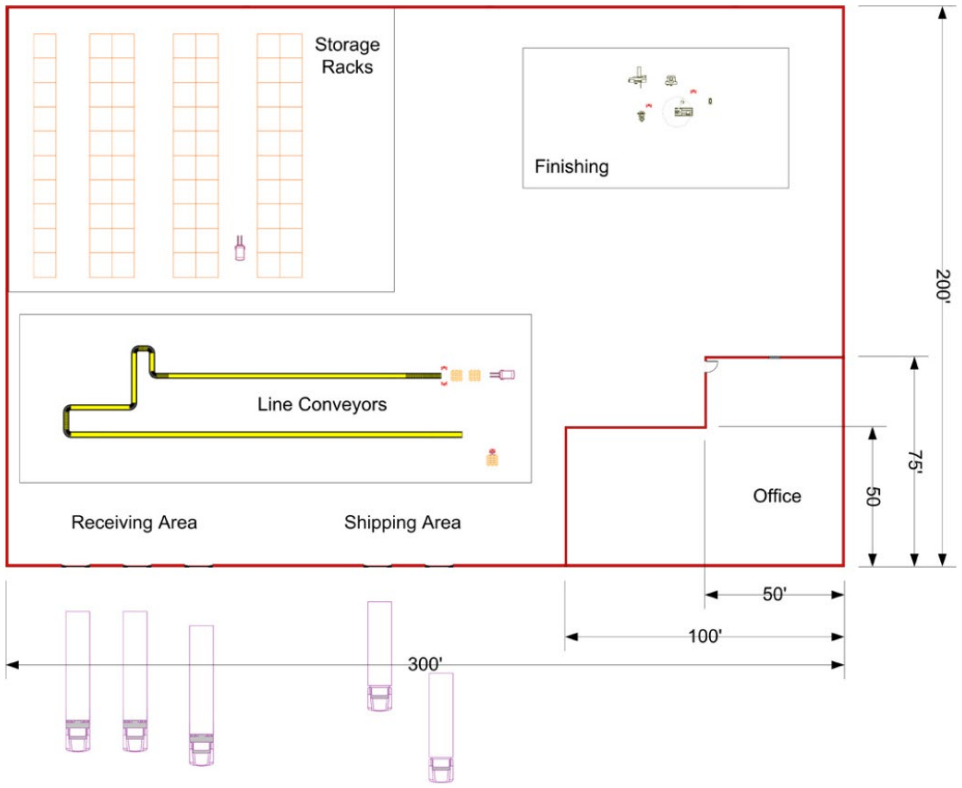
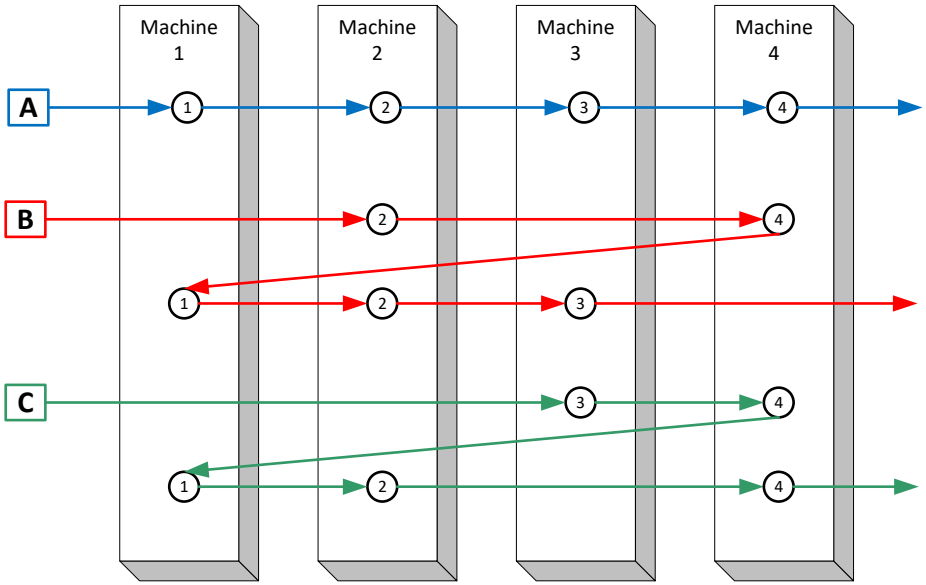
Facility Layout

