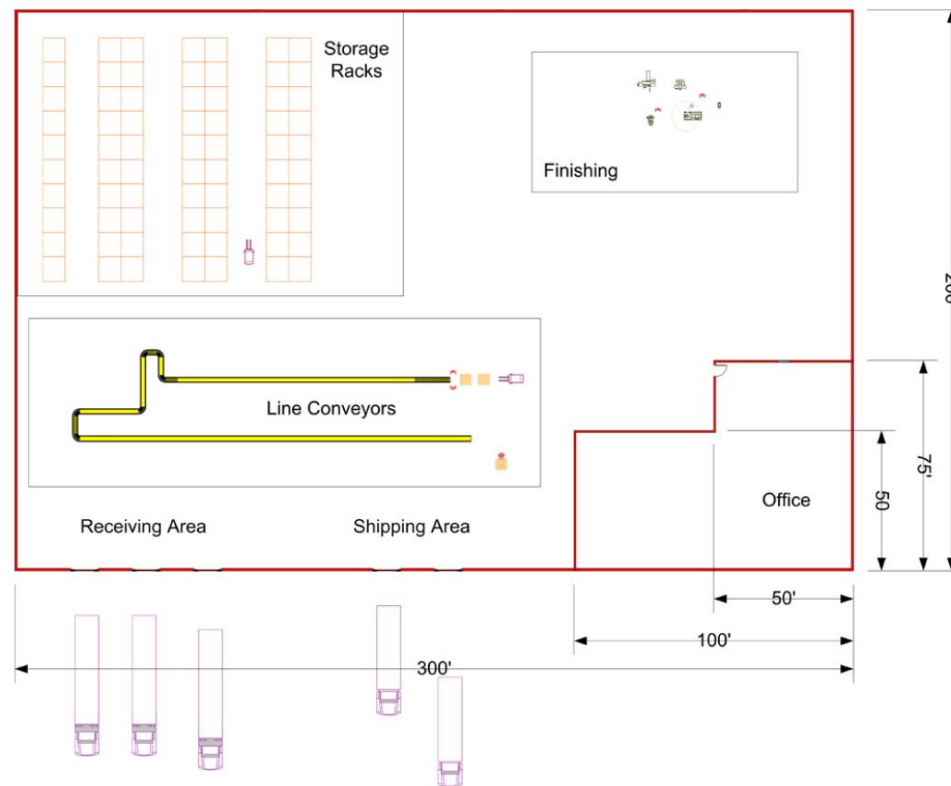


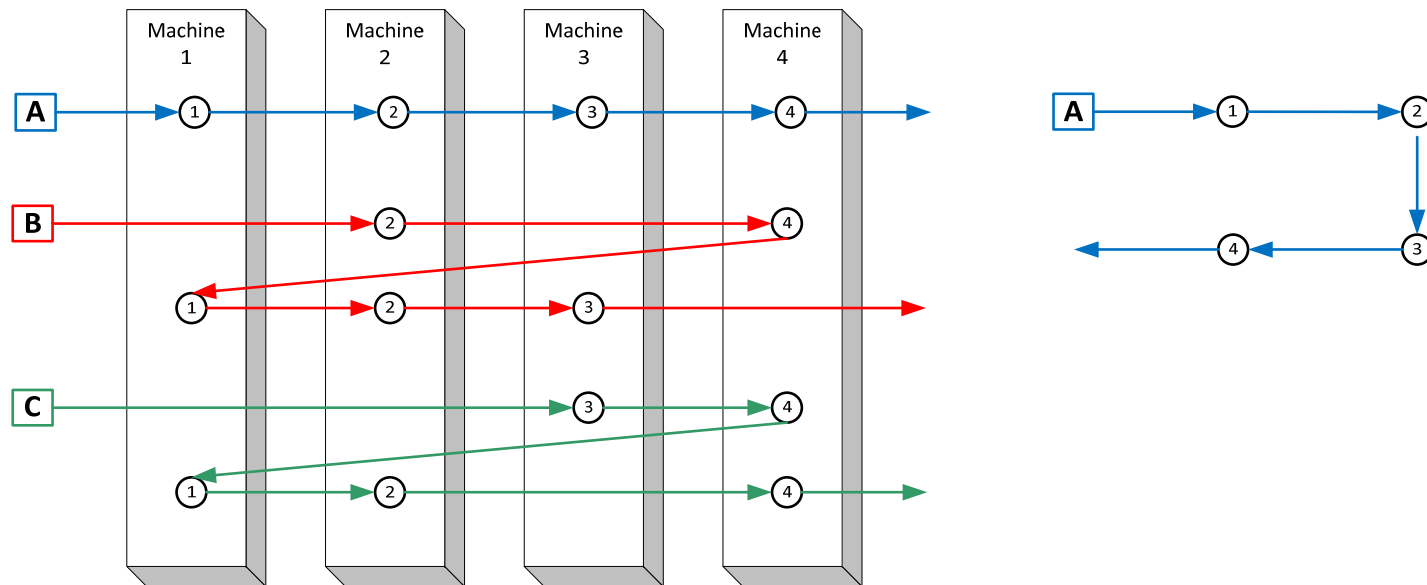
# Facility Layout

- Two levels of layout problems:
  - *Machine*: determine assignment of machines to sites
  - *Departmental*: determine space requirements of each department (or room) and its shape and relation of other departments

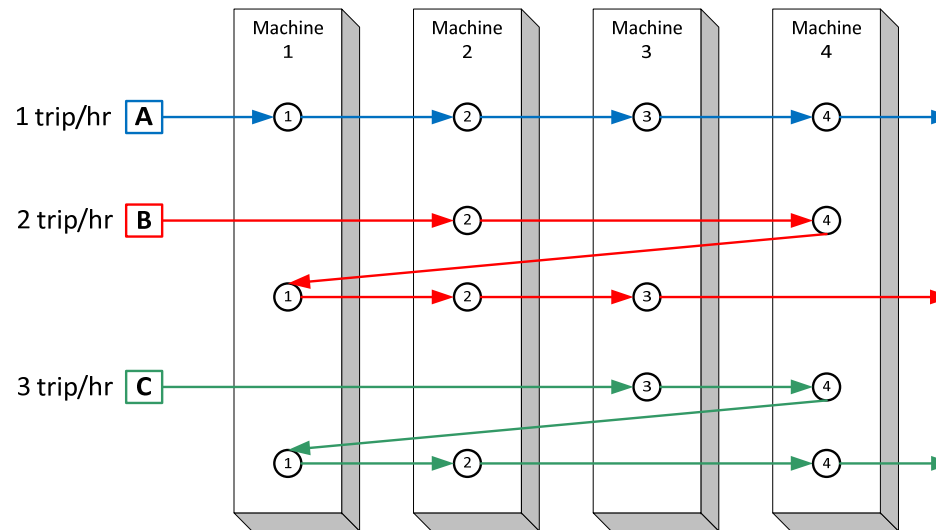


# Machine Layout

- A *routing* is the sequence of W/S (or M/C) that work visits during its production
  - Dedicated M/C  $\Rightarrow$  single routing  $\Rightarrow$  single flow of material  $\Rightarrow$  layout only involves choice of straight-line or U-shaped layout
  - Shared M/C  $\Rightarrow$  multiple routings  $\Rightarrow$  multiple flows of material  $\Rightarrow$  layout involves complex problem of finding assignment of M/C to Sites corresponding to the dominate flow



