Facilities planning

Facilities layout–computerized techniques

CRAFT (Computerized Relative Allocation of Facilities Technique)

- Characteristics and assumptions
  - Distance-based objective.
  - From-to chart is used.
  - Departments are not restricted to rectangular shape and the layout is represented in a discrete fashion.
  - Improvement algorithm.
  - Buildings are normally rectangular. However dummy departments can be used with nonrectangular buildings as well. Dummy departments have no flows or interaction with other departments.

Centroid of polygon

Finding centroid of a polygon R in the plane.

Suppose that R can be subdivided into k rectangles labeled R_1, R_2,...R_k with respective boundaries defined by $[(x_{1i},x_{2i})(y_{1i},y_{2i})]$for R_i.

$$M_x = \frac{1}{2}\sum_{i=1}^{k}\left(x_{2i}^2 - x_{1i}^2\right)\left(y_{2i} - y_{1i}\right)$$

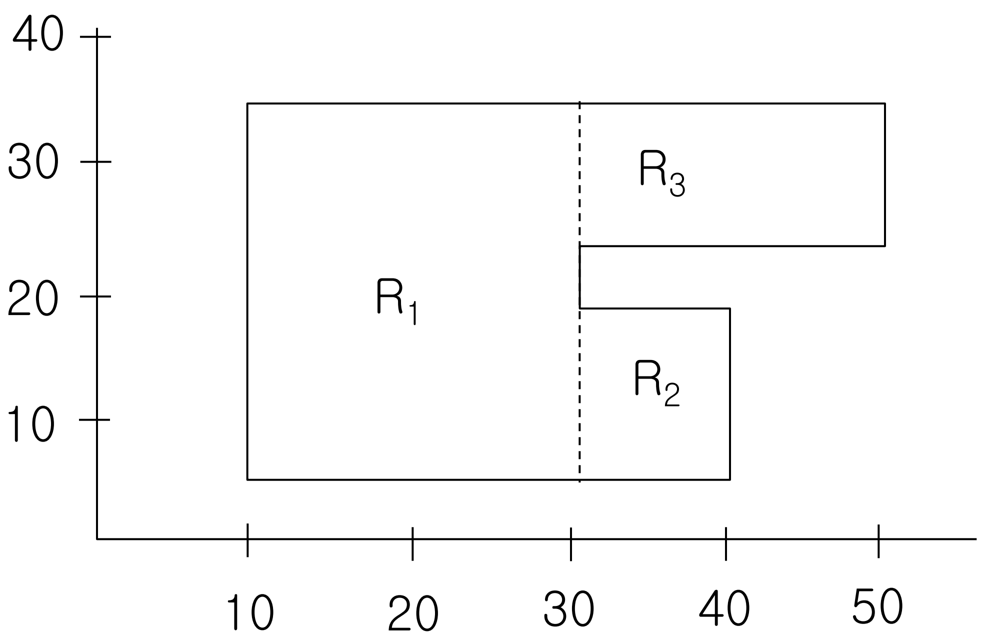
$$M_y = \frac{1}{2}\sum_{i=1}^{k}\left(y_{2i}^2 - y_{1i}^2\right)\left(x_{2i} - x_{1i}\right)$$

Let A(R) be the area of R. Then the centroid of R is given as follows:

$$\overline{x} = \frac{M_x}{A(R)}$$

$$\overline{y} = \frac{M_y}{A(R)}$$

Centroid of polygon



$$[(x_{11},x_{21})(y_{11},y_{21})]=[(10,30)(5,35)]$$

$$[(x_{12},x_{22})(y_{12},y_{22})]=[(30,40)(5,20)]$$

$$[(x_{13},x_{23})(y_{13},y_{23})]=[(30,50)(25,35)]$$

$$M_x = \frac{1}{2}\sum_{i=1}^{k}\left(x_{2i}^2 - x_{1i}^2\right)\left(y_{2i} - y_{1i}\right)$$

$$= \frac{1}{2}\left(30^2-10^2\right)\left(35-5\right)+\frac{1}{2}\left(40^2-30^2\right)\left(20-5\right)]$$

$$+\frac{1}{2}\left(50^2-30^2\right)\left(35-25\right)=25250$$

$$M_y = \frac{1}{2}\sum_{i=1}^{k}\left(y_{2i}^2 - y_{1i}^2\right)\left(x_{2i} - x_{1i}\right)$$

$$= \frac{1}{2}\left(35^2-5^2\right)\left(30-10\right)+\frac{1}{2}\left(20^2-5^2\right)\left(40-30\right)$$

$$+\frac{1}{2}\left(35^2-25^2\right)\left(50-30\right)=19875$$

$$A(R)=20(30)+10(15)+20(10)=950$$

$$\bar{x}=\frac{M_x}{A(R)}=\frac{25250}{950}=26.579$$

$$\bar{y}=\frac{M_y}{A(R)}=\frac{19875}{950}=20.921$$

CRAFT

- Procedure
  - Step1: Starts with an initial layout
  - Step2: Determine the centroids of the departments in the initial layout and calculate rectilinear distance between pairs of department centroids. Determine layout cost by multiplying from-to value with distance.
  - Step3: Consider all possible pairwise department exchanges and identifies the best exchange. Consider only departments that are adjacent or equal in area. Instead of actually exchanging the department locations to compute their new centroids and actual layout cost, it computed an estimated layout by treating the centrod of department *i* in the current layout as the centroid of department *j* and vice versa. Update the layout according to the best exchanges. Starting with grids labeled with smaller department, fill the left-most column of larger department.
  - Step4: Repeat step3 until no further reduction in layout cost can be obtained

CRAFT

- Example 6.1
  - Total available space=72000ft^2
  - One grid=20ft x 20ft
  - Total required space=70000ft^2
  - Dummy department (H)=2000ft^2
  - The initial locations of A and G are fixed.

