MIDTERM REVIEW INDU 421 (Fall 2013)

Problem #1:

A job shop has received on order for high-precision formed parts. The cost of producing each part is estimated to be $65,000. The customer requires that 8, 9 or 10 parts be supplied. Each good part sold will produce revenue of $100,000. However, if fewer than 8 good parts are produced, the customer cannot use them for their original purpose, but can make use of some major components. In this case he agrees to buy all of them (good or bad) for the price of the production cost. The manufacturer however needs to make some adjustments on each part which will cost him $475 per part. If 8 or more good parts are produced, the customer will buy only the good ones and will not make the purchase of the bad ones. If more than 10 good parts are produced, the excess will not be purchased for any value. Based on the historical records, the probability distributions have been estimated below. Determine the optimal batch size and expected profit. For the quantities of 10, 11 and 12, determine the probability of losing money on the transaction. Of these three choices, which one is most preferred?

Probability mass function

	Q		
X	10	11	12
0	0	0	0
1	0	0	0
2	0	0	0
3	0.0001	0	0
4	0.0012	0.0003	0.0001
5	0.0085	0.0023	0.0006
6	0.0401	0.0132	0.004
7	0.1298	0.0536	0.0193
8	0.2759	0.1517	0.0683
9	0.3474	0.2866	0.172
10	0.1969	0.3248	0.2924
11	0	0.1673	0.3012
12	0	0	0.14422
13	0	0	0

Solution:

Revenue	**Cost**	
65000*Q	65000*Q + 475*Q	X < 8
100000*X	65000*Q	X = 8, 9 or 10
100000*10	65000*Q	X>10

$$E[P(Q)] = \sum_{x=0}^{7}(65000Q - (65000Q + 475Q)\,p(x) + \sum_{x=8}^{10}\left(100000X - 65000Q\right)p(x) +$$

$$+\sum_{x=11}^{Q}\left(100000*10 - 65000Q\right)p(x)$$

$$E[P(Q)] = \sum_{x=0}^{7} -475Q * p(x) + \sum_{x=8}^{10}\left(100000X - 65000Q\right)p(x) + \sum_{x=11}^{Q}\left(1000000 - 65000Q\right)p(x)$$

Net income

	Q		
X	10	11	12
0	-4750	-5225	-5700
1	-4750	-5225	-5700
2	-4750	-5225	-5700
3	-4750	-5225	-5700
4	-4750	-5225	-5700
5	-4750	-5225	-5700
6	-4750	-5225	-5700
7	-4750	-5225	-5700
8	150000	85000	20000
9	250000	185000	120000
10	350000	285000	220000
11	0	285000	220000
12	0	0	220000
13	0	0	0

Probability mass function

	Q		
X	10	11	12
0	0	0	0
1	0	0	0
2	0	0	0
3	0.0001	0	0
4	0.0012	0.0003	0.0001
5	0.0085	0.0023	0.0006
6	0.0401	0.0132	0.004
7	0.1298	0.0536	0.0193
8	0.2759	0.1517	0.0683
9	0.3474	0.2866	0.172
10	0.1969	0.3248	0.2924
11	0	0.1673	0.3012
12	0	0	0.14422
13	0	0	0

Expected profit

	Q		
X	10	11	12
0	0	0	0
1	0	0	0
2	0	0	0
3	-0.475	0	0
4	-5.7	-1.5675	-0.57
5	-40.375	-12.0175	-3.42
6	-190.475	-68.97	-22.8
7	-616.55	-280.06	-110.01
8	41385	12894.5	1366
9	86850	53021	20640
10	68915	92568	64328
11	0	47680.5	66264
12	0	0	31728.4
13	0	0	0
TOTAL	196296.4	**205801.4**	184189.6

Probability of losing money

→ if 7 or less parts are produced:

10	11	12
0.1797	0.0694	**0.024**

The most preferred Q:

- if we want to earn most => **Q=11**
- if we don't want to lose money => **Q=12**

Problem #2:

A market estimate for a product is 550,000 pieces. In order to produce the product three operations are required (A, B and C) having scrap estimates $P_A=0.03$, $P_B=0.06$ and $P_C=0.02$.

a) What is the total input into the production in order to satisfy the market?
b) What is the production quantity scheduled for each operation?

