References

3. Dr-Ing. Daniel Kitaw, Industrial Management and Engineering Economy
The generation of layout alternatives is a critical step in the facilities planning process, since the layout selected will serve to establish the physical relationships between activities.
• Which comes first, the material handling system or the facility layout?
  
  ➢ Centralized versus decentralized storage of work in process (WIP), tooling, and supplies
  
  ➢ Fixed path versus variable path handling
  
  ➢ The degree of automation used in handling
  
  ➢ The type of level of inventory control, physical control, and computer control of materials.
Layout procedures

• A number of different procedures have been developed to aid the facilities planner in designing layouts.
  ➢ Construction type
  ➢ Improvement type
Apples plant layout procedure

- Procure the basic data
- Analyze the basic data
- Design the productive process
- Plan the material flow pattern
- Consider the general material handling plan
- Calculate equipment requirement
- Plan individual workstations
- Select specific material handling equipment
- Coordinate groups of related operations
- Design activity interrelationships

- Determine storage requirements
- Plan service and auxiliary activities
- Determine space requirements
- Allocate activities to total space
- Consider building type
- Construct master layout
- Evaluate, adjust, and check the layout with appropriate persons
- Obtain approvals
- Install the layout
- Follow up on implementation of the layout.
Reeds plant layout procedure

- Analyze the product or products to be produced
- Determine the process required to manufacture the product
- Prepare layout planning charts
- Determine workstations
- Analyze storage area requirements
- Establish minimum aisle widths
- Establish office requirement
- Consider personnel facilities and services
- Survey plant services
- Provide for future expansion
Layout planning chart is the most important single phase of the entire layout process, it incorporates the following:

- Flow process, including operations, transportation, storage, and inspection
- Standard time for each operation
- Machine selection and balance
- Material handling equipment
## Gulele garment factory process chart

### Part description: material preparation

#### Operation description

<table>
<thead>
<tr>
<th>Summary</th>
<th>Present</th>
<th>Time (sec)</th>
<th>Proposed</th>
<th>Time (sec)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td>5</td>
<td>270</td>
<td>5</td>
<td>270</td>
<td>0</td>
</tr>
<tr>
<td>Transport</td>
<td>3</td>
<td>197</td>
<td>3</td>
<td>72</td>
<td>3</td>
</tr>
<tr>
<td>Inspection</td>
<td>1</td>
<td>87</td>
<td>1</td>
<td>87</td>
<td>1</td>
</tr>
<tr>
<td>Delays</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Storages</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

### Layout planning chart

<table>
<thead>
<tr>
<th>Step</th>
<th>Details of present methods</th>
<th>Method</th>
<th>Operation</th>
<th>Transport</th>
<th>Inspection</th>
<th>Delays</th>
<th>Storages</th>
<th>Dist(m)</th>
<th>Qty.</th>
<th>Time (sec)</th>
<th>Cost/unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Materials in store</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Transport to temporary storage</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Pattern making</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Laid on tracing tables and cutting tables</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Tracing</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cutting</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Transported to checking and making point</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Checking</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Marking</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Transport to other workstations</td>
<td>Manual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>
Systematic Layout Planning (SLP) procedure

• Systematic Layout Planning (SLP) methodology was developed by Richard Muther.

• The framework is uses activity relationship diagram as a foundation activity.
• Based on the input data and an understanding of the roles and relationships between activities, a material flow analysis (from-to-chart) and an activity relationship analysis (activity relationship chart) are performed.

• From the analysis performed, a relationship diagram is developed.
• The relationship diagram positions activities spatially.

• Proximities are typically used to reflect the relationship between pairs of activities.
Cont'd

Relationship diagram

Space relationship diagram

Alternative block layouts
Algorithmic approaches

- Algorithmic approach is a formal procedure that can help the layout analyst to develop or improve a layout, and it provide objective criteria to facilitate the evaluation of various layout alternatives that emerge in the process.
Algorithm classification

- Most layout algorithms can be classified according to the type of input data they require.
  - Qualitative flow data (such as relationship chart)
  - Quantitative flow data (such as flow matrix expressed as a from-to-chart)
  - Some algorithms accept both relationship chart and from-to-chart
• Layout algorithms can also be classified according to their objective functions.