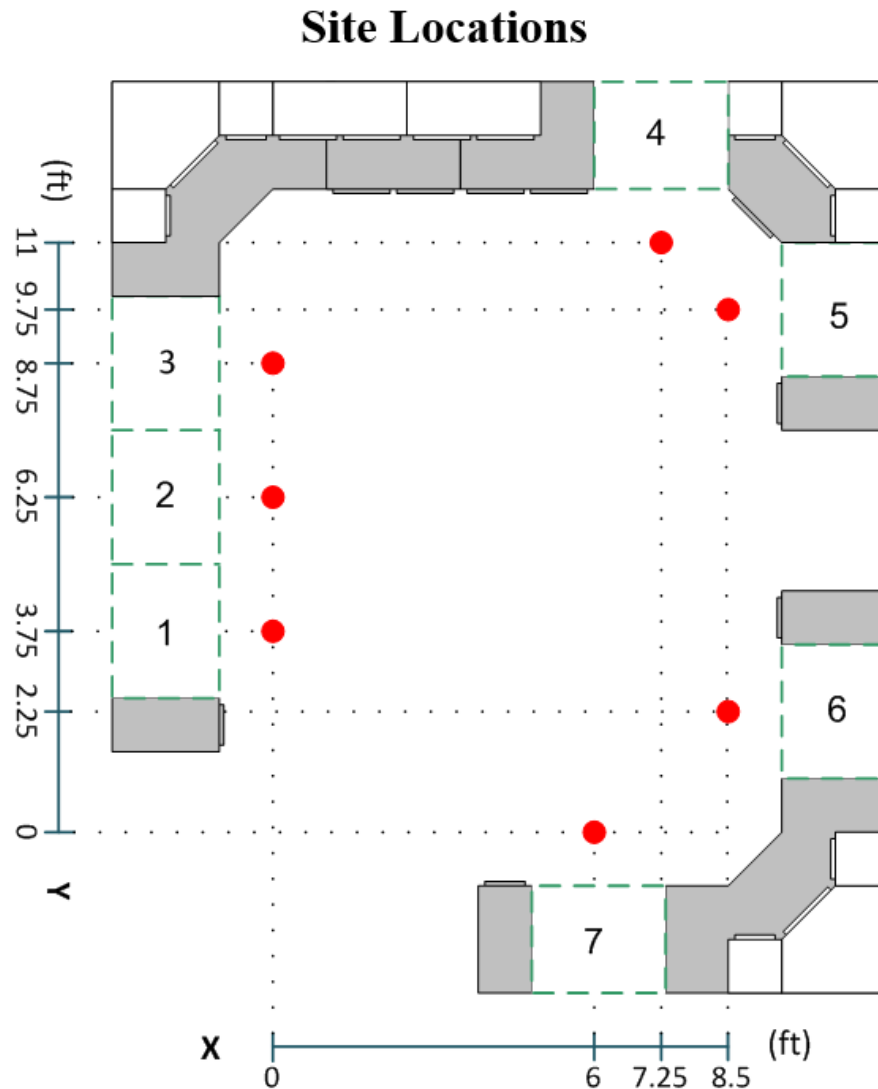
# From/To Chart

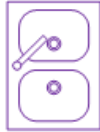


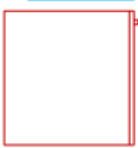
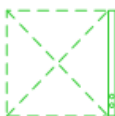

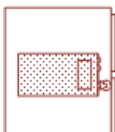


From \ To	1	2	3	4
1	—	1+2+3		
2		—	1+2	2+3
3			—	1+3
4	2+3			—

From \ To	1	2	3	4
1	—	6		
2		—	3	5
3			—	4
4	5			—

# Example: Kitchen Layout



Appliances		
	1	T/K Trash/Sink
	2	S Stove
	3	M Microwave
	4	R Refrigerator
	5	W/D <u>Worksurface/</u> Dishwasher
	6	P Pantry
	7	C Cupboard/ Coffeemaker

# Example: Kitchen Layout

**Table 1. Site-to-Site Distances**

Site	1	2	3	4	5	6	7
1	0.0	2.5	5.0	10.3	10.4	8.6	7.1
2	2.5	0.0	2.5	8.7	9.2	9.4	8.7
3	5.0	2.5	0.0	7.6	8.6	10.7	10.6
4	10.3	8.7	7.6	0.0	1.8	8.8	11.1
5	10.4	9.2	8.6	1.8	0.0	7.5	10.1
6	8.6	9.4	10.7	8.8	7.5	0.0	3.4
7	7.1	8.7	10.6	11.1	10.1	3.4	0.0

**Table 2. Distance from Location (0,0) to Sites**

Site	1	2	3	4	5	6	7
(0,0)	3.8	6.3	8.8	13.2	12.9	8.8	6.0

**Table 3. Meals Prepared During Each Week**

Meal	Freq.	Sequence
Snack	25	R-M (4-3)
Drink	10	C-R-W-T (7-4-5-1)
Breakfast	7	C-T-C-R-C-K (7-1-7-4-7-1)
Lunch	2	R-W-M-W-R-S-T (4-5-3-5-4-2-1)
Dinner	6	P-W-R-K-W-S-M-W-T (6-5-4-1-5-2-3-5-1)
Cleanup	8	K-D-K-R-K-D (1-5-1-4-1-5)

# Total Cost of Material Flow

**Equivalent Flow Volume :**  $w_{ij} = \sum_{k=1}^P f_{ijk} h_{ijk}$  (machine-to-machine)

where

$f_{ijk}$  = moves between machines  $i$  and  $j$  for item  $k$

$h_{ijk}$  = equivalence factor for moves between machines  $i$  and  $j$  for item  $k$

**Total Cost of Material Flow :**  $TC_{MF} = \sum_{i=1}^M \sum_{j=1}^M w_{a_i a_j} d_{ij}$

where

$a_i$  = machine assigned to site  $i$

$d_{ij}$  = distance between sites  $i$  and  $j$  (site-to-site)

