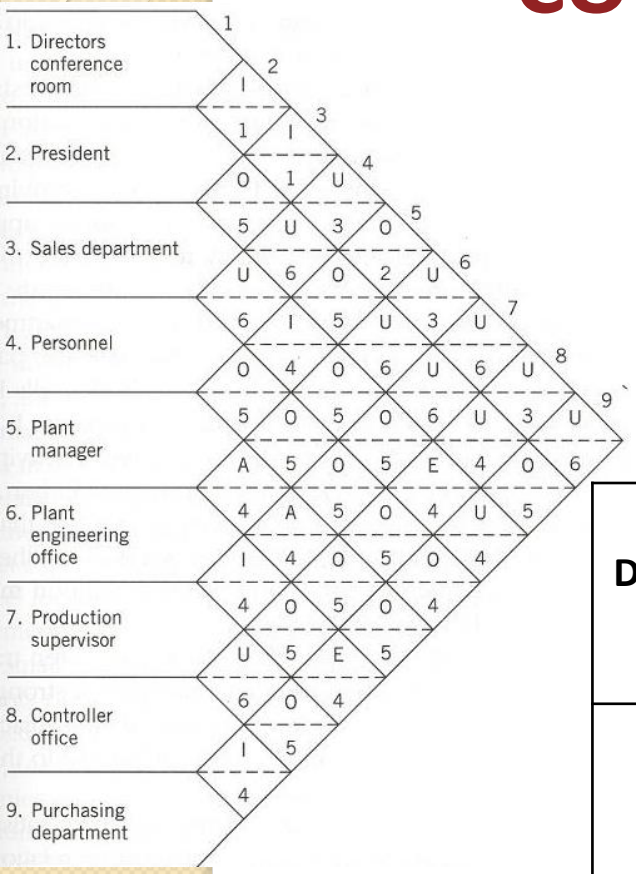
A=4, E=3, I=2, O=1, U=0, X=-1

The second department is the one with an A relationship with the first one (or E, I, etc.). If a tie exists, choose the one with the greatest TCR value. Any X relationships?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	

The placement sequence: **5-6**

CORELAP – Example 1



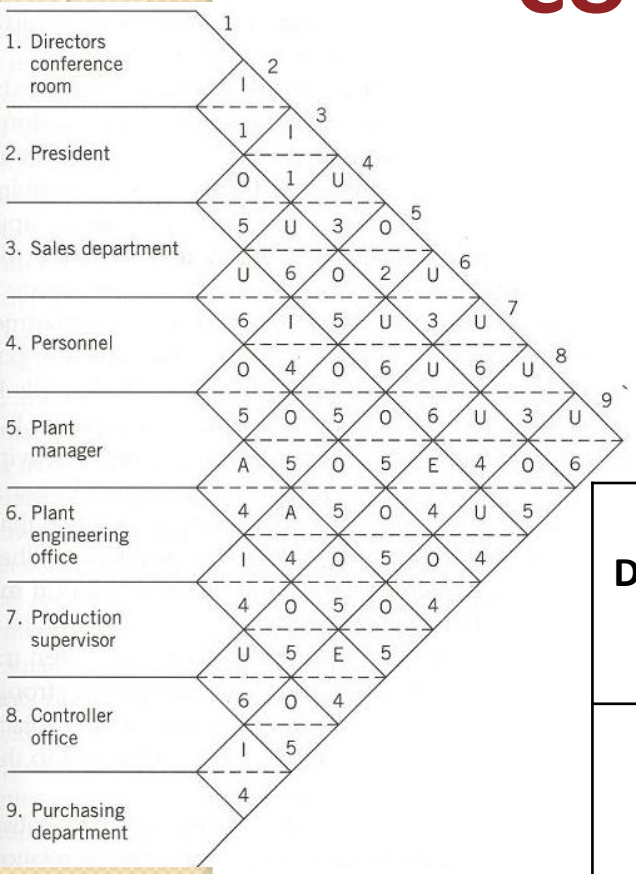
A=4, E=3, I=2, O=1, U=0, X=-1

The next department is the one with an A (E, I, etc.). relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	

The placement sequence: **5-6-7**

CORELAP – Example 1



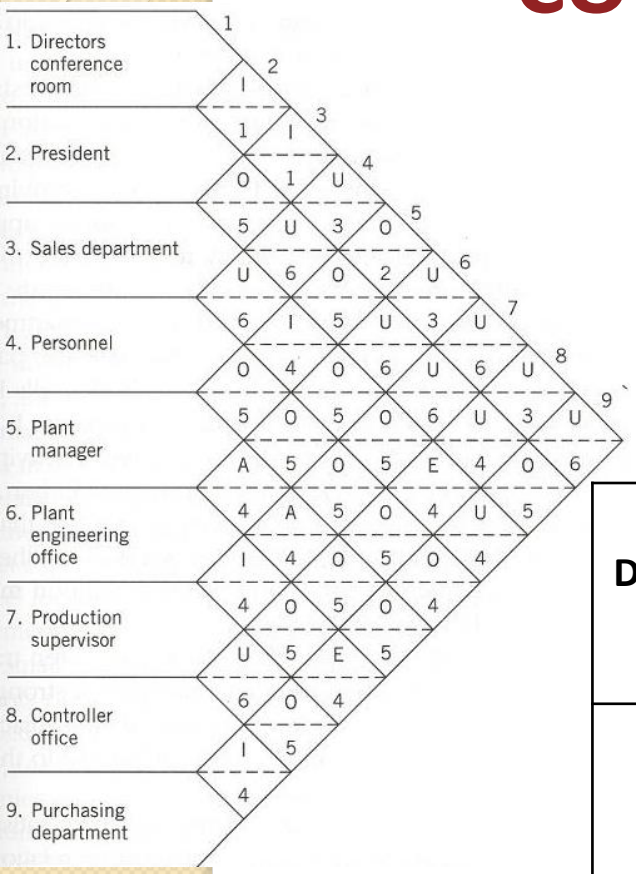
A=4, E=3, I=2, O=1, U=0, X=-1

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X ?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	4

The placement sequence: **5-6-7-9**

CORELAP – Example 1



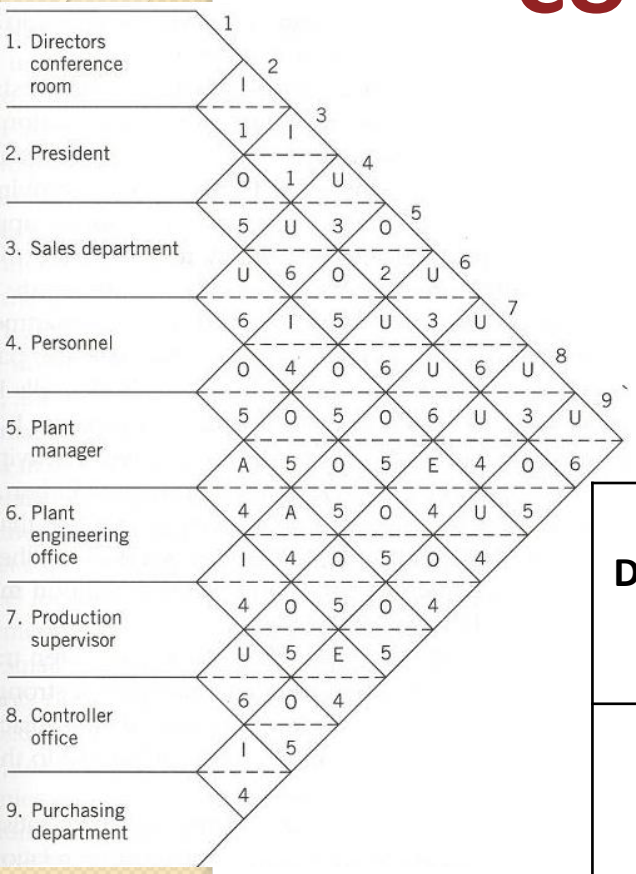
A=4, E=3, I=2, O=1, U=0, X=-1

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	5
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	4

The placement sequence: **5-6-7-9-3**

CORELAP – Example 1



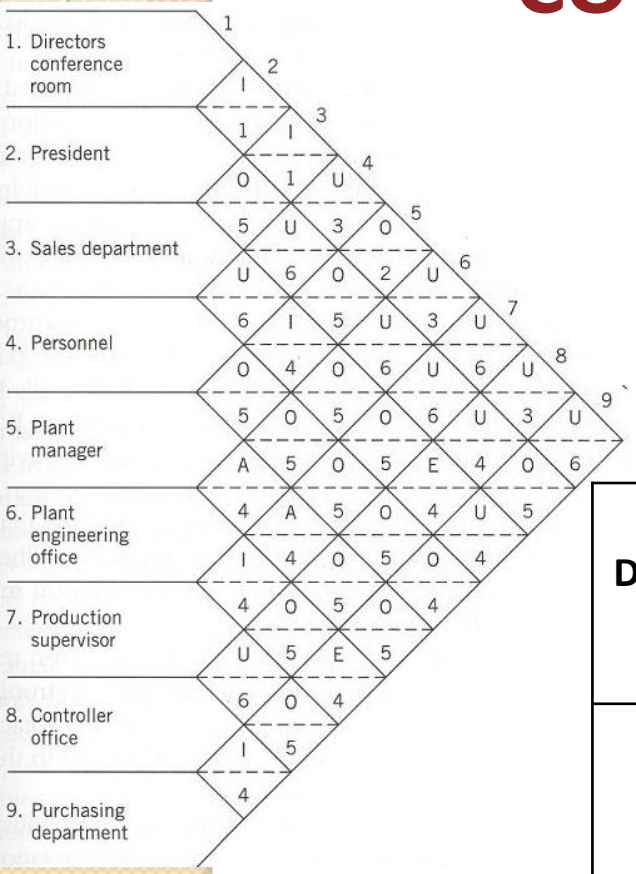
A=4, E=3, I=2, O=1, U=0, X=-1

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	5
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	6
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	4

The placement sequence: **5-6-7-9-3 - 8**

CORELAP – Example 1



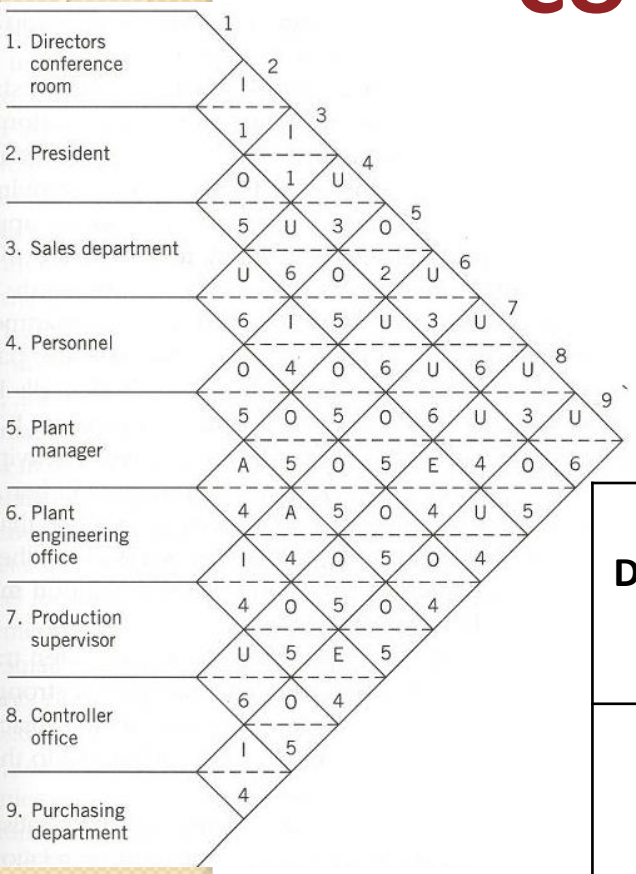
A=4, E=3, I=2, O=1, U=0, X=-1

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	7
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	5
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	6
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	4