Table 6.4 *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	8,000	20	0	0	0	30	25	15	0	0
3. C: Press	6,000	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	8,000	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	2,000	5	0	0	0	0	0	0	0	0

CRAFT

- Initial layout

	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	B	B	B	B	B	C	C	C	C	C	E	E	G	G	G	G	G	G
5	B				B	C				C	E	E	E	E	E	E	E	E
6	B				B	C	C	C	C	C	E	E	E	E	E	E	E	E
7	B	B	B	B	B	D	D	D	D	F	F	F	F	F	F	F	E	E
8	D	D	D	D	D	D			D	F						F	F	F
9	D							D	D	F	F	F	F	F				F
10	D	D	D	D	D	D	D	D	H	H	H	H	H	F	F	F	F	F

Number of grids

Figure 6.15 Initial CRAFT layout and department centroids for Example 6.1 ($z = 2974 \times 20 = 59{,}480$ units). Distance (ft)

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

from–to	A	B	C	D	E	F	G	H
A		45	15	25	10	5		
B				30	25	15		
C					5	10		
D		20			35			
E						65	35	
F		5			25		65	
G								
H								

cost	A	B	C	D	E	F	G	H	total cost
A		270	75	150	120	80			695
B				180	275	210			665
C					35	100			135
D		120			420				540
E						195	140		335
F		70			75		455		600
G									0
H									0
									2970

Exchange of E & F

	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	B	B	B	B	B	C	C	C	C	C	F	F	G	G	G	G	G	G
5	B				B	C				C	F	F	F	F	F	F	F	F
6	B				B	C	C	C	C	C	F	F	F	F	F	F		F
7	B	B	B	B	B	D	D	D	D	E	E	E	E	E	E	F		F
8	D	D	D	D	D	D			D	E					E	F		F
9	D							D	D	E	E	E	E	E	E	F		F
10	D	D	D	D	D	D	D	D	H	H	H	H	H	E	E	F	F	F

Figure 6.16 Intermediate CRAFT layout obtained after exchanging departments E and F ($z = 2953 \times 20 = 59{,}060$ units).

Exchange of E & F

Exchange of E & F

	distance								from-to								cost								
	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	total cost
A		6	5	6	16	12				45	15	25	10	5				270	75	150	160	60			715
B				6	14	11						30	25	15						180	350	165			695
C					10	7							5	10							50	70			120
D		6			8					20			35					120			280				400
E						3	7							65	35							195	245		440
F		11			3		4			5			25		65			55			75		260		390
G																									0
H																									0
																									2760

- Estimated cost reduction=2974-2772=202
- Best exchange-> department E and F

Exchange of E & F

	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	B	B	B	B	B	C	C	C	C	C	F	F	G	G	G	G	G	G
5	B				B	C				C	F	F	F	F	F	F	F	F
6	B				B	C	C	C	C	C	F	F	F	F	F	F		F
7	B	B	B	B	B	D	D	D	D	E	E	E	E	E	E	F		F
8	D	D	D	D	D	D			D	E					E	F		F
9	D							D	D	E	E	E	E	E	E	F		F
10	D	D	D	D	D	D	D	D	H	H	H	H	H	E	E	F	F	F

Figure 6.16 Intermediate CRAFT layout obtained after exchanging departments E and F ($z = 2953 \times 20 = 59{,}060$ units).

- Actual cost reduction=2974−2953=21

Exchange of B & C

	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	C	C	C	B	B	B	B	B	B	B	F	F	G	G	G	G	G	G
5	C		C	C	B					B	F	F	F	F	F	F	F	F
6	C			C	B	B	B	B	B	B	F	F	F	F	F	F		F
7	C	C	C	C	B	D	D	D	D	E	E	E	E	E	E	F		F
8	D	D	D	D	D	D			D	E					E	F		F
9	D							D	D	E	E	E	E	E	E	F		F
10	D	D	D	D	D	D	D	D	H	H	H	H	H	E	E	F	F	F

Figure 6.17 Final CRAFT layout ($z = 2833.50 \times 20 = 56{,}670$ units).

- Best exchange-> department B and C
- Estimated cost reduction=95
- Actual cost reduction=2953-2833.5=119.50
- No two-way or three-way exchange can further reduce the cost.

CRAFT

	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	C	C	C	B	B	B	B	B	B	B	F	F	G	G	G	G	G	G
5	C		C	C	B					B	F	F	F	F	F	F	F	F
6	C			C	B	B	B	B	B	B	F	F	F	F	F	F		F
7	C	C	C	C	B	D	D	D	D	E	E	E	E	E	E	F		F
8	D	D	D	D	D	D			D	E					E	F		F
9	D							D	D	E	E	E	E	E	E	F		F
10	D	D	D	D	D	D	D	D	H	H	H	H	H	E	E	F	F	F

Figure 6.17 Final CRAFT layout ($z = 2833.50 \times 20 = 56{,}670$ units).