Solution:

a)

$$Input = \frac{FinalOutput}{(1-P_{s_1})(1-P_{s_2})...(1-P_{s_n})} = \frac{550000}{(1-0.03)(1-0.06)(1-0.02)} = 615513$$

Total input to satisfy the market is 615 512 units.

b)

Process C: $\frac{550000}{(1-0.02)} = 561225$

Process B: $\frac{561225}{(1-0.06)} = 597047$

Process A: $\frac{597048}{(1-0.03)} = 615513$

Production quantity scheduled for operation A is 615 513 units, for operation B it is 597 047 units and for operation C it is 561 225 units.

Problem #3:

A part requires operations A and B on a milling machine. It was calculated that in order to produce sufficient number of these parts to satisfy the demand, the production quantity of 5000 parts per week should be scheduled. The milling machine requires tool changes and preventive maintenance after every lot of 500 parts. These changes require 30 minutes. Find the number of machines required assuming that the company will be operating 5 days per week, 18 hours per day. The following information is known:

Operation	Standard time	Efficiency	Reliability
A	5 min	95%	85%
B	10 min	95%	90%

Solution:

Q=5000
5000/500 = 10 times per week maintenance
Repair time: 30min * 10=300 min
Available time: 18hr *60*5=5400 min
H=5400-300 = 5100 min

A: F=SQ / EHR = (5*5000)/(0.95*5100*0.85) = 6.07

B: F=SQ / EHR = (10*5000)/(0.95*5100*0.9) = 11.47

Total number of machines needed = 6.07 + 11.47 = 17.54

Minimum of 18 machines are needed to ensure that weekly demand is met.

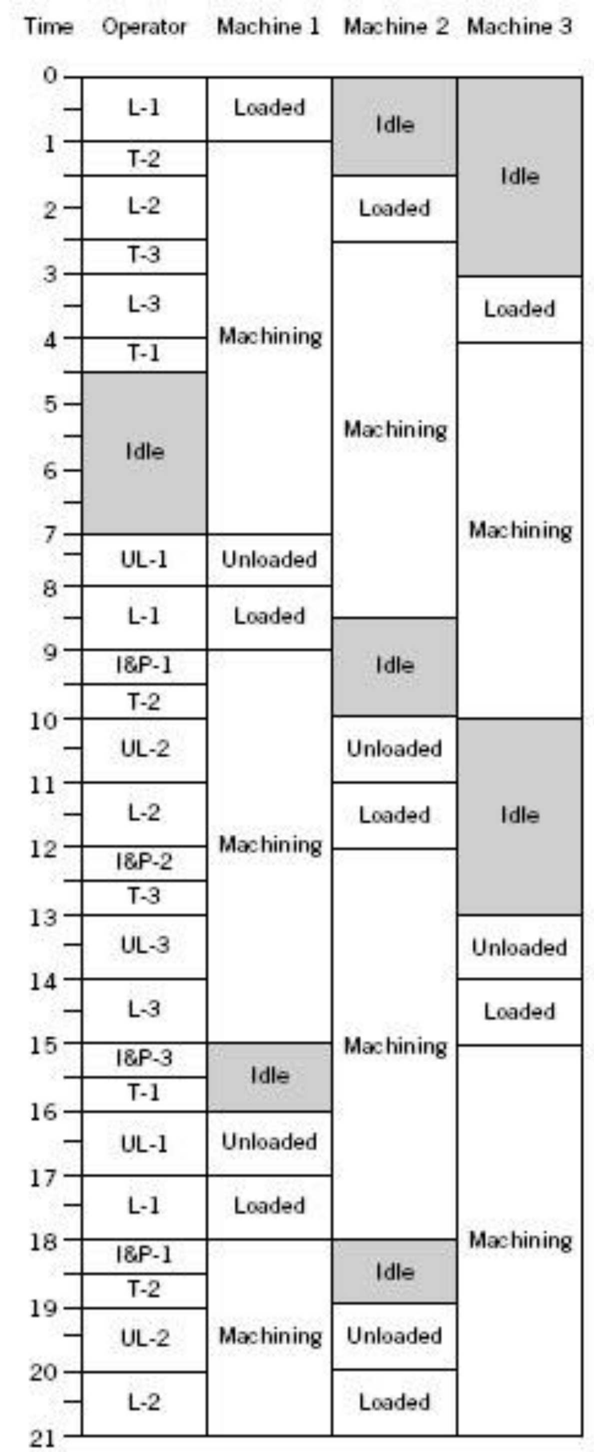
Problem #4:

Multiple activity chart on the right shows the activities of <u>3 identical</u> machines and 1 operator.

a) Determine the length of independent machine activity, independent operator activity and their concurrent activity.

b) Estimate the minimum cycle length.

a) Determine the ideal number of machines per operator.