The placement sequence: **5-6-7-9-3-8 - 1**

CORELAP – Example 1



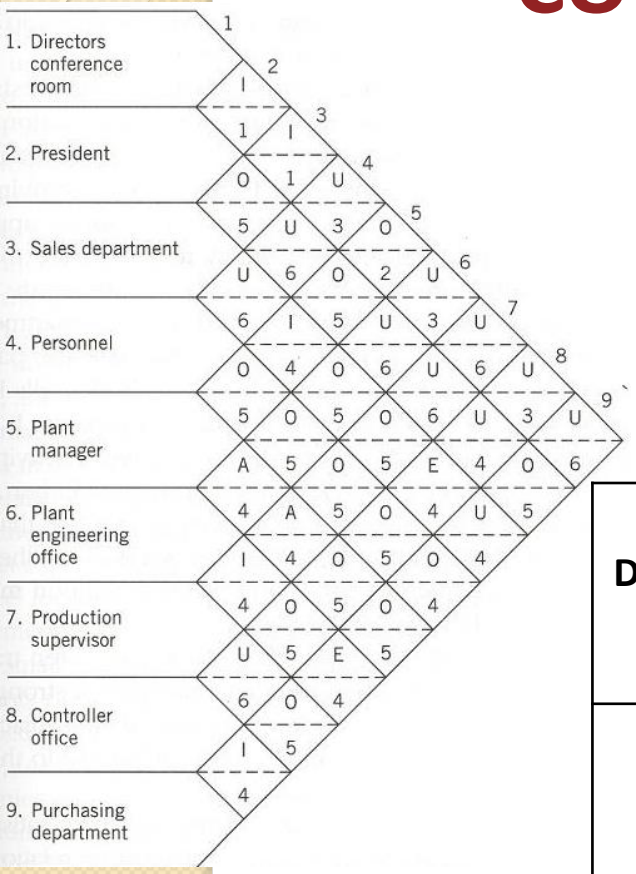
A=4, E=3, I=2, O=1, U=0, X=-1

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	7
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	8
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	5
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	6
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	4

The placement sequence: **5-6-7-9-3-8-1 - 2**

CORELAP – Example 1



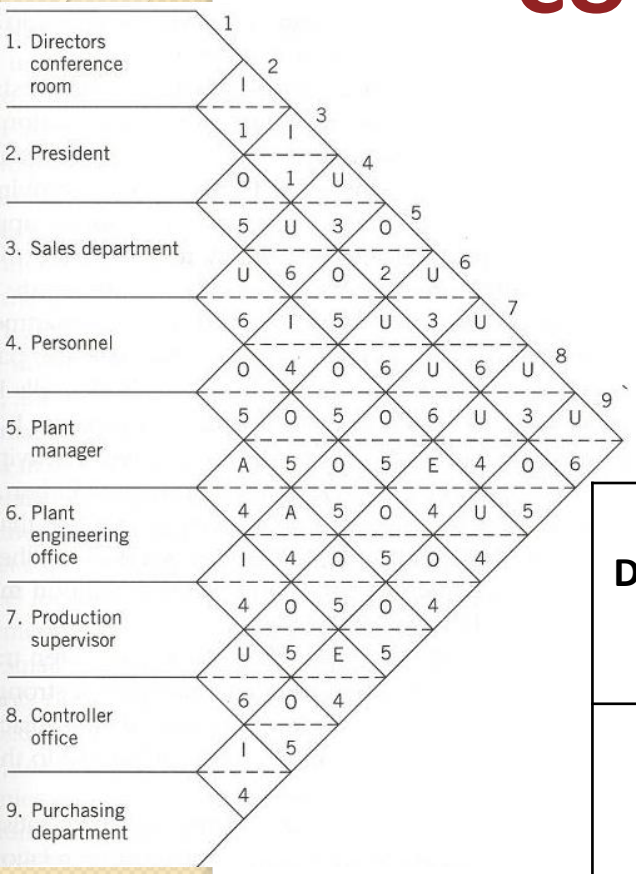
A=4, E=3, I=2, O=1, U=0, X=-1

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	7
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	8
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	5
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	9
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	6
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	4

The placement sequence: **5-6-7-9-3-8-1-2-4**

CORELAP – Example 1



A=4, E=3, I=2, O=1, U=0, X=-1

Final table of TCR Values with the placement sequence:

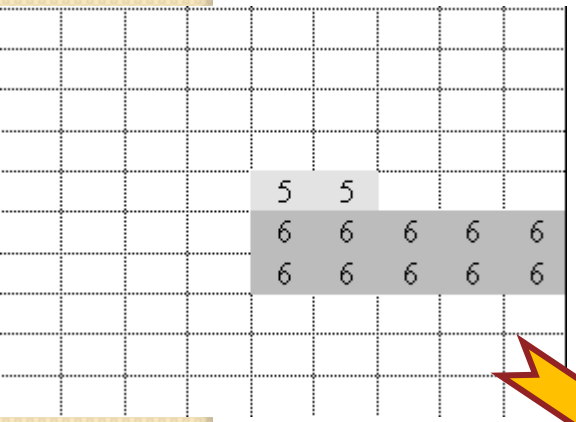
Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	I	I	U	O	U	U	U	U	0	0	2	1	5	0	5	7
2	I	-	O	U	O	U	U	U	O	0	0	1	3	4	0	5	8
3	I	O	-	U	I	O	O	E	U	0	1	2	3	2	0	10	5
4	U	U	U	-	O	O	O	O	O	0	0	0	5	3	0	5	9
5	O	O	I	O	-	A	A	O	O	2	0	1	5	0	0	15	1
6	U	U	O	O	A	-	I	O	E	1	1	1	3	2	0	12	2
7	U	U	O	O	A	I	-	U	O	1	0	1	3	3	0	9	3
8	U	U	E	O	O	O	U	-	I	0	1	1	3	3	0	8	6
9	U	O	U	O	O	E	O	I	-	0	1	1	4	2	0	9	4

