chapter (6) Layout planning models & design algorithms.

* Basic layout type → Block [location & size]
  → Detailed [exact location for equipment ....]

* type of layout — product
  — GT (Product family)
  — Process
  — Fixed — Hybrid.

* (6.3) Layout procedures :

[1] Construction → layout from scratch

[2] Improvement → alternative based on existing.

* Layout Techniques :

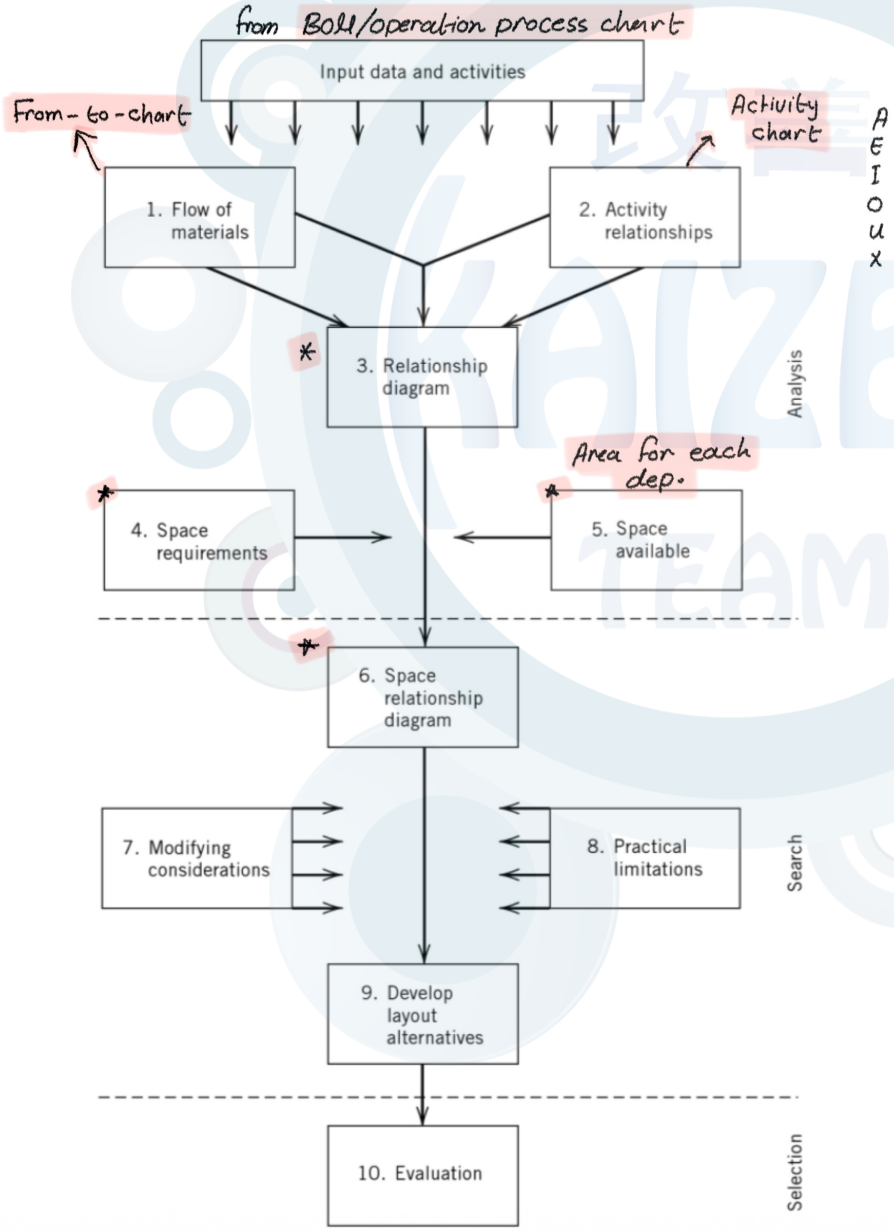
1. Manual :

- Systimatic layout planning (SLP).
- Graph based method.

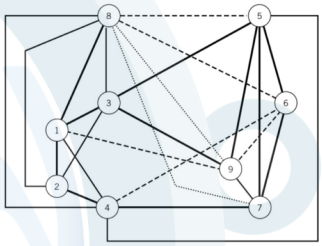
2. Computerized :

- CRAFT : Computerized Relative allocation of Facilities Technique

(1) Systimatic layout planning (SLP).



* Relationship diagram : positions activity spatially



relationship as boldness.

Figure 6.5 Relationship diagram.

* Space relationship diagram.

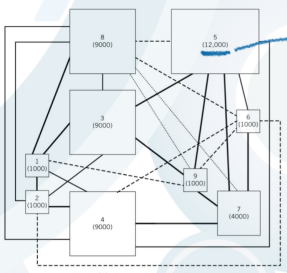


Figure 6.6 Space relationship diagram.

Systematic layout planning :

6.7 Four departments are to be located in a building of 600′ × 1000′. The expected personnel traffic flows and area requirements for the departments are shown in the tables below. Develop a block layout using SLP.

