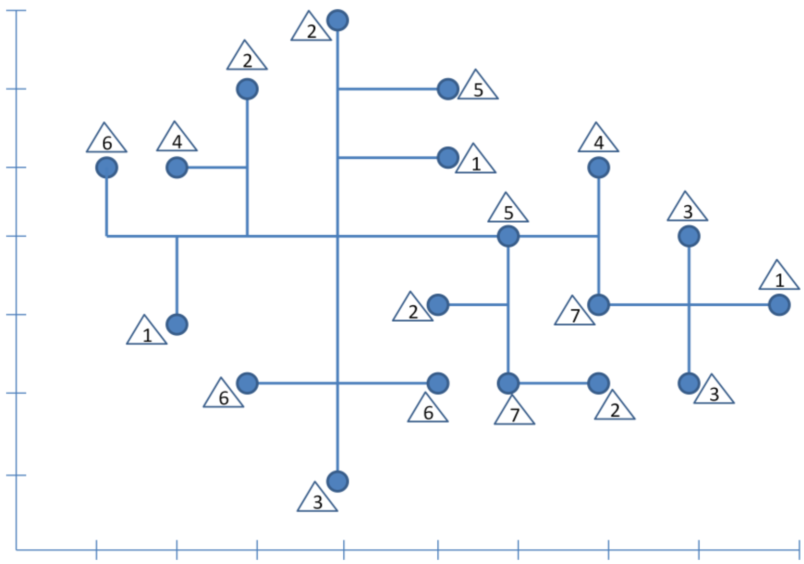
Final review lecture (INDU 421 2013)

Question #1:

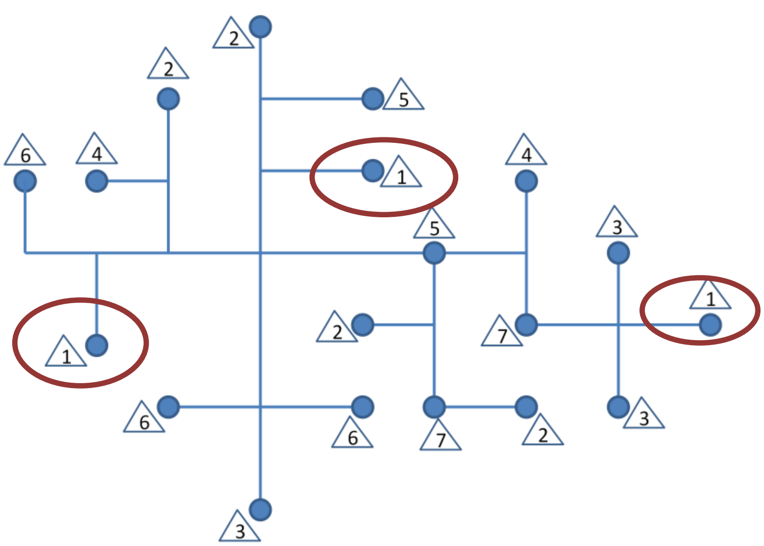
A new warehouse serving 18 existing manufacturing facilities should be built in a way that the total flow between the warehouse and the facilities is minimized. The facilities are connected by a network of roads and the flow between them is represented by the weights as shown in the network below. Where should be the new warehouse located?

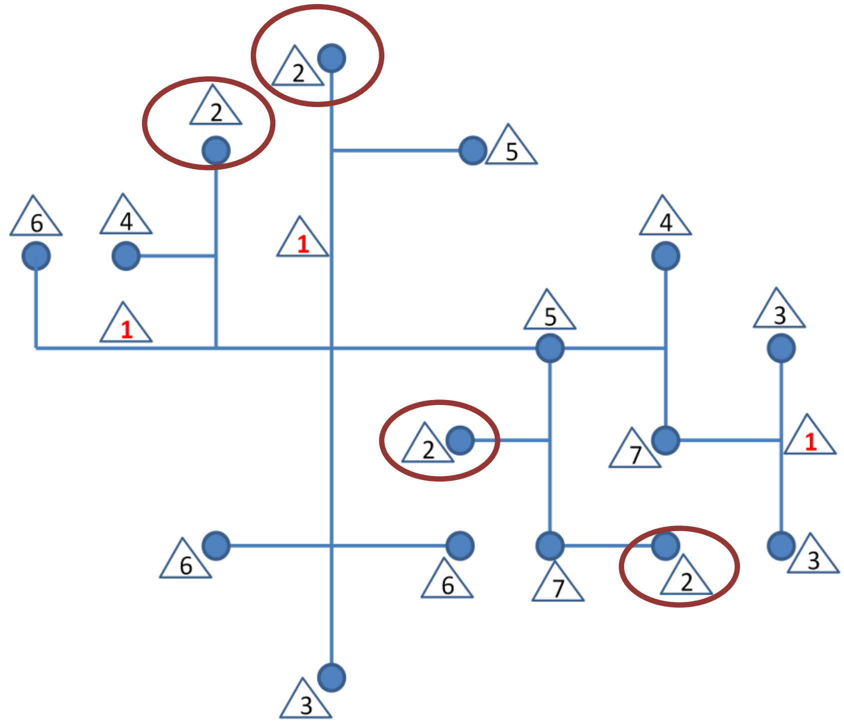
a) Use Chinese algorithm
b) Use Majority algorithm



- **Solution:**

a) **Chinese algorithm**:

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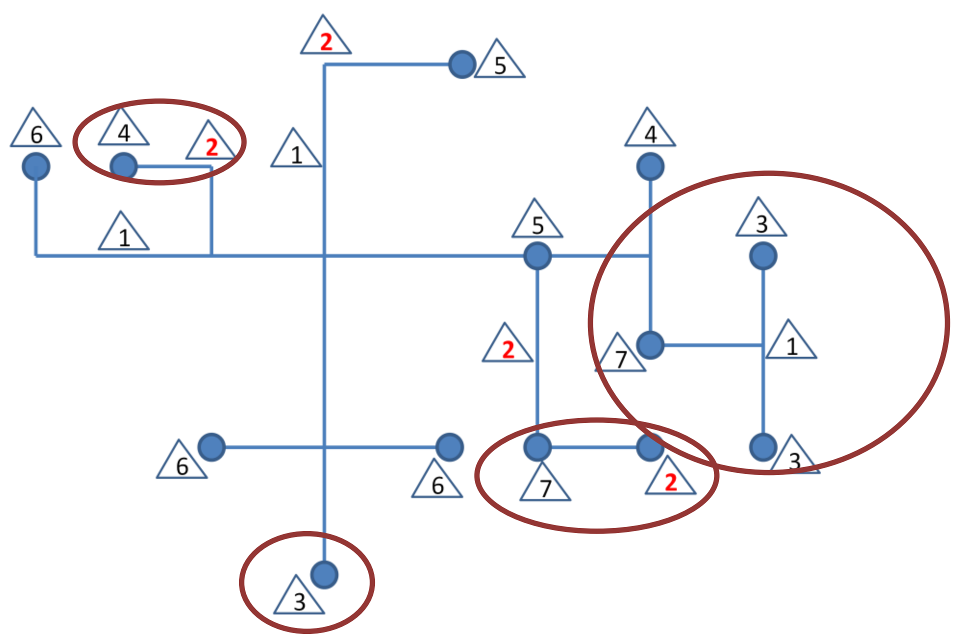
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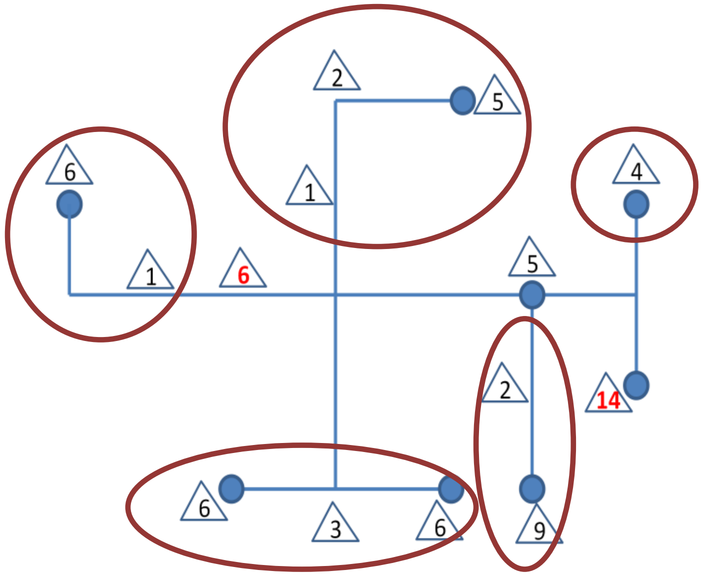
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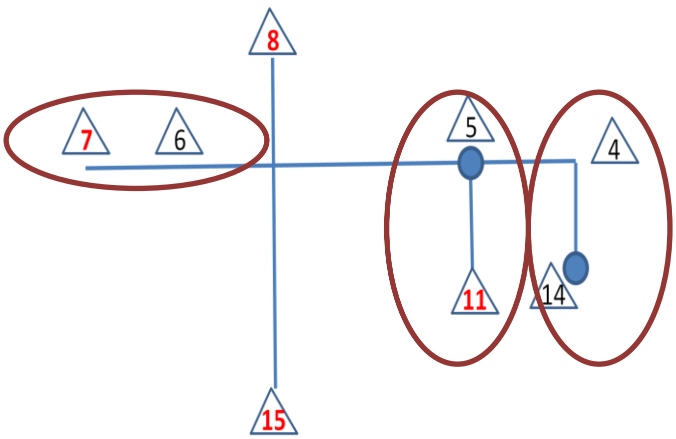
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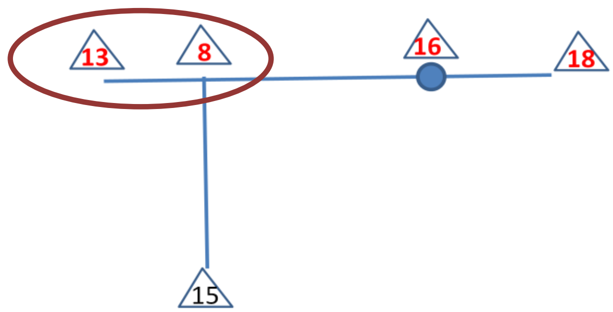
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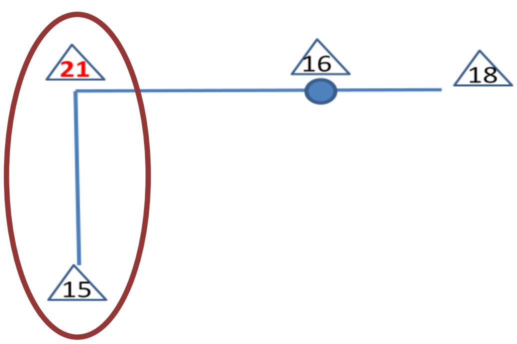
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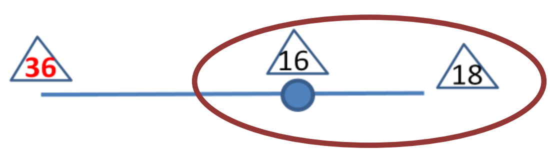
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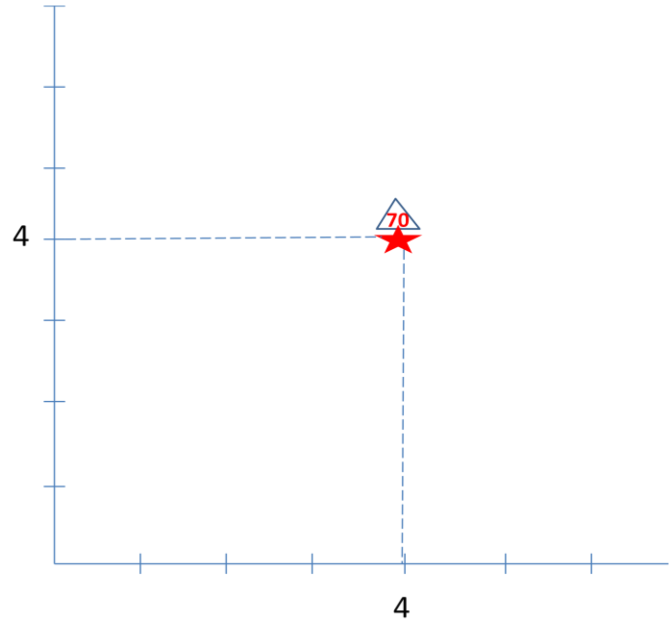
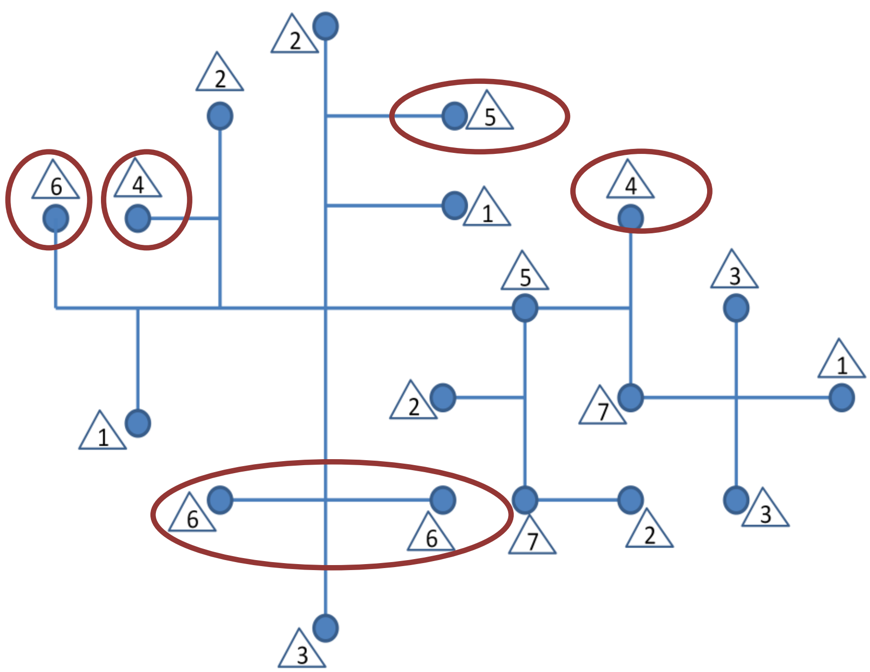
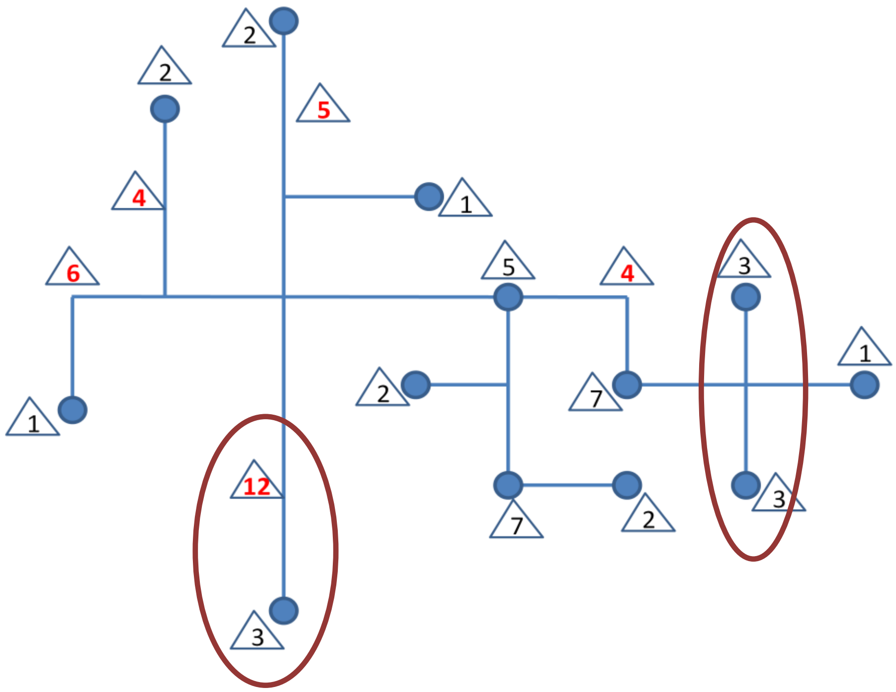


