Definition:

Plant layout (or more generally, “facility layout”) is the design and installation of systems of men, materials and equipment. In other words, it is the joint determination of the locations, sizes and configurations of multiple activities within a facility.
Some of the objectives of the plant layout

1. Minimize investment in equipment
2. Minimize overall production time
3. Utilize existing space most effectively
4. Minimize material handling cost

Systematic Layout Planning

- Input Data and Activities
  - Flow of materials
  - Activity Relationships

- Relationship Diagram
  - Space Requirements
  - Space Availability

- Space Relationship Diagram
  - Modifying Considerations
  - Practical Limitations

- Develop Layout Alternatives

- Evaluation
From – to chart

- Provides information concerning the number of material handling trips between departments (work centers)

### From-to Chart Example

<table>
<thead>
<tr>
<th>Component</th>
<th>Production quantity / day</th>
<th>Routing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>A→C→B→D→E</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>A→B→D→E</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>A→C→D→B→E</td>
</tr>
</tbody>
</table>

Component 1 and 2 have the same size. Component 3 is almost twice as large. Therefore, moving two units of components 1 or 2 is equivalent to moving one unit of component 3. Show material flows between machines on a from-to chart.
Example solution

<table>
<thead>
<tr>
<th>Component</th>
<th>Production quantity / day</th>
<th>Routing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>A→C→B→D→E</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>A→B→D→E</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>A→C→D→B→E</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From</th>
<th>To A</th>
<th>To B</th>
<th>To C</th>
<th>To D</th>
<th>To E</th>
<th>From Sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
<td>44</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>42</td>
<td>14</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>30</td>
<td>14</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>14</td>
<td>14</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>14</td>
<td>42</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To Sums</td>
<td>---</td>
<td>56</td>
<td>44</td>
<td>56</td>
<td>56</td>
<td>212</td>
</tr>
</tbody>
</table>

Machine Sequencing

- Machining centers (departments) are laid out in such way that the total forward flows on the line is maximized, or total backward flows are minimized.
- Hollier developed two heuristic algorithms that can achieve ordering of machines for minimizing backtrack flows
Hollier Method 1

Step 1:
Develop the “From-To” chart from part routing data. The data contained in the chart indicates numbers of parts moves between machines (or work stations) in the cell. Moves into and out of the cell are not included in the chart.

Step 2:
Determine the “From” and “To” sums for each machine. This is accomplished by summing all of the “From” trips and “To” trips for each machine.

Step 3:
Assign machines to the cell based on minimum “From” or “To” sums. The machine having the smallest sum is selected. If the minimum value is a “To” sum, then the machine is placed at the beginning of the sequence. If the minimum value is a “From” sum, then the machine is placed at the end of the sequence.
Hollier Method 1

Tie breaker rules:
- If a tie occurs between minimum “To” sums or minimum “From” sums, then the machine with the minimum “From/To” ratio is selected.
- If both “To” and “From” sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.
- If a minimum “To” sum is equal to a minimum “From” sum, then both machines are selected and placed at the beginning and end of the sequence, respectively.

Step 4:
Reformat the From-To chart. After each machine has been selected, restructure the From-To chart by eliminating the row and column corresponding to the selected machine and recalculate the “From” and “To” sums.

Step 5:
Repeat steps 3 and 4 until all machines have been assigned.
Example 5.1

An analysis of 50 parts processed on four machines has been summarized in the From-to chart of the following table.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>From:</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>10</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Additional information is that 50 parts enter the machine grouping at machine 3, 20 parts leave after processing at machine 1, 30 parts leave after machine 4. Determine a logical machine arrangement using Hollier method 1.

Example 5.1 (solution)

Iteration No.1

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>“From” Sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>From:</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>10</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>“To” Sums</td>
<td>50</td>
<td>45</td>
<td>0*</td>
<td>40</td>
<td>135</td>
</tr>
</tbody>
</table>

* The minimum sum value is the “To” sum for machine 3.

Machine sequence: 3 4 2 1
### Example 5.1 (solution)

#### Iteration No.2

<table>
<thead>
<tr>
<th>To:</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>“From” Sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>From:</td>
<td>0</td>
<td>5</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>0</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>“To” Sums</td>
<td>40</td>
<td>5*</td>
<td>40</td>
<td>85</td>
</tr>
</tbody>
</table>

* The minimum sum value is the “To” sum for machine 2.