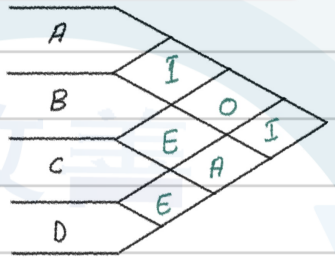
Dept.	A	B	C	D
A	0	250	25	240
B	125	0	400	335
C	100	0	0	225
D	125	285	175	0

Department	Department Dimension (space required)
A	200′ × 200′
B	400′ × 400′
C	600′ × 600′
D	200′ × 200′

① To develop from-to-chart. ⇝ area from two direction [A+B = B+A]

	A	B	C	D
A	—	I (3) 375	O (5) 125	I (4) 365
B		—	E (2) 400	A (1) 620
C			—	E (2) 400
D				—

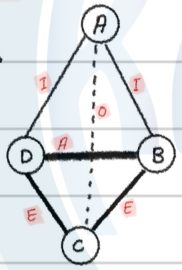
② Activity Relationship :



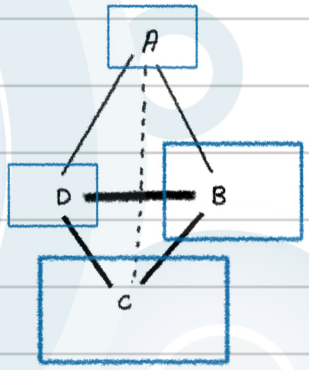
③ Relationship design :

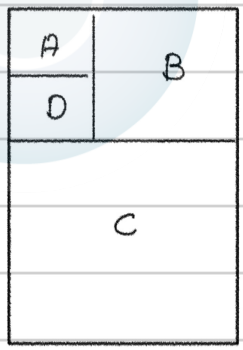
* proximity reflect :

with line boldness.



④ Space Relationship diagram





6.8 XYZ Inc. has a facility with six departments (A, B, C, D, E, and F). A summary of the processing sequence for 10 products and the weekly production forecasts for the products are given in the tables below.

a. Develop the from-to chart based on the expected weekly production.

b. Develop a block layout using SLP.

Product	Processing Sequence	Weekly Production
1	ABCDEF	960
2	ABCBEDCF	1200
3	ABCDEF	720
4	ABCEBCF	2400
5	ACEF	1800
6	ABCDEF	480
7	ABDECBF	2400
8	ABDECBF	3000
9	ABCDF	960
10	ABDEF	1200

Dept.	Dimension
A	40′ × 40′
B	45′ × 45′
C	30′ × 30′
D	50′ × 50′
E	60′ × 60′
F	50′ × 50′

1. From-to-chart :

	A	B	C	D	E	F
A	—	13320	1800	0	0	0
B		—	15720	6600	3600	5400
C			—	4320	9600	3600
D				—	9960	960
E					—	5160
F						—

15720
13320 (A)

9960
9600 (E)

6600
5400
5160 (I)
4320

3600
3600 (O)

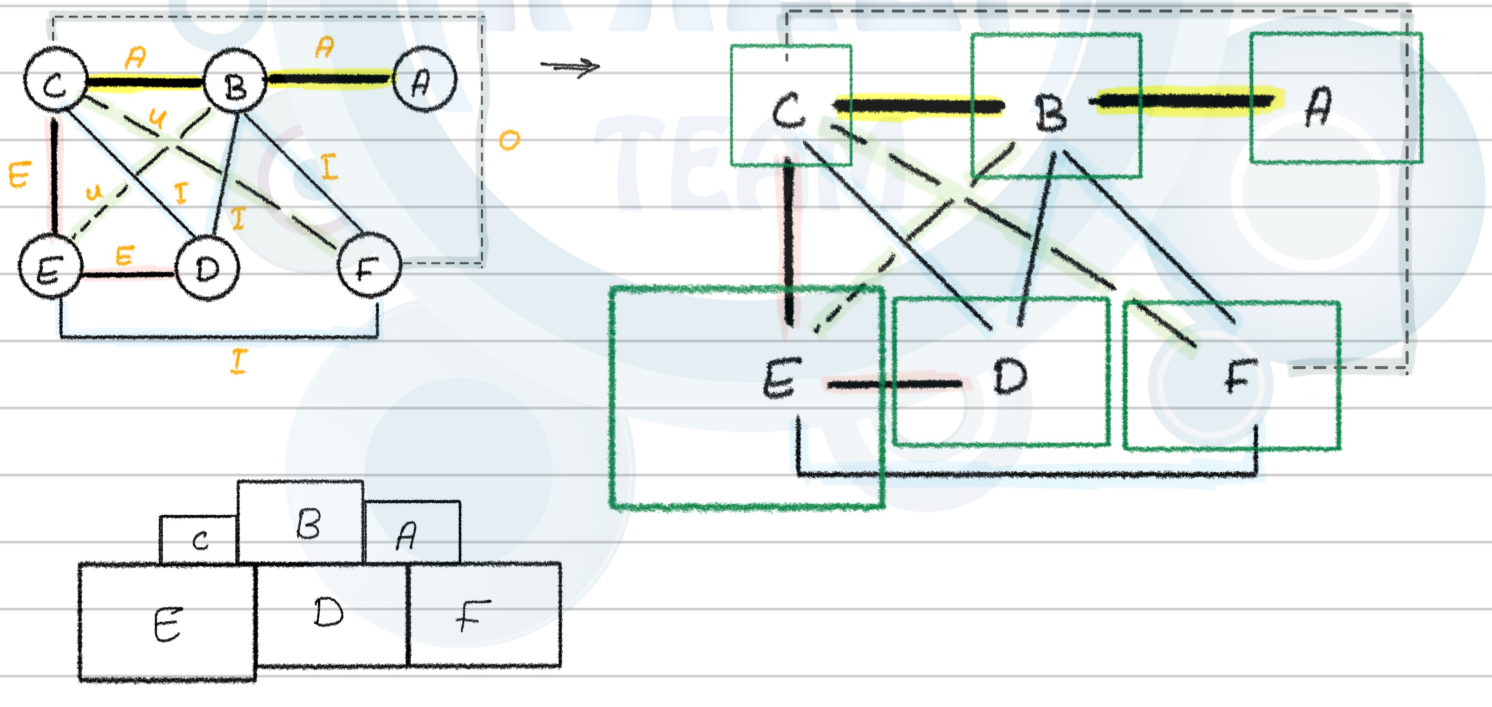
1800
960 (U)