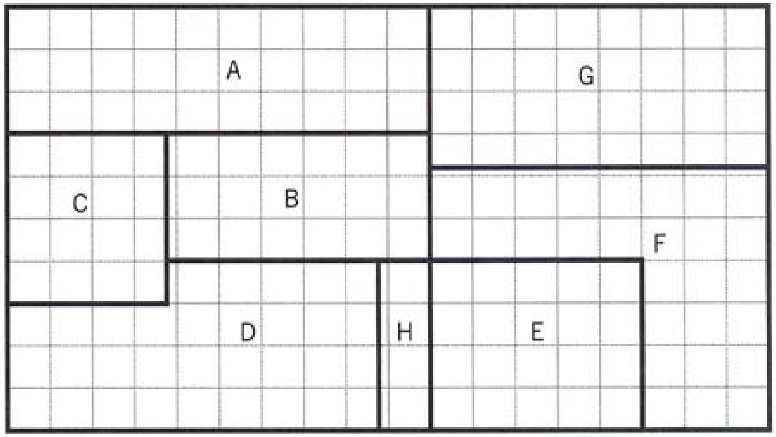


Figure 6.18 Final "massaged" layout obtained with CRAFT.

CRAFT

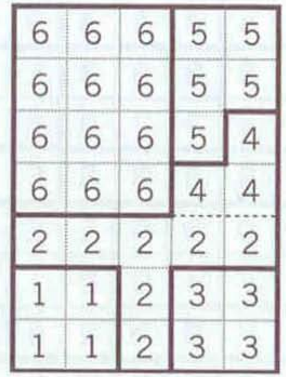


Figure 6.19 Example to show that CRAFT may not be able to exchange two adjacent departments that are not equal in area.

ALDEP (Automated Layout Design Program)

- Characteristics and assumptions
  - Adjacency-based objective
  - Activity relationship chart is needed.
  - Construction algorithm
  - It provides multiple layouts: up to 20 layouts.
  - It can handle multiple floor layout: up to three floors.

ALDEP

- Placement routine

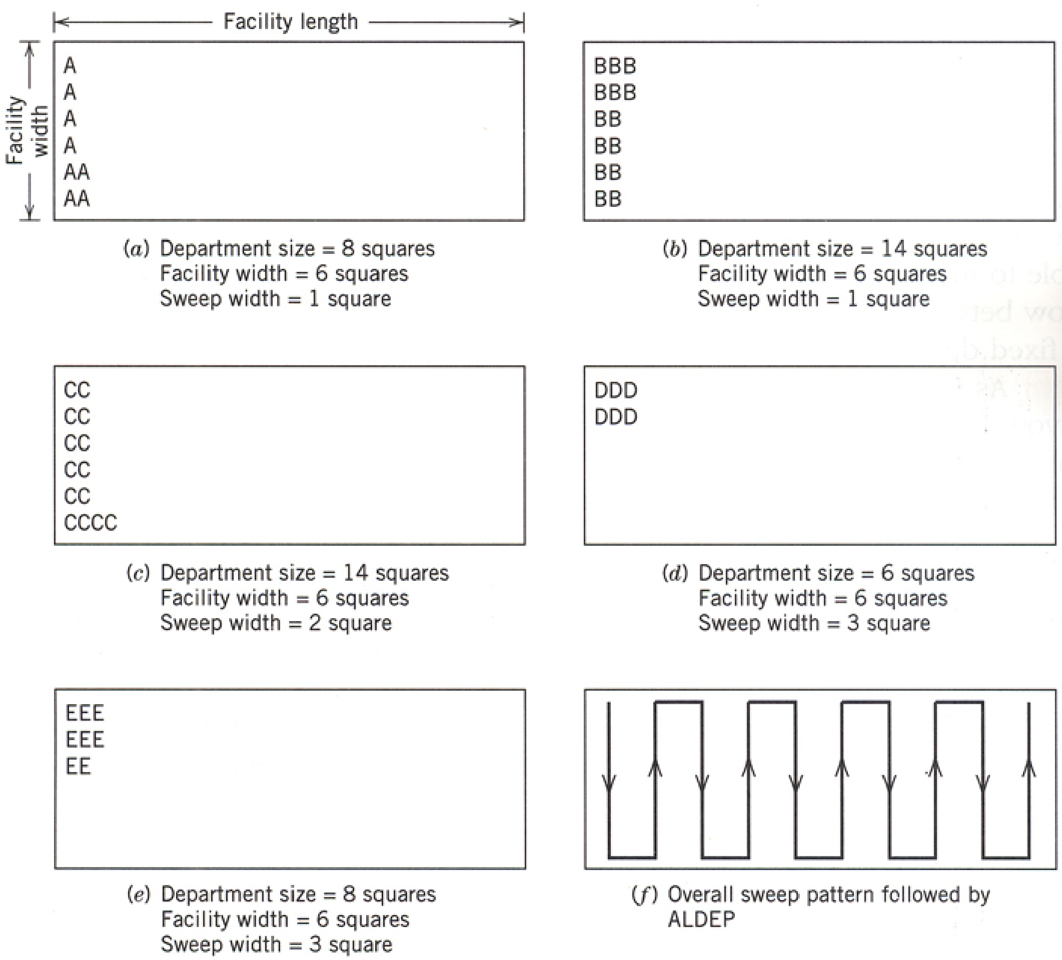
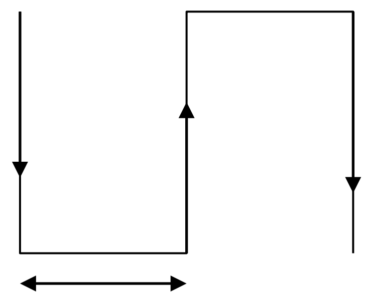


Figure 6.A4 ALDEP placement procedure.