Solution by Chinese algorithm is in the point **X*[4,4].**

b) Majority algorithm:

Half the weight = 70/2 = 35

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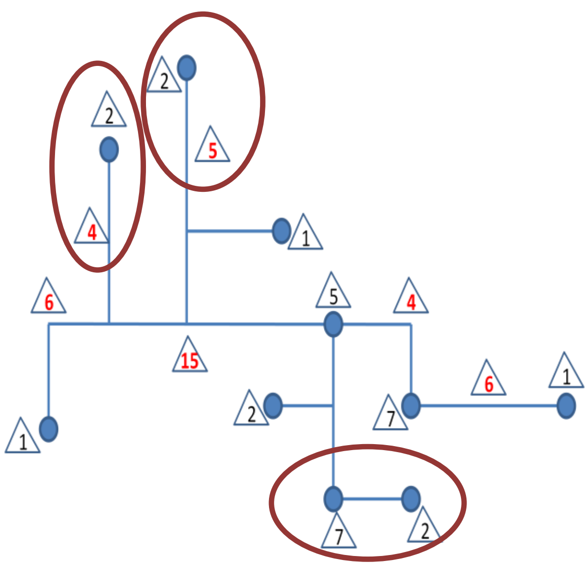
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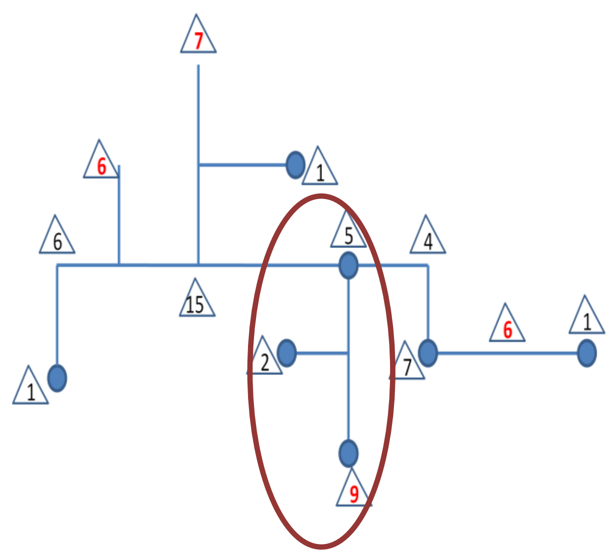
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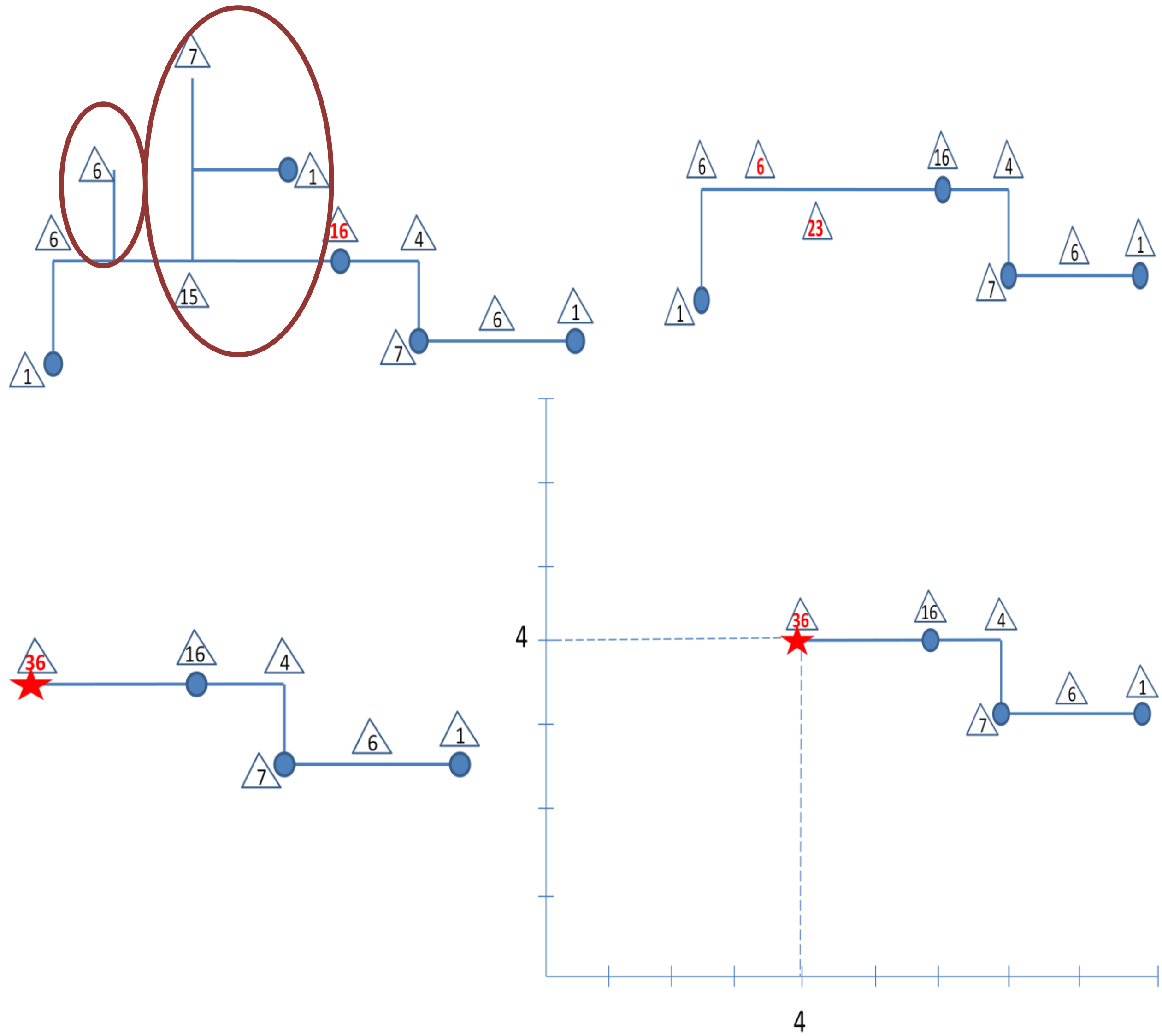
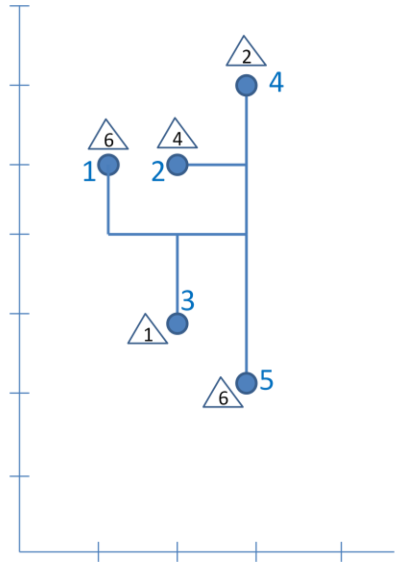