0
0
0 (X)

	A	B	C	D	E	F
A	—	A	U	X	X	X
B		—	A	I	O	I
C			—	I	E	O
D				—	E	U
E					—	I
F						—

$(6 \times 5)/2 = 15$

15



(6.4) Algorithmic Approaches: → focus on 1. closeness rating 2. material flow intensities

→ classification
1. qualitative flow (relationship chart).
2. quantitative flow (from-to-chart).
] based on type of input. (1)

(2) based on the objective function:

1. Minimize the sum of flows time distance (Distance based.) $\text{Min. } z = \sum\sum (f_{ij})(d_{ij})(c_{ij})$ — used when from-to-chart input.
↳ cost/unit load. unit distance.

2. Maximize the closeness (adjacency score) $\text{Max. } z = \sum (f_{ij})(x_{ij})$ X=1 : Shear a border
↳ to compare two alternative layout.

* layout algorithm classification

- Discrete (integer # of Grids).
- Continuous (no Grid).
] (3) According to the format.

- improvement type
- Construction type
] (4) According to the primary function.

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* Layout evaluation:

1. $\text{Min } z = \sum^{m} f_{ij} \cdot d_{ij} \cdot c_{ij}$ → Min. the total cost, [Distance based scoring], Data (from-to-chart / Distance chart).
↳ rectilinear between centroids.

2. $\text{Max. } z = \sum f_{ij}(x_{ij})$ → Max. total relationship. [Adjacency Based score] Data (relationship chart / relationship diagram)
A E I O U X.

* [Adjacency Based score]:

→ Efficiency rating $z = \dfrac{\sum f_{ij}(x_{ij})}{\sum f_{ij}} = \dfrac{\text{flow between adjacent (+ve)}}{\text{Total flow}}$, all values are positive.

$z = \dfrac{\sum(+) f_{ij}(x_{ij}) - \sum(-) f_{ij}(1-x_{ij})}{\sum(+) f_{ij} - \sum(-) f_{ij}}$, in case there are (−ve) flow.

6.12 Suppose five departments labeled A through E are located as shown in the layout below. Given the corresponding flow-between chart, compute the efficiency rating for the layout.

A	B
C	
D	E

	A	B	C	D	E
A	—	5	0	4	−3
B		—	6	−1	2
C			—	−6	0
D				—	3
E					—

Relationship value: 5(1) + 6(1) + −6(1) + 3(1) = 8.

+ve flow: 5+4+6+2+3 = 20

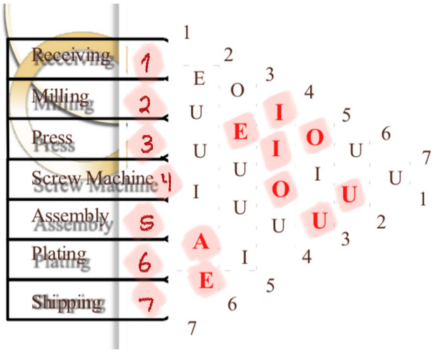
−ve flow: −1−3−6 = −10.

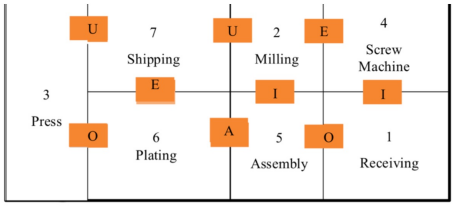
$\sum + F_{ij}(x_{ij}) = 5(1) + 6(1) + 3(1) = 14.$

$\sum - F_{ij}(1-x_{ij}) = -3(1-0) - 1(1-0) - 6(1-1) = -4$

$z = \dfrac{14-(-4)}{20-(-10)} = 0.6.$

To calculate the adjacency score:





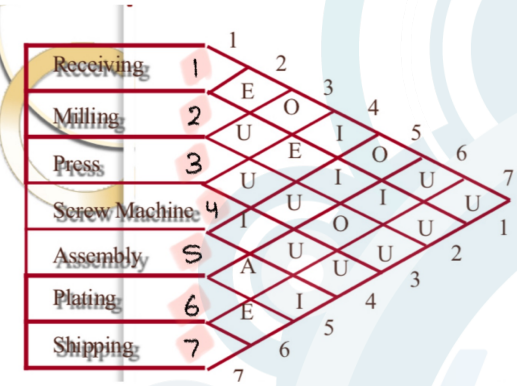
Weights:
A=64
E=16
I=4
O=1
U=0
X=-1024

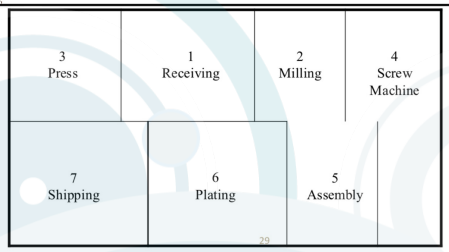
Solution:

	1	2	3	4	5	6	7	Weight
1	–	/	/	I	O	/	/	5
2		–	/	E	I	/	U	20
3			–	/	/	O	U	1
4				–	/	/	/	0
5					–	A	/	64
6						–	E	16
7							–	–

total score = 106

Exercise: Find the score of the layout shown below. Use A=8, E=4, I=2, O=1, U=0 and X=-8.





Solution:

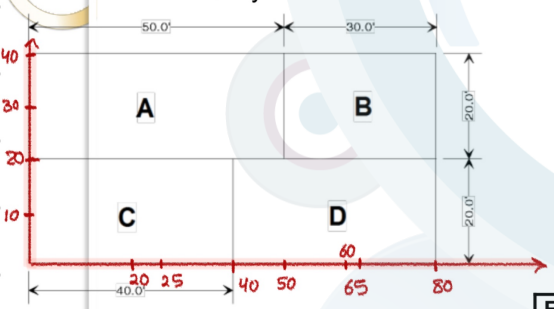
	1	2	3	4	5	6	7	weight
1	–	E	O	/	/	U	U	5
2		–	/	E	I	I	/	8
3			–	/	/	/	U	0
4				–	I	/	/	2
5					–	A	/	8
6						–	E	4
7							–	

total score = 27 #.

Distance Based Scoring

Example

Initial Layout



Flow Data f_{ij}

From/To	A	B	C	D
A	-	2	4	4
B	1	-	1	3
C	2	1	-	2
D	4	1	0	-

Distance Data d_{ij}

From/To	A	B	C	D
A	-	40	25	55
B	40	-	65	25
C	25	65	-	40
D	55	25	40	-

Total Score (Cost) Z

From/To	A	B	C	D	Total
A	-	80	100	220	400
B	40	-	65	75	180
C	50	65	-	80	195
D	220	25	0	-	245
Total	310	170	165	375	1020

[1]

	Centroid
A	(25, 30)
B	(65, 30)
C	(20, 10)
D	(60, 10).

* Distance = $|x_2 - x_1| + |y_2 - y_1|$

6.4.2 Pairwise exchange method :

— Improvement type for adjacency x Distance

Example:

From \ To	1	2	3	4
1	-	10	15	20
2		-	10	5
3			-	5
4				-

Material Flow Matrix

From \ To	1	2	3	4
1	-	1	2	3
2		-	1	2
3			-	1
4				-

Distance matrix based on existing layout

for solution : initial solution (1 2 3 4) , # iterations = $\frac{n(n-1)}{2}$

# of iteration = $(4*3)/2 = 6$, cost = flow . distance

1 Iteration (0) : (1234) | 1 | 2 | 3 | 4 |

$Tc_{(1-2)} = 10(1) + 15(1) + 20(2) + 10(2) + 5(3) + 5(1) = 105$

$Tc_{(1-3)} = 10(1) + 15(3) + 20(1) + 10(1) + 5(2) + 5(3) = 95$ ←

2 Iteration (1) : (3214) | 3 | 2 | 1 | 4 |

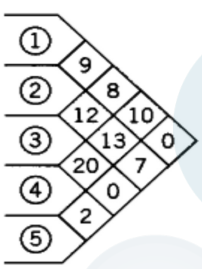
$Tc_{(1-2)} = 10(2) + 15(1) + 20(1) + 10(1) + 5(3) + 5(2) =$

$= 10(\ ) + 15(\ ) + 20(\ ) + 10(\ ) + 5(\ ) + 5(\ ) =$

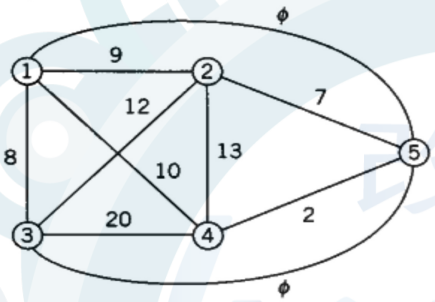
Limitation:

- Depends on the initial solution.
- No consideration for the shape & size.

(6.4.3) Graph-Based Method :

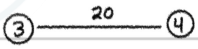


(a) Relationship Chart



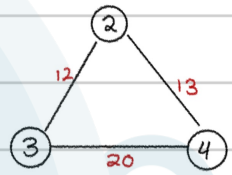
(b) Relationship Diagram

1) Largest weight



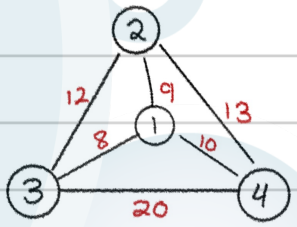
2.)