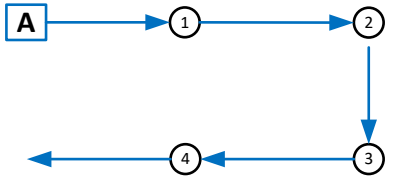
- Two levels of layout problems:
  - *Machine*: determine assignment of machines to (fixed) sites
  - *Departmental*: determine space requirements of each department (or room) and its shape and relation of other departments



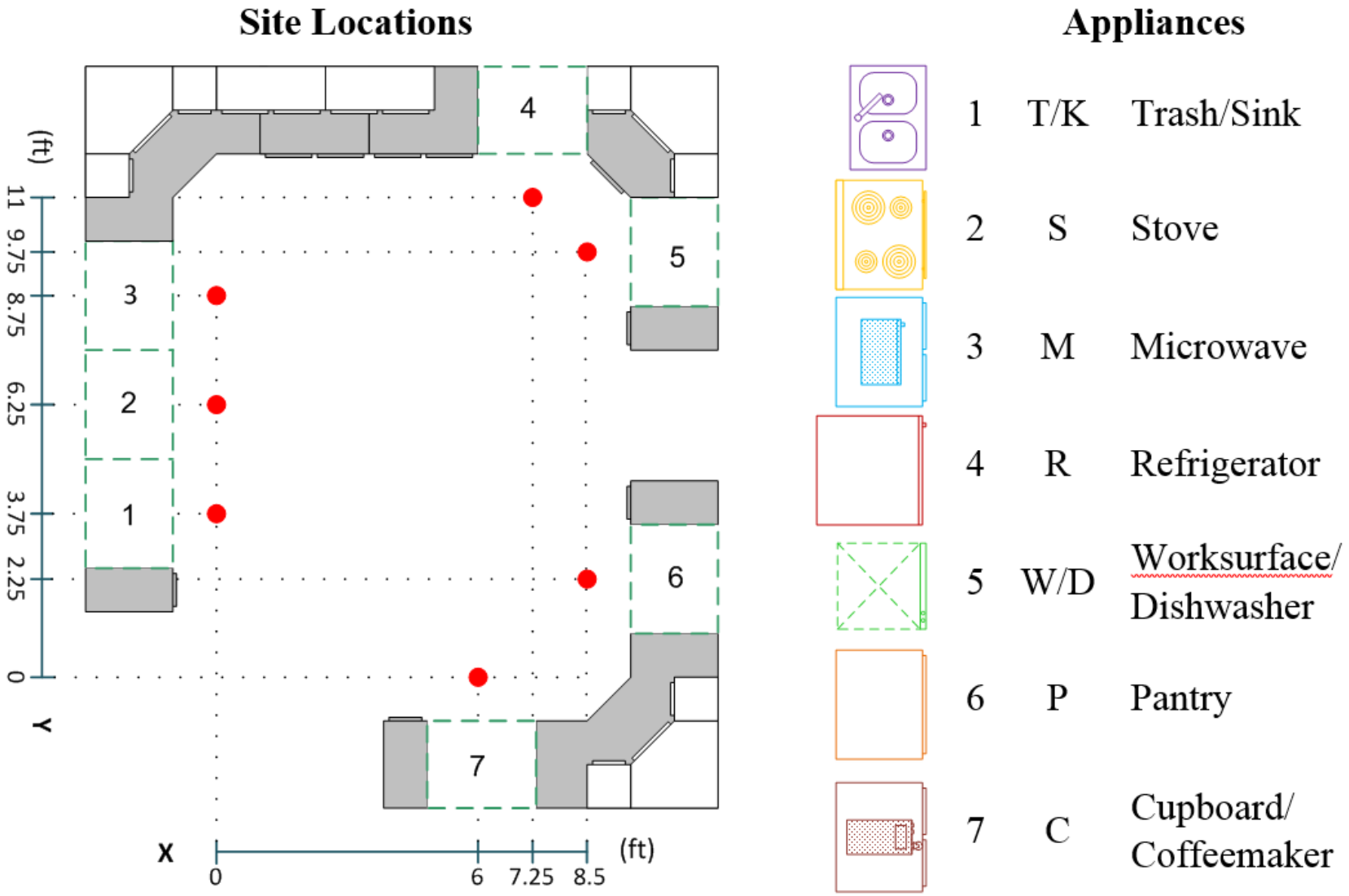
Machine Layout

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





Example: Kitchen Layout



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

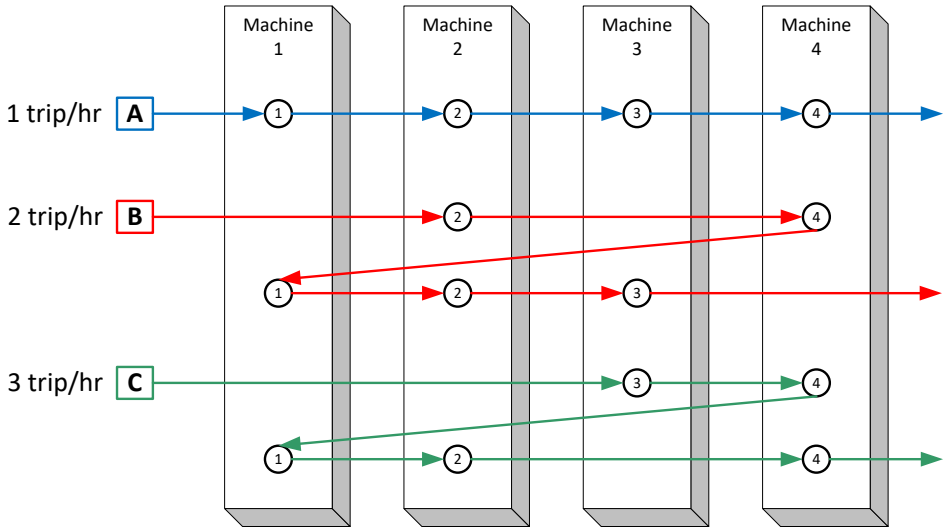
Table 2. Distance from Location (0,0) to Sites

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)