Solution:

a) Concurrent activity: a= 1+1 =<u>2</u>
Independent operator: b=0.5+0.5 =<u>1</u>
Independent machine: t=<u>6</u>

b) Min cycle length is the maximum of:
a+t = 2+6 = 8
and
3*(a+b) = 3* (2+1) = 9

Min cycle length is <u>9</u>

c) n'=(a+t) /(a+b) = (2+6)/(2+1) = <u>2.67</u>

L.….Loading
T…..Walking
UL…Unloading
I&P…Inspection & Packing

Problem #5:

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 table below.

a) Develop the From-To Chart based on the expected weekly production
b) Develop Relationship Diagram using Method II. Indicate the sequence in which the departments are placed into the diagram.
c) Develop a block layout based on the given dimensions

Product	*Processing sequence*	*Weekly production*
1	A B C D E F	960
2	A B C B E D C F	1,200
3	A B C D E F	720
4	A B C E B C F	2,400
5	A C E F	1,800
6	A B C D E F	480
7	A B D E C B F	2,400
8	A B D E C B F	3,000
9	A B C D F	960
10	A B D E F	1,200

Department	*Dimensions (ft.xft.)*
A	40x40
B	40x40
C	30x30
D	50x50
E	60x60
F	50x50

Solution:

a) From-To Chart

TO	A	B	C	D	E	F
FROM						
A	---	13320	1800	0	0	0
B	0	---	9120	6600	1200	5400
C	0	6600	---	3120	4200	3600
D	0	0	1200	---	8760	960
E	0	2400	5400	1200	---	5160
F	0	0	0	0	0	---

Frequency Table

Department	**Frequency**	**New Sequence**
AB	13320	2
AC	1800	11
BC	15720	1
BD	6600	5
BE	3600	9
BF	5400	6
CD	4320	8
CE	9600	4
CF	3600	10
DE	9960	3
DF	960	12
EF	5160	7

Ordered table

BC	15720	A
AB	13320	
DE	9960	E
CE	9600	
BD	6600	I
BF	5400	
EF	5160	
CD	4320	
BE	3600	O
CF	3600	
AC	1800	U
DF	960	

b) Development of relationship diagram – **Method II.**

Relationship diagram worksheet

	A	**B**	**C**	**D**	**E**	**F**
A	**B**	**A,C**	**B**			
E			**E**	**E**	**D,C**	
I		**D, F**	**D**	**B,C**	**F**	**B,E**
O		**E**	**F**		**B**	**C**
U	**C**		**A**	**F**		**D**

Step 1. **B** is selected – *more A relationships*

	A	**B**	**C**	**D**	**E**	**F**
A	B	**A,C**	B			
E			E	E	D,C	
I		D, F	D	B,C	F	B,E
O		E	F		B	C
U	C		A	F		D

Step 2. **C** is selected – *more E relationships*

	A	**B**	**C**	**D**	**E**	**F**
A	B	A,**C**	B			
E			E	E	D,C	
I		D, F	D	B,C	F	B,E
O		E	F		B	C
U	C		A	F		D

Step 3. **A** is selected – *A* with others*

	A	**B**	**C**	**D**	**E**	**F**
A	B	**A**,C	B			
E			E	E	D,C	
I		D, F	D	B,C	F	B,E
O		E	F		B	C
U	C		**A**	F		D

Step 4. **E** is selected – *E* with others*

	A	**B**	**C**	**D**	**E**	**F**
A	B	A,C	B			
E			**E**	E	D,C	
I		D, F	D	B,C	F	B,E
O		**E**	F		B	C
U	C		A	F		D

Step 5. **D** is selected – *EII with others (F has II*)*

	A	**B**	**C**	**D**	**E**	**F**
A	B	A,C	B			
E			E	E	**D**,C	
I		**D**, F	**D**	B,C	F	B,E
O		E	F		B	C
U	C		A	F		D

Step 6. **F** is selected

	A	B	C	D	E	F
A	B	A,C	B			
E			E	E	D,C	
I		D, **F**	D	B,C	**F**	B,E
O		E	F		B	C
U	C		A	F		D

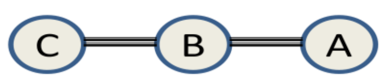
Sequence: B – C – A – E – D – F

Relationship diagram

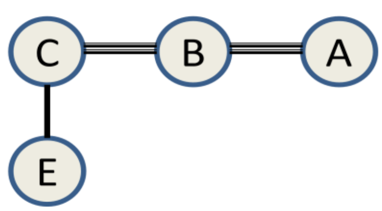
Step 1:

Step 2:

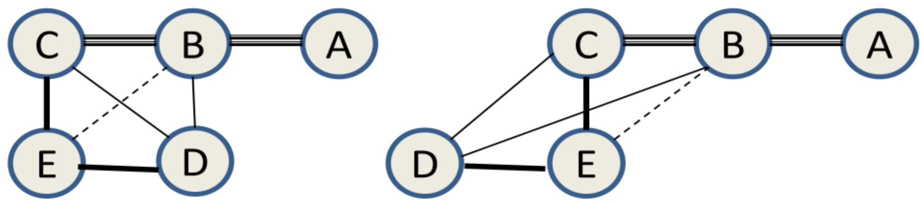
Step 3:



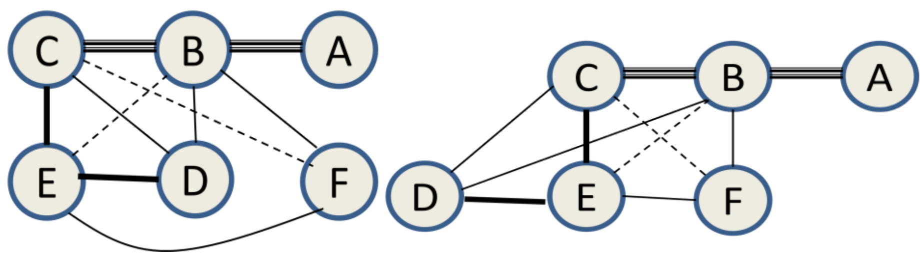
Step 4:



Step 5:

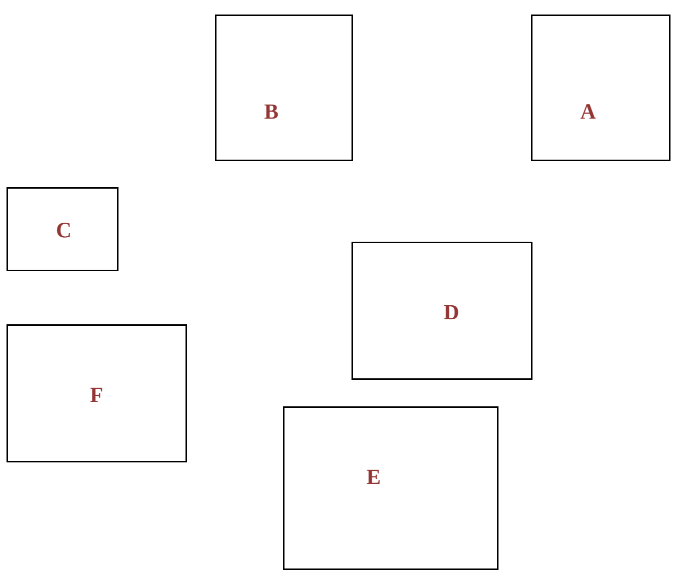


Step 6:

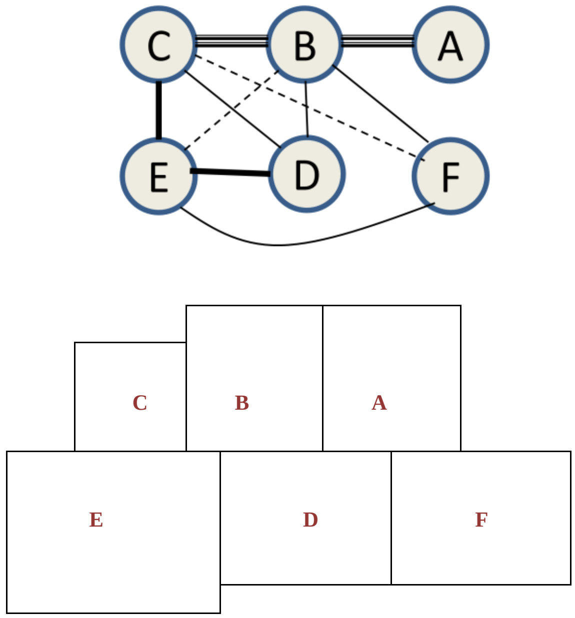


c) Block layout

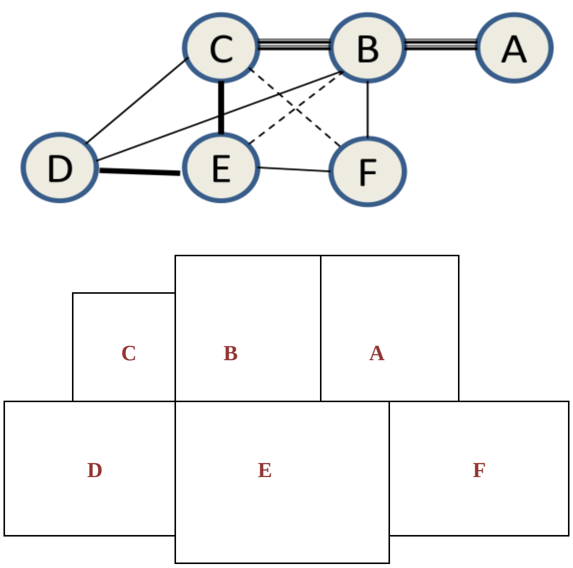
Department	*Dimensions (ft.xft.)*
A	40x40
B	40x40
C	30x30
D	50x50
E	60x60
F	50x50



Block layout for the diagram:



Alternative block layout for the diagram:



Problem #6:

A manufacturing facility produces 5 components. The components 1, 2 and 3 are of equivalent size and weight. The component 4 is three times bigger and heavier than the components 1, 2 and 3, whereas the component 5 is just half size of the components 1, 2 and 3. Facility includes departments A, B, C, D, E and F and the overall flow path is A-B-C-D-E-F. The quantities to be produced and the routing for each component are given below. Develop a From-To Chart for this facility while taking the factor of ease of handling into consideration.

Component	Production quantity	Routing
1	400	A-C-D-B-C-E
2	200	C-B-A-D-E-F
3	100	B-D-E
4	100	A-B-C-E-F
5	400	A-B-C-D-E-F

Solution:

Component	Production quantity	Routing
1	400	A-C-D-B-C-E
2	200	C-B-A-D-E-F
3	100	B-D-E
4	**300**	A-B-C-E-F
5	**200**	A-B-C-D-E-F

	A	B	C	D	E	F
A		300+200 =500	400	200		
B	200		400+300+ 200=900	100		
C		200		400+200 =600	400+300 =700	
D		400			200+100+ 200=500	
E						200+300+ 200=700
F						

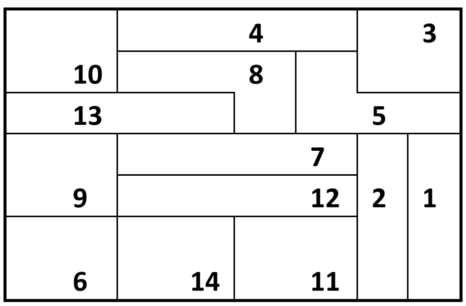
Question #7:

Two layouts below have been recommended for a new facility. Evaluate them based on **adjacency-based scorings** and decide which one corresponds better to the requirements of the facility, given the Relationship Chart below.
a) Use these weights: A=64, E=16, I=4, O=1, U=0 and X=-1024
b) Use these weights: A=8, E=4, I=2, O=1, U=0 and X=8

Layout 1:

10	**4**	**3**	**1**	**11**	**7**	**6**
13	**8**	**5**	**2**	**12**	**9**	**14**

Layout 2:



Relationship Chart:

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
D1			A			I			E					O
D2				I		I			O			E		O
D3					E		I					I		O
D4					A		I		O	I			U	O
D5						I	I	A	I		E	E	U	I
D6									I			I		O
D7											E	I	U	I
D8											I		U	O
D9											O			
D10											O			
D11												A	U	
D12													O	O
D13														
D14														

Solution:

a)

$$\max z = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} f_{ij} x_{ij}$$

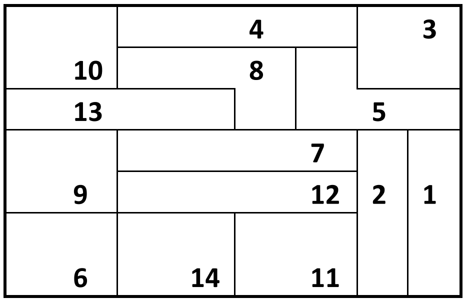
Layout 1:

10	4	3	1	11	7	6
13	8	5	2	12	9	14

a) A=64, E=16, I=4, O=1, U=0 and X=-1024
b) A=8, E=4, I=2, O=1, U=0 and X=8

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	a)	b)
D1			A			I			E					O	**64**	**8**
D2				I		I			O			E		O	**16**	**4**
D3					E		I					I		O	**16**	**4**
D4					A		I		O	I			U	O	**4**	**2**
D5						I	I	A	I		E	E	U	I	**64**	**8**
D6									I			I		O	**1**	**1**
D7											E	I	U	I	**16**	**4**
D8											I		U	O	**0**	**0**
D9											O				**0**	**0**
D10											O				**0**	**0**
D11												A	U		**64**	**8**
D12													O	O	**0**	**0**
D13															**0**	**0**
D14															**0**	**0**
														Total adjacency score	**245**	**39**