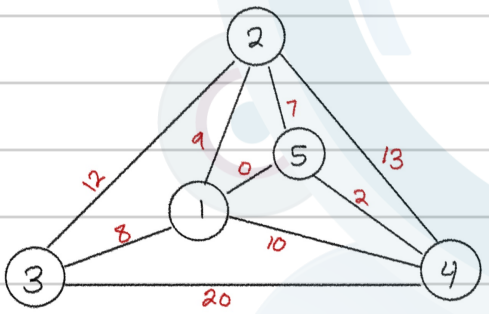
	3	4	
1	8	10	18
2	12	13	25
5	0	2	2



3.)

	3	4	2	
1	8	10	9	27
5	0	2	7	9

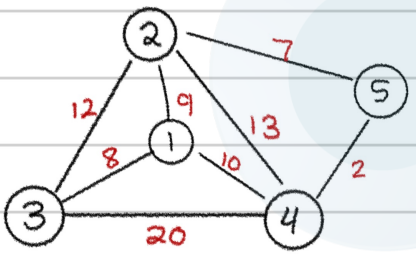




← 4.) Faces :

	1	2	3	4
5	0	7	0	2

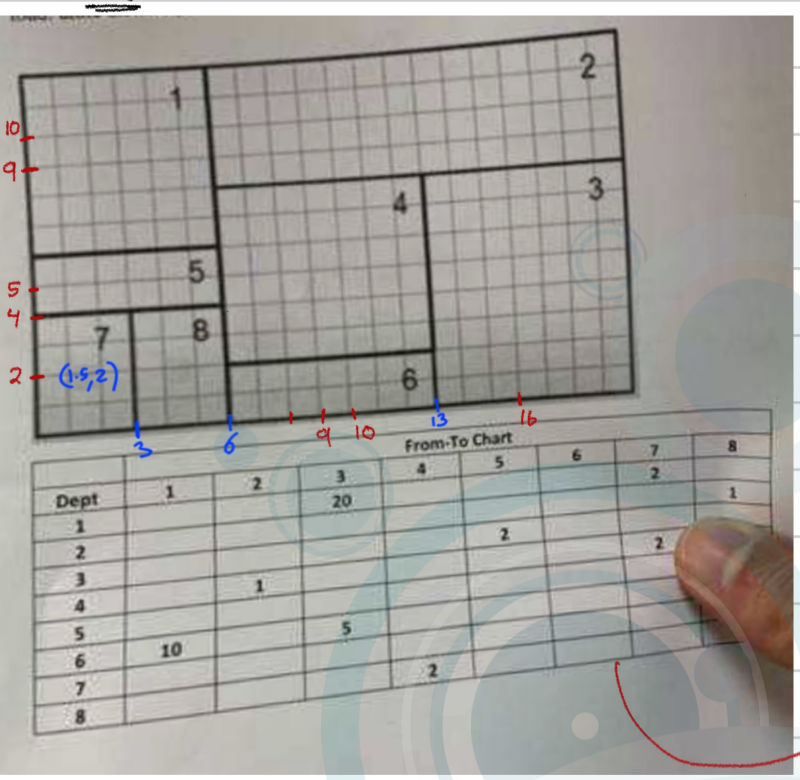
	Score .
124	9
123	7
134	2
234	9



5.) Total score = 81.

Craft : min. $z = \sum f_{ij} c_{ij} d_{ij}$.

Craft 8



From-To Chart

Dept	1	2	3	4	5	6	7	8
1			20				2	
2					2			1
3		1					2	
4								
5			5					
6	10			2				
7								
8								

1.1 Area & centroid.

$A_1 = 36$ (3, 9)

$A_2 = 56$ (13, 10)

$A_3 = 56$ (16.5, 4)

$A_4 = 42$ (9.5, 5)

$A_5 = 12$ (3, 5)

$A_6 = 14$ (9.5, 1)

$A_7 = 12$ (1.5, 2).

$A_8 = 12$ (4.5, 2)

* Distance matrix :

	1	2	3	4	5	6	7	8
1	—	11	18.5	10.5	4	14.5	8.5	8.5
2		—	9.5	8.5	15	12.5	19.5	16.5
3			—	8	14.5	10	17	14
4				—	6.5	4	11	8
5					—	10.5	4.5	4.5
6						—	9	6
7							—	3
8								—

A facility with 7 departments

Cost of carrying any material $c_{ij} = 1$ for all i and j pairs.

Each grid size is *20 X 20,* total *72,000 m²* is available

Total requirement is *70,000* m²

Location of receiving (A) and shipping (G) departments are fixed

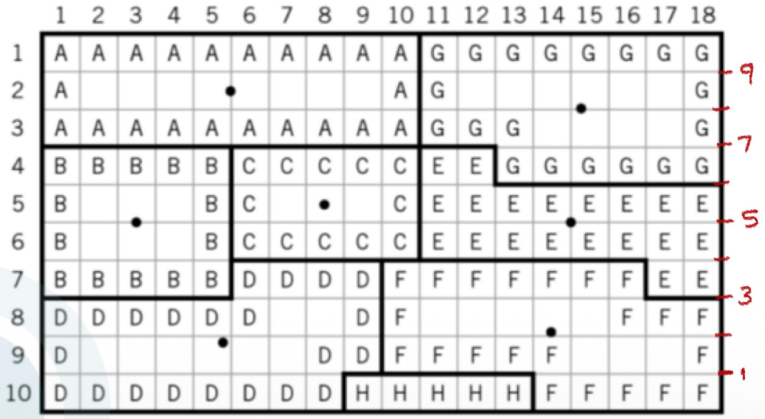


Table 6.3 *Departmental Data and From-To Chart for Example 6.1*

Department Name	Area (ft^2)	No. of Grids	Flow A	B	C	D	E	F	G	H
1. A: Receiving	12,000	30	0	45	15	25	10	5	0	0
2. B: Milling	8000	20	0	0	0	30	25	15	0	0
3. C: Press	6000	15	0	0	0	0	5	10	0	0
4. D: Screw m/c	12,000	30	0	20	0	0	35	0	0	0
5. E: Assembly	8000	20	0	0	0	0	0	65	35	0
6. F: Plating	12,000	30	0	5	0	0	25	0	65	0
7. G: Shipping	12,000	30	0	0	0	0	0	0	0	0
8. H: Dummy	2000	5	0	0	0	0	0	0	0	0