Solution by Majority algorithm is in the point **<u>X*[4,4].</u>**

<u>Question #2:</u>

Solve the problem above if the objective is to minimize maximum weighted distance between the new warehouse and any other existing facility. Consider only first five facilities as shown in the network below.



	X,Y	*w*
1	1,5	6
2	2,5	4
3	2,3	3
4	3,6	2
5	3,2	6

- **Solution:**

Create distance matrix:

	1	***2***	***3***	***4***	***5***
1	-	5	3	5	5
2		-	4	2	4
3			-	4	4
4				-	4
5					-

Calculate b_{ij} for each pair of i and j:

$$b_{ij} = w_i w_j d(v_i, v_j)/(w_i + w_j)$$

	1	***2***	***3***	***4***	***5***
1	-	12	6	7.5	**15**
2		-	6.85	2.66	9.6
3			-	4.8	8
4				-	6
5					-

6*4*5/(6+4)=12

Max value b_{15} = 15 corresponds to vertices 1 and 5.

X* is located on the path connecting vertex 1 and vertex 5.

Question 3:

Manufacturing company plans to build a warehouse somewhere near to its three existing plants. The coordinates of the existing plants and the number of trips to the warehouse a day are given below.

a) Determine the location for the warehouse which minimizes the maximum distance between the warehouse and any existing facility.
b) What is the maximum distance?
c) Determine the location for the warehouse which minimizes the total cost.
d) Calculate the total cost if the warehouse is built there.
e) Plot the iso-cost contour line which passes through the point [20,35].
f) It was found that the warehouse cannot be built in the omptimal location. Based on the iso-cost contour line, suggest which of the following locations should be preferably considered: [20,35], [20,25], [20,25], [40,35] and [40,20]

	a	**b**	**w**
1	20	20	2
2	40	25	3
3	25	35	4

➢ **Solution:**

a) Use minimax method

	a	**b**	**a+b**	**-a+b**
1	20	20	40	0
2	40	25	65	-15
3	25	35	60	10

c_1 = minimum $(a_i + b_i) = 40$
c_2 = maximum $(a_i + b_i) = 65$
c_3 = minimum $(-a_i + b_i) = -15$
c_4 = maximum $(-a_i + b_i) = 10$
$c_5 = \max(c_2-c_1, c_4-c_3) = \max(25, 35) = 35$

Optimum solution for the new facility location is on the line segment connecting the points :

$(x_1^*, y_1^*) = 0.5(c_1-c_3, c_1+c_3+c_5) = 0.5\ (55,60) =$ **(27.5, 30)**
$(x_2^*, y_2^*) = 0.5(c_2-c_4, c_2+c_4 - c_5) = 0.5\ (55,-25) =$ **(27.5, -12.5)**

b) Max distance equals $c_5/2 =$ **17.5**

c) Use minisum method

Determine X coordinate

	a	w	∑w
1	20	2	2
3	25	4	6
2	40	3	9

∑w /2=4.5

X=25

Determine Y coordinate

	b	w	∑w
1	20	2	2
2	25	3	5
3	35	4	9

∑w /2=4.5

Y=25

The best location is N [25,25]

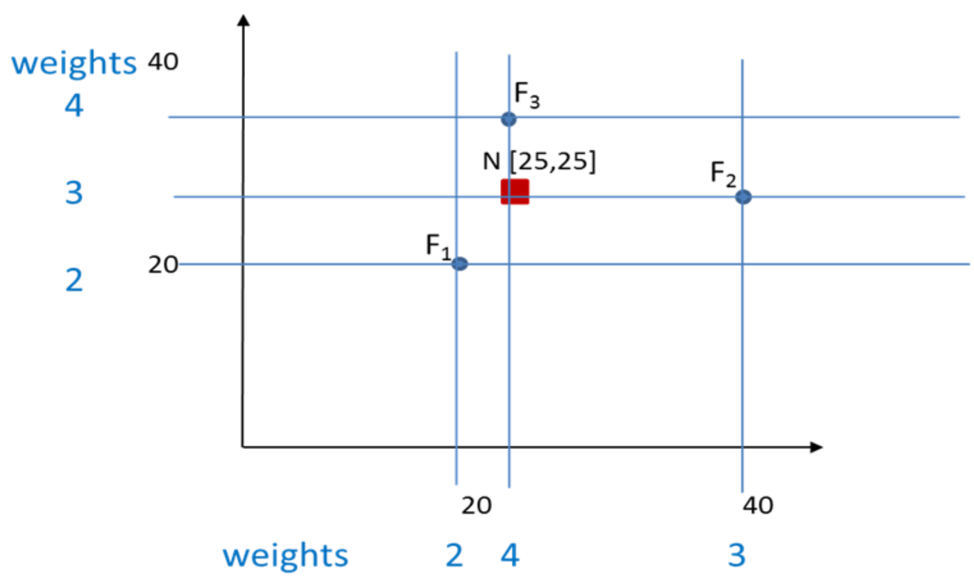
d) Total cost:

$$f(x) = \sum_{i=1}^{m} \mathrm{w}_{\mathrm{i}} |x - a_i| + \sum_{i=1}^{m} w_i |y - b_i|$$