Sweep width

ALDEP

- Procedure
  - Step1: Randomly select a department.
  - Step2: Select a department having “A” relationship with the first department. Ties are broken arbitrarily. If no departments have a relationship at least equal to the minimum acceptable closeness rating specified by the user, the second department to enter the layout will be selected randomly.
  - Step3: The third department is selected considering relationship with the second department.
  - Step4: Repeat the selection procedure until all departments have been selected to enter the layout.

ALDEP

- Example 6.A2
  - Sweep width=2, minimum acceptable level of importance="E"
  - One grid=20ft x 20ft
  - Facility layout is 10grids wide and 18grids in length.

Table 6.4 *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	8,000	20	0	0	0	30	25	15	0	0
3. C: Press	6,000	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	8,000	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	2,000	5	0	0	0	0	0	0	0	0

ALDEP

- Example 6.A2

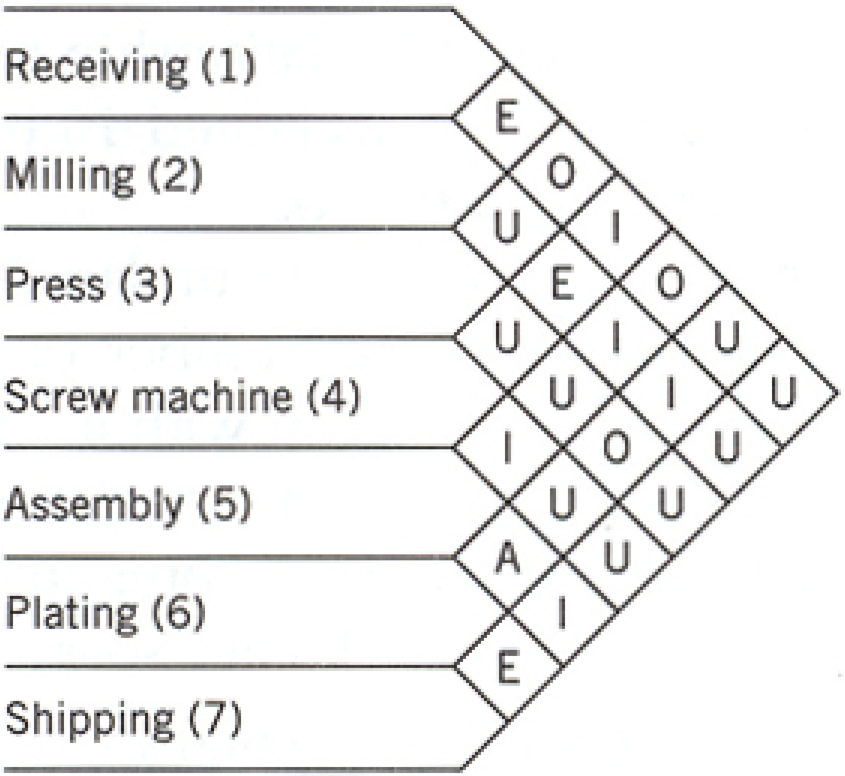


Figure 6.A2 Activity relationship chart.

ALDEP

Step1: Randomly selected department is 4

4	4		
4	4		
4	4		
4	4		
4	4		
4	4	4	4
4	4	4	4
4	4	4	4
4	4	4	4
4	4	4	4

(*a*) Partial layout consisting of department 4

4	4	2	2	2	2
4	4	2	2	2	2
4	4	2	2	2	2
4	4	2	2	2	2
4	4	2	2	2	2
4	4	4	4		
4	4	4	4		
4	4	4	4		
4	4	4	4		
4	4	4	4		

(*b*) Partial layout after placing department 2

Step2: Department 2 has an "E" relationship with department 4

Step3: Department 1 has an "E" relationship with department 2

4	4	2	2	2	2	1	1
4	4	2	2	2	2	1	1
4	4	2	2	2	2	1	1
4	4	2	2	2	2	1	1
4	4	2	2	2	2	1	1
4	4	4	4	1	1	1	1
4	4	4	4	1	1	1	1
4	4	4	4	1	1	1	1
4	4	4	4	1	1	1	1
4	4	4	4	1	1	1	1

(*c*) Partial layout after placing department 1

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

(*d*) Final layout

Step4: No department has above "E" relationship with department 1.

Randomly select department 6.

Figure 6.A5 ALDEP layout construction for Example 6.A2.

ALDEP

Table 6.A5 *ALDEP Scoring (Rating) Procedure Applied to Example 6.A2*

Adjacent Departments	Relationship	Value	Rating
4-2 and 2-4	E	16	32
4-1 and 1-4	I	4	8
2-1 and 1-2	E	16	32
1-6 and 6-1	U	0	0
6-5 and 5-6	A	64	128
6-7 and 7-6	E	16	32
5-7 and 7-5	I	4	8
7-3 and 3-7	U	0	0
		Total	240

Rating: “A”(64), “E”(16), “I”(4), “O”(1), “X”(−1024)

CRAFT manual

Line 갯수	Column 번호	Format	내용	예
1	1 ~ 80	20A4	문제 설명	
1	1 ~ 2	I2	부서의 수 (≤ 40)	08
	4 ~ 5	I2	배치안의 row 개수 (≤ 30)	10
	7 ~ 8	I2	배치안의 column 개수 (≤ 30)	18
	10 ~ 11	I2	부서의 교환방법 00 : 2-way interchange 01 : 3-way interchange 02 : 2-way 후 3-way 03 : 3-way 후 2-way 04 : 둘 중 좋은 방법 사용	04
	13 ~ 14	I2	입출력 조정 00 : 초기 및 최종 배치안만 출력 01 : 각 단계별 배치안을 모두 출력	01
	16 ~ 17	I2	Debugging parameter 00 : error message 없음 01 : 부서교환의 실패 시 알려줌 02 : 부서교환 실패 시 알려주고 best interchange 도 알려줌	
	19 ~ 20	I2	고정배치부서의 수	
	※ **주의** : 3, 6, 9, 12, 15, 18 번째 column 은 공란으로 할 것			