# of Grid = $\frac{72000}{400}$ = 180 available.

$\frac{70000}{400}$ = 175 required.

= 5 Dummy.

possiable exchange

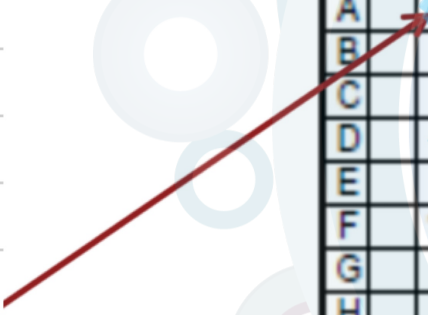
[B-C, B-D, B-E, C-E, C-D, D-F, E-F]

centroid for (D

dep	A	B	C	D	E	F	G
centroid	(5,8.5)	(2.5,5)	(7.5,5.5)	( )	(14,5)	(13.5,2)	(14.2,8)

- **Distance Matrix**

	A	B	C	D	E	F	G	H
A		6	5	6	13	16		
B				6	11	14		
C					7	10		
D		6			12			
E						3	4	
F		14			3		7	
G								
H								



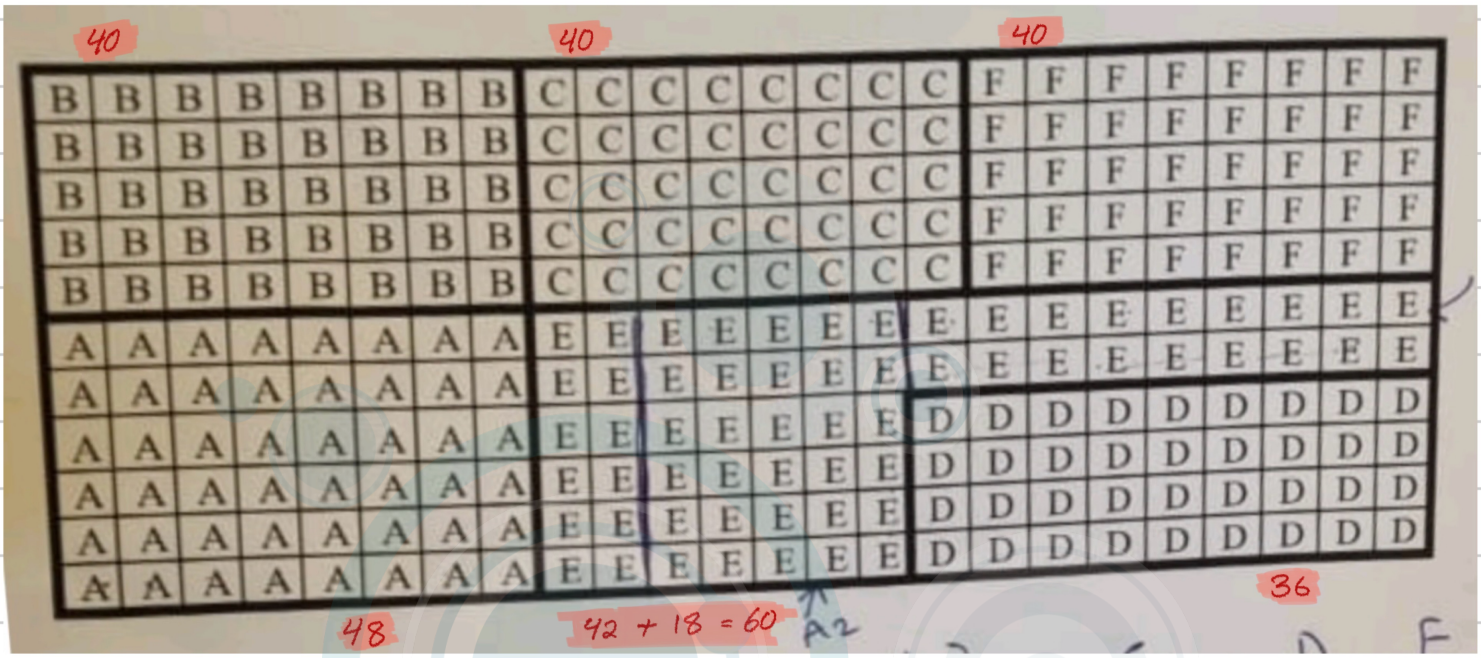
كل ال distance من الجدول بس من الدا كون في flow ← flow الي فيها من فيها الي مافيها flow مافيش.

⟹ then total cost.

= 2980 $.

exchange E-F.

Ex: $4 / unit load · unit distance.