Layout 2:



a) A=64, E=16, I=4, O=1, U=0 and X=-1024
b) A=8, E=4, I=2, O=1, U=0 and X=8

	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**	**D12**	**D13**	**D14**	**a)**	**b)**
D1			A			I			E					O	**0**	**0**
D2				I		I			O			E		O	**16**	**4**
D3					E		I					I		O	**16**	**4**
D4					A		I		O	I			U	O	**68**	**10**
D5						I	I	A	I		E	E	U	I	**68**	**10**
D6									I			I		O	**5**	**3**
D7											E	I	U	I	**4**	**2**
D8											I		U	O	**0**	**0**
D9											O				**0**	**0**
D10											O				**0**	**0**
D11												A	U		**64**	**8**
D12													O	O	**1**	**1**
D13															**0**	**0**
D14															**0**	**0**
														Total adjacency score	**242**	**42**

Layout 1 corresponds better to the requirements of the facility based on the closeness values given in a)

Layout 2 corresponds better to the requirements of the facility based on the closeness values given in b)

Question #8:

Two layouts below have been recommended for a new facility. Evaluate them based on **distance-based scorings** and decide which one corresponds better to the requirements of the facility, given the Relationship Chart and the Distance Matrices for each of them below.

From-To Chart

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
D1			200			45			110					5
D2				55		55			3			100		2
D3					95		60					45		3
D4					150		65		2	60			1	5
D5				105		65	55	170	50		100	90	1	50
D6					60				65			45		3
D7											105	55	1	65
D8				2	60						50		1	5
D9				50		100					2			
D10				65							4			
D11						105						180	1	
D12													5	3
D13			150											
D14														

Distance matrix for Layout 1

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
D1		20	100	20	120	60	60	20	80	140	40	100	160	180
D2			20	180	60	140	140	100	40	80	140	20	80	40
D3				80	200	20	200	40	40	20	110	60	200	160
D4					20	140	110	100	140	180	20	40	140	20
D5						180	20	40	40	80	180	110	60	120
D6							80	140	110	200	20	160	160	80
D7								20	180	120	200	110	80	20
D8									80	40	110	180	200	40
D9										20	140	120	20	120
D10											110	20	80	110
D11												200	160	40
D12													40	120
D13														160
D14														

Distance matrix -Layout 2

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
D1		35	90	20	120	47	60	20	80	13	40	84	160	78
D2			20	45	73	68	97	55	40	80	76	20	221	84
D3				33	68	20	76	65	40	20	110	58	45	58
D4					35	140	46	80	78	45	20	43	57	20
D5						47	20	40	58	80	180	65	60	120
D6							97	68	110	57	20	160	160	59
D7								20	76	46	200	45	98	57
D8									84	73	110	69	97	40
D9										46	140	120	58	120
D10											46	20	80	78
D11												78	76	73
D12													40	95
D13														76
D14														

Solution:

$$\min z = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij}c_{ij}d_{ij}$$

Flow-between Chart

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
D1			200			45			110					5
D2				55		55			3			100		2
D3					95		60					45	150	3
D4					255		65	2	52	125			1	5
D5						125	55	230	50		100	90	1	50
D6									165		105	45		3
D7											105	55	1	65
D8											50		1	5
D9											2			
D10											4			
D11												180	1	
D12													5	3
D13														
D14														

Cost matrix - Layout 1

	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**	**D12**	**D13**	**D14**
D1			20000			2700			8800					900
D2				9900		7700			120			2000		80
D3					19000	0	12000					2700	30000	480
D4					5100	0	7150	200	7280	22500			140	100
D5						22500	1100	9200	2000	0	18000	9900	60	6000
D6									18150	0	2100	7200	0	240
D7											21000	6050	80	1300
D8											5500		200	200
D9											280			
D10											440			
D11												36000	160	
D12													200	360
D13														
D14														

Total cost **327070**

Cost matrix-Layout 2

	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**	**D12**	**D13**	**D14**
D1			18000			2115			8800					390
D2				2475		3740			120			2000	0	168
D3					6460		4560					2610	6750	174
D4					8925		2990	160	4050	5625	0	0	57	100
D5						5875	1100	9200	2900		18000	5850	60	6000
D6									18150		2100	7200		177
D7											21000	2475	98	3705
D8											5500		97	200
D9											280			
D10											184			
D11												14040	76	
D12													200	285
D13														
D14														

Total cost **205027**

Total cost of Layout 2 is lower ($205,027) than total cost of Layout 1 ($327,070).