$M$  = number of sites and machines

# Equivalent Factors

- Problem: Cost of move of item  $k$  from site  $i$  to  $j$  ( $h_{ijk}$ ) usually depends on layout
  - equivalent factor used to represent likely “cost” differences due to, e.g., item volume

$$\text{All } h_{ijk} = 1 \Rightarrow [w_{ij}] = \begin{bmatrix} 0 & 6 & 0 & 0 \\ 0 & 0 & 3 & 5 \\ 0 & 0 & 0 & 4 \\ 5 & 0 & 0 & 0 \end{bmatrix}$$

$$[f_{ijA}] = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$[f_{ijB}] = \begin{bmatrix} 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 2 \\ 0 & 0 & 0 & 0 \\ 2 & 0 & 0 & 0 \end{bmatrix}$$

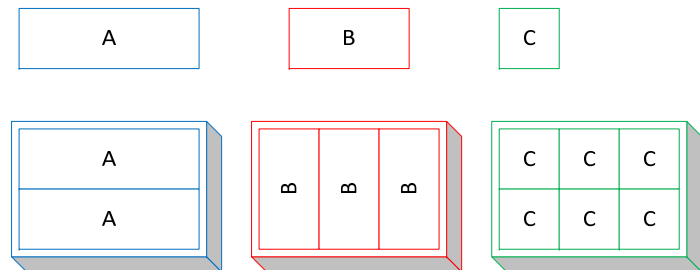
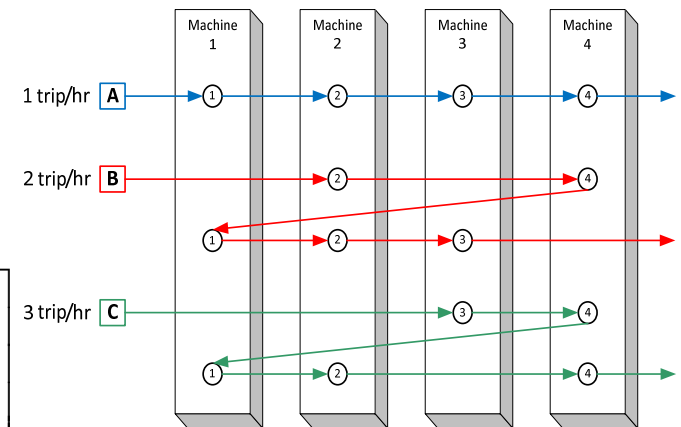
$$[f_{ijC}] = \begin{bmatrix} 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 3 \\ 0 & 0 & 0 & 3 \\ 3 & 0 & 0 & 0 \end{bmatrix}$$