Machine sequence: [3 2 ]

---

### Example 5.1 (solution)

#### Iteration No.3

<table>
<thead>
<tr>
<th>To:</th>
<th>1</th>
<th>4</th>
<th>“From” Sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>From:</td>
<td>0</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>0</td>
<td>10*</td>
</tr>
<tr>
<td>“To” Sums</td>
<td>10*</td>
<td>25</td>
<td>35</td>
</tr>
</tbody>
</table>

* There are two minimum sum values in this chart. The minimum “To” sum value for machine 1 is equal to the minimum “From” sum value for machine 4.

Machine sequence: [3 2 1 4]
Flow diagram

Percentage of in-sequence moves

(%) which is computed by adding all of the values representing in-sequence moves and dividing by the total number of moves

Number of in-sequence moves = 40 + 30 + 25 = 95
Total number of moves = 95 + 15 + 10 + 10 + 5 = 135

Percentage of in-sequence moves = 95/135 = 0.704 = 70.4%
Percentage of backtracking moves

(%) which is computed by adding all of the values representing backtracking moves and dividing by the total number of moves

![Diagram showing backtracking moves](image)

Number of backtracking moves = 10 + 5 = 15
Total number of moves = 95 + 15 + 10 + 10 + 5 = 135
Percentage of backtracking moves = 15/135 = 0.704 = 11.1%

Activity relationship analysis

- A number of factors other than material handling cost might be of primary concern in layout design
- Activity relationship chart (REL chart) should be constructed in order to realize the closeness rating between departments
Activity relationship (REL chart)

- Facilitates consideration of qualitative factors by replacing the numbers in a from-to chart by a qualitative closeness rating

Construction steps of REL chart

1. List all departments or activities to be included
2. Obtain closeness ratings by interviewing or surveying persons
3. Assign a closeness rating to each pairwise combination of activities
4. Review the REL chart with those providing input in step 2
An example of REL chart

A = Absolutely necessary

E = Especially important

X = Undesirable

U = Unimportant

O = Important

I = Ordinary closeness

Proportion of each rating

<table>
<thead>
<tr>
<th>Rating</th>
<th>Proportion to the whole relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>A &amp; X</td>
<td>≤ 5%</td>
</tr>
<tr>
<td>E</td>
<td>≤ 10%</td>
</tr>
<tr>
<td>I</td>
<td>≤ 15%</td>
</tr>
<tr>
<td>O</td>
<td>≤ 20%</td>
</tr>
<tr>
<td>Hence, U</td>
<td>≥ 50%</td>
</tr>
</tbody>
</table>
Relationship diagram

- Constitutes the 3rd step of SLP. It converts the information in the REL chart into a diagram
- REL diagram can either be constructed manually or by using computer algorithms

Layout algorithms

- In general, layout algorithms are of two types as Improvement and Construction
- Improvement algorithms begin with an initial layout and search for improved solutions
  - CRAFT (require quantitative flow input)
  - COFAD
- Construction algorithms add departments to the layout, one by one, until all departments have been placed
  - ALDEP
  - CORELAP (require qualitative input)
  - PLANET
  - RDP (Relationship Diagramming Process)
Relationship Diagramming Process (RDP)

RDP is a construction algorithm, which adds departments to the layout one by one until all departments have been placed.

**Stage 1:** Involves 5 steps to determine the order of placement

**Step 1** ➔ the numerical values are assigned to the closeness rating as:
\[ A = 10000, \quad E = 1000, \quad I = 100, \quad O = 10, \quad U = 0, \quad X = -10000 \]

**Step 2** ➔ TCR (Total Closeness Rating) for each department is computed. TCR refers to the sum of the absolute values for the relationships with a particular department.

**Step 3** ➔ The department with the greatest TCR is selected as the first placed department in the sequence of placement.
Relationship Diagramming Process (RDP)

Step 4 ➔ Next department in the sequence of placement is determined to satisfy the highest closeness rating with the placed department(s). With respect to the closeness priorities A>E>I>O>U.