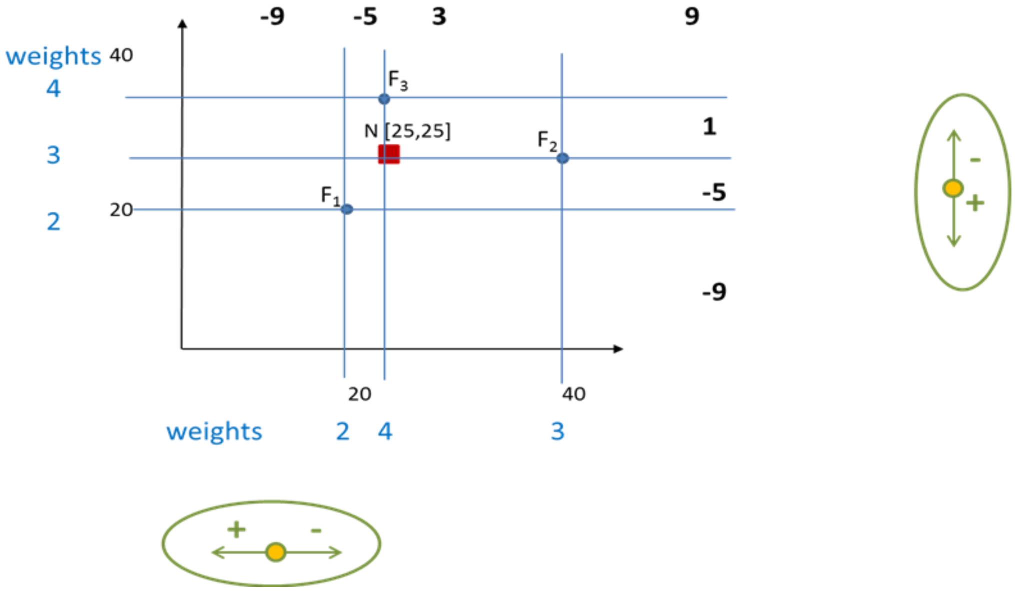
TC=2[(25-20)+(25-20)] + 3[(40-25)+(25-25)] + 4[(25-25)+(35-25)] = 105

e) Iso-cost lines:

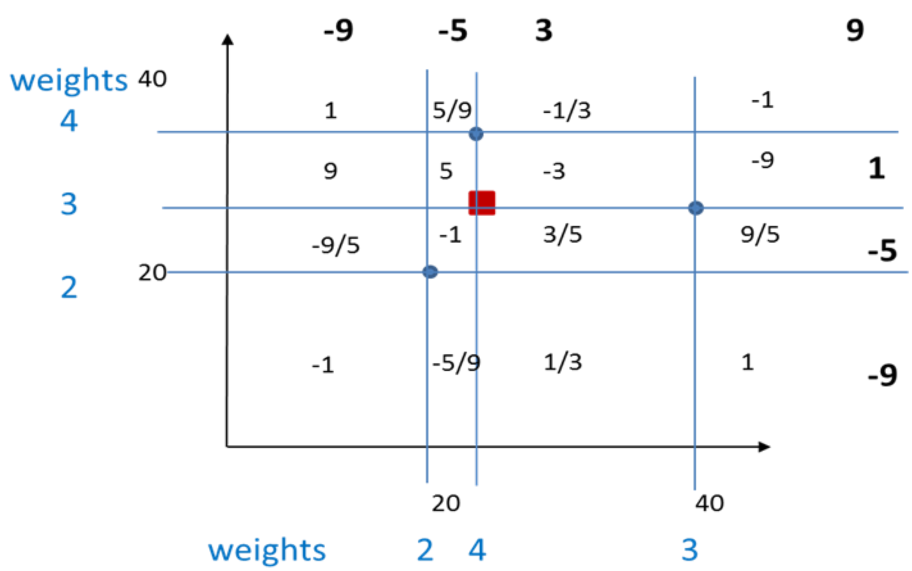
Assign weights:



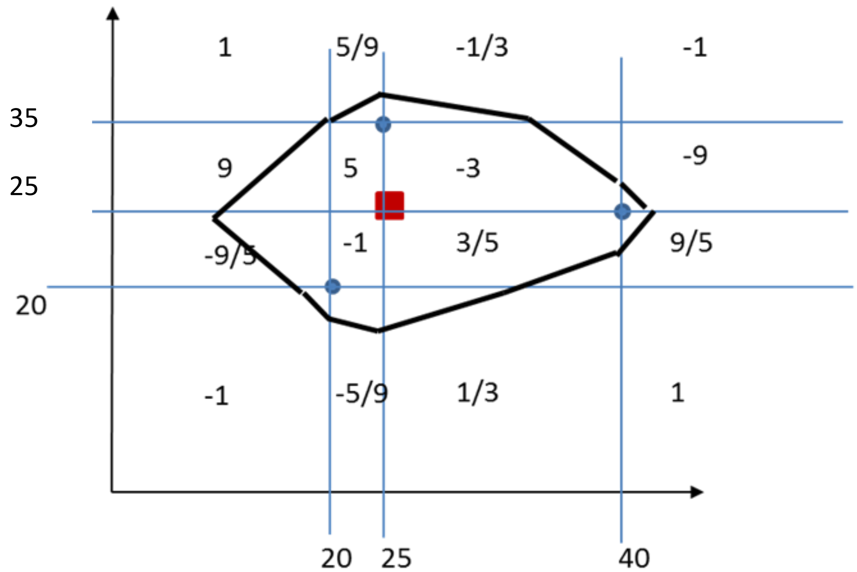
Calculate net pulls:



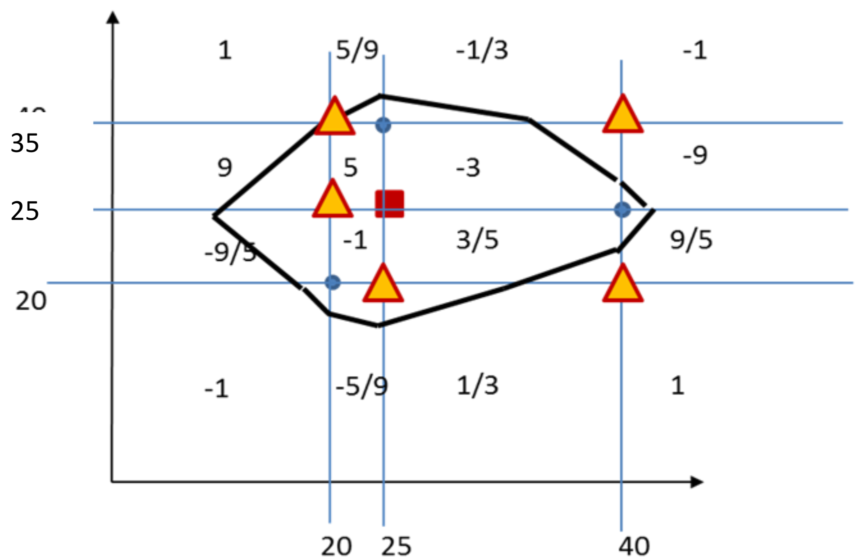
Calculate slopes for each region:



Plot the contour line based on a slope in each region starting from [20,35]:



f) Alternative locations



Out of the new locations the ones which should be also considered are [20,25] and [25,20]. Both have lower cost than the other three options.