The placement sequence: **5-6-7-9-3-8-1-2-4**

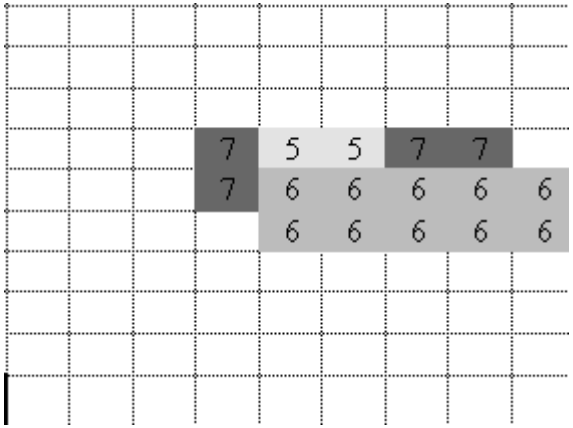
CORELAP – Example 1

A=4, E=3, I=2, O=1, U=0, X=-1

Departments: ***5 & 6***



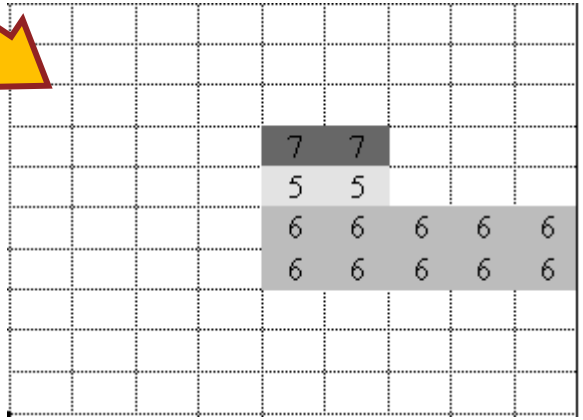
Entering department: ***7***



Both options give the same PR Score

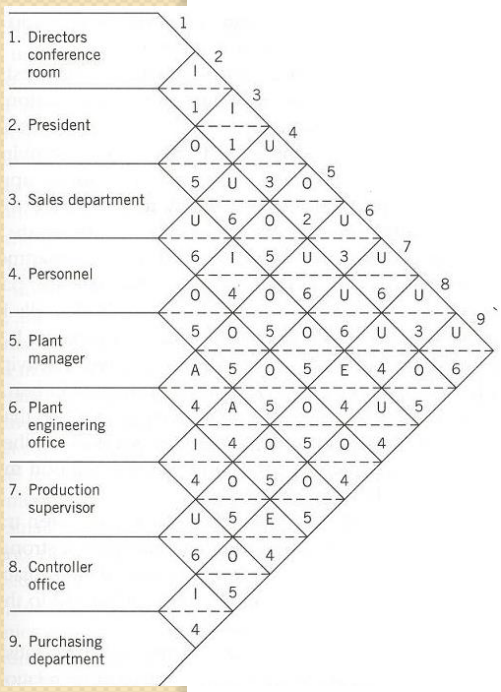
$PR = A_{[5,7]} + I_{[6,7]}$

$= 4 + 2 = \underline{\mathbf{6}}$



If the location for the department 7 is chosen as shown, the PR would be

$PR = A_{[5,7]} = \mathbf{4}$

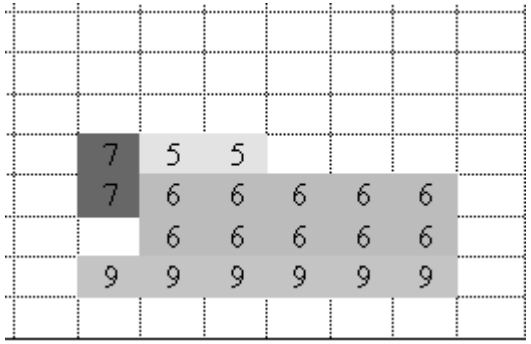


The placement sequence: **5-6-<u>7</u>-9-3-8-1-2-4**

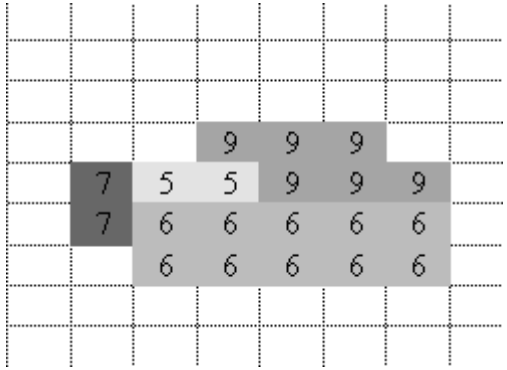
CORELAP – Example 1

A=4, E=3, I=2, O=1, U=0, X=-1

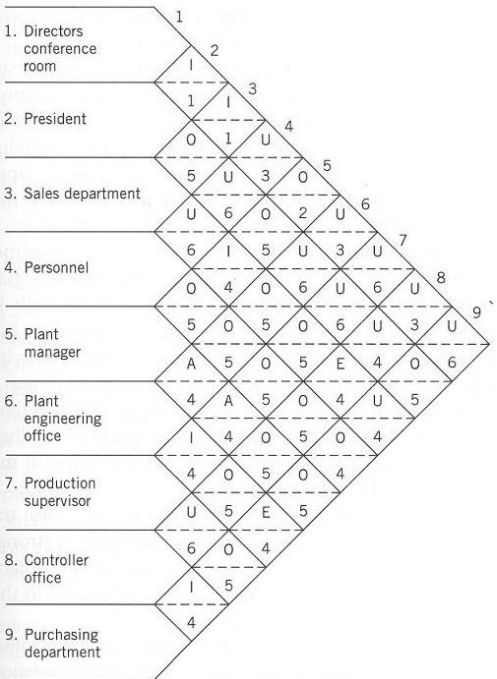
Entering department: ***9***



PR = $E_{[6,9]}$ = **3**



PR = $E_{[6,9]}$ +$O_{[5,9]}$ = 3 + 1= **4**

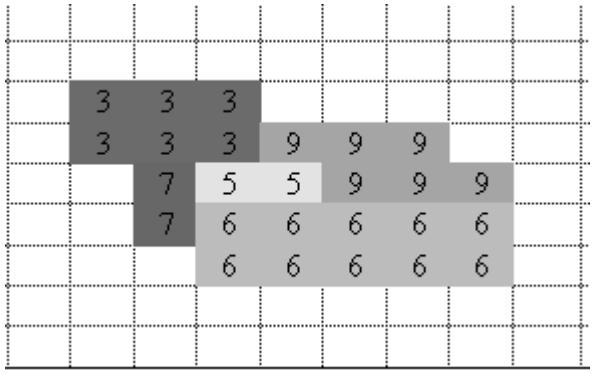


The placement sequence: **5-6-7-9-3-8-1-2-4**

CORELAP – Example 1

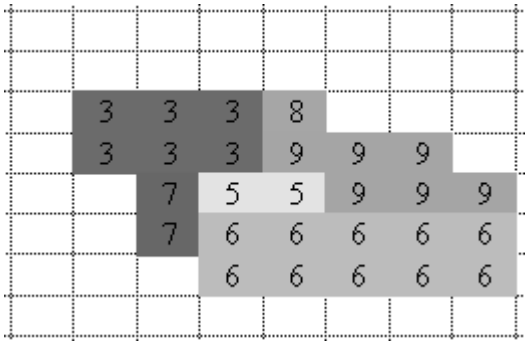
A=4, E=3, I=2, O=1, U=0, X=-1

Entering department: ***3***

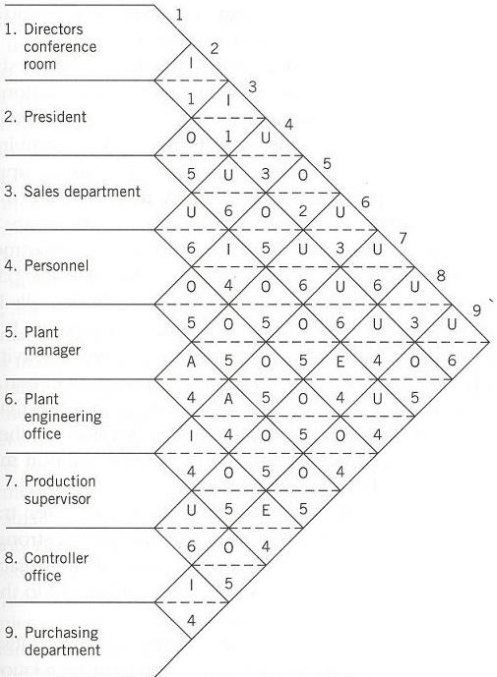


PR = $I_{[3,5]}$ + $O_{[3,7]}$ + $U_{[3,9]}$ = 2 + 1 + 0 = **3**

Entering department: ***8***



PR = + $E_{[3,8]}$ + $I_{[8,9]}$ = 3 + 2 = **5**

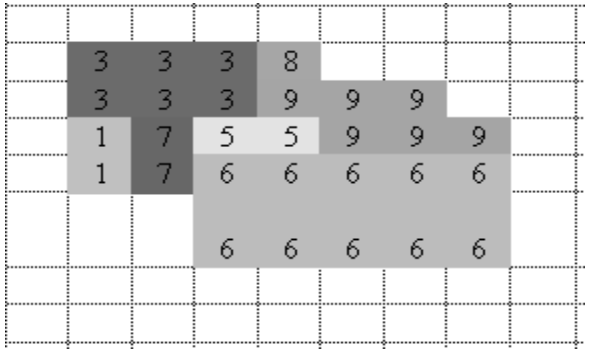


The placement sequence: **5-6-7-9-3-8-1-2-4**

CORELAP – Example 1

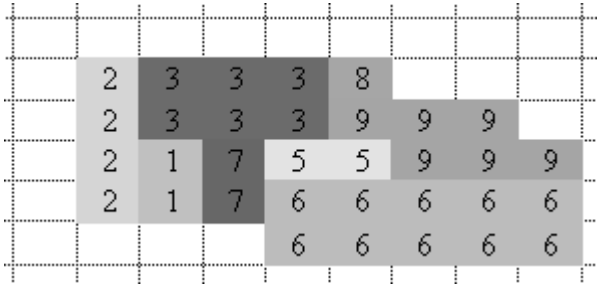
A=4, E=3, I=2, O=1, U=0, X=-1

Entering department: ***1***

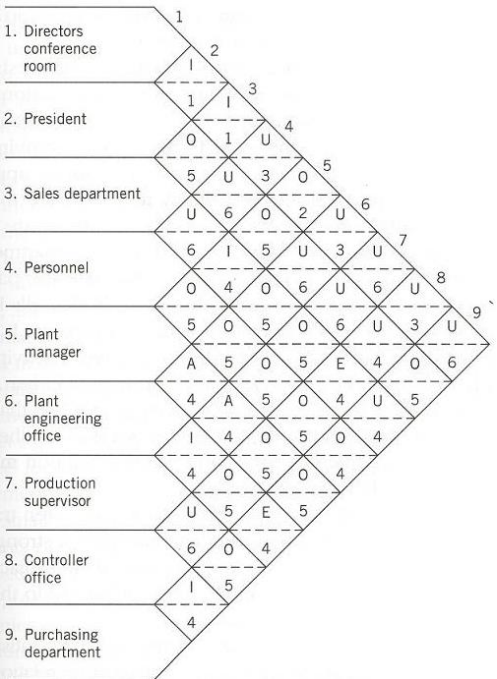


PR = $I_{[1,3]} + U_{[1,7]} = 2 + 0 = \mathbf{2}$

Entering department: ***2***



PR = $I_{[1,2]} + I_{[2,3]} = 2 + 2 = \mathbf{4}$

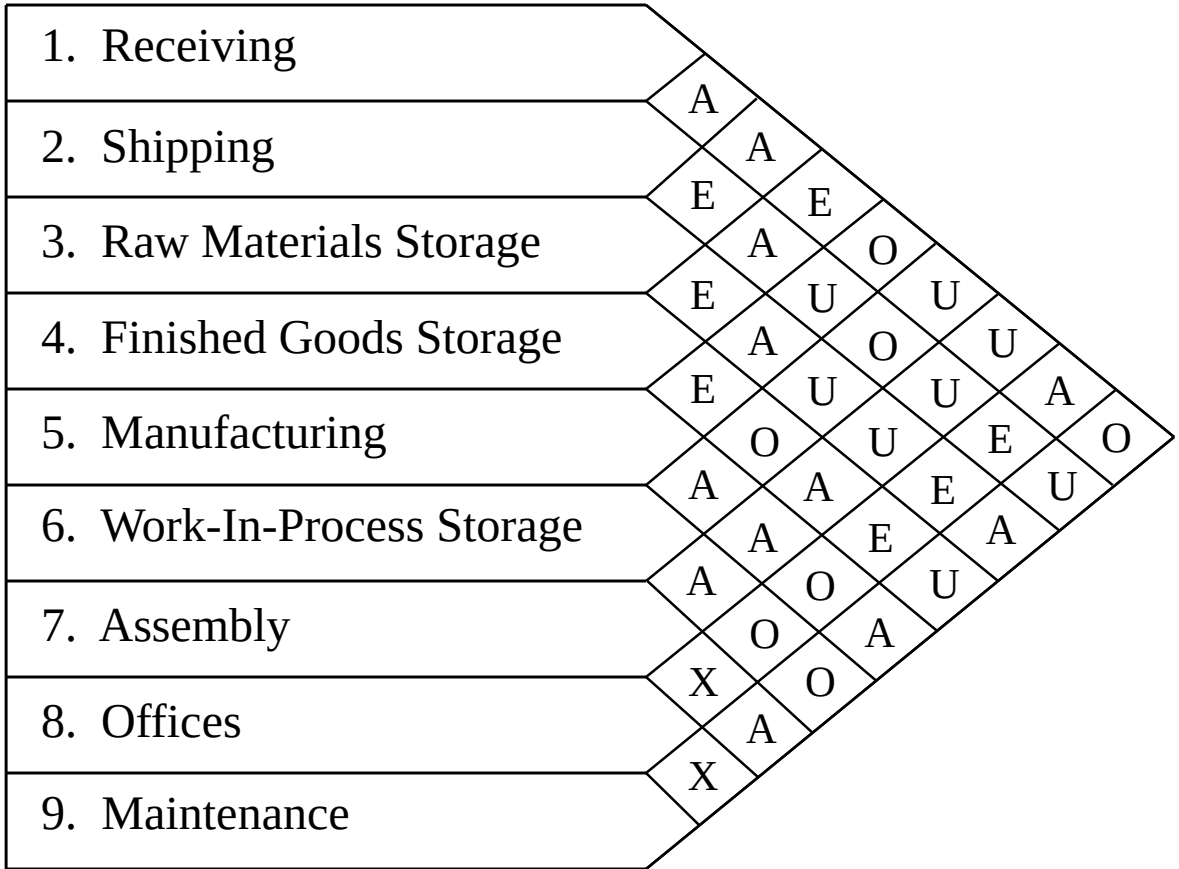


Continue with Department 4.

The placement sequence: **5-6-7-9-3-8-1-2-4**

CORELAP – Example 2

➢ Given the relationship chart below, determine the sequence of the placement of the departments and find the best layout with CORELAP algorithm assuming that all the departments have the same size. Use these closeness values: A=125, E=25, I=5, O=1, U=0, X=-125 and consider half weight if the departments are only touching by one point.



CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

Table of TCR values:

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

The first department placed in the layout is the one with the greatest TCR value. If there is a tie, then choose the one with more A (E, etc.).
Any X? ➔ Yes, X with 8.

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	

The placement sequence: **7**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

If a department has an X relationship with the first one, it is placed last in the layout. If a tie exists, choose the one with the smallest TCR value.

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	

The placement sequence: **7-** **-8**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

The second department is the one with an A relationship with the first one (or E, I, etc.). If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	2
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	

The placement sequence: **7- 5-** **- 8**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X? ➔ Yes, X with 8.

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	2
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	3

The placement sequence: **7- 5 - 9 - - 8**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	4
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	2
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	3

The placement sequence: **7- 5 - 9 - 3 - 8**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	5
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	4
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	2
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	3

The placement sequence: **7- 5 - 9 - 3 - 1 - 8**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	5
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	4
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	6
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	2
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	3

The placement sequence: **7- 5 - 9 - 3 - 1 - 4 - 8**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

The next department is the one with an A (E, I, etc.) relationship with the already placed departments. If a tie exists, choose the one with the greatest TCR value. Any X?

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	5
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	7
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	4
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	6
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	2
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	8
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	3

The placement sequence: **7- 5 - 9 - 3 - 1 - 4 - 2 - 6 - 8**

CORELAP – Example 2

A=125, E=25, I=5, O=1, U=0, X=-125

Final table of TCR values with the placement sequence:

Dept.	Department relationships									Summary						TCR	Placement Sequence
	1	2	3	4	5	6	7	8	9	A	E	I	O	U	X		
1	-	A	A	E	O	U	U	A	O	3	1	-	2	2	-	402	5
2	A	-	E	A	U	O	U	E	U	2	2	-	1	3	-	301	7
3	A	E	-	E	A	U	U	E	A	3	3	-	-	2	-	450	4
4	E	A	E	-	E	O	A	E	U	2	4	-	1	1	-	351	6
5	O	U	A	E	-	A	A	O	A	4	1	-	2	1	-	527	2
6	U	O	U	O	A	-	A	O	O	2	-	-	4	2	-	254	8
7	U	U	U	A	A	A	-	X	A	4	-	-	-	3	1	625	1
8	A	E	E	E	O	O	X	-	X	1	3	-	2	-	2	452	9
9	O	U	A	U	A	O	A	X	-	3	-	-	2	2	1	502	3

The placement sequence: **7- 5 - 9 - 3 - 1 - 4 - 2 - 6 - 8**

A=125, E=25, I=5, O=1, U=0, X=-125

CORELAP – Example 2

The placement sequence: **7-5-9-3-1-4-2-6-8**

Department 5?

62.5	125	62.5
125	**7**	125
62.5	125	62.5

7-5…A=125

Department 9?

62.5	187.5	187.5	62.5
125	**5**	**7**	125
62.5	187.5	187.5	62.5

7-9…A=125

5-9…A=125

A=125, E=25, I=5, O=1, U=0, X=-125

CORELAP – Example 2

The placement sequence: **7-5-9-3-1-4-2-6-8**

Department 3?

62.5	125	62.5	0
187.5	**5**	**7**	0
187.5	**9**	187.5	0
62.5	125	62.5	

3-5…A=125
3-7…U=0
3-9…A=125

Department 1?

62.5	125.5	63.5	0.5	0
125	**3**	**5**	**7**	0
62.5	126.5	**9**	1.5	0
	0.5	1	0.5	

1-3…A=125
1-7…U=0
1-5…O=1
1-9…O=1

A=125, E=25, I=5, O=1, U=0, X=-125

CORELAP – Example 2

The placement sequence: **7-5-9-3-1-4-2-6-8**

Department 4?

12.5	37.5	100	137.5	62.5
37.5	**3**	**5**	**7**	125
37.5	**1**	**9**	137.5	62.5
12.5	25	12.5	0	

7-4…A=125
9-4…U=0
3-4…E=25
1-4…E=25
5-4…E=25

Department 2?

12.5	25	12.5	0	0
87.5	**3**	**5**	**7**	62.5
137.5	**1**	**9**	**4**	125
62.5	125	125	125	62.5

2-1…A=125
2-4…A=125
2-3…E=25
2-5…U=0
2-7…U=0
2-9…U=0

A=125, E=25, I=5, O=1, U=0, X=-125

CORELAP – Example 2

The placement sequence: **7-5-9-3-1-4-2-6-8**

Department 6?