  ➢ Minimizing the sum of flows times distances

  ➢ Maximizing an adjacency score
• Distance based objective

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

- \( m \) = the number of departments
- \( f_{ij} \) = the flow from department \( i \) to department \( j \) (unit load/unit time)
- \( c_{ij} \) = the cost of moving a unit load one distance unit from department \( i \) to \( j \)
- \( d_{ij} \) = the distance from department \( i \) to \( j \)
• Adjacency based objective

\[
\max z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij}x_{ij}
\]

\[m = \text{the number of departments}\]
\[f_{ij} = \text{the flow from department } i \text{ to department } j (\text{unit load/unit time})\]
\[x_{ij} = \text{the adjacent of department } i \text{ and } j \text{ in the layout}\]

• The adjacency score is helpful in comparing two or more alternative layouts
• According to the primary functions layout algorithms can be classified as:

  - **Improvement type:** start with an initial layout and seek to improve the objective function through incremental change.

  - **Construction type:** develop a layout from scratch
Modeling techniques/methods

- The overall modeling techniques and/or methods used in various layout algorithms:
  - Pairwise exchange method
  - A graph based method
  - CRAFT
  - BLOCPLAN
  - MIP
  - LOGIC
  - MULTIPLE
Graph-based method

- The graph-based method is a construction-type layout algorithm.
- Uses the adjacency based objective.
Graph-based method—Considerations

- The adjacency score does not account for distance, nor does it account for relationships other than those between adjacent departments.
- Dimensional specifications of departments are not considered; the length of common boundaries between adjacent departments are also not considered.
- The arcs do not intersect; this property of graphs is called planarity.
- The score is very sensitive to the assignment of numerical weights in the relationship chart.
Graph-based method

- Consider a company want to develop layout for its new five departments of equal sizes.

![Relationship chart](image1)

![Relationship diagram](image2)
Graph-based method

Procedure

Step 1: from the relationship chart select a department pair with the largest weight.

- Departments 3 and 4 are selected to enter the graph.
Graph-based method

Procedure

Step 2: Select the third department to enter, the third department is selected based on the sum of the weights with respect to departments 3 and 4.

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>13</td>
<td>25(best)</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Department 2 is chosen with a value of 25.
Graph-based method

Procedure

Step 3: Pick the fourth department to enter by evaluating the value of adding one of the unassigned departments represented by a node on a face of the graph.

<table>
<thead>
<tr>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Department 1 is chosen with a value of 27.
Graph-based method

Procedure

Step 4: Determine on which face to insert the last department.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5</strong></td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Faces   Total

1-2-3   7
1-2-4   9(best)
1-3-4   2
2-3-4   9(best)
Graph-based method

Procedure

Step 5: Construct a corresponding block layout.
Computerized Relative Allocation of Facility Technique (CRAFT)

- Introduced in 1963 by Armour, Buffa, and Vollman.
- CRAFT is a tool used to help improve the existing layout of the facilities.
- The facility is improved by switching two or three departments to help arrange the facility in an optimal floor plan.
Computerized Relative Allocation of Facility Technique (CRAFT)

- This procedure requires the following inputs:
  - From-To Chart,
  - Cost Matrix,
  - Distances (determined for a given layout) and an Initial layout.
- **Craft is used when the number of departments is so large that the computation by hand would be very intensive and make the improvement not worth the time for many companies.**
Computerized Relative Allocation of Facility Technique (CRAFT)

- The major features of CRAFT are:
  - Attempts to minimize transportation cost,
    \[ \text{Transportation cost} = \text{flow} \times \text{distance} \times \text{unit cost} \]
  - CRAFT is a path-oriented method, the final layout is dependent on the initial layout.
  - Requires an assumption that:
    1. Move costs are independent of the equipment utilization and
    2. Move costs are linearly related to the length of the move
Computerized Relative Allocation of Facility Technique (CRAFT)

- **CRAFT requirements:**
  - Initial layout
  - Flow data
  - Cost per unit distance
  - Total number of departments
  - Fixed departments and their location
  - Area of departments
Computerized Relative Allocation of Facility Technique (CRAFT)

- The procedures adopted for using CRAFT are:
  - Determine department centroids.
  - Calculate rectilinear distance between centroids.
  - Calculate transportation cost for the layout.
  - Consider department exchanges of either equal area departments or of departments sharing a common border.