$$[h_{ijA}] = 3$$

$$[h_{ijB}] = 2$$

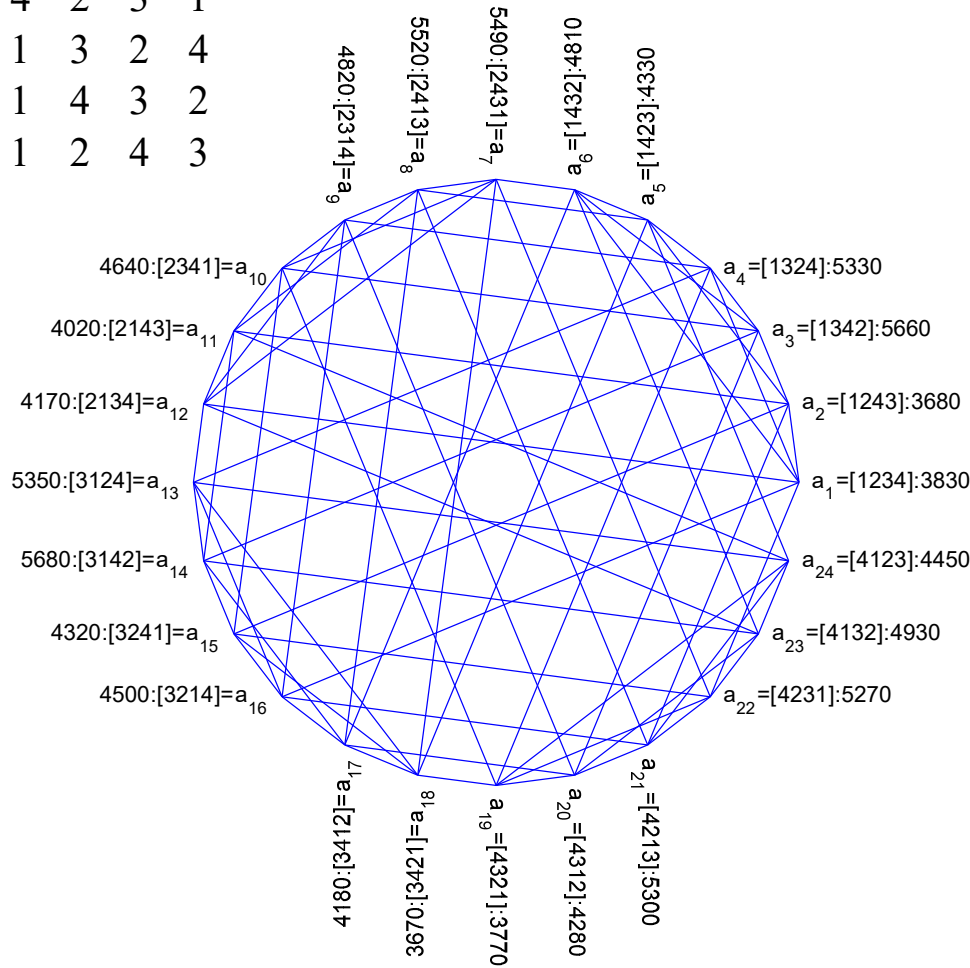
$$[h_{ijC}] = 1$$

$$[w_{ij}] = \begin{bmatrix} 0 & 10 & 0 & 0 \\ 0 & 0 & 7 & 7 \\ 0 & 0 & 0 & 6 \\ 7 & 0 & 0 & 0 \end{bmatrix}$$



# SDPI Heuristic

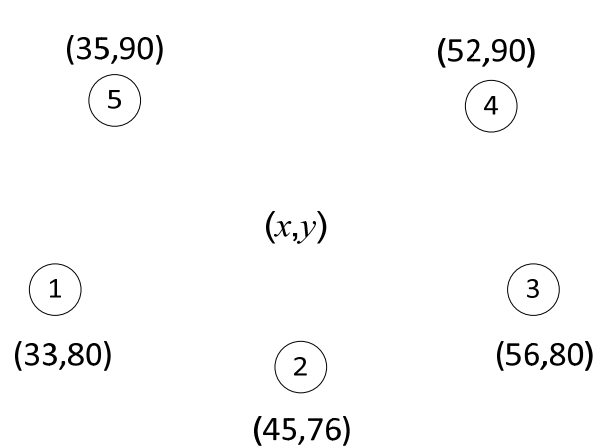
Interchange	1	2	3	4
1,2	2	1	3	4
1,3	3	2	1	4
1,4	4	2	3	1
2,3	1	3	2	4
2,4	1	4	3	2
3,4	1	2	4	3



		1	2	3	4	TC
<b>a<sub>14</sub></b>		3	1	4	2	5680
<b>a<sub>3</sub></b>		1	3	4	2	5660
<b>a<sub>23</sub></b>		4	1	3	2	4930
<b>a<sub>11</sub></b>		2	1	4	3	4020
<b>a<sub>17</sub></b>		3	4	1	2	4180
<b>a<sub>15</sub></b>		3	2	4	1	4320
<b>a<sub>13</sub></b>		3	1	2	4	5350
<b>a<sub>11</sub></b>		2	1	4	3	4020
<b>a<sub>2</sub></b>		1	2	4	3	3680
<b>a<sub>2</sub></b>		1	2	4	3	3680
<b>a<sub>11</sub></b>		2	1	4	3	4020
<b>a<sub>21</sub></b>		4	2	1	3	5300
<b>a<sub>15</sub></b>		3	2	4	1	4320
<b>a<sub>5</sub></b>		1	4	2	3	4330
<b>a<sub>3</sub></b>		1	3	2	2	5660
<b>a<sub>1</sub></b>		1	2	3	4	3830



# Layout Distances: Metric



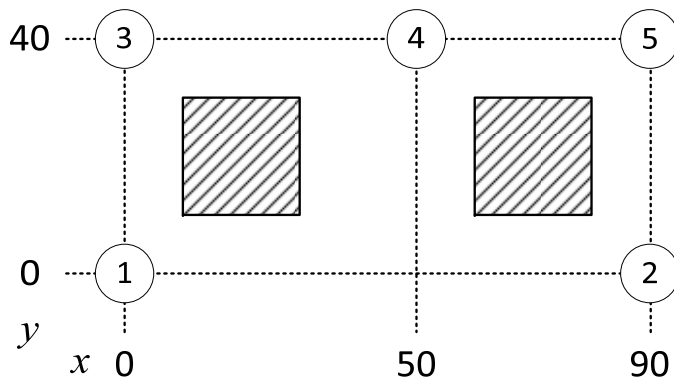
(a) Open space.