	0	62.5	125	188	62.5
0.5	1	**3**	**5**	**7**	125
1	**2**	**1**	**9**	**4**	63.5
0.5	1	1	1.5	1.5	0.5

5-6…A=125
7-6…A=125
2-6…O=1
9-6…O=1
4-6…O=1
3-6…U=0
1-6…U=0

Department 8?

			0.5	1	0.5
	12.5	25.5	-60.5	**6**	-61.5
12.5	112.5	**3**	**5**	**7**	-112
25	**2**	**1**	**9**	**4**	-37.5
12.5	87.5	75	-62.5	-37.5	12.5

9-8…A=125
1-8…A=125
3-8…E=25
2-8…E=25
4-8…E=25
5-8…O=1
6-8…O=1
7-8…X=-125

A=125, E=25, I=5, O=1, U=0, X=-125

CORELAP – Example 2

The placement sequence: **7-5-9-3-1-4-2-6-8**

			6
8	3	5	7
2	1	9	4

The final layout

CORELAP - Comments

- The final layouts are evaluated by the distance-based layout score
  - CORELAP uses the shortest rectilinear path between the departments (receiving/dispatch areas are assumed to be on the side of the departments nearest its neighbor)
- The layouts often result in irregular building shapes

ALDEP – Automated Layout Design Program

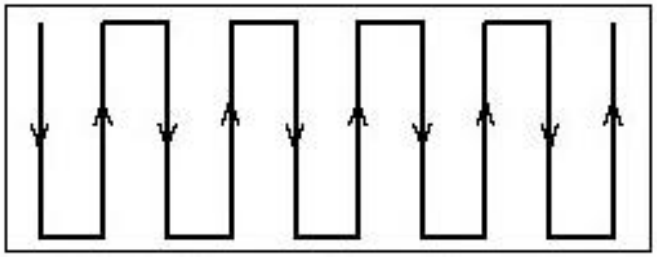
- Similar to CORELAP (objectives, requirements)
  - Adjacency-based method
- The main differences:
  - Randomness
  - Multi-floor capability
  - CORELAP attempts to produce the best layout, ALDEP produces many layouts

ALDEP - Procedure

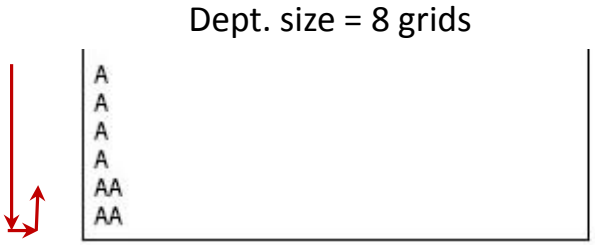
- Department selection
  - *Randomly* selects the first department
  - Out of those departments which have “A” relationship with the first one (or “E”, “I”, etc. – min level of importance is determined by the user) it selects *randomly* the second department
  - If no such department exists it selects the second one completely *randomly*
  - The selection procedure is repeated until all the departments are selected (Always search for the departments having relationships with the last one placed in the layout – not all)
- Department placement
  - Starts from upper left corner and extends it downward
  - ***Vertical sweep pattern***
  - ***Sweep width*** is determined by the user
- Adjacency-based evaluation
  - If minimum requirements met, it prints out the layout and the scores
- Repeats the procedure (max 20 layouts per run)
- User evaluation

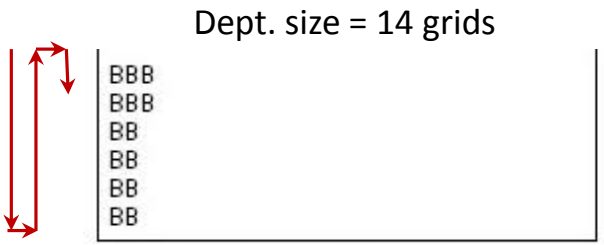
ALDEP

- Vertical sweep pattern

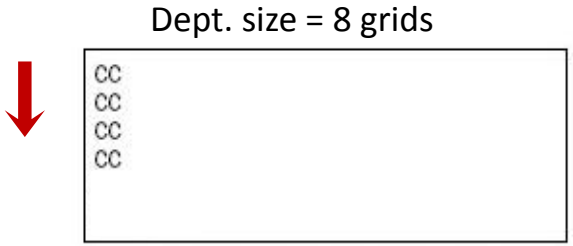


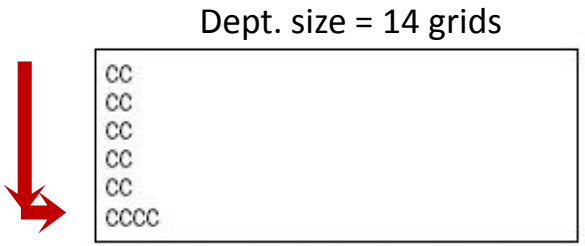
- Sweep width
  - 1 grid



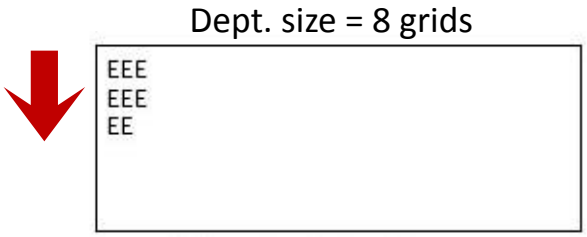


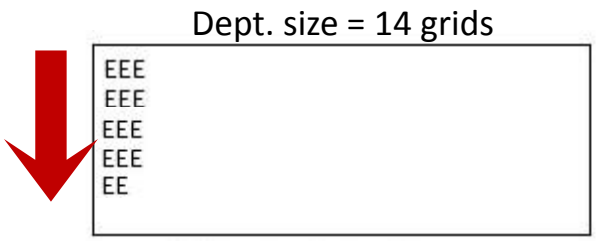
  - 2 grids





  - 3 grids

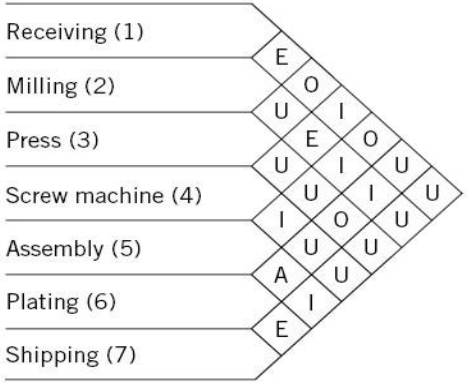




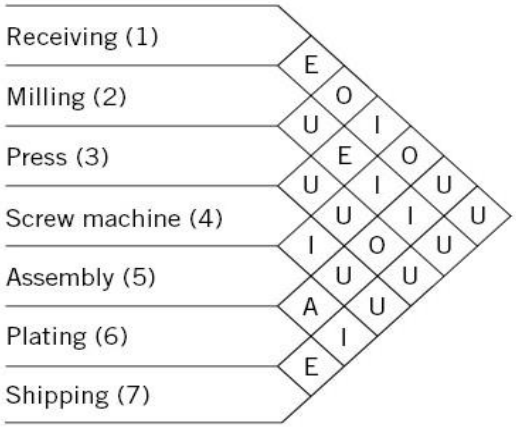
ALDEP Example

- Use ALDEP procedure to determine the layout vector, construct and evaluate the layout for the facility based on the relationship chart and the departmental dimensions given below. The dimensions of the facility are 10x18. Use the sweep width of 2 and the minimum acceptable level of importance “E”. The closeness values: A=64, E=16, I=4, O=1, U=0, X=-1024

Dept.	Area	# of unit area templates
1	12,000	30
2	8000	20
3	6000	15
4	12,000	30
5	8000	20
6	12,000	30
7	12,000	30



ALDEP Example



- Department selection

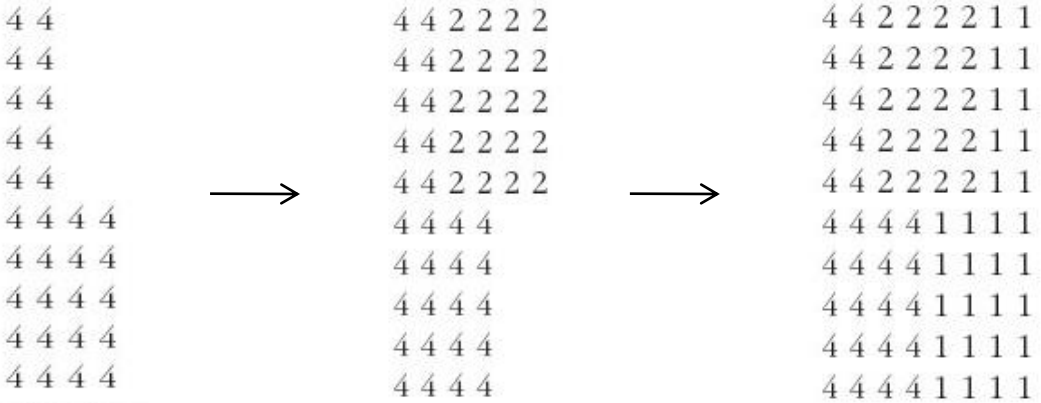
Step	Department selected	Reason for selection
1	4	random
2	2	“E” with 4
3	1	“E” with 2
4	6	random
5	5	“A” with 6
6	7	random
7	3	remaining

- Layout vector
  - **4-2-1-6-5-7-3**

ALDEP Example

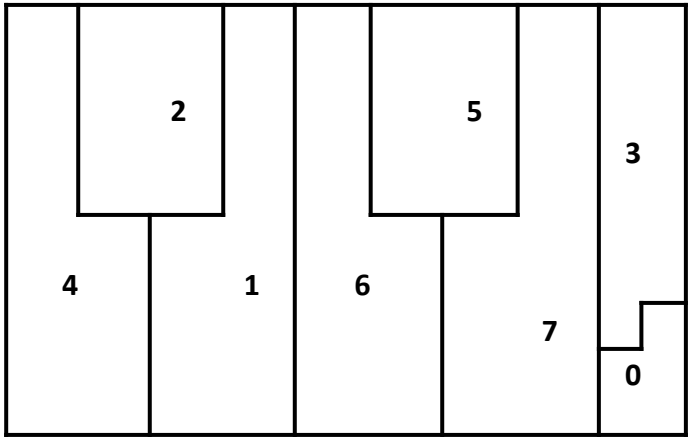
Dept.	# of unit area templates
1	30
2	20
3	15
4	30
5	20
6	30
7	30

- Layout construction
  - Layout vector: **4-2-1-6-5-7-3**
  - Sweep width: 2

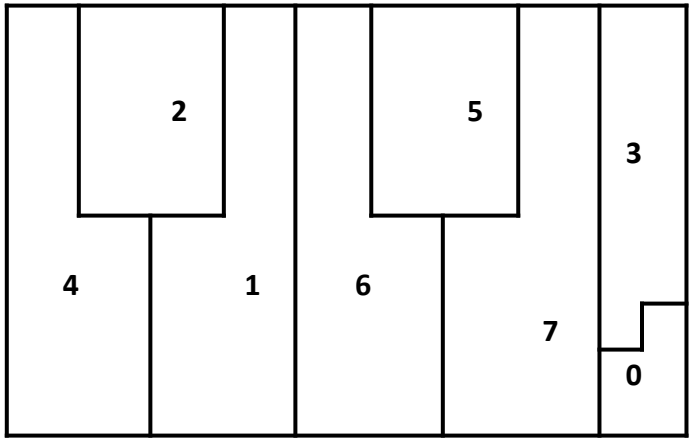


- Final layout

4 4 2 2 2 2 1 1 6 6 5 5 5 5 7 7 3 3
4 4 2 2 2 2 1 1 6 6 5 5 5 5 7 7 3 3
4 4 2 2 2 2 1 1 6 6 5 5 5 5 7 7 3 3
4 4 2 2 2 2 1 1 6 6 5 5 5 5 7 7 3 3
4 4 2 2 2 2 1 1 6 6 5 5 5 5 7 7 3 3
4 4 4 4 1 1 1 1 6 6 6 6 7 7 7 7 3 3
4 4 4 4 1 1 1 1 6 6 6 6 7 7 7 7 3 3
4 4 4 4 1 1 1 1 6 6 6 6 7 7 7 7 3 0
4 4 4 4 1 1 1 1 6 6 6 6 7 7 7 7 0 0
4 4 4 4 1 1 1 1 6 6 6 6 7 7 7 7 0 0