4 - 32
Computerized Relative Allocation of Facility Technique (CRAFT)

- Determine transportation cost of each departmental interchange.
- Select and implement the departmental interchange that offers the greatest reduction in transportation cost.
- Repeat the procedure for the new layout until no interchange is able to reduce the transportation cost.
**Computerized Relative Allocation of Facility Technique (CRAFT)**

- **Major disadvantages of using CRAFT**
  - Because the basis is the cost of material handling, only production departments are considered. No service departments are considered.
  - An initial idea of the layout is required. Therefore the technique is only applies to the modification of an existing layout.
  - The distances between the departments is taken as straight lines whereas in practice movement is usually rectangular along orthogonal lines.
Example: consider the following layout problem with unit cost matrix. Use Craft algorithm to obtain layout. The initial layout and the flow matrix is shown below:

**Initial layout**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

**Flow matrix**

<table>
<thead>
<tr>
<th>Department</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>30</td>
<td>25</td>
<td>45</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td></td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>20</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>D</td>
<td>100</td>
<td>10</td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>
**Computerized RELationship LAYOUT Planning (CORELAP)**

- Developed for main frame computers
- Adjacency-based method
  - CORELAP uses $A=4$, $E=3$, $I=2$, $O=1$, $U=0$ and $X=-1$ values
- Selection of the departments to enter the layout is based on Total Closeness Rating.
- **Total Closeness Rating (TCR)** for a department is the sum of the numerical values assigned to the closeness relationships between the department and all other departments.

$$TCR = \sum_{j=1, i \neq j}^{n} w_{ij}$$
Department selection

1. The first department placed in the layout is the one with the greatest TCR value. If there is a tie, then choose the one with more A’s (E’s, etc.).

2. If a department has an X relationship with the first one, it is placed last in the layout. If a tie exists, choose the one with the smallest TCR value.

3. The second department is the one with an A relationship with the first one (or E, I, etc.). If a tie exists, choose the one with the greatest TCR value.
4. If a department has an X relationship with the second one, it is placed next-to-the-last or last in the layout. If a tie exists, choose the one with the smallest TCR value.

5. The third department is the one with most A (E, I, etc.) relationships with the already placed departments. If a tie exists, choose the one with the greatest TCR value.

6. The procedure continues until all departments have been placed.
Department placement

- Placing rating (PR) is the sum of the weighted closeness ratings between the department to enter the layout and its neighbors.

\[ PR = \sum_{k}^{n} w_{ik} \], where \( k \)-{departments already placed}
Computerized RELationship LAYOUT Planning (CORELAP)

• The placement of departments is based on the following steps:

  1. The first department selected is placed in the middle.

  2. The placement of a department is determined by evaluating PR for all possible locations around the current layout in counterclockwise order beginning at the “western edge”.

  3. The new department is located based on the greatest PR value.
Example

Given the relationship chart and the departmental dimensions below determine the sequence of the placement of the departments in the layout based on the CORELAP algorithm. Place the departments in the layout while evaluating each placement.

<table>
<thead>
<tr>
<th>Department Sizes</th>
<th>Sq.ft.</th>
<th>Num of Grids</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conf Room</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>2. President</td>
<td>200</td>
<td>4</td>
</tr>
<tr>
<td>3. Sales</td>
<td>300</td>
<td>6</td>
</tr>
<tr>
<td>4. Personnel</td>
<td>500</td>
<td>10</td>
</tr>
<tr>
<td>5. Plant Mng.</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>6. Plant Eng</td>
<td>500</td>
<td>10</td>
</tr>
<tr>
<td>7. P. Supervisor</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>8. Controller Office</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>9. Purchasing Dept</td>
<td>300</td>
<td>6</td>
</tr>
</tbody>
</table>
Table of TCR Values