XY =

33	80
45	76
56	80
52	90
35	90

D =

	0	12.6491	23.0000	21.4709	10.1980
12.6491		0	11.7047	15.6525	17.2047
23.0000	11.7047		0	10.7703	23.2594
21.4709	15.6525	10.7703		0	17.0000
10.1980	17.2047	23.2594	17.0000		0



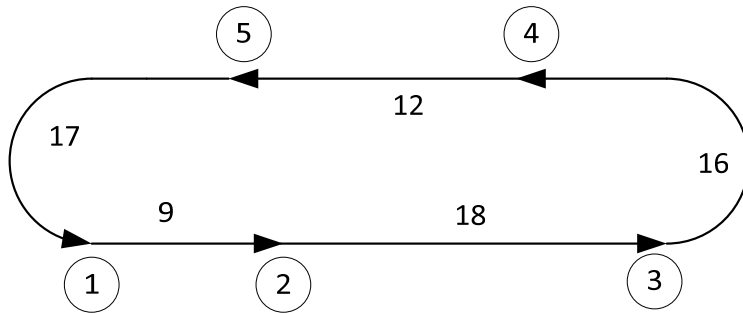
(b) Rectangular grid.

XY =

0	90	40	90	130
90	0	130	80	40
40	130	0	50	90
90	80	50	0	40
130	40	90	40	0

D =

# Layout Distances: Network



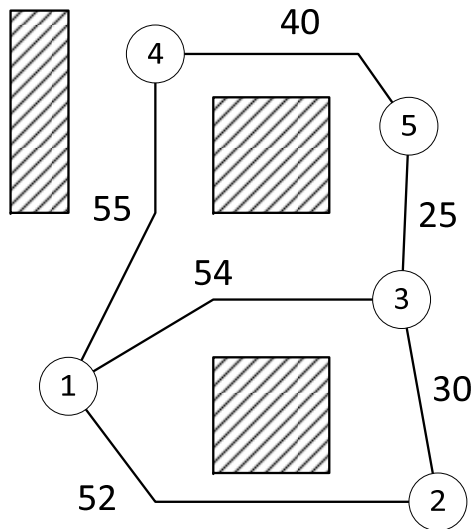
(c) Circulating conveyor.

IJD =

1	2	9
2	3	18
3	4	16
4	5	12
5	1	17

D =

0	9	27	43	55
63	0	18	34	46
45	54	0	16	28
29	38	56	0	12
17	26	44	60	0



(d) General network.