ALDEP Example



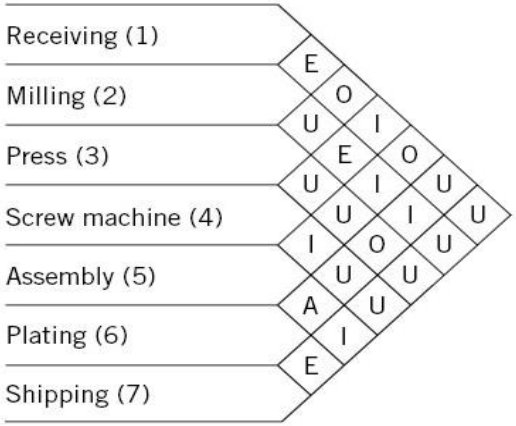
- Adjacency score

A=64, E=16, I=4, O=1, U=0, X=-1024

Adjacent Departments	Relationship	Value
4-2	E	16
4-1	I	4
2-1	E	16
1-6	U	0
6-5	A	64
6-7	E	16
5-7	I	4
7-3	U	0

Total adjacency score 120

ALDEP Example
- alternative solution



- Department selection

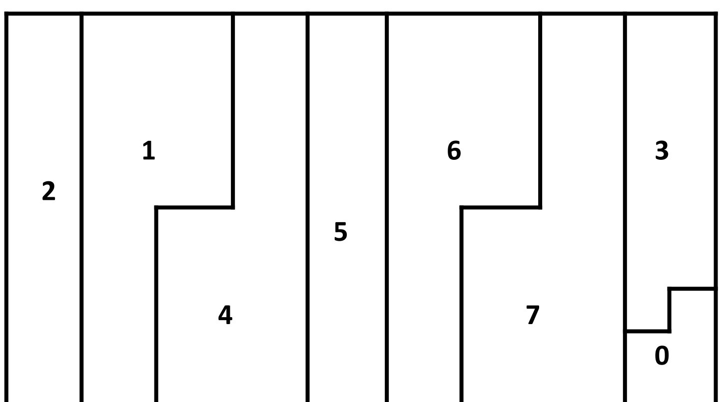
Step	Department selected	Reason for selection
1	2	random
2	1	“E” with 2
3	4	random
4	5	random
5	6	“A” with 5
6	7	“E” with 6
7	3	remaining

- Layout vector
  - **2-1-4-5-6-7-3**

ALDEP **Example - alternative solution**

- Layout construction
  - Layout vector: **2-1-4-5-6-7-3**
  - Sweep width: 2
- Final layout

2	2	1	1	1	1	4	4	5	5	6	6	6	6	7	7	3	3
2	2	1	1	1	1	4	4	5	5	6	6	6	6	7	7	3	3
2	2	1	1	1	1	4	4	5	5	6	6	6	6	7	7	3	3
2	2	1	1	1	1	4	4	5	5	6	6	6	6	7	7	3	3
2	2	1	1	1	1	4	4	5	5	6	6	6	6	7	7	3	3
2	2	1	1	4	4	4	4	5	5	6	6	7	7	7	7	3	3
2	2	1	1	4	4	4	4	5	5	6	6	7	7	7	7	3	3
2	2	1	1	4	4	4	4	5	5	6	6	7	7	7	7	3	0
2	2	1	1	4	4	4	4	5	5	6	6	7	7	7	7	0	0
2	2	1	1	4	4	4	4	5	5	6	6	7	7	7	7	0	0



- Adjacency score

A=64, E=16, I=4, O=1, U=0, X=-1024

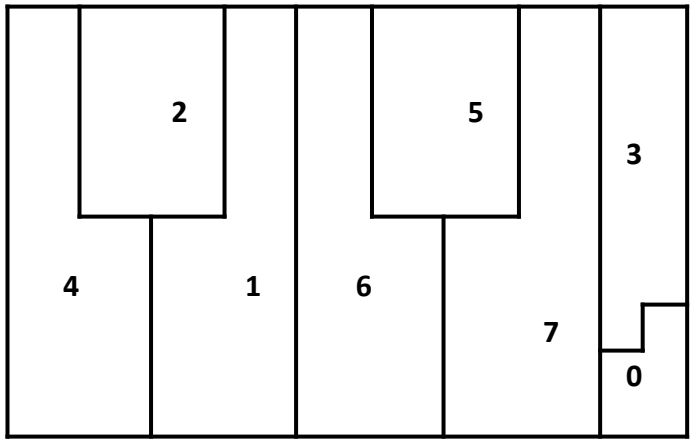
Adjacent departments	Relationship	Value
2-1	E	16
1-4	I	4
4-5	I	4
5-6	A	64
6-7	E	16
7-3	U	0
	Total	104

Total adjacency score 104

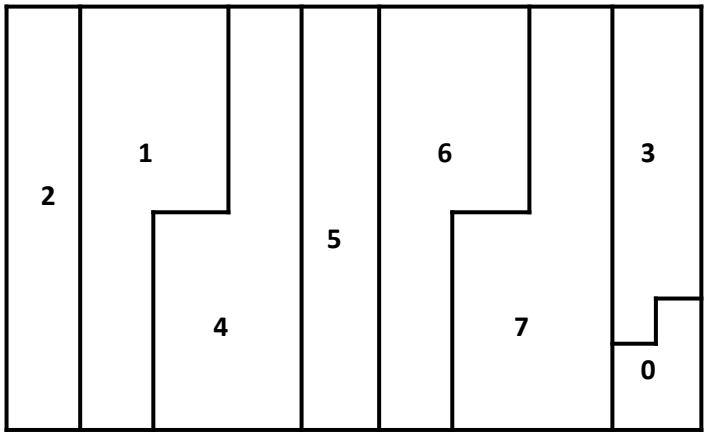
ALDEP Example – solution comparison

- Final layouts:

4-2-1-6-5-7-3



2-1-4-5-6-7-3



- Adjacency scores

120 104

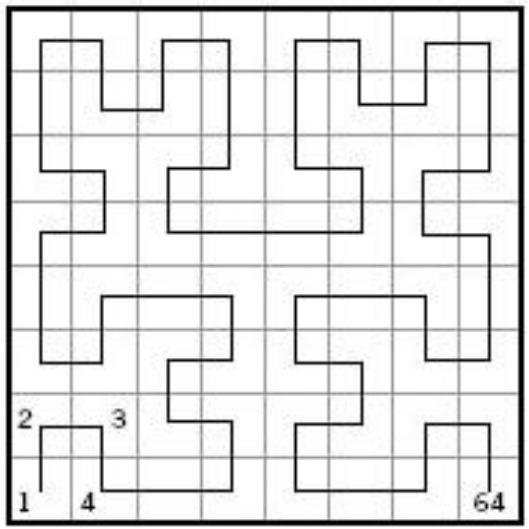
- The final decision depends on the facility planner
- It is necessary to consider many alternatives

MULTIPLE – Multi-floor Plant Layout Evaluation

- Construction and improvement algorithm
- Distance-based algorithm
- Similar to CRAFT (departments not restricted to rectangular shapes, discrete presentation, two-way exchanges)
- But MULTIPLE can exchange non-adjacent departments
- Uses spacefilling curves to reconstruct a new layout after each iteration

MULTIPLE - Spacefilling Curves (SFC)

- Spacefilling curve connects all the grids in a layout
  - Each grid is visited exactly once
  - Next grid visited is always adjacent to the current grid (only horizontal or vertical moves)
- SFC is generated by the computer
- SFC allows MULTIPLE to map a layout vector into a two-dimensional layout
- Procedure:
  - The departments are placed based on the layout vector (similar as MCRAFT)
  - The SFC is followed until the required number of grid for each department is reached

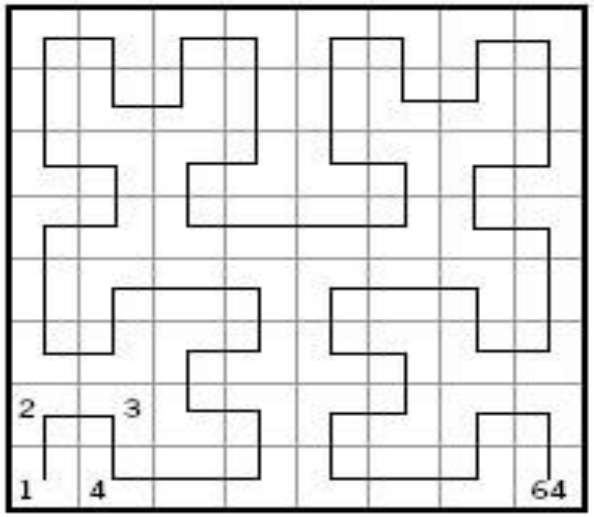


MULTIPLE – Improvement Algorithm

Example

- Create a MULTIPLE layout for the departments below based on the layout vector 1-2-3-4-5-6. Then build a new layout by exchanging the departments 1 and 5. The facility and SFC are given below.

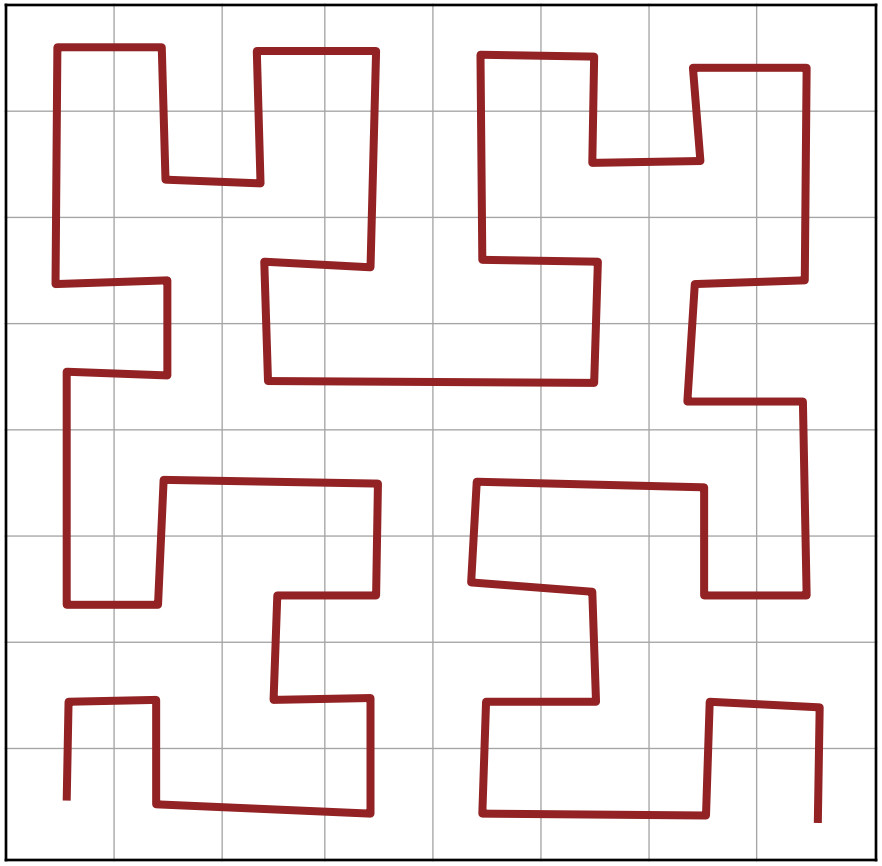
Department	Area (m^2)
1	16
2	8
3	4
4	16
5	8
6	12