Step 5 ➔ Departments having X relationship with the placed department(s) are labeled as the last placed department.

Note: If ties exist during this process, TCR values are utilized to break the ties arbitrarily.

Stage 2: Involves 3 steps to determine the relative locations of the departments.

Step 6 ➔ Calculate Weighted Placement Value (WPV) of locations to which the next department in the order will be assigned. WPV refers to the sum of the numerical values for all pairs of adjacent department(s). When a location is fully adjacent, its weight equals to 1.0, and when it is partially adjacent its weight equals to 0.5.
Relationship Diagramming Process (RDP)

**Step 7** → Evaluate all possible locations in counter clockwise order, starting at the western edge of the partial layout.

**Step 8** → Assign the next department to the location with the largest WPV.

**Note:** If ties exist during this process, first location with the largest WPV is selected.

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**Example 5.2**

Given the activity relationship diagram (REL) determine the layout of departments using RDP.
Example 5.2 (solution) 1st stage

Calculate the Total closeness ratings (TCR) with values of A=10,000; E=1000; I=100; O=10; U=0

<table>
<thead>
<tr>
<th>Department</th>
<th>A</th>
<th>E</th>
<th>I</th>
<th>O</th>
<th>U</th>
<th>X</th>
<th>TCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Offices</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1010</td>
</tr>
<tr>
<td>2 Foreman</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1310</td>
</tr>
<tr>
<td>3 Conf. room</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1100</td>
</tr>
<tr>
<td>4 Receiving</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>10100</td>
</tr>
<tr>
<td>5 Parts ship.</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>11000</td>
</tr>
<tr>
<td>6 Storage</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>20100</td>
</tr>
</tbody>
</table>

Selected as the first placed department

Example 5.2 (solution) 1st stage

Next department in the sequence of placement is determined to satisfy the highest closeness rating with the placed department(s). With respect to the closeness priorities A>E>I>O>U

If ties exist during this process, TCR values are utilized to break the ties arbitrarily. \( TCR_5 = 11,000 > TCR_4 = 10,100 \)

5 is selected as the next to be placed
Example 5.2 (solution) 1st stage

With respect to the closeness priorities A>E>I>O>U

Placed Dept.

<table>
<thead>
<tr>
<th></th>
<th>Offices</th>
<th>Foreman</th>
<th>Conference room</th>
<th>Receiving</th>
<th>Parts shipment</th>
<th>General storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O</td>
<td>E</td>
<td>U</td>
<td>I</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>2</td>
<td>I</td>
<td>I</td>
<td>E</td>
<td>E</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>3</td>
<td>I</td>
<td>I</td>
<td>E</td>
<td>U</td>
<td>I</td>
<td>U</td>
</tr>
<tr>
<td>4</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>I</td>
<td>U</td>
<td>I</td>
</tr>
<tr>
<td>5</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>

6 is selected as the next to be placed

Example 5.2 (solution) 1st stage

With respect to the closeness priorities A>E>I>O>U

Placed Dept.

<table>
<thead>
<tr>
<th></th>
<th>Offices</th>
<th>Foreman</th>
<th>Conference room</th>
<th>Receiving</th>
<th>Parts shipment</th>
<th>General storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O</td>
<td>E</td>
<td>U</td>
<td>I</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>2</td>
<td>I</td>
<td>I</td>
<td>E</td>
<td>I</td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>3</td>
<td>I</td>
<td>I</td>
<td>E</td>
<td>U</td>
<td>I</td>
<td>U</td>
</tr>
<tr>
<td>4</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>I</td>
<td>U</td>
<td>I</td>
</tr>
<tr>
<td>5</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>I</td>
<td>A</td>
</tr>
</tbody>
</table>

2 is selected as the next to be placed
Example 5.2 (solution) 1st stage

With respect to the closeness priorities A>E>I>O>U

Placement sequence: 6,5,4,2,3,1

3 is selected as the next to be placed

Example 5.2 (solution) 2nd stage

Fully adjacent

WPV1 = $1(10,000) = 10,000$

WPV2 = $0.5(10,000) = 5000$

Partially adjacent

WPV3 = $1(10,000) = 10,000$
WPV4 = $0.5(10,000) = 5000$
WPV5 = $1(10,000) = 10,000$
WPV6 = $0.5(10,000) = 5000$
WPV7 = $1(10,000) = 10,000$
WPV8 = $0.5(10,000) = 5000$
Example 5.2 (solution) 2nd stage