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			—

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} = equivalance 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

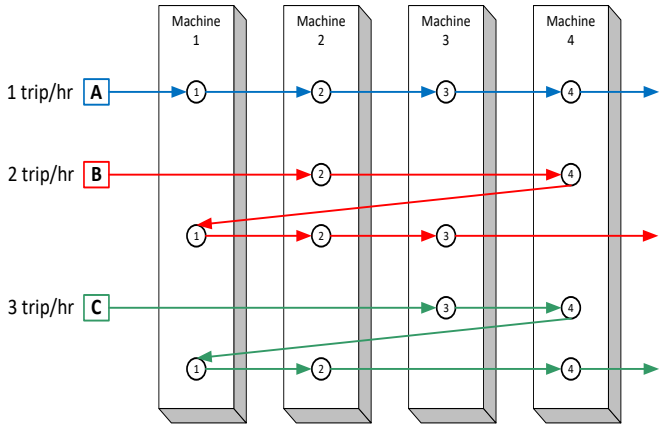
- Problem: Cost of move of item k from site i to j (h_{ijk}) usually depends on layout
  - equivalent factor used to represent likely "cost" differences due to, e.g., item volume

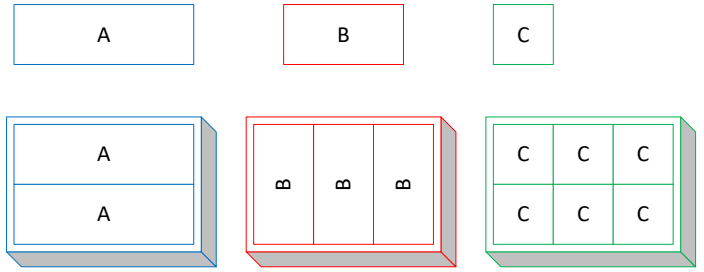
$$\text{All } h_{ijk} = 1 \Rightarrow [w_{ij}] = \begin{bmatrix} 0 & 6 & 0 & 0 \\ 0 & 0 & 3 & 5 \\ 0 & 0 & 0 & 4 \\ 5 & 0 & 0 & 0 \end{bmatrix}$$