Question 4:

Consider the previous question. The management has decided that in order to reduce the total costs it may build more than 1 warehouse. Determine the optimal number of warehouses and which plants should be served by which warehouse. It costs 40 units to build each warehouse.

- **Solution:**

Cases to consider:

<table>
<tr><td></td><td># of warehouses</td><td colspan="3">Facilities served by each warehouse</td></tr>
<tr><td>A</td><td>1</td><td colspan="3">1 – 2 - 3</td></tr>
<tr><td>B</td><td>2</td><td colspan="2">1</td><td>2 - 3</td></tr>
<tr><td>C</td><td>2</td><td colspan="2">1 - 2</td><td>3</td></tr>
<tr><td>D</td><td>2</td><td colspan="2">1 - 3</td><td>2</td></tr>
<tr><td>E</td><td>3</td><td>1</td><td>2</td><td>3</td></tr>
</table>

Use minisum method for each case.

Case A: **1, 2, 3**

1 warehouses: N_A [25,25] serves plants 1,2 and 3

Total cost:

TC= 105 + 40 = 145

Case B: **1 - 2, 3**

Determine X coordinate

	a	w	∑w
3	25	4	4
2	40	3	7

∑w /2=3.5

X=25

Determine Y coordinate

	b	w	∑w
2	25	3	3
3	35	4	7

∑w /2=3.5

Y=35

2 warehouses: N_{B1} [20,20] serves plant 1

N_{B2} [25,35] serves plants 2 and 3

Total cost:

TC = 3(15+10) + 4(0) + 2x40 = 155

$$f(x) = \sum_{i=1}^{m} w_i |x - a_i| + \sum_{i=1}^{m} w_i |y - b_i|$$

Case C: **1, 2 - 3**

Determine X coordinate

	a	w	∑w
1	20	2	2
2	40	3	5

∑w /2=2.5

X=40

Determine Y coordinate

	b	w	∑w
1	20	2	2
2	25	3	5

∑w /2=2.5

Y=25

2 warehouses: N_{C1} [40,25] serves plants 1 and 2
N_{C2} [25,35] serves plant 3

Total cost:

TC = 2(20+5) + 3(0) + 2x40 = 130

Case D: **1,3 - 2**

Determine X coordinate

	a	w	∑w
1	20	2	2
3	25	4	6

∑w /2=3

X=25

Determine Y coordinate

	b	w	∑w
1	20	2	2
3	35	4	6

∑w /2=3

Y=35

2 warehouses: N_{D1} [25,35] serves plants 1 and 3
N_{D2} [40,25] serves plant 2

Total cost:

TC = 2(5+15) + 4(0) + 2x40 = 120

Case E: **1 - 2 - 3**

3 warehouses: N_{E1} [20,20] serves plant 1
N_{E2} [40,25] serves plant 2
N_{E3} [25,35] serves plant 3

Total cost:

TC = 3x40 = 120

In order to minimize costs the company should either build 3 warehouses, one for each plant or 2 warehouses, one for plants 1and 3 and one for plan 2.

Question 5:

Facility has 5 departments. Given the relationship chart below determine the most suitable layout for the facility. Consider A=4, E=3, I=2, O=1, U=0, X=-4. If the departments are only touching by one point, consider half weight.

a) Find TCR values
b) Clearly indicate the sequence in which the departments are entered into the layout.
c) Use CORELAP to find the best layout.

Relationship chart:

	1	2	3	4	5
1	-	E	A	I	E
2		-	I	O	I
3			-	X	U
4				-	U
5					-

- **Solution:**

a) TCR values

	1	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**		**TCR**	**Order**
1	-	E	A	I	E		-	3	4	2	3		**12**	**1**
2	E	-	I	O	I		3	-	2	1	2		**8**	**3**
3	A	I	-	X	U		4	2	-	-4	0		**2**	**2**
4	I	O	X	-	U		2	1	-4	-	0		**-1**	**5**
5	E	I	U	U	-		3	2	0	0	-		**5**	**4**

b) Sequence

Sequence: **1 - 3 – 2 - 5 - 4**

a) Procedure for the layout

2	4	2
4	1	4
2	4	2

3?

1-3 => 4

1.5	4	3.5	1
3	1	3	2
1.5	4	3.5	1

2?

1-2 => 3
3-2 => 2

There is a mistake here. The department 5 should have been placed here, because 4 is the highest Placing Rating!

1	2	1	
3.5	2	3.5	0
4	1	3	0
1.5	3	1.5	0

5?

1-5 => 3
2-5 => 2
3-5 => 0

0.5	1	0.5	0
2	2	5	-2
3	1	3	-4
1	2	-3	-2

4?

1-4 => 2
2-4 => 1
3-4 => -4
5-4 => 0

4	2	5
	1	3

Question #6:

Suppose the following layout is provided as the initial layout for CRAFT. The flow-between matrix and the distance matrix are given below.

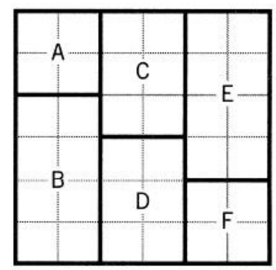
a) Given the data and the initial layout, which department pairs will NOT be considered for exchange?
b) Compute the cost of the initial layout
c) Computed the *estimated* layout cost assuming that departments E and F are exchanged.
d) Recommend if you would exchange the departments. If the change is recommended show the new layout and calculate the new cost.

Flow-Between Matrix

	A	B	C	D	E	F
A	—	0	8	0	4	0
B		—	0	5	0	2
C			—	0	1	0
D				—	6	0
E					—	4
F						—

Distance Matrix

	A	B	C	D	E	F
A	—	30	25	55	50	80
B		—	45	25	60	50
C			—	30	25	55
D				—	45	25
E					—	30
F						—



➢ **Solution:**

a) The areas of the departments are: A=4, B=8, C=6, D=6, E=8 and F=4. The departments A and F have the same area, also C and D and also B and E. The departments which can be exchanged are only those which are either adjacent or of the same size. Therefore, the department pairs which cannot be exchanged by CRAFT are: AD, AE, BF and CF.

b) The initial layout cost:

TC=(8*25)+(4*50)+(5*25)+(2*50)+(1*25)+(6*45)+(4*30)=1040

c) Estimated cost of the exchange of E and F:

Distance matrix for the cost calculation

	A	B	C	D	E	F
A	-		25		**80**	
B		-		25		**60**
C			-		**55**	
D				**-**	**25**	
E					-	30
F						-

Total estimated cost:

TC=(8*25)+(4*80)+(5*25)+(2*60)+(1*55)+(6*25)+(4*30)=<u>1090</u>

The cost is higher, so the exchange is not recommended.