⇨ **Layout 2 corresponds better to the requirements of the facility.**

Problem #9:

Create manufacturing cells based on the machine-part matrix below.

a) Use Cluster Identification Algorithm
b) Use Cost Analysis Algorithm. The maximum number of machines in one cell is 3.
c) If conflicts or exceptional parts exist, propose alternative approaches.

Solution:

a) Cluster Identification Algorithm

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			

All the machines and all the parts ended up in the same cell! This is not an efficient algorithm to solve this problem.

b) **Cost Analysis Algorithm** with the maximum number of 3 machines in one cell

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

P2 added
P10 added
M1 added

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

P9 is an exception

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
M1		1								1	
M2				1			1		1		
M3	1					1					1
M4		1	1						1	1	
M5	1			1	1		1				1
M6					1						1
M7			1							1	
M8	1							1			
cost	22	15	85	24	35	30	32	25	10	7	17

Cell #1: Machines M1, M4, M7

Parts: P2,P3 and P10
P9 an exception

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

P7 added

P4 added

M2 added

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

P1 is an exception

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

	P1	P4	P5	P6	P7	P8	P11
M2		1			1		
M3	1			1			1
M5	1	1	1		1		1
M6			1				1
M8	1					1	
cost	22	24	35	30	32	25	17

P11 is an exception

Cell #2: Machines M2,M5 and M6
Parts P4, P5 and P7
P1 and P11 are exceptions

	P6	P8
M3	1	
M8		1
cost	30	25

Cell #3: Machines M3 and M8
Parts P6 and P8

	P2	P3	P10	P4	P5	P7	P6	P8	P9	P1	P11
M1	1		1								
M4	1	1	1						1		
M7		1	1								
M2				1		1			1		
M5				1	1	1				1	1
M6					1						1
M3							1			1	1
M8								1		1	
cost	15	85	7	24	35	32	30	25	10	22	17

c) P9, P1 and P11 are exceptional parts. What could be done with the exceptional parts?

- The product could be redesigned so that different machines are needed
- Machines could be duplicated (the same machine in two different cells)
- The bottleneck machine could be placed on the boundary between the cells so that both cells can make use of it.
- The parts could be purchased from suppliers

Problem # 10:

Create manufacturing cells based on the machine-part matrix below. If conflicts or exceptional parts exist, propose alternative approaches. Use **Binary Ordering Algorithm.**

	P1	P2	P3	P4	P5	P6	P7
M1		1	1			1	1
M2	1				1		
M3			1			1	1
M4				1	1		1
M5		1	1				1
M6	1			1			

Solution:

Assign binary weights

	64	32	16	8	4	2	1	
	P1	P2	P3	P4	P5	P6	P7	
M1		1	1			1	1	51
M2	1				1			68
M3			1			1	1	19
M4				1	1		1	13
M5		1	1				1	49
M6	1			1				72

Assign binary weights

32	M6	1			1				72	↑ Reorder
16	M2	1				1			68	
8	M1		1	1			1	1	51	
4	M5		1	1				1	49	
2	M3			1			1	1	19	
1	M4				1	1		1	13	
		P1	P2	P3	P4	P5	P6	P7		
		48	12	14	33	17	10	15		

		64	32	16	8	4	1	2
32	M6	1	1					
16	M2	1		1				
8	M1				1	1	1	1
4	M5				1	1	1	
2	M3				1	1		1
1	M4		1	1	1			
		P1	P4	P5	P7	P3	P2	P6
		48	33	17	15	14	12	10

Reorder

Assign binary weights

	64	32	16	8	4	2	1	
M6	1	1						96
M2	1		1					80
M1				1	1	1	1	15
M5				1	1	1		14
M3				1	1		1	13
M4		1	1	1				56
	P1	P4	P5	P7	P3	P2	P6	

32	M6	1	1						96
16	M2	1		1					80
8	M4		1	1	1				56
4	M1				1	1	1	1	15
2	M5				1	1	1		14
1	M3				1	1		1	13
		P1	P4	P5	P7	P3	P2	P6	
		48	40	24	15	7	6	5	

Reorder

Assign binary weights

No need for reordering – matrix is unchanged

The resulting cells:

M6	1	1						96
M2	1		1					80
M4		1	1	1				56
M1				1	1	1	1	15
M5				1	1	1		14
M3				1	1		1	13
	P1	P4	P5	P7	P3	P2	P6	

Cell #1: Machines M2, M4 and M6 producing parts P1, P4 and P5

Cell #2: Machines M1, M3 and M5 producing parts P2, P3 and P6

Exceptional part P7.