MULTIPLE – Improvement Algorithm

Example

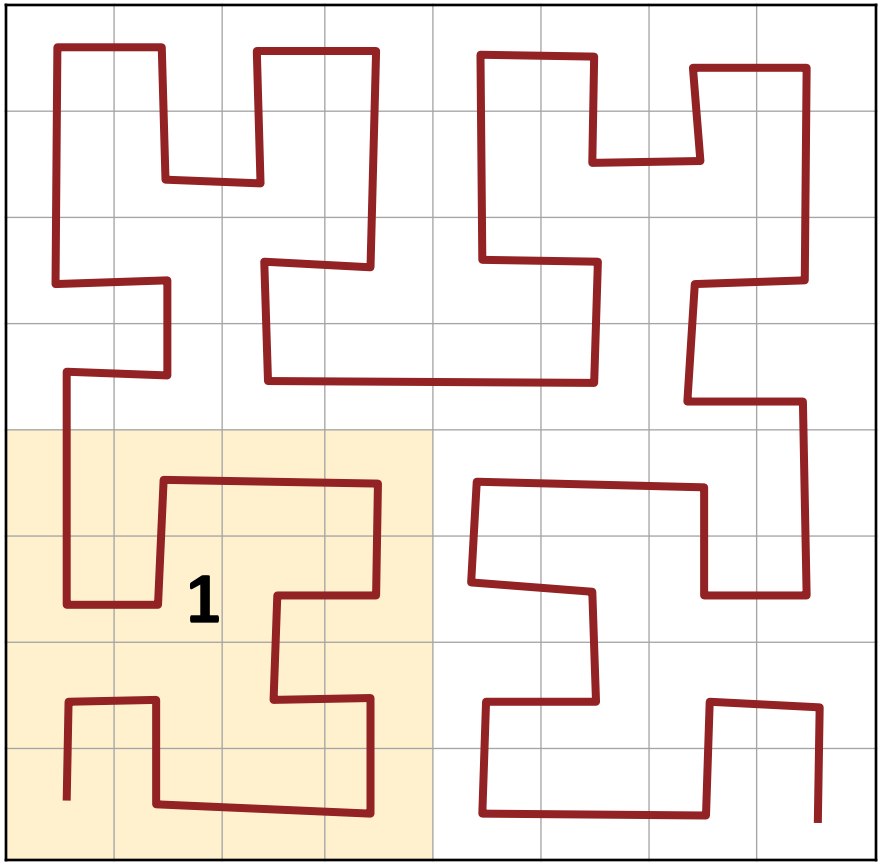
- Layout vector **1-2-3-4-5-6**



MULTIPLE – Improvement Algorithm

Example

- Layout vector **1-2-3-4-5-6**

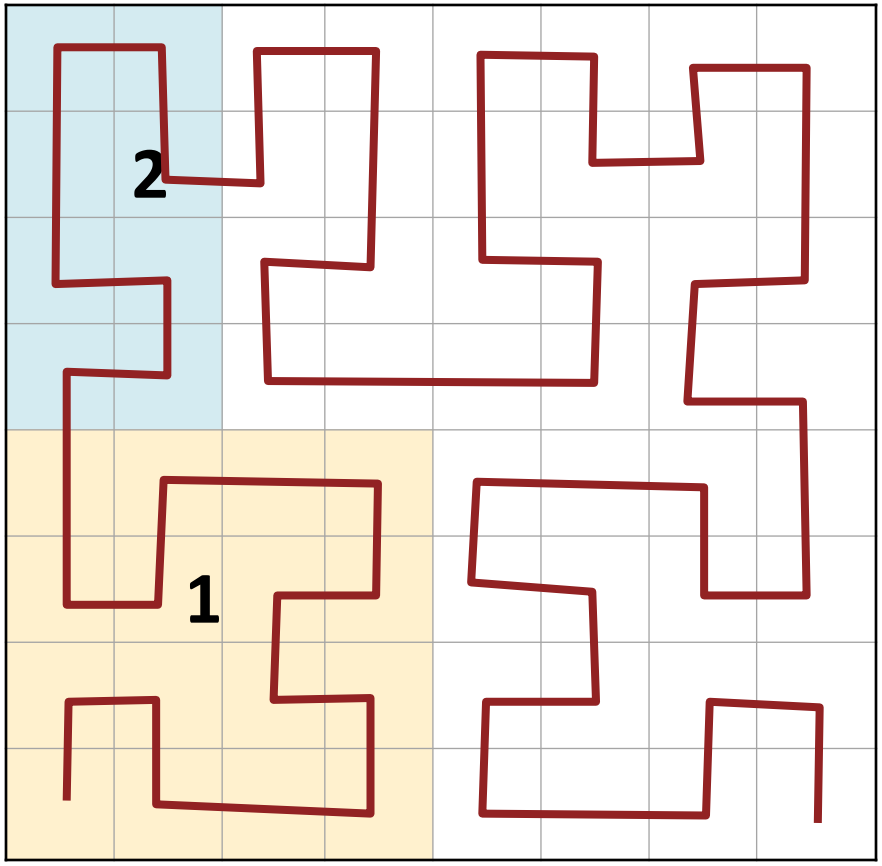


Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12

MULTIPLE – Improvement Algorithm

Example

- Layout vector **1-2-3-4-5-6**

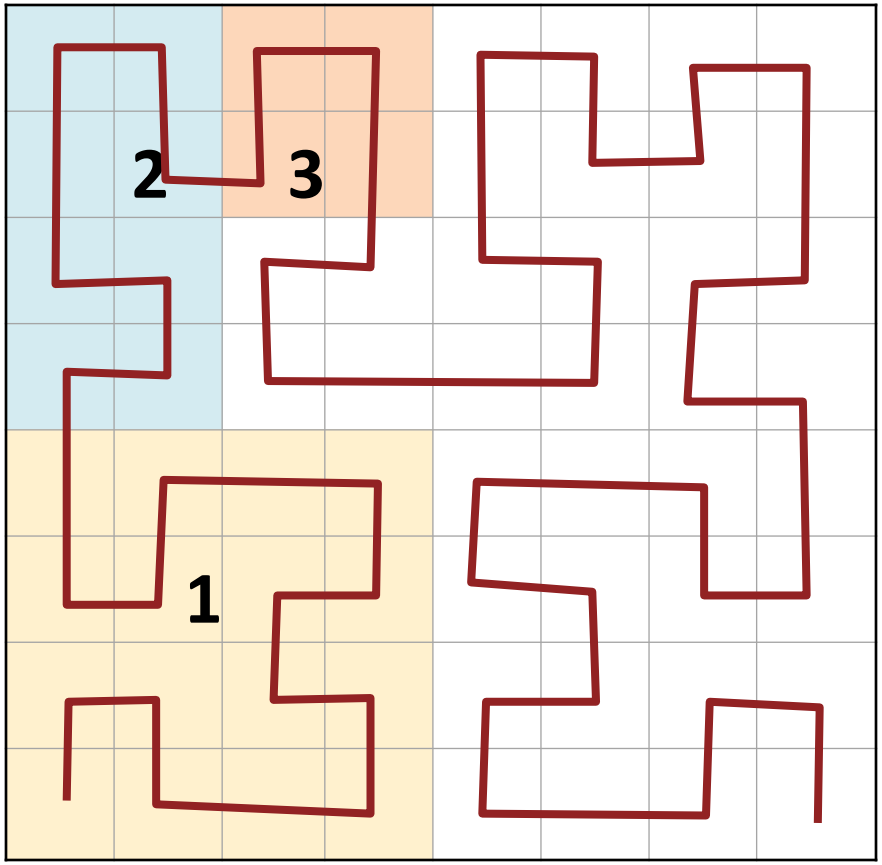


Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12

MULTIPLE – Improvement Algorithm

Example

- Layout vector **1-2-3-4-5-6**

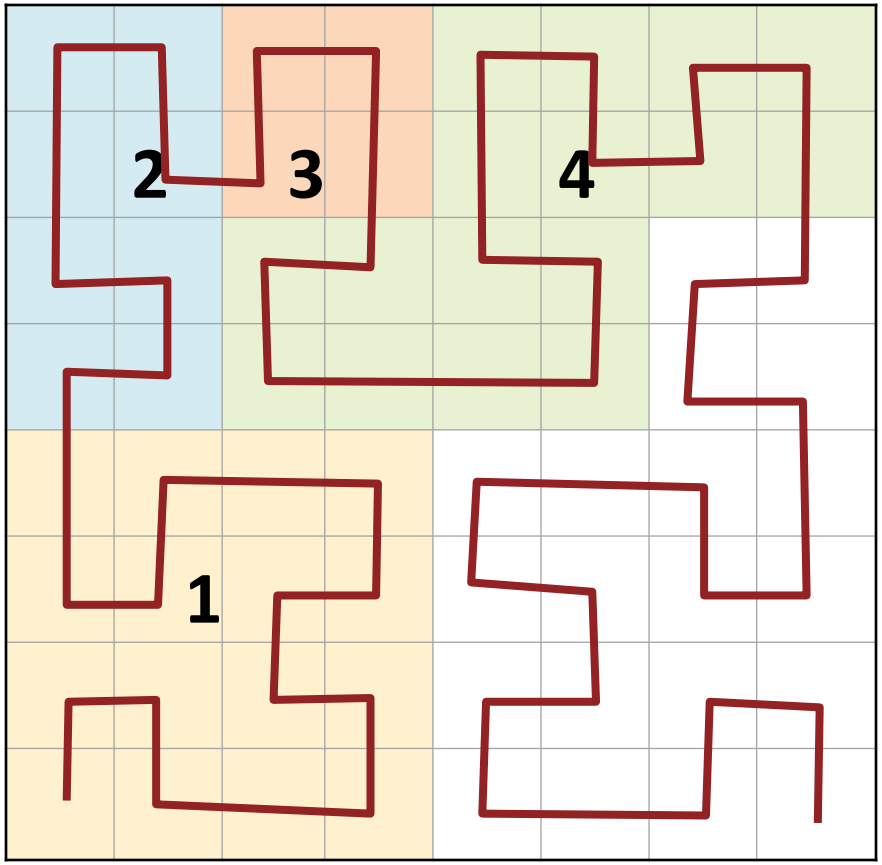


Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12

MULTIPLE – Improvement Algorithm

Example

- Layout vector **1-2-3-4-5-6**

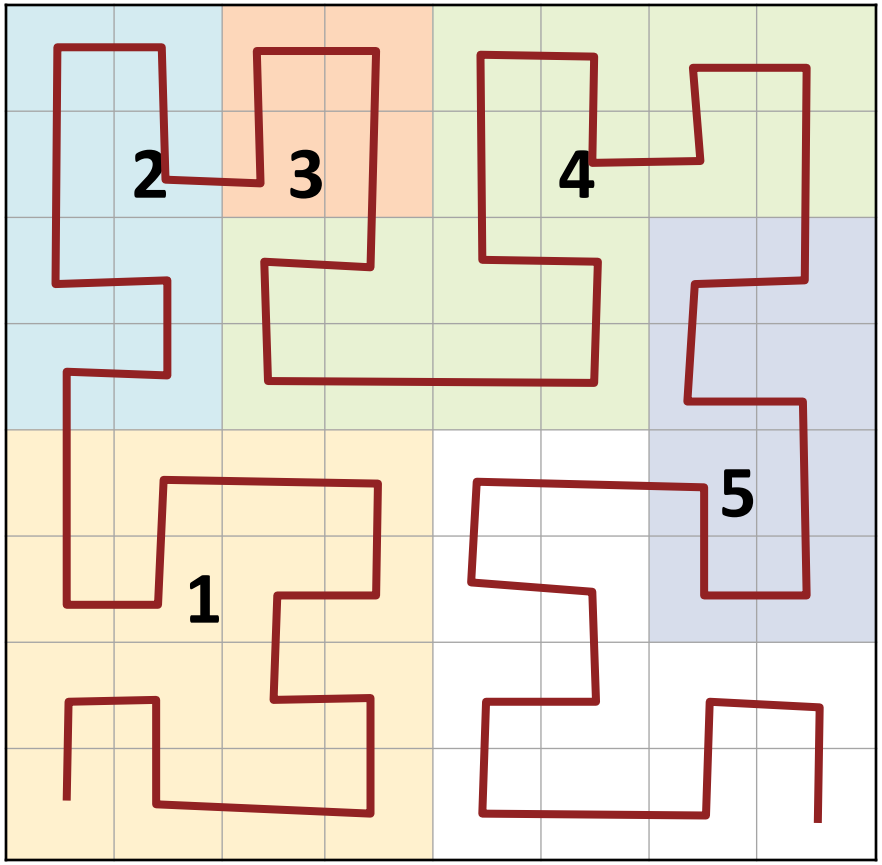


Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12

MULTIPLE – Improvement Algorithm

Example

- Layout vector **1-2-3-4-5-6**

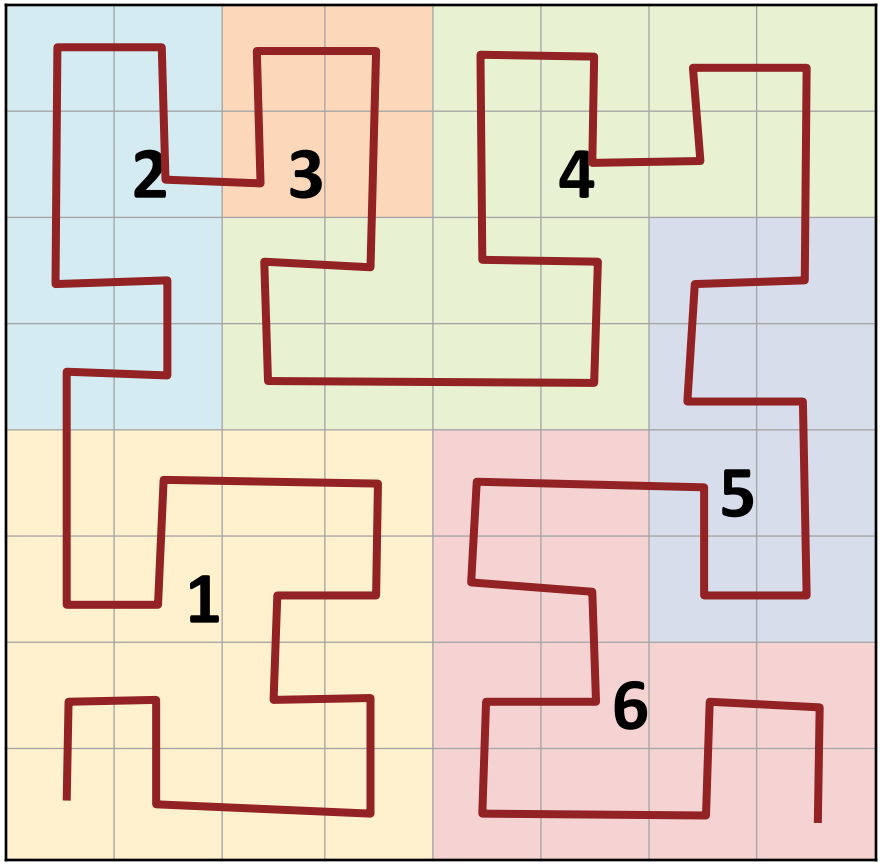


Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12

MULTIPLE – Improvement Algorithm

Example

- Layout vector **1-2-3-4-5-6**

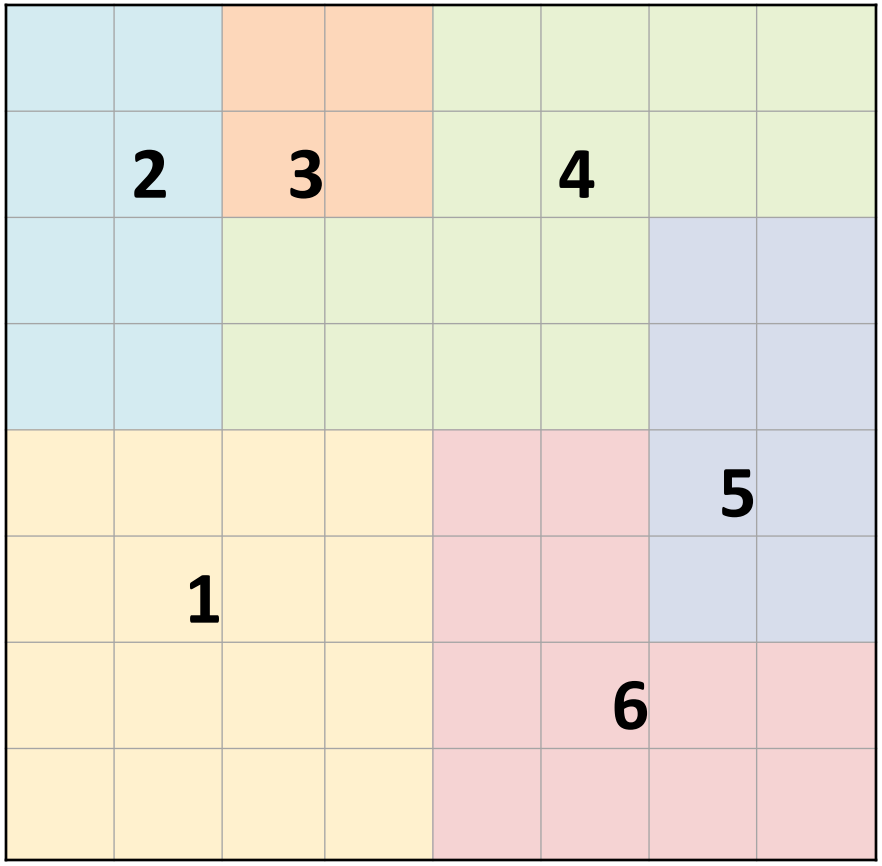


Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12

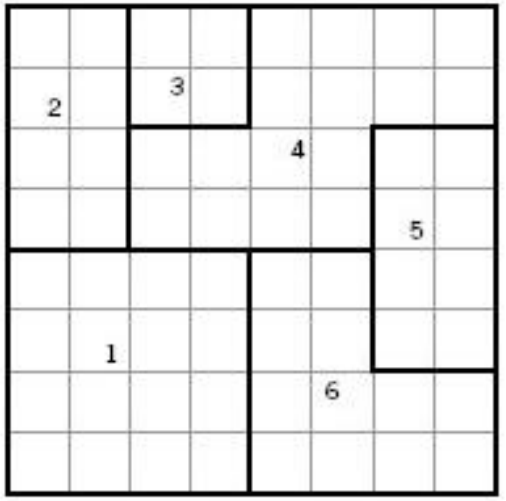
MULTIPLE – Improvement Algorithm

Example

- Layout vector **1-2-3-4-5-6**



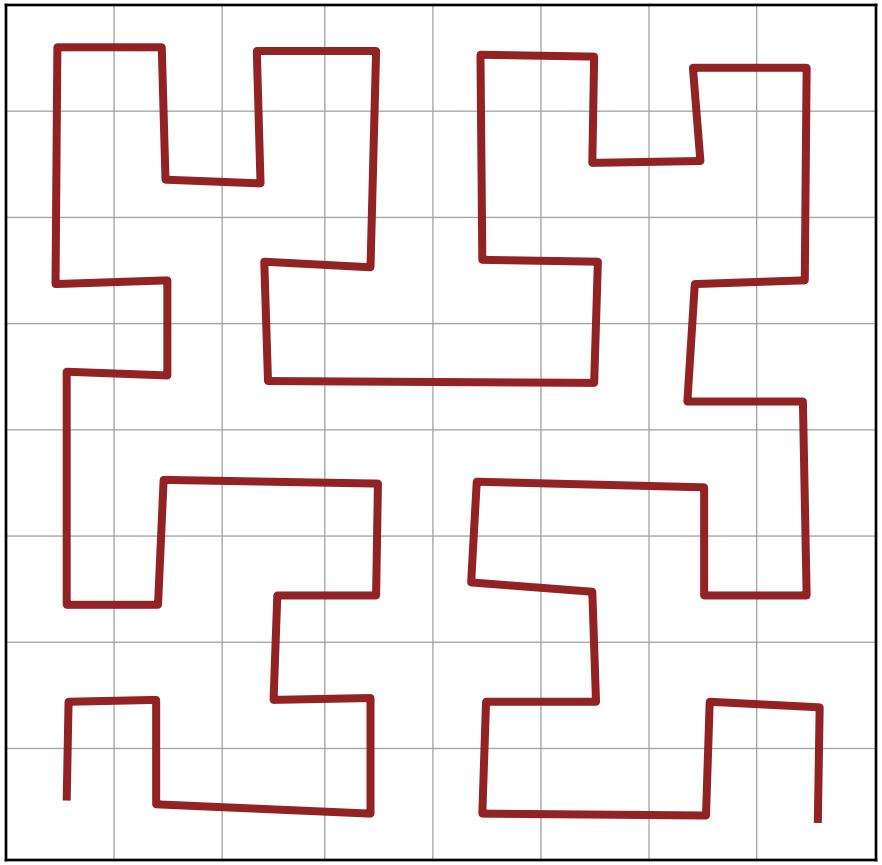
Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12



MULTIPLE – Improvement Algorithm

Example

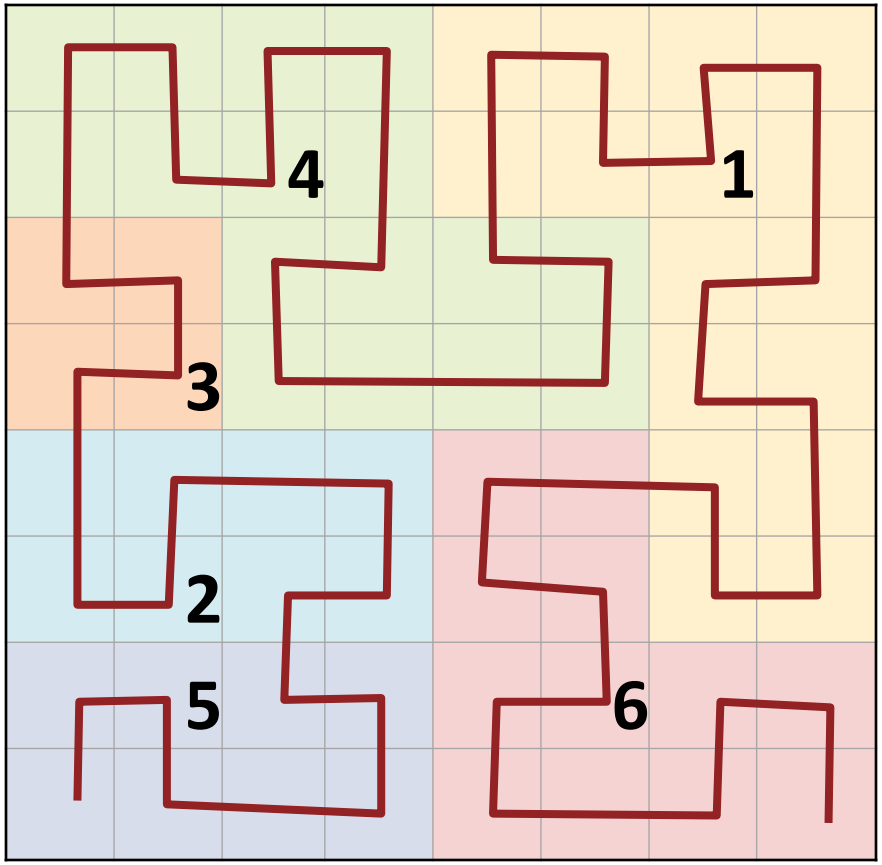
- Exchange 1 and 5 - Layout vector **5-2-3-4-1-6**