<u>Question # 7:</u>

Using BLOCPLAN's procedure, convert the following From-to chart to a Relationship chart:

From-to chart:

To / From	A	B	C	D	E	F	G	H
A	—	8		3		6		
B	1	—			5			
C			—				4	
D		9		—			18	
E			4	1	—			
F	4			4		—		
G				2			—	20
H				7				—

<u>Solution:</u>

Flow-between chart:

	A	B	C	D	E	F	G	H
A	–	9	0	3	0	10	0	0
B		–	0	9	5	0	0	0
C			–	0	4	0	4	0
D				–	1	4	20	7
E					–	0	0	0
F						–	0	0
G							–	20
H								–

The highest value is 20

20 / 5 = 4

5 intervals, each with 4 units are created:

- 17 to 20 units …..A
- 13 to 16 units …..E
- 9 to 12 units …....I
- 5 to 8 units ……...O
- 0 to 4 units ..……U

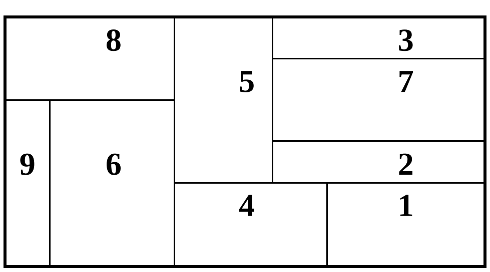
Relationship chart:

	A	B	C	D	E	F	G	H
A	–	I	U	U	U	I	U	U
B		–	U	I	O	U	U	U
C			–	U	U	U	U	U
D				–	U	U	A	O
E					–	U	U	U
F						–	U	U
G							–	A
H								–

Question #8:

The dimensions of a facility with 9 departments are 60mx100m. It was decided to improve its layout and that the MCRAFT algorithm is the most appropriate one for this task.

a) Show two options for the MCRAFT input layout based on different number of bands. Always clearly show the sequence of placing the departments in the layout.
b) Which layout will you use as an initial input into MCRAFT?

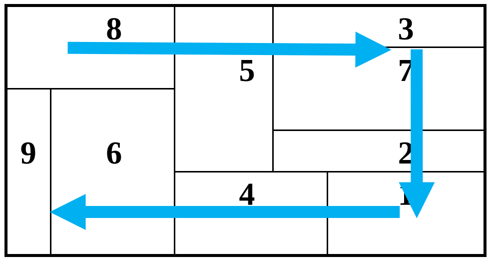


Department	Area (m^2)
1	60
2	40
3	40
4	60
5	80
6	120
7	80
8	80
9	40

Solution:

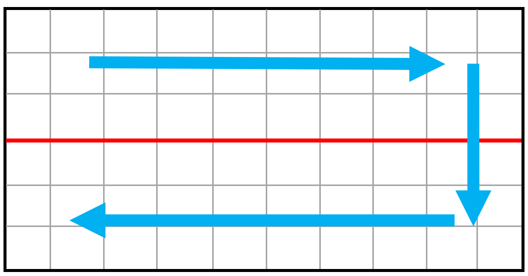
a) Two different solutions based on 2 and 3 bands.

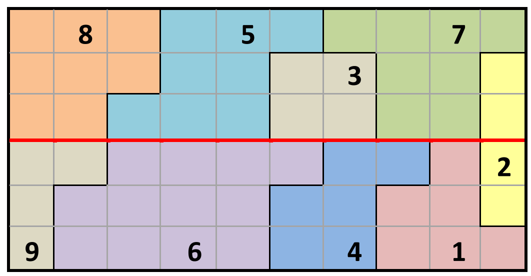
2 bands:



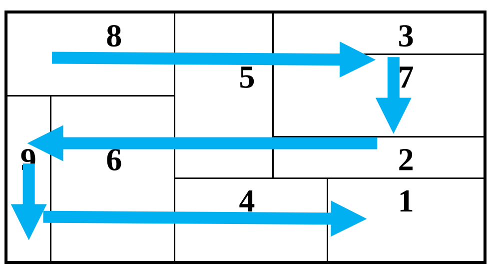
Sequence of placing the departments in the layout: ***8-5-3-7-2-1-4-6-9***

Band width; 60m / 2 =30m



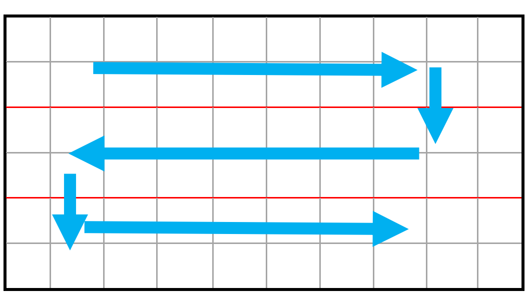


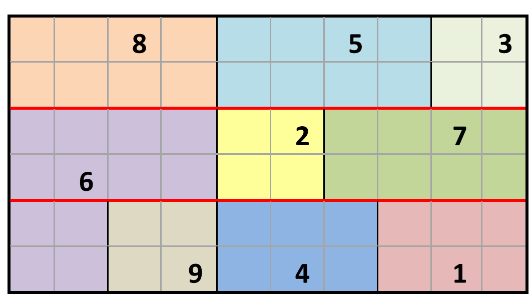
3 bands:



Sequence of placing the departments in the layout: ***8-5-3-7-2-6-9-4-1***

Band width; 60m / 3 =20m



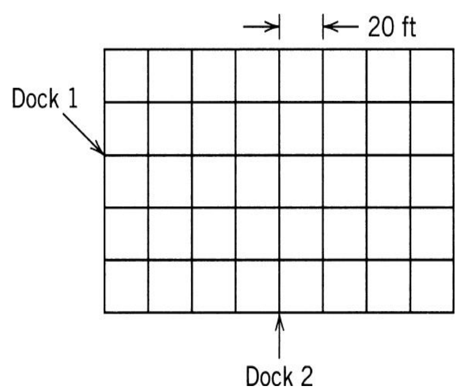


b) Which layout(s) will you use as an initial input into MCRAFT?

The best strategy is to use both layouts as initial inputs, to generate 2 solutions and to evaluate both alternatives afterwards.

Question #9:

Consider warehouse below. 40 bays (20ft x 20ft) are available for storage. Six product families are to be stored. Products are received from Dock1 and are shipped out Dock 2. The area requirement and weekly load rate are below. Determine the layout that will minimize the average distance traveled per week.



Product Family	Area (ft^2)	Load Rate
1	2,400	600
2	3,200	400
3	2,000	800
4	2,800	400
5	4,000	400
6	1,600	800

➢ **Solution:**

1 storage bay is 20x20=400 ft^2

Product (j)	Area (ft^2)	# of Bays (S_j)	Load Rate (T_j)	T_j/S_j
1	2,400	6	600	100
2	3,200	8	400	50
3	2,000	5	800	160
4	2,800	7	400	57.14
5	4,000	10	400	40
6	1,600	4	800	200

Product ranking: **6 > 3 > 1 > 4 > 2 > 5**

$$f_k = \sum_{i=1}^{m} p_i d_{ik}$$

Dock 1 …50%
Dock 2 …50%

Cell 1: $f_1 = (0.5 * 2 * 20) + (0.5 * 9 * 20) = 110$

110	110	110	110	110	120	140	160
90	90	90	90	90	100	120	140
80	80	80	80	80	90	110	130
80	80	80	80	80	90	110	130
80	80	80	80	80	90	110	130

0.5

0.5

2	2	2	2	5	5	5	5
4	4	4	4	4	2	5	5
6	6	3	1	1	2	5	5
6	6	3	1	1	4	2	5
3	3	3	1	1	4	2	5

0.5

0.5

Question 10:

Consider the layout of 5 equal-sized departments. The material flow matrix is given in the figure below. Develop the final adjacency graph using the graph-based procedure.