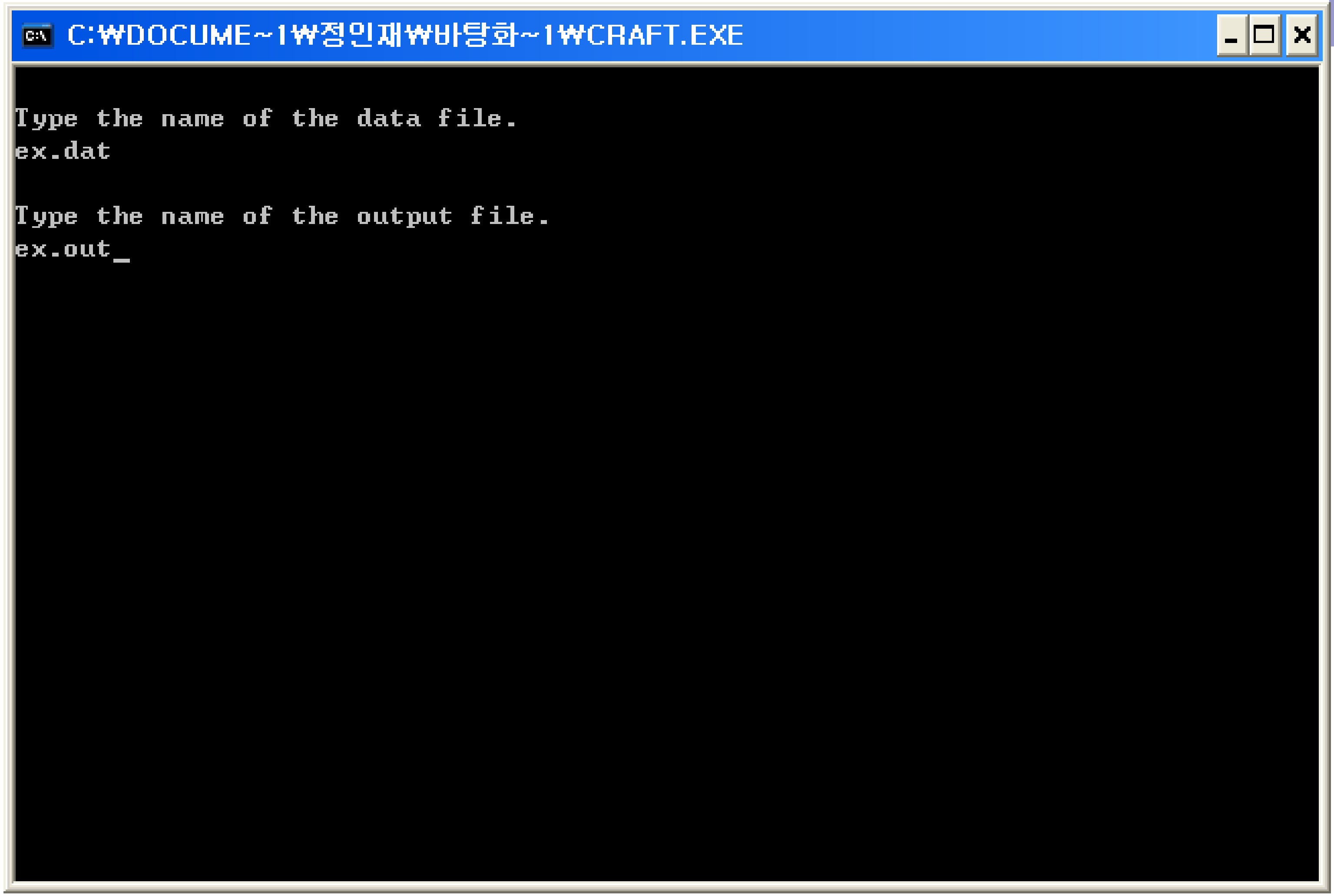
CRAFT manual

1	1 ~ 2	I2	첫 번째 고정배치 부서	
	3 ~ 4	I2	두 번째 고정배치 부서	
	…		※고정배치 부서가 없으면, 즉 첫 라인의 19 ~ 20 칸 값이 zero 였다면 이 라인은 생략	
부서의 갯수	1 ~ 80	20F4.0	유입유출표 ※부서의 수가 20 을 넘을 경우는 자동으로 다음 라인 사용 : 이 경우 라인 수는 부서수의 2 배 ※대각요소(자신으로의 이동량)의 값은 반드시 zero : 그렇지 않으면 data error	
부서의 갯수	1 ~ 80	20F4.3	Move Cost Chart ※부서 *i* 에서 부서 *j* 로 이동하는데 드는 단위거리당 비용 ※부서의 수가 20 을 넘을 경우 다음 라인 사용	
배치안의 row 수	1 ~ 60	30I2	초기배치안 Ex) 0101010112122222222… 0101010412122222222… 0404040412121222222… …	
1	1 ~ 3	A3	"END"라고 표기	