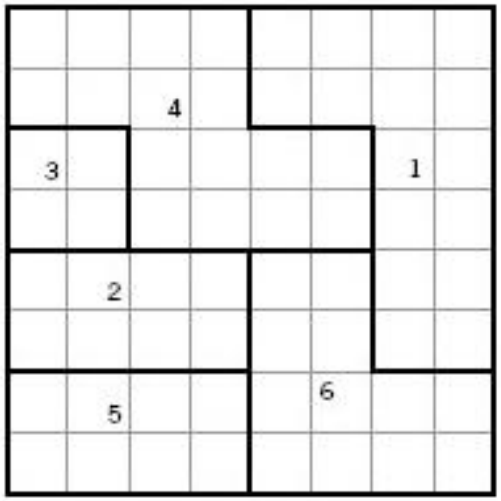
MULTIPLE – Improvement Algorithm

Example

- Layout vector **5-2-3-4-1-6**



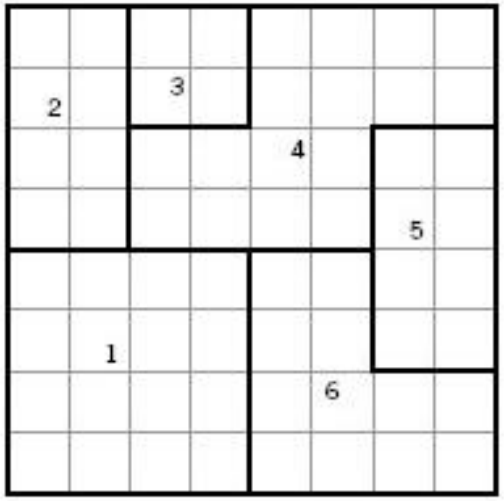
Dep.	Area
1	16
2	8
3	4
4	16
5	8
6	12



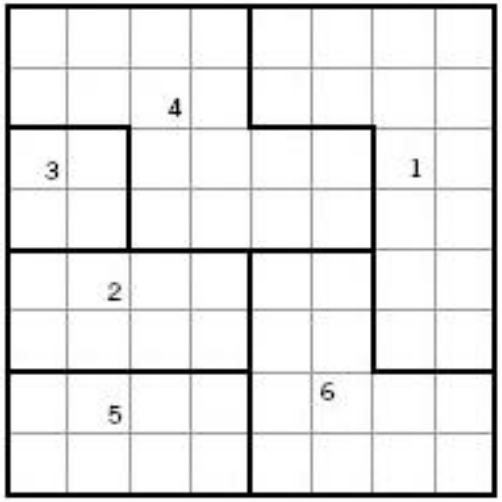
MULTIPLE – Improvement Algorithm

Example

- Initial layout



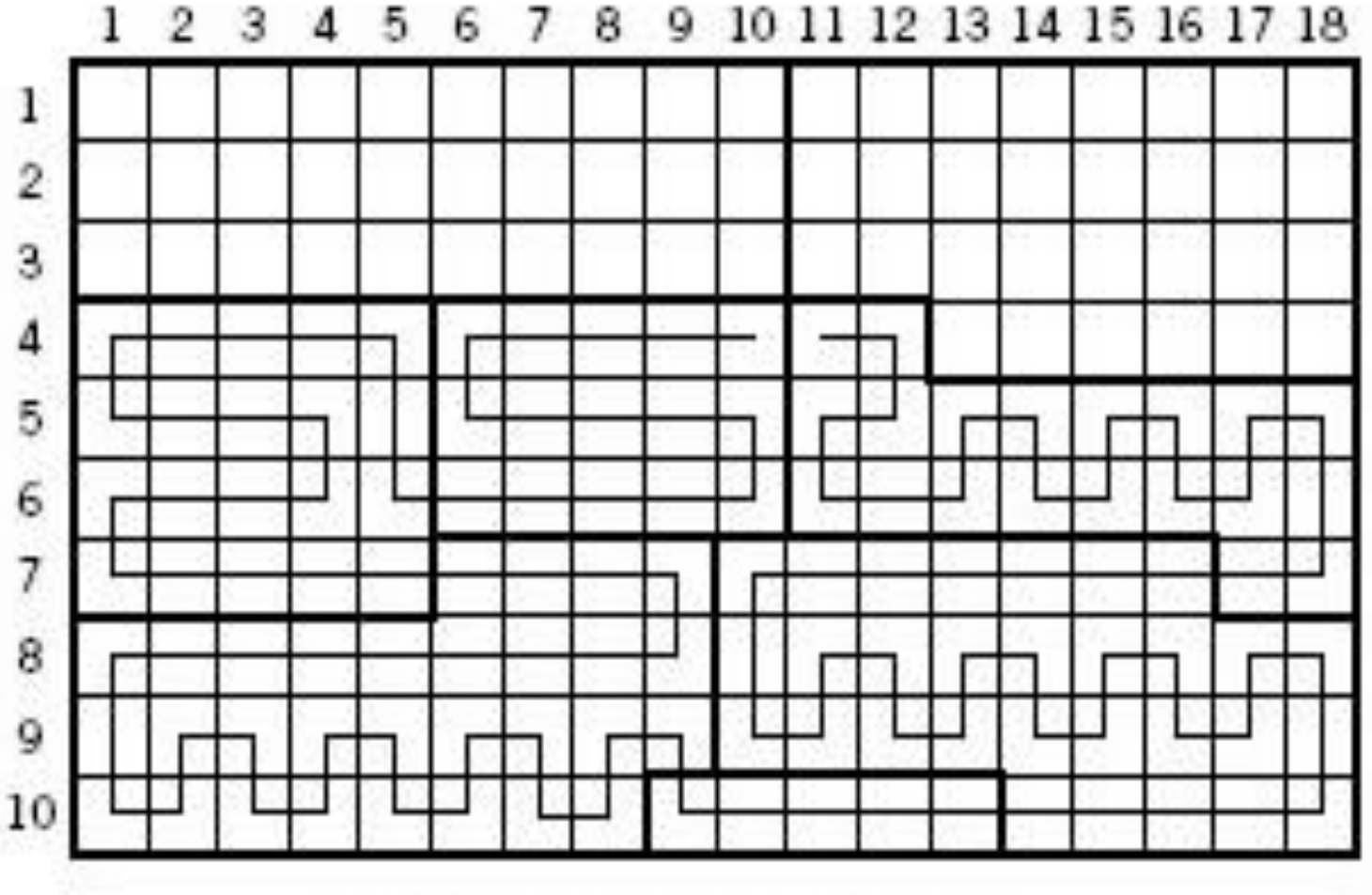
- Layout after the exchange



MULTIPLE - Conforming Curves

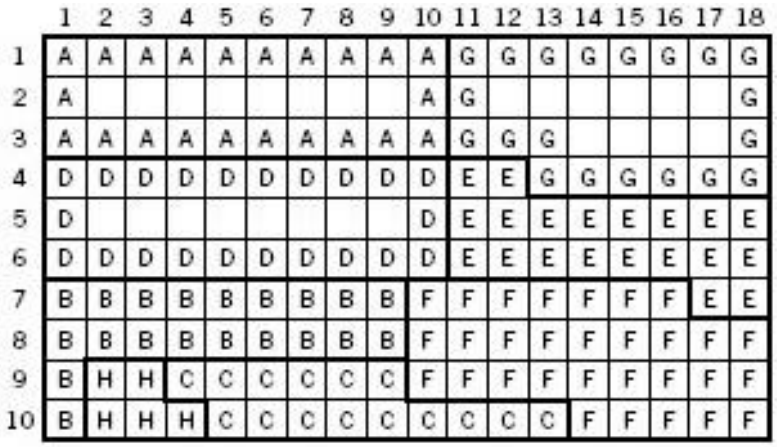
- Conforming curves are hand-generated curves
- They are used:
  - If the building shape is irregular
  - If we want to capture the initial layout exactly
  - If there are numerous obstacles (walls)
  - If there are fixed departments
- Procedure:
  - May start and end at any grid
  - The curve visits all the grids assigned to a particular department before visiting other department
  - The fixed departments and obstacles are not visited

MULTIPLE - Conforming Curves



MULTIPLE – Improvement Algorithm

- Final MULTIPLE layout for the CRAFT example



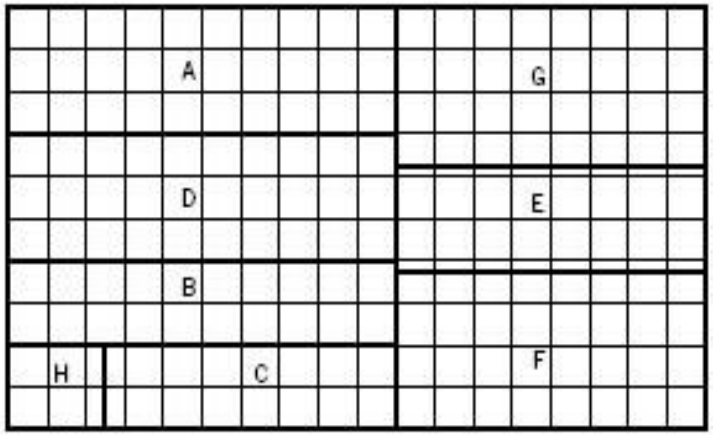
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	A	A	A	A	A	A	A	A	A	A	G	G	G	G	G	G	G	G
2	A									A	G							G
3	A	A	A	A	A	A	A	A	A	A	G	G	G					G
4	D	D	D	D	D	D	D	D	D	D	E	E	G	G	G	G	G	G
5	D									D	E	E	E	E	E	E	E	E
6	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E
7	B	B	B	B	B	B	B	B	B	F	F	F	F	F	F	F	E	E
8	B	B	B	B	B	B	B	B	B	F	F	F	F	F	F	F	F	F
9	B	H	H	C	C	C	C	C	C	F	F	F	F	F	F	F	F	F
10	B	H	H	H	C	C	C	C	C	C	C	C	C	F	F	F	F	F

- The cost is lower than for the final layout found by CRAFT!
  - MULTIPLE is very likely to obtain lower-cost solutions than CRAFT, since it considers a larger set of possible solutions at each iteration

MULTIPLE – Improvement Algorithm

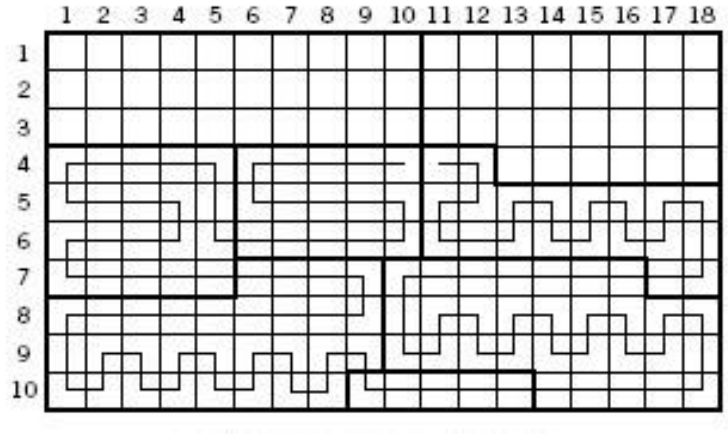
- Final MULTIPLE layout for the CRAFT example may also need massaging to smooth the department borders

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	A	A	A	A	A	A	A	A	A	A	G	G	G	G	G	G	G	G
2	A									A	G							G
3	A	A	A	A	A	A	A	A	A	A	G	G	G					G
4	D	D	D	D	D	D	D	D	D	D	E	E	G	G	G	G	G	G
5	D									D	E	E	E	E	E	E	E	E
6	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E
7	B	B	B	B	B	B	B	B	B	F	F	F	F	F	F	F	E	E
8	B	B	B	B	B	B	B	B	B	F	F	F	F	F	F	F	F	F
9	B	H	H	C	C	C	C	C	C	F	F	F	F	F	F	F	F	F
10	B	H	H	H	C	C	C	C	C	C	C	C	C	F	F	F	F	F



MULTIPLE - Construction algorithm

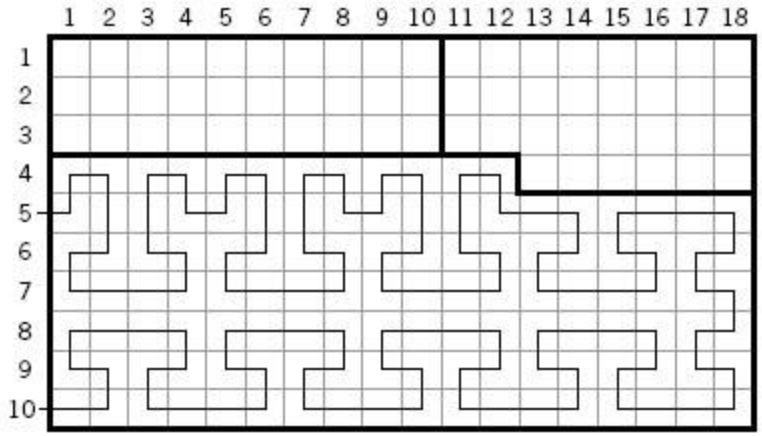
- Any SFC or conforming curves could be used to fill the vacant building
- Any vector can be used as the initial layout vector
- Alternative layouts can be generated by trying different SFC
  - The cost may not be much different



- Original layout vector:

D-B-H-C-F-E

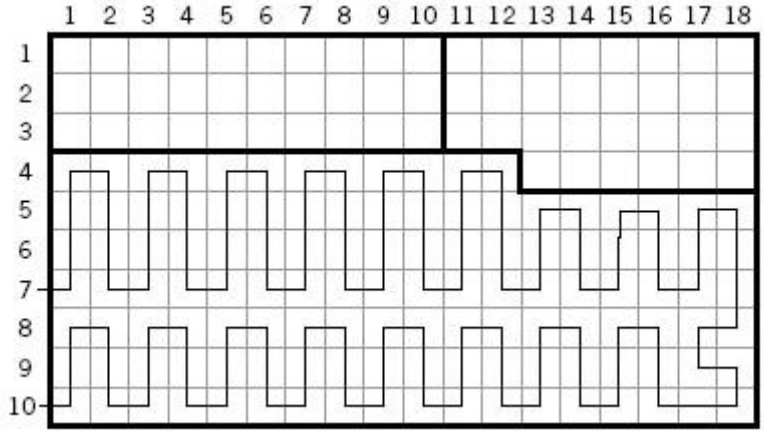
Final layout cost z=54,200



- Alternative layout vector:

D-E-F-B-C-H

Final layout cost z=54,900



- Alternative layout vector:

D-E-F-H-B-C

Final layout cost z=54,540

Conclusion

Layout generation algorithms

- Each layout algorithm has certain strengths and weaknesses
  - Capturing well the initial layout, the building shape, fixed departments →CRAFT, MULTIPLE
  - Generating acceptable shapes (rectangular) →BLOCPLAN, LOGIC
  - Generating many alternatives → ALDEP, MULTIPLE
- **No algorithm generates an optimal layout**
- No computer-based algorithm can capture all the significant aspects of a facility layout problem
- Human layout planner will continue to play a key role in developing and evaluating the facility layout

Next lecture

- Facility location I.