Flow-Between Matrix

	A	B	C	D	E	F
A	----	0	80	0	32	0
B		----	0	20	0	8
C			----	0	4	0
D				----	24	0
E					----	16
F						----

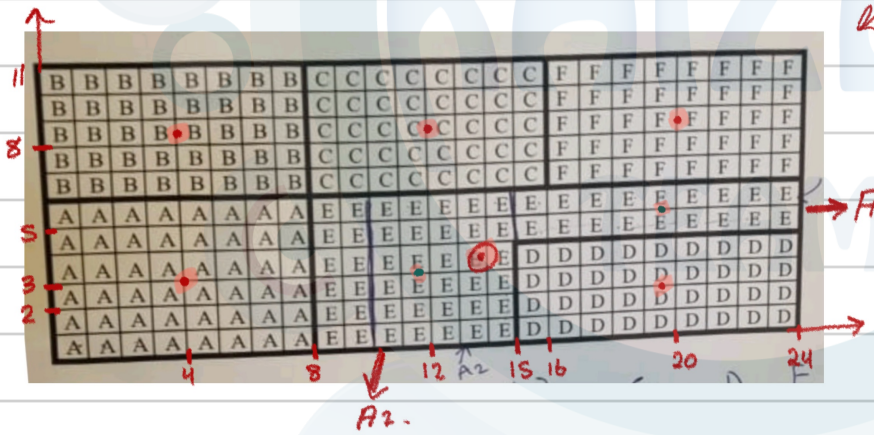
1) Area for each dep

2) Total area = 264

3.) possibale exchange : (8 exchange).

A-B B-C C-F D-E

A-E B-F C-E E-F



4.)

Dep.	Centroid
A	4, 3
B	4, 8.5
C	12, 8.5
D	19.5, 2
E	13.9, 3.6
F	20, 8.5

for E :

A_1 : (19.5, 5)	Area = 18	Ax = 19.5 * 18 = 351	Ay = 90
A_2 : (11.5, 3)	Area = 42	Ax = 483	Ay = 126
tot :	60	834	216

$X = \frac{834}{60} = 13.9$, $y = 3.6$

5. Distance matrix:

	A	B	C	D	E	F
A	—	5.5	13.5	16.5	10.5	21.5
B		—	8	22	14.8	16
C			—	14	6.8	8
D				—	7.2	7
E					—	11
F						—

6. Cost matrix : (4$)

	A	B	C	D	E	F
A	—	0	4320	0	1344	0
B		—	0	1760	0	512
C			—	0	108.8	0
D				—	691.2	0
E					—	704
F						—

total cost = 9440

منقدر نطلع (total cost) بدونزا لاي ما بتاجوا

---

exchang B-F

	A	B	C	D	E	F
A	—	21.5	13.5	16.5	10.5	5.5
B		—	8	7	11	16
C			—	14	6.8	8
D				—	7.2	22
E					—	14.8
F						—

total cost = 8483.2.

* Estimated but.

Area (B) = Area (F) ⇒ actual

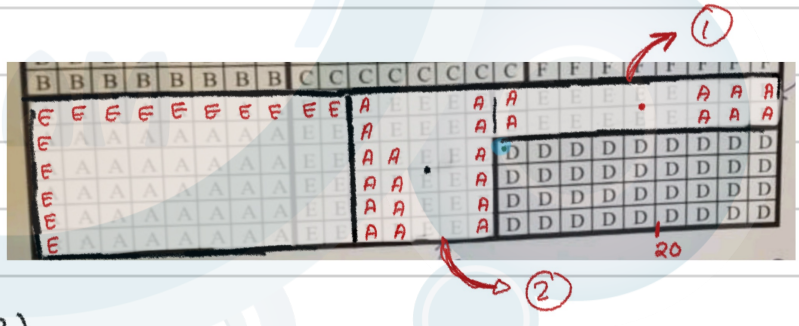
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exchange A-E

	A	B	C	D	E	F
A	—	14.8	6.8	7.2	10.5	11
B		—	8	22	5.5	16
C			—	14	13.5	8
D				—	16.5	7
E					—	21.5
F						—

total estimated cost = 8968 $

for the actual : A = 48 E = 60.



---

centroid for E = (5,3)

for A = A_1 (19.5, 5) Area = 18 Ax = 351 Ay = 90

A_2 (12.5, 3) Area = 30 Ax = 375 Ay = 90

X = 15.125 y = 3.75

new distance matrix.

	A	B	C	D	E	F
A	—	15.875	7.875	6.125	10.875	9.625
B		—	8	22	6.5	16
C			—	14	12.5	8
D				—	15.5	7
E					—	20.5
F						—

Dep.	Centroid
A	15.125, 3.75
B	4, 8.5
C	12, 8.5
D	19.5, 2
E	5, 3
F	20, 8.5

* Total actual cost = 9184 $

improvement = 9440 − 9184
= 256 $.

* عكس ما نعمل هاي كلها وكتغير مسلم flow انا نطلع اي قيمة الـ ≠0.

6.18 The ABC Cooling and Heating Company manufactures several different types of air conditioners. Five departments are involved in the processing required for the products. A summary of the processing sequences required for the five major products and the weekly production volumes for the products are shown in the tables below along with the department area. Based on the graph-based construction method, develop a block layout.