Example 6.1: input data

```
CRAFT EXAMPLE PROBLEM
08 10 18 00 01 02 02
0107
00000045001500250010000500000000
00000000000000300025001500000000
00000000000000000005001000000000
00000020000000000035000000000000
00000000000000000000006500350000
00000005000000000025000000650000
00000000000000000000000000000000
00000000000000000000000000000000
10001000100010001000100010001000
10001000100010001000100010001000
10001000100010001000100010001000
10001000100010001000100010001000
10001000100010001000100010001000
10001000100010001000100010001000
10001000100010001000100010001000
10001000100010001000100010001000
010101010101010101010707070707070707
010101010101010101010707070707070707
010101010101010101010707070707070707
020202020203030303030505070707070707
020202020203030303030505050505050505
020202020203030303030505050505050505
020202020204040404040606060606060505
040404040404040404040606060606060606
040404040404040404040606060606060606
040404040404040408080808080606060606
END
```

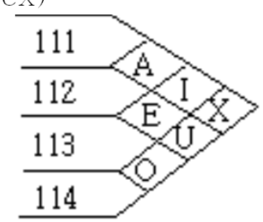
Example 6.1: craft.exe



ALDEP manual

Line	Column	Format	내 용	예
1	1 ~ 4	A4	문제 이름	EX01
1	1 ~ 4	I4	random number seed (임의의 홀수)	0931
	5 ~ 6	I2	3 층에서 부서배치를 시작하는 column (보통 01)	01
	7 ~ 8	I2	3 층	
	9 ~ 12	I4		
	13 ~ 16	I4		
	17 ~ 20	I4		
	21 ~ 22	I2	2 층에서 부서배치를 시작하는 column (보통 01)	01
	23 ~ 24	I2	2 층의 부서배치 두께 (sweep width)	02
	25 ~ 28	I4	2 층에 가용한 unit square 의 개수 ≤ a×b	0180
	29 ~ 32	I4	2 층의 가로길이 (unit square 개수) = a	0018
	33 ~ 36	I4	2 층의 세로길이 (unit square 개수) = b	0010
	37 ~ 38	I2	1 층에서 부서배치를 시작하는 column (보통 01)	01
	39 ~ 40	I2	1 층의 부서배치 두께 (sweep width)	
	41 ~ 44	I4	1 층에 가용한 unit square 의 개수 ≤ a×b	
	45 ~ 48	I4	1 층의 가로길이 (unit square 개수) = a	
	49 ~ 52	I4	1 층의 세로길이 (unit square 개수) = b	
	53 ~ 57	F5.1	unit square 의 실제 면적	04000
	58 ~ 61	F4.2	각 부서의 면적을 unit square 의 수로 환산하기 위한 반올림 조건 (ex. 0.6 이상은 unit square 1 개)	0060
	62 ~ 65	I4	만들어야 할 layout 수 (최대 20)	0020
	66 ~ 69	I4	작성된 layout 중 프린트 대상의 최소 점수	0240
	70 ~ 72	I4	근접부서 탐색 조건 ex) 64 : 관계 A 를 갖는 부서, 없으면 임의, 16 : E, 4 : I, 1 : O (보통 16 or 4)	0004