$$[f_{ijA}] = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad [f_{ijB}] = \begin{bmatrix} 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 2 \\ 0 & 0 & 0 & 0 \\ 2 & 0 & 0 & 0 \end{bmatrix} \quad [f_{ijC}] = \begin{bmatrix} 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 3 \\ 0 & 0 & 0 & 3 \\ 3 & 0 & 0 & 0 \end{bmatrix}$$

$$[h_{ijA}] = 3 \qquad [h_{ijB}] = 2 \qquad [h_{ijC}] = 1$$

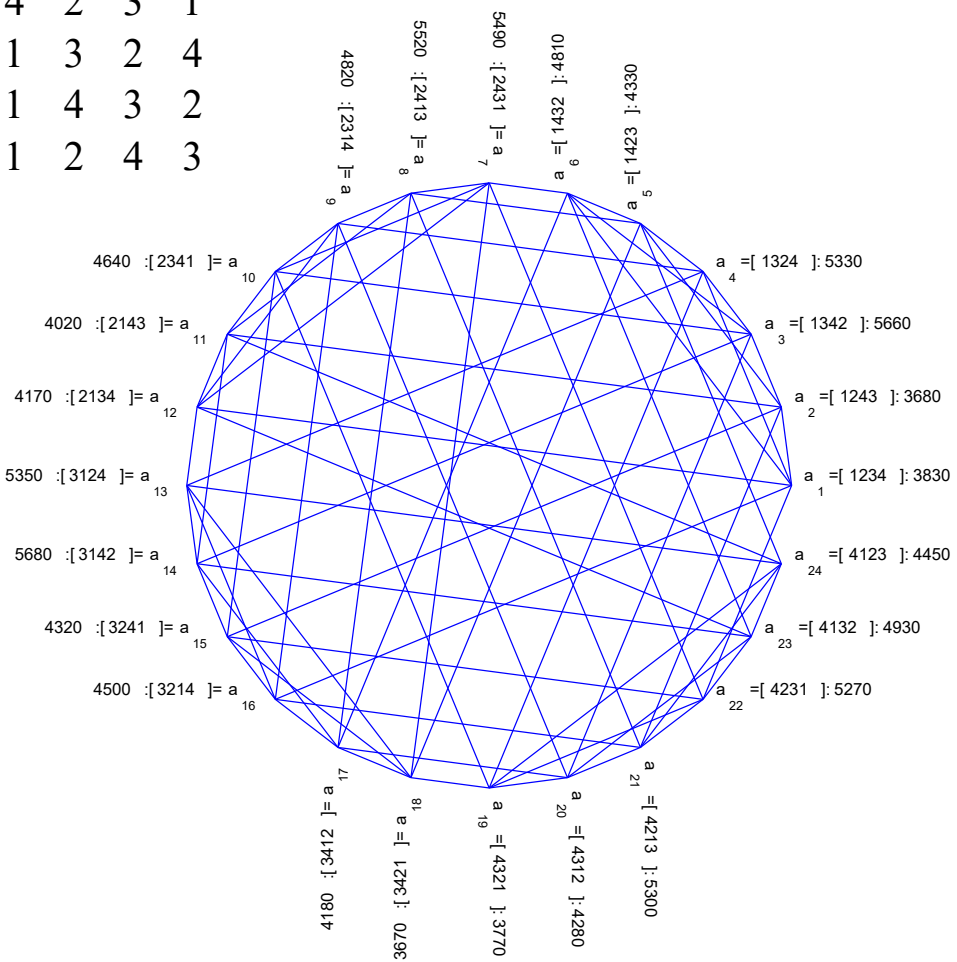
$$[w_{ij}] = \begin{bmatrix} 0 & 10 & 0 & 0 \\ 0 & 0 & 7 & 7 \\ 0 & 0 & 0 & 6 \\ 7 & 0 & 0 & 0 \end{bmatrix}$$