	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	—

- **Solution:**

Construct Flow-Between Chart

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

1. Department with largest weight : C and D ; weight = 60
2. Select the third department to enter : B ; weight = 80

	C	D	Total
A	5	55	60
B	45	35	80
E	35	10	25

3. Select the next department to enter : E ; weight = 100

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

4. Which face should department A be located?

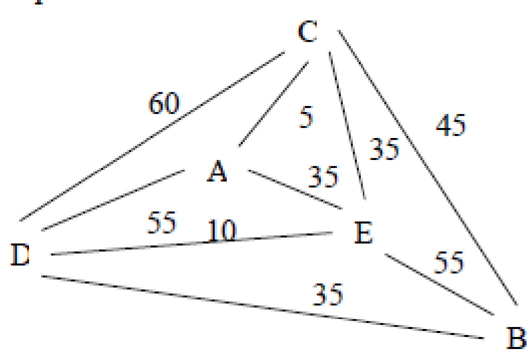
	C	D	E	Total
A	5	55	35	95

	B	C	E	Total
A	0	5	35	40

	B	D	E	Total
A	0	55	35	90

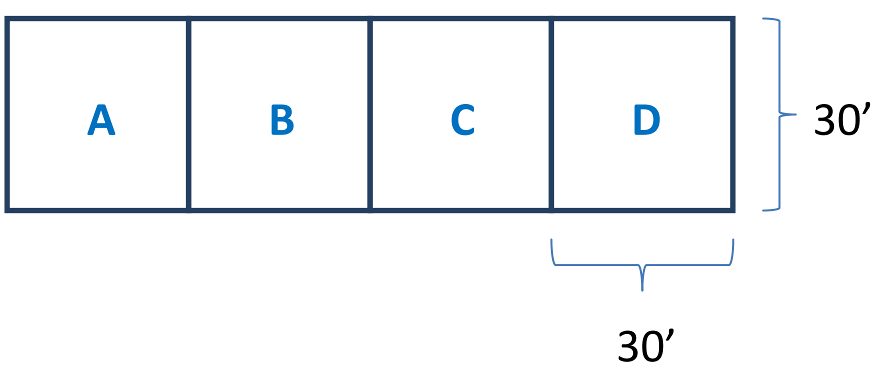
A should be located in Face C-D-E

Adjacency Graph



Question 11:

A Facility has 4 departments of the same size as shown below. A layout rearrangement is being considered in order to minimize the total cost. The weekly flow of material is represented by the Flow-Between Chart below. Use a pairwise exchange method to determine the optimal solution.



Flow-Between Chart:

Department	A	B	C	D
A	-	200	3300	700
B		-	200	2800
C			-	1200
D				-

Solution:

Potential arrangements:
A B C D: 30(200 + 200 + 1200) + 60(3300 + 2800) + 90(700) = 477,000
B A C D: 30(200 + 3300 + 1200) + 60(200 + 700) + 90(2800) = 477,000
C B A D: 30(200 + 200 + 700) + 60(3300 + 2800) + 90(1200) = 507,000
D B C A: 30(2800 + 200 + 3300) + 60(1200 + 200) + 90(700) = 336,000
Switch A and D:

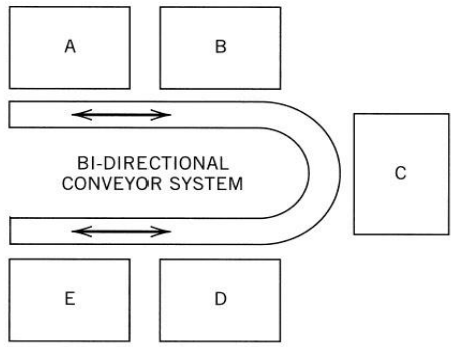
B D C A: 30(2800 + 1200 + 3300) + 60(200 + 700) + 90(200) = 291,000
C B D A: 30(200 + 2800 + 700) + 60(1200 + 200) + 90(3300) = 492,000
A B C D: 30(200 + 200 + 1200) + 60(3300 + 2800) + 90(700) = 477,000
Switch B and D:

C D B A: 30(1200 + 2800 + 200) + 60(200 + 700) + 90(3300) = 477,000
A D C B: 30(700 + 2800 + 200) + 60(3300 + 2800) + 90(200) = 495,000
Not improved.

Final Arrangement: **B D C A**

Question 12:

Five machines located in a manufacturing cell are arranged in a “U” configuration as shown in the layout below. The material handling system employed is a bidirectional conveyor system. Determine the best machine given the product routing information and production rates in the table.



Product	Machine Sequence:	Prod. Rate
1	B-E-A-C	100
2	C-E-D	200
3	B-C-E-A-D	500
4	A-C-E-B	150
5	B-C-A	200

M/C	Distance (ft.)	M/C	Distance (ft.)
A-B	20	B-D	100
A-C	70	B-E	120
A-D	120	C-D	50
A-E	140	C-E	70
B-C	50	D-E	20

- **Solution:**

Construct Flow-Between Chart based on routing information

Dept	A	B	C	D	E
A	—	0	450	500	600
B		—	700	0	250
C			—	0	850
D				—	200
E					—

Construct Distance Matrix

	1	2	3	4	5
1 (A)	—	20	70	120	140
2 (B)		—	50	100	120
3 (C)			—	50	70
4 (D)				—	20
5 (E)					—

Arrangements/Costs

ABCDE: 450(70) + 500(120) + 600(140) + 50(700) + 250(120) + 850(70) + 200(20) = 304,000
BACDE: 450(50) + 500(100) + 600(120) + 700(70(120) + 250(140) + 850(70) + 200(20) = 292,000
CBADE: 450(70) + 500(50) + 600(70) + 700(20) + 250(120) + 850(140) + 200(20) = 265,500
DBCAE: 450(50) + 500(120) + 600(20) + 700(50) + 250(120) + 850(70) + 200(140) = 247,000
EBCDA: 450(50) + 500(20) + 600(140) + 700(50) + 250(20) + 850(70) + 200(120) = 240,000
ACBDE: 450(20) + 500(120) + 600(140) + 700(50) + 250(70) + 850(120) + 200(20) = 311,500
ADCBE: 450(70) + 500(20) + 600(140) + 700(50) + 250(20) + 850(120) + 200(120) = 291,500
AECDB: 450(70) + 500(120) + 600(20) + 700(70) + 250(120) + 850(50) + 200(100) = 245,000
ABDCE: 450(120) + 500(70) + 600(140) + 700(100) + 250(120) + 850(20) + 200(70) = 304,000
ABEDC: 450(140) + 500(120) + 600(70) + 700(120) + 250(50) + 850(70) + 200(500) = 331,000
ABCED: 450(70) + 500(140) + 600(120) + 700(50) + 250(100) + 850(50) + 200(20) = 280,000

Final arrangement E B C D A