ALDEP manual

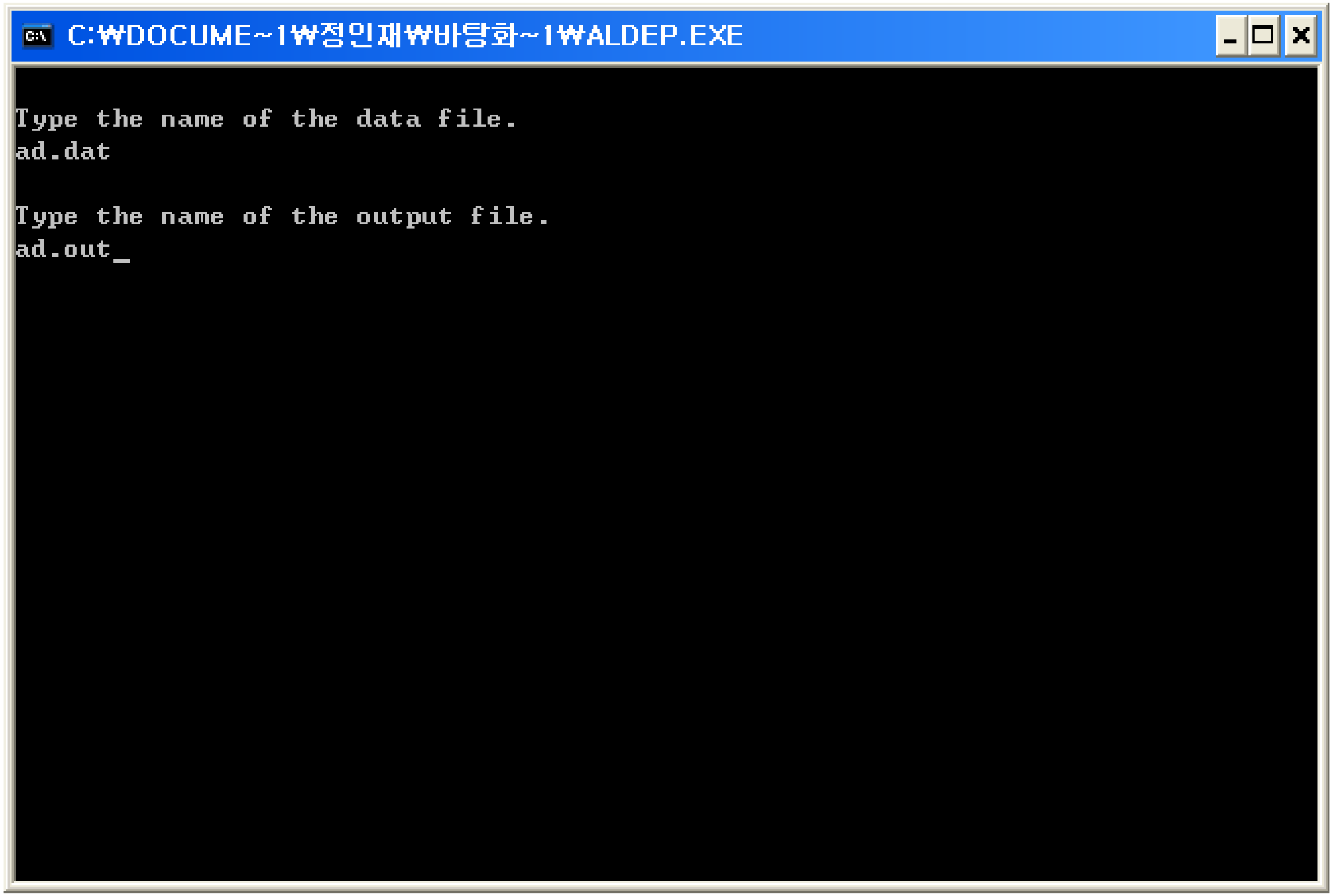
부서 갯수	1 ~ 4	I4	부서 1 : 0111, 부서 2 : 0112, ... (64 개 이하)	
	5 ~ 6	공란		
	7 ~ 13	F7.0	부서의 면적	
1	빈 line			
부서 갯수	1 ~ 3	I3	부서 1 : 111, 부서 2 : 112, ...	
	4 ~ 67	63A1	활동상호관계표, 자신과의 관계 : "S" (순서 : 부서 1 과의 관계, 부서 2 와의 관계, ..., S) ex)  111S 112AS 113IES 114XUOS	
고정 배치 부서 의 갯수	1	A1	A : 특정 부서를 특정 영역(Area)에 고정 F : 특정 부서를 특정 층(Floor)에 고정	A
	2 ~ 3	I2	계속 여부 표시 (1 : 1st line, 2 : 2nd line, ...)	01, 02
	4 ~ 7	I4	고정배치 부서번호, 혹은 1(dock), 2(E/V), 3(계단), 4(로비), 19(복도), 88(dummy)	0113
	8 ~ 9	I2	층 고정 (1 : 3 층, 2 : 2 층, 3 : 1 층)	02
	10 ~ 12	I3	고정배치 총 면적 (unit square 갯수)	020
	13 ~ 72	30I2	고정배치 대상영역의 column & row number(2 자리 정수의 column, 2 자리 정수의 row), 고정배치용 영역의 unit square 수가 15 개를 넘으면 계속성(column 2 ~ 3)을 표시하고 다음 line 에 계속	
1	1	A1	End 의 "E" 표기	

Example 6.A1: input data

```
MED1
016901            010201800018001001            040000060002002400016
0111  0012000
0112  0008000
0113  0006000
0114  0012000
0115  0008000
0116  0012000
0117  0012000

111S
112ES
113OUS
114IEUS
115OIUIS
116UIOUAS
117UUUUIES
A01011402030010101020103010401050106010701080109011002010202020302040205
A02011402030020602070208020902100306030703080309031004060407040804090410
E
```

Example 6.A1: aldep.exe



Quantitative facility layout models

- Quadratic assignment problem(QAP)

c_{jkhl}:cost of assigning new facility j to site k

when new facility h is assigned to site l

$x_{jk} = 1$, if facility j is assigned to site k; 0, otherwise

$$\min\ z = \sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{h=1}^{n}\sum_{l=1}^{n} c_{jkhl} x_{jk} x_{hl}$$

$$\text{st} \qquad \sum_{j=1}^{n} x_{jk} = 1, \forall k$$

$$\sum_{k=1}^{n} x_{jk} = 1, \forall j$$

$$x_{jk} = \{0,1\}$$

We assume $c_{jkhl} = f_{jh} d_{kl}$

Quantitative facility layout models

- Example) Four machines(A,B,C,D) are to be placed in four site (1,2,3,4) of a jobshop.
- Initial layout is (A:1, B:2, C:3, D:4)

flow	A	B	C	D
A	–	5	2	0
B	0	–	2	3
C	3	4	–	0
D	0	0	5	–

distance	1	2	3	4
1	–	5	10	4
2	4	–	6	7
3	8	5	–	5
4	6	6	5	–

Quantitative facility layout models

Table 10.5 *Pairwise Exchange Results for the Initial Solution to Example 10.6*

		Distances						
	Facility	Initial	Pairwise Exchanges					
Flows	Pairs	Solution	AB	AC	AD	BC	BD	CD
5	AB	5	4	5	6	10	4	5
2	AC	10	6	8	5	5	10	4
2	BC	6	10	4	6	5	5	7
3	BD	7	4	7	4	5	6	6
3	CA	8	5	10	5	4	8	6
4	CB	5	8	5	5	6	5	6
5	DC	5	5	6	10	6	6	5
	Total cost	147	136	150	149	151	142	132

New solution: (A:1, B:2, C:4, D:3)

Quantitative facility layout models

Table 10.6 *Pairwise Exchange Results for the First Improved Solution to Example 10.6*