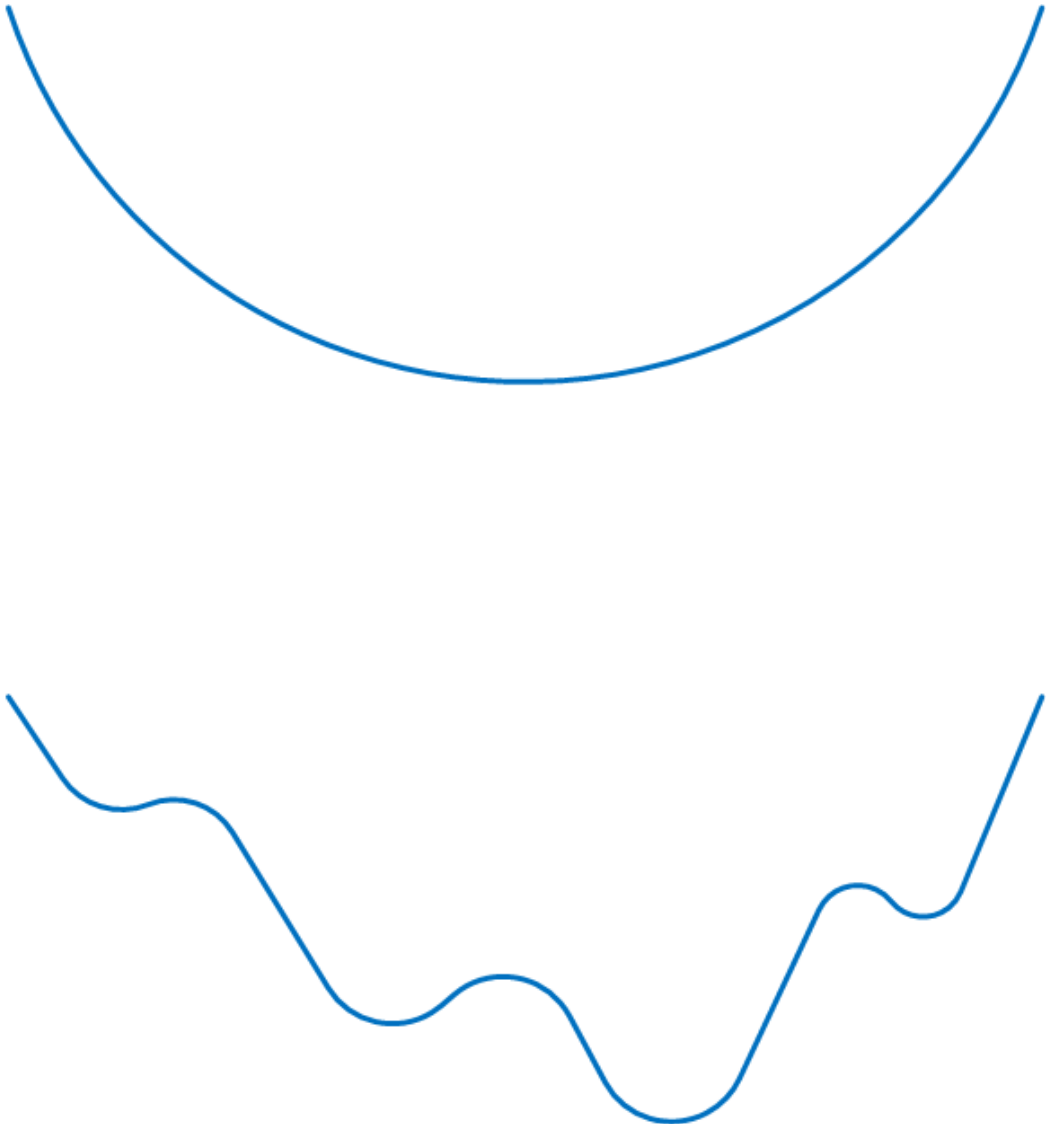
SDPI Heuristic

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

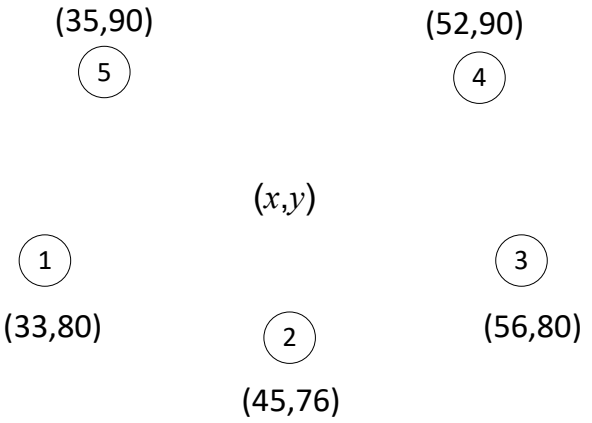


		1	2	3	4	*TC*
$\mathbf{a}_{14}$		3	1	4	2	5680
	$\mathbf{a}_3$	1	3	4	2	5660
	$\mathbf{a}_{23}$	4	1	3	2	4930
	$\mathbf{a}_{11}$	2	1	4	3	4020
	$\mathbf{a}_{17}$	3	4	1	2	4180
	$\mathbf{a}_{15}$	3	2	4	1	4320
	$\mathbf{a}_{13}$	3	1	2	4	5350
$\mathbf{a}_{11}$		2	1	4	3	4020
	$\mathbf{a}_2$	1	2	4	3	3680
	$\mathbf{a}_{24}$	4	1	2	3	4450
	$\mathbf{a}_{14}$	3	1	4	2	5680
	$\mathbf{a}_8$	2	4	1	3	5520
	$\mathbf{a}_{10}$	2	3	4	1	4640
	$\mathbf{a}_{12}$	2	1	3	4	4170
$\mathbf{a}_2$		1	2	4	3	3680
	$\mathbf{a}_{11}$	2	1	4	3	4020