Placing Order

Next to be placed

WPV1 = 1(0) = 0
WPV2 = 0.5(0) = 0
WPV3 = 1(0)+0.5(10,000) = 5000
WPV4 = 0.5(0)+1(10,000) = 10,000
WPV5 = 0.5(10,000) = 5000
WPV6 = 1(10,000) = 10,000
WPV7 = 0.5(10,000) = 5000
WPV8 = 1(10,000)+0.5(0) = 10,000
WPV9 = 0.5(10,000)+1(0) = 5000
WPV10 = 0.5(0) = 0

A = 10,000 ; U = 0

E = 1000 ; I = 100
Example 5.2 (solution) 2nd stage

Placing Order

Next to be placed

WPV1 = 50
WPV2 = 100
WPV3 = 50
WPV4 = 100
WPV5 = 50
WPV6..12 = 0

I = 100; U = 0

Example 5.2 (solution) 2nd stage

Placing Order

Next to be placed

WPV1 = 1000
WPV2 = 500
WPV3 = 1005
WPV4 = 510
WPV5 = 5
WPV6..12 = 0
WPV13 = 1005
WPV14 = 500

E = 1000; O = 10; U = 0
Example 5.2 (solution) 2nd stage

Final relationship diagram of the layout

5 6
3 2 4
1

Layout Representation Format

- **Discrete**
  - The area of each department is rounded off to the nearest integer number of grids
  - A smaller grid size yields a finer resolution and gives more flexibility in department shapes but results in a larger number of grids which complicates computations

- **Continuous**
  - Does not use a grid
  - Smoother department shapes but more difficult to use
ALDEP – Automated Layout DEsign Program

- Construction algorithm
- Input requirements are as follows:
  - Relationship chart
  - Department areas
  - Sweep width
- Arbitrarily selects first department
- Allows fixed departments

Steps in ALDEP

- First department selected randomly
- Next department selected based on relationship with placed departments
  - If more than one with same relationship, choice is random
  - If no departments with minimally acceptable relationship exist, choice is random
- Place first department in the upper left corner and extend downward
- Additional departments begin where the previous one ended
- Sweep width < area of smallest department
  - Why?
ALDEP Example

<table>
<thead>
<tr>
<th>Dept. name</th>
<th>Area (m²)</th>
<th># of grids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>70</td>
<td>14</td>
</tr>
<tr>
<td>Foreman</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Conference room</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Receiving</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>Parts shipment</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>General storage</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

1 grid = 5 m²  
Sweep width = 3

ALDEP layout solution

Start laying out departments top-down and left to right, when you came to border continue laying out bottom-up and left to right...

# of grids

<table>
<thead>
<tr>
<th>Dept. name</th>
<th># of grids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>14</td>
</tr>
<tr>
<td>Foreman</td>
<td>4</td>
</tr>
<tr>
<td>Conference room</td>
<td>6</td>
</tr>
<tr>
<td>Receiving</td>
<td>8</td>
</tr>
<tr>
<td>Parts shipment</td>
<td>6</td>
</tr>
<tr>
<td>General storage</td>
<td>10</td>
</tr>
</tbody>
</table>
Suppose dept. 1 (offices) is selected first to be placed.

ALDEP layout solution

Dept. 3 (conf. room) is selected due to “E” rating with 1.
ALDEP layout solution
Dept. 2 (foreman) is selected due to “I” rating with 3

Dept. 5 (parts shipment) is selected due to “E” rating with 2
ALDEP layout solution
Dept. 6 (general storage) is selected due to “A” rating with 5

<table>
<thead>
<tr>
<th>1</th>
<th>1</th>
<th>1</th>
<th>6</th>
<th>6</th>
<th>6</th>
<th>6</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
</tbody>
</table>

# of grids
1 Offices 14
2 Foreman 4
3 Conference room 6
4 Receiving 8
5 Parts shipment 6
6 General storage 10

ALDEP layout solution
Dept. 4 (receiving) is selected due to “A” rating with 6

<table>
<thead>
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</tbody>
</table>
ALDEP final layout

Total score of the final layout is computed using the following values: “A= 64, E=16, I=4, O=1, U=0, X=-1024”, and only fully adjacent departments take points.