Product	Process Sequence	Weekly Production
1	ABC	150
2	ABED	200
3	ACE	50
4	ACBE	200
5	ADE	250

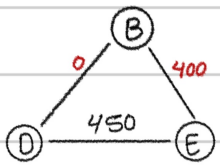
Department	Area (ft^2)
A	1500
B	1500
C	1000
D	2000
E	2000

	A	B	C	D	E
A	—	350	250	250	0
B		—	350	0	400
C			—	0	50
D				—	450
E					—

1.) D —450— E

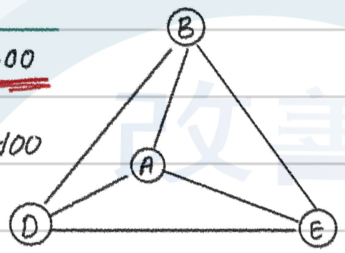
2.)

	D	E	
A	250	0	250
B	0	400	400
C	0	50	50



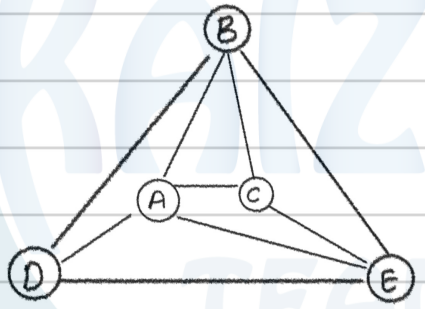
3.

	B	D	E	
A	350	250	0	600
* C	350	0	50	400



4.

	A	B	D	E
C	250	350	0	50



Face	ABE	ABD	ADE	BDE
Score	650	600	300	400

6.21 Consider the layout of five equal-sized departments. The material flow matrix is given in the figure below.

a. Develop the final adjacency graph using the graph-based procedure.

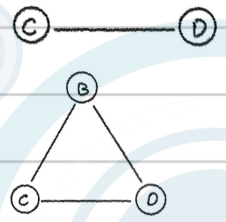
b. Develop a block layout based on the final adjacency graph obtained in part a.

	A	B	C	D	E
A	—	0	5	25	15
B	0	—	20	30	25
C	0	25	—	40	30
D	30	5	20	—	0
E	20	30	5	10	—

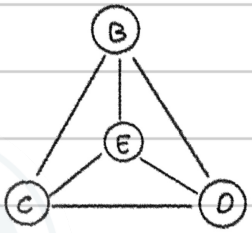
1.)

	A	B	C	D	E
A	—	0	5	55	35
B		—	45	35	55
C			—	60	35
D				—	10
E					—

	C	D	
A	5	55	60
B	45	35	80
E	35	10	45

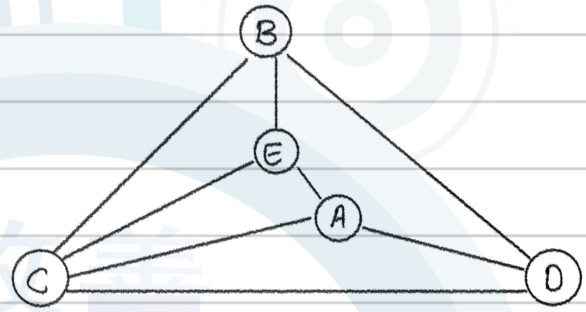


	B	C	D	
A	0	5	55	60
E	55	35	10	100

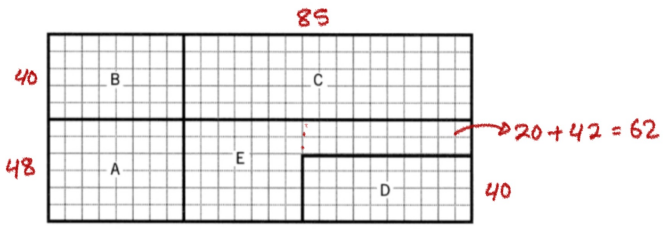


	B	C	D	E
A	0	5	55	35

Face	BDE	BCE	CDE	BCD
Score	90	40	95	60



6.28



Suppose the flow data, the unit cost data, and the distance matrix are given as follows:

Flow-Between Matrix

	A	B	C	D	E
A	—	0	5	0	5
B		—	6	2	0
C			—	3	0
D				—	7
E					—

Unit Cost ($/Unit Dist.)

	A	B	C	D	E
A	—	0	1	0	1
B		—	1	4	0
C			—	3	0
D				—	1
E					—

Distance Matrix

	A	B	C	D	E
A	—	6	20	18	11
B		—	12	22	15
C			—	10	8
D				—	7
E					—

a. Using the CRAFT two-way exchange procedure, indicate all the department pairs CRAFT would consider exchanging in the above layout.
b. Compute the *estimated* cost of exchanging departments A and E.

~~#~~ of exchange

A-B, A-E, B-C, B-D, C-E

E-D

exchange A-E →

Distance Matrix

	A	B	C	D	E
A	—	15	8	7	11
B		—	12	22	6
C			—	10	20
D				—	18
E					—

total cost = 559 unit.

Craft Example:

Suppose the following layout is provided as the initial layout for CRAFT. The flow-between matrix is given below. (All the *cij* values are equal to $2/ (unite load. unite distance).

Flow-Between Matrix					
	A	B	C	D	E
A	----	8	2	8	14
B		----	12	8	16
C			----	6	10
D				----	4
E					----