	$\mathbf{a}_{21}$	4	2	1	3	5300
	$\mathbf{a}_{15}$	3	2	4	1	4320
	$\mathbf{a}_5$	1	4	2	3	4330
	$\mathbf{a}_3$	1	3	2	2	5660
	$\mathbf{a}_1$	1	2	3	4	3830

SDPI Heuristic

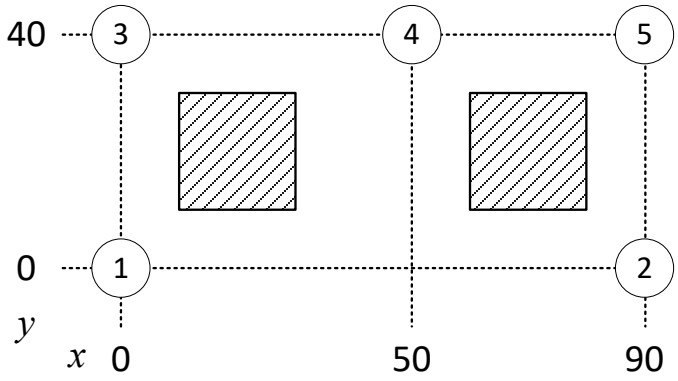


Layout Distances: Metric



(a) Open space.

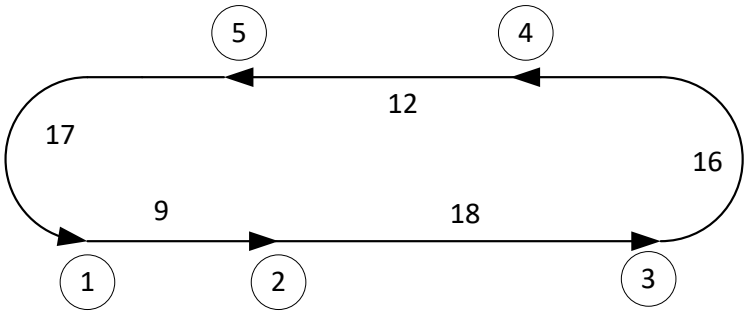
```
XY =
    33    80
    45    76
    56    80
    52    90
    35    90

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
```



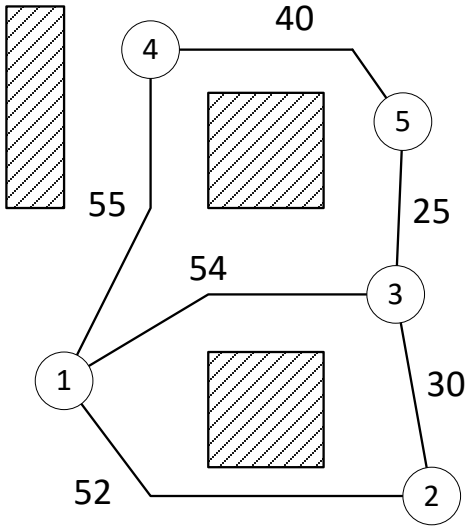
(b) Rectangular grid.

```
XY =
     0     0
    90     0
     0    40
    50    40
    90    40
D =
     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
```

Layout Distances: Network



(c) Circulating conveyor.