Problem #11:

Use Direct Clustering Algorithm to arrange the machines and parts in the machine-part matrix below to the manufacturing cells. If there are bottleneck machines, decide what you can do.

Machines

Parts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		1			1		1				1			1		1		
2	1			1		1			1	1		1	1					
3		1			1		1				1			1		1		
4	1			1		1			1	1		1	1					
5		1			1		1				1			1		1		
6	1			1		1			1	1		1	1					
7			1				1	1						1	1		1	1
8			1				1	1						1	1		1	1
9		1			1		1				1			1		1		
10			1				1	1						1	1		1	1

➢ **Solution:**

Sum the 1s in each column and row:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1		1			1		1				1			1		1			6
2	1			1		1			1	1		1	1						7
3		1			1		1				1			1		1			6
4	1			1		1			1	1		1	1						7
5		1			1		1				1			1		1			6
6	1			1		1			1	1		1	1						7
7			1				1	1						1	1		1	1	7
8			1				1	1						1	1		1	1	7
9		1			1		1				1			1		1			6
10			1				1	1						1	1		1	1	7
	3	4	3	3	4	3	7	3	3	3	4	3	3	7	3	4	3	3	

Order the rows in descending and the columns in ascending order:

	1	6	3	4	12	13	15	8	9	10	17	18	2	5	11	16	7	14	
2	1	1		1	1	1			1	1									7
4	1	1		1	1	1			1	1									7
6	1	1		1	1	1			1	1									7
7			1				1	1			1	1					1	1	6
8			1				1	1			1	1					1	1	6
10			1				1	1			1	1					1	1	6
1													1	1	1	1	1	1	5
3													1	1	1	1	1	1	5
5													1	1	1	1	1	1	5
9													1	1	1	1	1	1	5
	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	7	7	

Sort the columns (1 in the first row moves the column to the left, then 1 in the second row, etc.:

	1	6	4	12	13	9	10	3	15	8	17	18	7	14	2	5	11	16
2	1	1	1	1	1	1	1											
4	1	1	1	1	1	1	1											
6	1	1	1	1	1	1	1											
7								1	1	1	1	1	1	1				
8								1	1	1	1	1	1	1				
10								1	1	1	1	1	1	1				
1													1	1	1	1	1	1
3													1	1	1	1	1	1
5													1	1	1	1	1	1
9													1	1	1	1	1	1

Sort the rows (1 in the first column moves the row upward, then 1 in the second column, etc.:
Already sorted!

There are bottleneck machines. What can we do?
We create only 2 cells:

	1	6	4	12	13	9	10	3	15	8	17	18	7	14	2	5	11	16
2	1	1	1	1	1	1	1											
4	1	1	1	1	1	1	1											
6	1	1	1	1	1	1	1											
7								1	1	1	1	1	1	1				
8								1	1	1	1	1	1	1				
10								1	1	1	1	1	1	1				
1													1	1	1	1	1	1
3													1	1	1	1	1	1
5													1	1	1	1	1	1
9													1	1	1	1	1	1

We locate the bottleneck machines M7 and M14 between the cells, so that both cells can make use of them.

	1	6	4	12	13	9	10	3	15	8	17	18	7	14	2	5	11	16
2	1	1	1	1	1	1	1											
4	1	1	1	1	1	1	1											
6	1	1	1	1	1	1	1											
7								1	1	1	1	1	1	1				
8								1	1	1	1	1	1	1				
10								1	1	1	1	1	1	1				
1													1	1	1	1	1	1
3													1	1	1	1	1	1
5													1	1	1	1	1	1
9													1	1	1	1	1	1

We can duplicate machines M7 and M14.

	1	6	4	12	13	9	10	3	15	8	17	18	7a	14a	7b	14b	2	5	11	16
2	1	1	1	1	1	1	1													
4	1	1	1	1	1	1	1													
6	1	1	1	1	1	1	1													
7								1	1	1	1	1	1	1						
8								1	1	1	1	1	1	1						
10								1	1	1	1	1	1	1						
1															1	1	1	1	1	1
3															1	1	1	1	1	1
5															1	1	1	1	1	1
9															1	1	1	1	1	1

We cannot solve the problem by outsourcing parts or redesigning the product, because we would need to outsource or redesign all of the parts except three.