<table>
<thead>
<tr>
<th>Adjacent dept</th>
<th>Rating</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 3</td>
<td>E</td>
<td>16</td>
</tr>
<tr>
<td>2 – 3</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>2 – 5</td>
<td>E</td>
<td>16</td>
</tr>
<tr>
<td>5 – 6</td>
<td>A</td>
<td>64</td>
</tr>
<tr>
<td>4 – 6</td>
<td>A</td>
<td>64</td>
</tr>
</tbody>
</table>

Total score = 164

CRAFT-(Computerized Relative Allocation of Facilities Technique)

- First computer-aided layout algorithm (1963)
- The input data is represented in the form of a From-To chart, or qualitative data.
- The main objective behind CRAFT is to minimize total transportation cost:

\[
\min z = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij} c_{ij} d_{ij}
\]

- \( f_{ij} \) = material flow between departments \( i \) and \( j \)
- \( c_{ij} \) = unit cost to move materials between departments \( i \) and \( j \)
- \( d_{ij} \) = rectilinear distance between departments \( i \) and \( j \)

- Improvement-type layout algorithm
Steps in CRAFT

- Calculate centroid of each department and rectilinear distance between pairs of departments centroids (stored in a distance matrix).
- Find the cost of the initial layout by multiplying the
  - From-To (flow) chart,
  - Unit cost matrix, and
  - From-To (distance) matrix
- Improve the layout by performing all-possible two or three-way exchanges
  - At each iteration, CRAFT selects the interchange that results in the maximum reduction in transportation costs
  - These interchanges are continued until no further reduction is possible

Example (Craft)

Initial layout

\[
d(A, C) = |15 - 5| + |5 - 15| = 20 \text{ distance-units}
\]

Total movement cost = \((20 \times 15) + (20 \times 10) + (40 \times 50) + (20 \times 20) + (20 \times 5) + (20 \times 10) = 3200\)
The possible interchanges for the initial layout are:

A ↔ B, A ↔ C, A ↔ D, B ↔ C, B ↔ D, C ↔ D

The movement cost for the initial layout is:

\[
\text{Movement Cost} = (20 \times 15) + (30 \times 10) + (10 \times 50) \\
+ (10 \times 20) + (30 \times 5) + (20 \times 10) = 1650
\]

The reduction in movement cost is:

\[
\text{The reduction in movement cost} = 3200 - 1650 = 1550
\]
A_CFG interchanging

\[ g_y_C = \frac{(100)15 + (200)5}{300} = 8.33 \]
\[ g_x_C = \frac{(100)5 + (200)10}{300} = 8.33 \]

Movement Cost = \((10 \times 15) + (20 \times 10) + (10 \times 50) + (23.34 \times 20) + (20 \times 5) + (30 \times 10) = 1716.8\]

The reduction in movement cost = \(3200 - 1716.8 = 1483.2\)

Other interchanges and savings

A_CFG D savings: 0

B_CFG C savings: 0

B_CFG D savings: 1383.2

C_CFG D savings: 1550
Current layout after $A \leftrightarrow B$ interchange

With this layout new pair wise interchanges are attempted as follows:

- $A \leftrightarrow D$, $B \leftrightarrow C$, $C \leftrightarrow D$
- $A \leftrightarrow B$ not considered since it will result no savings
- $A \leftrightarrow C$ not considered since they don’t have common borders
- $B \leftrightarrow D$ not considered since they don’t have common borders

Interchanges and savings

So, the current layout is the best layout that CRAFT can find.
CRAFT Facts

- CRAFT only exchanges departments that are
  - Adjacent (share at least one common edge)
  - Have equal areas
- Adjacency is a necessary but not sufficient criteria for swapping departments
- Quality of final solution depends on the initial layout
- Final solution may be locally optimal, not globally optimal