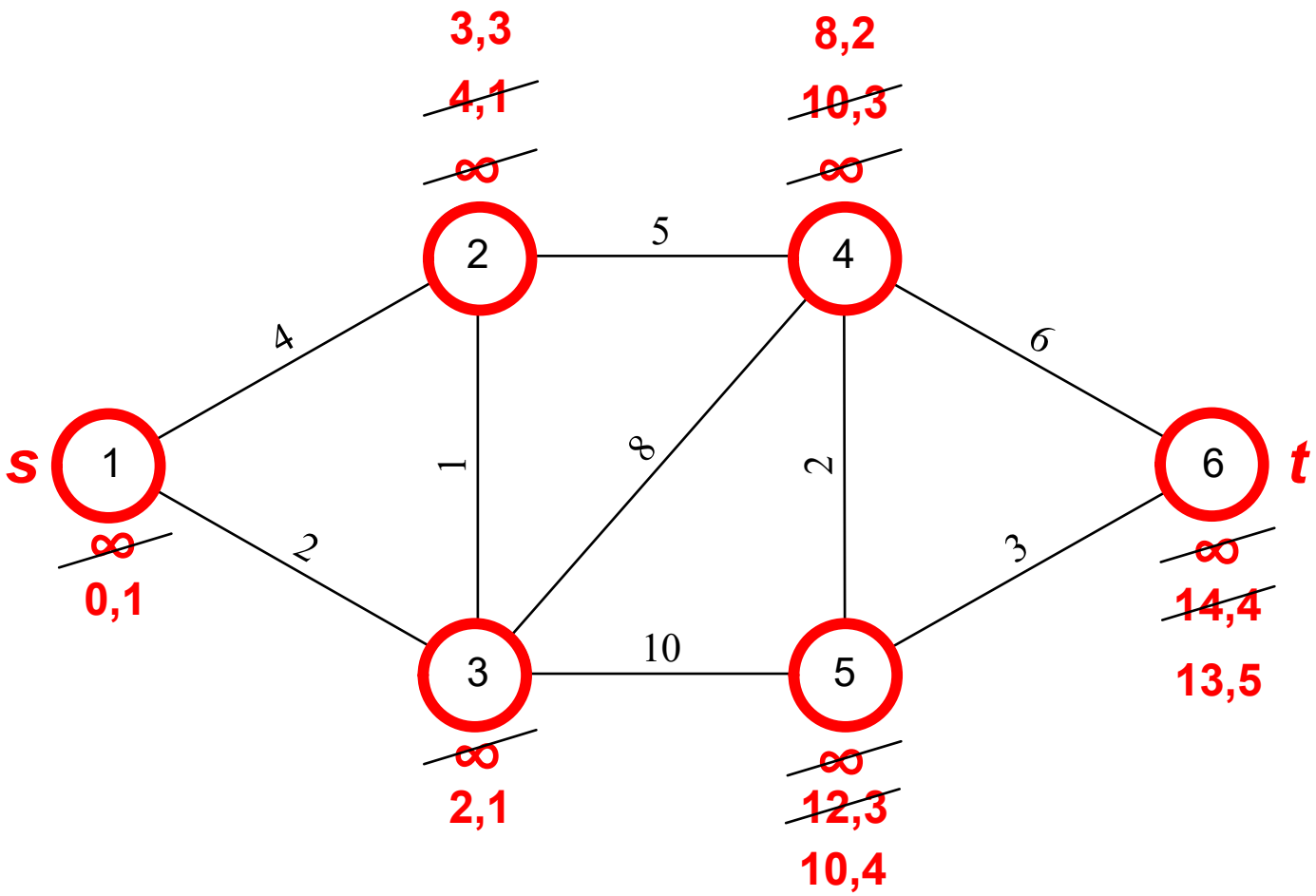


(d) General network.

```
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
```