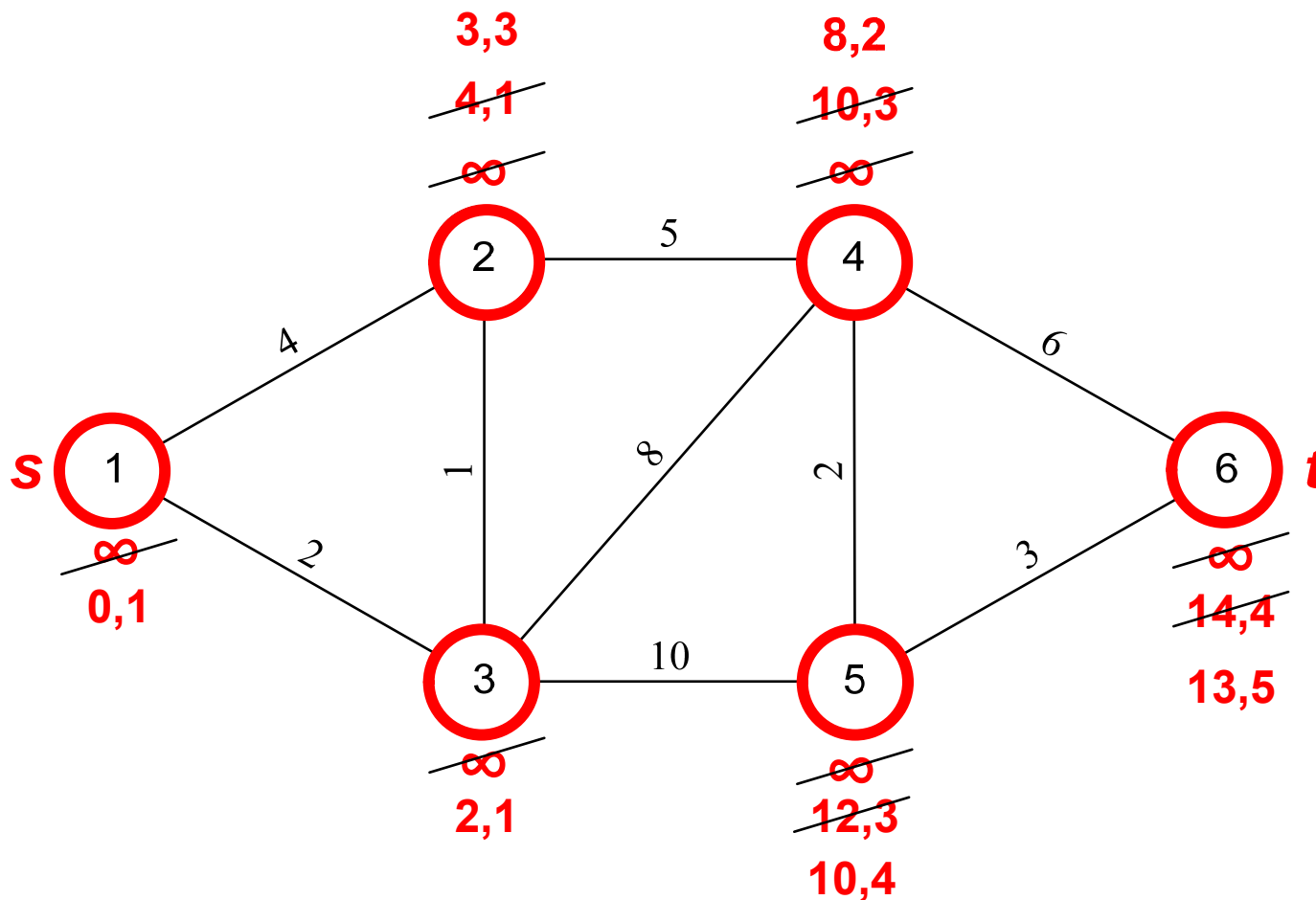
IJD =

1	-2	52
1	-3	54
1	-4	55
2	-3	30
3	-5	25
4	-5	40

D =

0	52	54	55	79
52	0	30	95	55
54	30	0	65	25
55	95	65	0	40
79	55	25	40	0

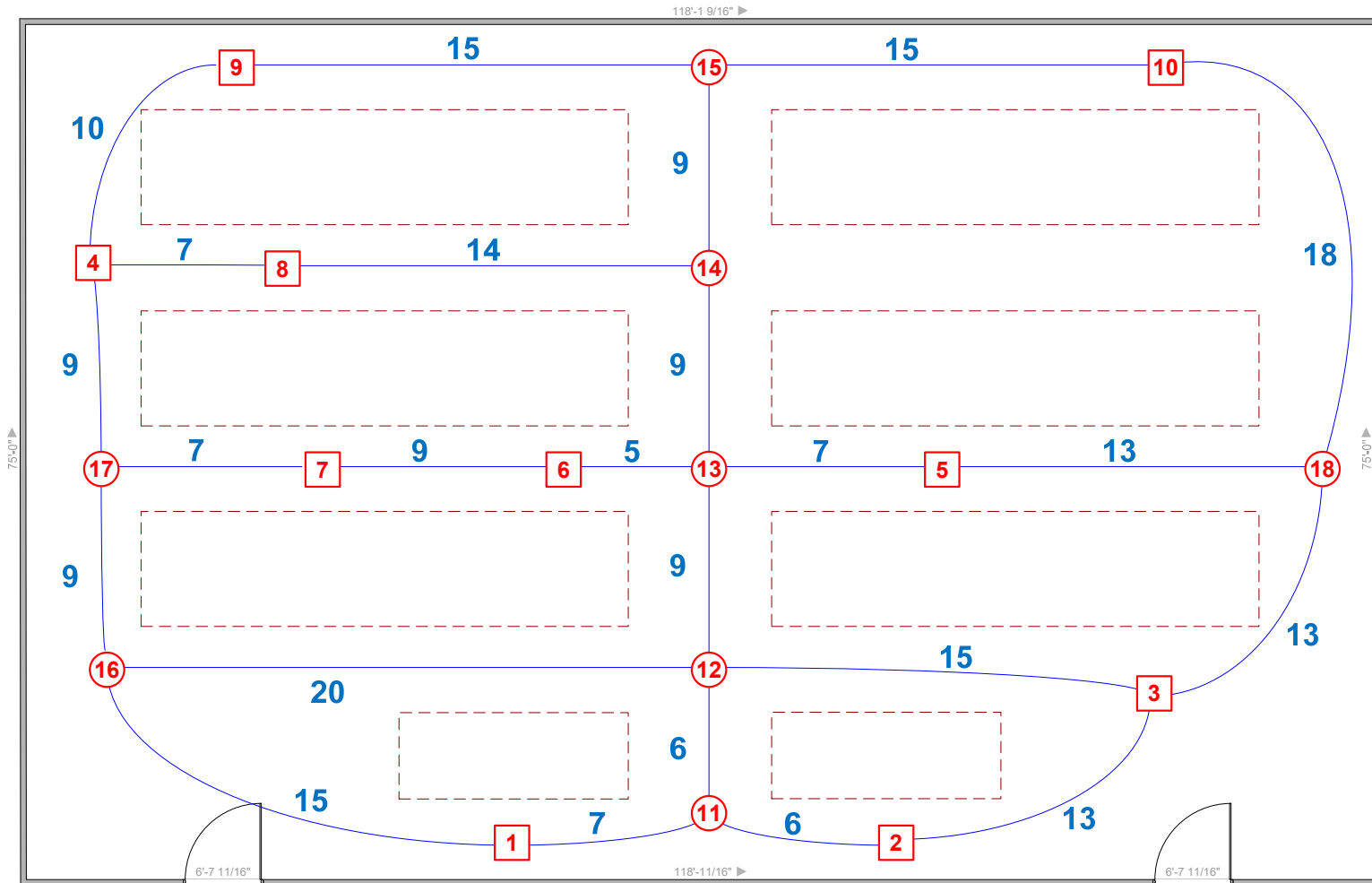
# Dijkstra Shortest Path Procedure



Path:  $1 \leftarrow 3 \leftarrow 2 \leftarrow 4 \leftarrow 5 \leftarrow 6$ : 13

# General Network Distances

DAN 407



# General Network Distances

- Only need  $10 \times 10$  distances between site locations, can throw away distances between intersection nodes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0	13	26	33	29	27	31	40	43	55	7	13	22	31	40	15	24	39
2	13	0	13	46	28	26	35	44	54	44	6	12	21	30	39	28	37	26
3	26	13	0	53	26	29	38	47	57	31	19	15	24	33	42	35	44	13
4	33	46	53	0	37	25	16	7	10	40	40	38	30	21	25	18	9	50
5	29	28	26	37	0	12	21	30	40	31	22	16	7	16	25	36	28	13
6	27	26	29	25	12	0	9	28	35	38	20	14	5	14	23	25	16	25
7	31	35	38	16	21	9	0	23	26	47	29	23	14	23	32	16	7	34
8	40	44	47	7	30	28	23	0	17	38	38	32	23	14	23	25	16	43
9	43	54	57	10	40	35	26	17	0	30	48	42	33	24	15	28	19	48
10	55	44	31	40	31	38	47	38	30	0	48	42	33	24	15	58	49	18
11	7	6	19	40	22	20	29	38	48	48	0	6	15	24	33	22	31	32
12	13	12	15	38	16	14	23	32	42	42	6	0	9	18	27	20	29	28
13	22	21	24	30	7	5	14	23	33	33	15	9	0	9	18	29	21	20