			Distances					
			Pairwise Exchanges					
Flows	Facility Pairs	Initial Solution	AB	AC	AD	BC	BD	CD
5	AB	5	4	6	5	4	10	5
2	AC	4	7	6	5	5	4	10
2	BC	7	4	4	7	6	5	6
3	BD	6	10	6	4	5	5	7
3	CA	6	6	4	5	4	6	8
4	CB	6	6	5	6	7	5	5
5	DC	5	5	8	4	5	7	5
	Total cost	132	139	140	120	122	156	147

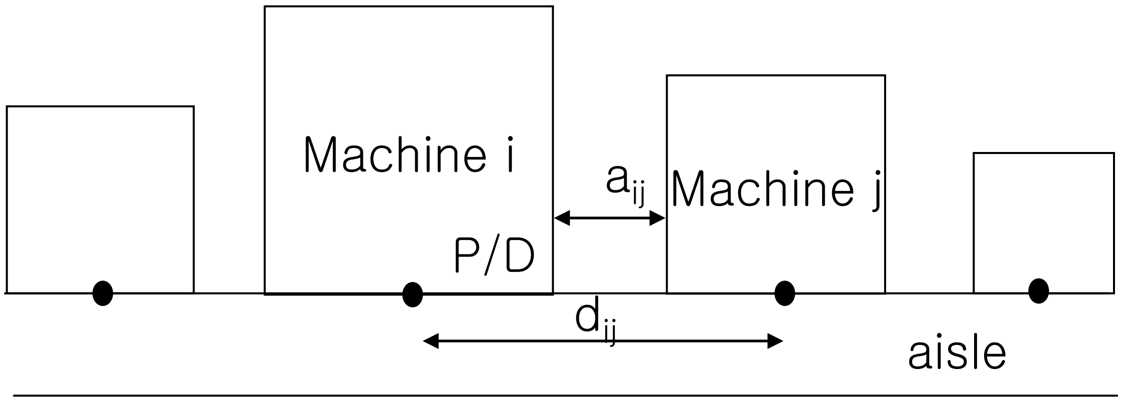
New solution: (A:3, B:2, C:4, D:1)

Quantitative facility layout models

- The improvement procedure terminates at the first local optimal solution.
- The quality of the final solution depends very much on the initial solution.
- The procedure must be executed with alternative initial solutions.
- How good is the final solution? ->Comparison with a lower bound.
- LB=fd=(0,0,0,0,0,2,2,3,3,4,5,5)(10,8,7,6,6,6,5,5,5,5,4,4)=112

Quantitative facility layout models

- Machine layout models



f_{ij} : total flow between machine i and j.

the sum of loaded trip and empty trip.

a_{ij} : minimum clearance between machine i and j.

d_{ij} : distance between P/D point of machine i and j.

Assumption: P/D point is located at the mid point along the edge of the machine paralle to the aisle.

Quantitative facility layout models

Solution procedure

Step1:Select machines with the maximum f_{ij} and arbitrarily select order $i \rightarrow j$.

Step2:Evaluate all possible placement orders,

$k \rightarrow i \rightarrow j$, $i \rightarrow j \rightarrow k$ for remaining machines

and select the placement order with minimum cost.

Step3:Repeate Step2 until all machines are assigned.

Quantitative facility layout models

- Example

	1	2	3	4
m/c dimensions	2 x 2	3 x 3	4 x 4	5 x 5

flow	1	2	3	4
1	–	18	12	11
2	18	–	12	19
3	12	12	–	17
4	11	19	17	–

$a_{ij}=19$

Step1:maximum $f_{ij}=19$ and arbitrarily select order $2 \rightarrow 4$.

Step2:

For $1 \rightarrow 2 \rightarrow 4$: $\text{cost}=f_{12}d_{12}+f_{14}d_{14}=18(3.5)+11(8.5)=156.5$

For $2 \rightarrow 4 \rightarrow 1$: $\text{cost}=f_{21}d_{21}+f_{41}d_{41}=$ 18(9.5)+11(4.5)=220.5

For $3 \rightarrow 2 \rightarrow 4$: $\text{cost}=f_{32}d_{32}+f_{34}d_{34}=$ 12(4.5)+17(9.5)=215.5

For $2 \rightarrow 4 \rightarrow 3$: $\text{cost}=f_{23}d_{23}+f_{43}d_{43}=$ 12(10.5)+17(5.5)=219.5

Select $1 \rightarrow 2 \rightarrow 4$

For $3 \rightarrow 1 \rightarrow 2 \rightarrow 4$: $\text{cost}=f_{31}d_{31}+f_{32}d_{32}+f_{34}d_{34}=12(4)+12(7.5)+17(12.5)=350.5$

For $1 \rightarrow 2 \rightarrow 4 \rightarrow 3$: $\text{cost}=f_{13}d_{13}+f_{23}d_{23}+f_{43}d_{43}=17(14)+12(10.5)+12(5.5)=430$

Final placement order is $3 \rightarrow 1 \rightarrow 2 \rightarrow 4$ with total cost 602

HW#1

- 6.10(4th edition, 6.10)
- 6.14(4th edition, 6.14)
- 6.18(4th edition, 6.18)
- 6.27(4th edition, 6.27. Do not use the computerized program)
- Consider the from to chart in SLP example. A product line will be constructed such that one main aisle will run the length of the factory. The aisle will be 12 ft wide. The relative location among departments are shown in the following figure.

Department	X length (min, max)	Perimeter (min, max)
1	(100,150)	(320,450)
2	(50,80)	(280,320)
3	(140,180)	(450,500)
4	(120,150)	(400,500)

Formulate the LP and solve the LP using Excel Solver. Provide screen captures of Excel file for solution and the corresponding objective function value. Also construct the corresponding block layout .