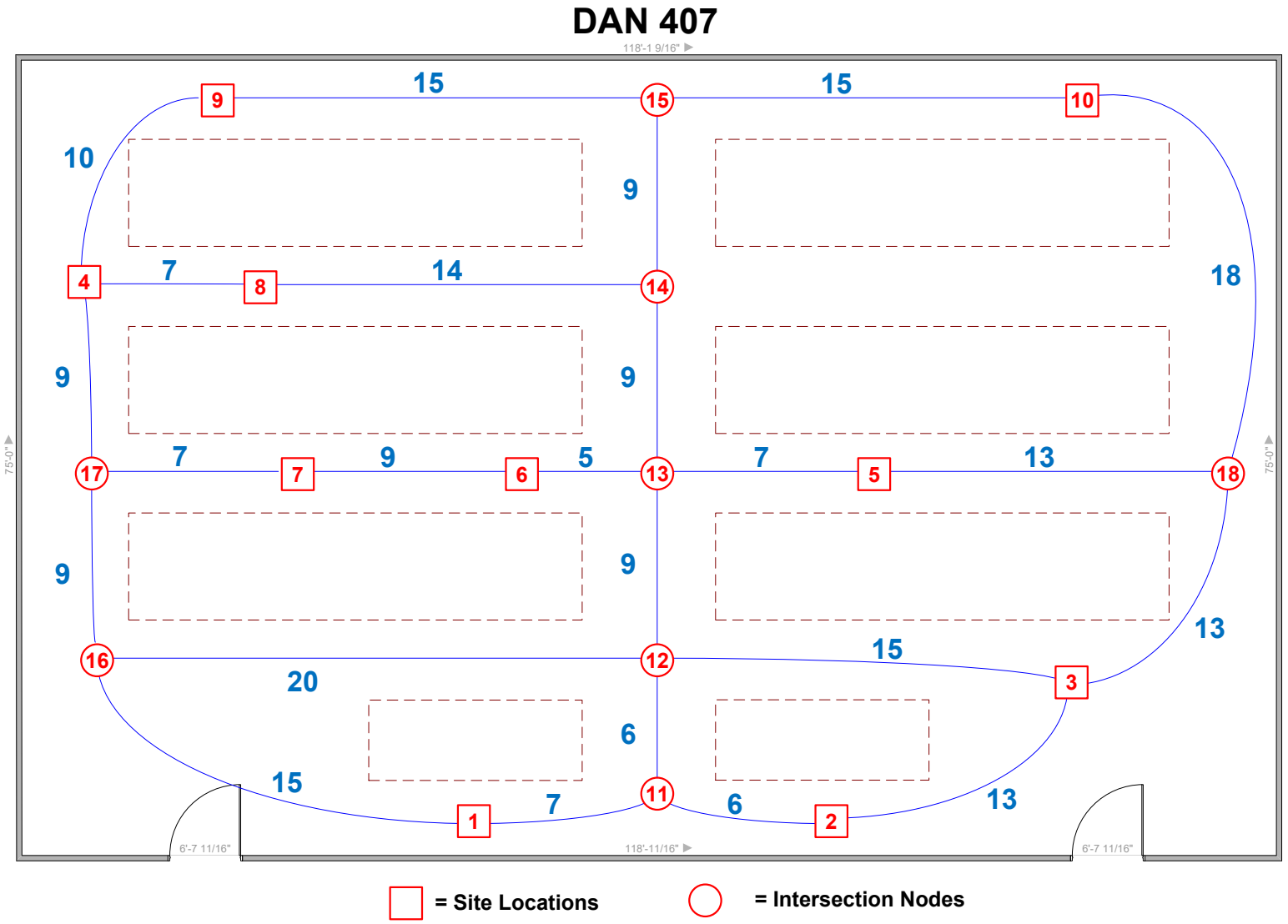
```
IJD =
     1    -2    52
     1    -3    54
     1    -4    55
     2    -3    30
     3    -5    25
     4    -5    40
D =
     0    52    54    55    79
    52     0    30    95    55
    54    30     0    65    25
    55    95    65     0    40
    79    55    25    40     0
```

Dijkstra Shortest Path Procedure



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

General Network Distances



General Network Distances

- Only need 10 × 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