<table>
<thead>
<tr>
<th>Dept.</th>
<th>Department relationships</th>
<th>Summary</th>
<th>TCR</th>
<th>Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>- I I U O U U U U</td>
<td>0 0 2 1 5 0</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>I - O U O U U U O</td>
<td>0 0 1 3 4 0</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>I O - U I O O E U</td>
<td>0 1 2 3 2 0</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>U U U - O O O O O</td>
<td>0 0 5 3 0</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>O O I O - A A O O</td>
<td>2 0 1 5 0 0</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>U U O O A - I O E</td>
<td>1 1 1 3 2 0</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>U U O O A I - U O</td>
<td>1 0 1 3 3 0</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>U U E O O O U I</td>
<td>0 1 1 3 3 0</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>U O U O O E O I -</td>
<td>0 1 1 4 2 0</td>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>

The placement sequence: 5-6-7-9-3-8-1-2-4
A=4, E=3, I=2, O=1, U=0, X=-1

Both options gives the same PR Score

\[ PR = A_{[5,7]} + I_{[6,7]} \]

\[ = 4 + 2 = 6 \]

If the location for the department 7 is chosen as shown, the PR would be

\[ PR = A_{[5,7]} = 4 \]

The placement sequence: 5-6-7-9-3-8-1-2-4
A=4, E=3, I=2, O=1, U=0, X=-1

\[ PR = E_{[6,9]} = 3 \]

\[ PR = E_{[6,9]} + O_{[5,9]} = 3 + 1 = 4 \]

The placement sequence: 5-6-7-9-3-8-1-2-4
A=4, E=3, I=2, O=1, U=0, X=-1

PR = \|_{3,5} + O_{[3,7]} + U_{3,9} = 2 + 1 + 0 = 3

PR = + E_{[3,8]} + I_{[8,9]} = 3 + 2 = 5

The placement sequence: 5-6-7-9-3-8-1-2-4
A = 4, E = 3, I = 2, O = 1, U = 0, X = -1

\[ PR = I_{[1,3]} + U (1,7) = 2 + 0 = 2 \]

\[ TCR - I_{[1,2]} \downarrow I_{[2,3]} = 2 \uparrow 2 - 4 \]

Continue with Department 4.

The placement sequence: 5-6-7-9-3-8-1-2-4
ALDEP — Automated Layout Design Program

• Similar to CORELAP (objectives, requirements)
• The main differences:
  ◦ Randomness
  ◦ Multi-floor capability
  ◦ CORELAP attempts to produce the best layout, ALDEP produces many layouts
ALDEP - Procedure

• Department selection
  o *Randomly selects the first department*
  o Out of those departments which have “A” relationship with the first one (or “E”, “I”, etc. - min level of importance is determined by the user) it selects *randomly the second department*.
  o If no such department exists it selects the second one completely *randomly*
  o The selection procedure is repeated until all the departments are selected
Department placement

- Starts from upper left corner and extends it downward
- *Vertical sweep pattern*
- *Sweep width is determined by the user*

Adjacency-based evaluation

- If minimum requirements met, it prints out the layout and the scores
- Repeats the procedure (max 20 layouts per run)
- User evaluation
ALDEP Example

Use ALDEP procedure to determine the layout vector, construct and evaluate the layout for the facility based on the relationship chart and the departmental dimensions given below. Use the sweep width of 2 and the minimum acceptable level of importance “E”. The closeness values: \( A=64, \ E=16, \ I=4, \ O=1, \ U=0, \ X=-1024 \)

<table>
<thead>
<tr>
<th>Dept.</th>
<th>Area</th>
<th># of unit area templates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12,000</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>8000</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>6000</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>12,000</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>8000</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>12,000</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>12,000</td>
<td>30</td>
</tr>
</tbody>
</table>
ALDEP Example

• Department selection

<table>
<thead>
<tr>
<th>Step</th>
<th>Department selected</th>
<th>Reason for selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>random</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>&quot;E&quot; with 4</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>&quot;E&quot; with 2</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>random</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>&quot;A&quot; with 6</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>random</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>remaining</td>
</tr>
</tbody>
</table>

• Layout vector
  - 4-2-1-6-5-7-3
ALDEP Example

• Layout construction
  ◦ Layout vector: 4-2-1-6-5-7-3
  ◦ Sweep width: 2

• Final layout