14	31	30	33	21	16	14	23	14	24	24	24	18	9	0	9	38	30	29
15	40	39	42	25	25	23	32	23	15	15	33	27	18	9	0	43	34	33
16	15	28	35	18	36	25	16	25	28	58	22	20	29	38	43	0	9	48
17	24	37	44	9	28	16	7	16	19	49	31	29	21	30	34	9	0	41
18	39	26	13	50	13	25	34	43	48	18	32	28	20	29	33	48	41	0

# Layout Justification

- Medical staff in a clinic (DAN 407) perform 5 procedures using equipment at 10 sites
  - Use savings in staff travel time to justifying changing layout
  - Initial investment cost is the labor to relocate equipment
  - 10.62 month payback

	Current TD (ft/hr)	2476
	New TD (ft/hr)	2154
	Net (ft/hr)	322
	Annual Operating Hours (H, hr/yr)	2000
	Labor Cost (\$/hr)	60
	Walking speed (2 mph) (ft/min)	176
	(ft/hr)	10560
	TD Savings (ft/yr)	644000
	Hourly Savings (hr/yr)	60.98485
	Savings (OP, \$/yr)	3659.091
	Number M/C Relocated	6
	Hours per M/C Relocation (hr)	9
	Total Relocation Cost (only labor costs) (IV, \$)	3240
	Payback Period (yr)	0.885466
	(month)	10.62559

Routing :	1	2	3	4	5	6	7	8	9	10
	2	4	6	8	10					
	3	1	3	5	7	9				
	4	3	6	9						
	5	4	8							
Item :	1	2	3	4	5	6	7	8	9	10
Flow :	5	4	3	8	12					
Handling Cost :	1	1	1	1	1					

	1	2	3	4	5	6	7	8	9	10	TD
Current Layout:	1	2	3	4	5	6	7	8	9	10	2476
New Layout:	3	2	1	6	5	4	8	7	9	10	2154