Computerized Layout Planning

- Focus on how computers can aid the facility layout process.
  - Designer must interact with multiple design databases and provide the integration between them to translate information and ensure consistency.
  - We will concentrate on decision aids for block layout planning.
    - Information required
    - Common elements
    - “Classical” layout programs
      - Craft, Corelap, Aldep, and Planet
    - “Newer” layout programs
      - M-Craft, LayOpt, FactoryPlan

- Information in layout planning
  - Numeric information
    - Space required for an activity
    - Total flow between two activities
  - Logic information
    - Preferences of the designer, i.e., activity relationship chart
  - Graphical information
    - Drawing of the block plan
  - Key element of computerized layout planning is the representation and manipulation of these three types of information.
    - Graphical representation is most challenging. A method suitable for display is not suitable for manipulation and vice-versa.

Computerized Layout Planning

- Graphical Representation
  - “Points and lines” representation is not convenient for analysis

Computerized Layout Planning

- Graphical Representation (cont.)
  - Unit Square Area approximation can also be represented by a two dimensional array or matrix of numbers
    - Easy to manipulate (e.g., determine adjacency) but difficult to visually interpret

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Computerized Layout Planning

- Layout Evaluation
  - Algorithm needs to distinguish between “good” layouts and “bad” ones
  - Develop scoring model, \( s = g(X) \)
    - Adjacency-based scoring
      - Based on the relationship chart and diagram
        - Space available and space required for each activity are expressed as an integer multiple of the unit area.

  - Aldep uses \( A=64, E=16, I=4, O=1, U=0, \) and \( X=-1024 \)
  - Scoring model has intuitive appeal; the ranking of layouts is sensitive to the weight values. Layout “B” may be preferred to “C” with certain weights but not with others.
  - Therefore, correct specification of the weights is very important – but how do you do that?
Computerized Layout Planning

• Layout Evaluation (cont.)
  - Distance-based scoring
    » Approximate the cost of flow between activities
    » Requires explicit evaluation of the flow volumes and costs
      \[ s = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} \phi_{ij} \]
    » \( c_{ij} \) covers both the \( i \) to \( j \) and \( j \) to \( i \) material flows
    » \( \phi_{ij} \) can be determined with any appropriate distance metric
    » Often the rectilinear distance between department centroids
    » Assumes that the material flow system has already been specified
    » Assumes that the variable flow cost is proportional to distance
    » Distance often depends on the aisle layout and material handling equipment

- Distance-weighted adjacency-based scoring
  » A smaller score is better
  » As before, the scoring model is sensitive to the adjacency class weights, \( w_{ij} \)

- More complex scoring methods
  » Could employ simulation to determine material handling equipment utilization, etc.
  » Would probably better reflect the preferences of the layout planner
  » Certainly more difficult to compute and could affect the number of alternatives considered

Computerized Layout Planning

• Layout Generation
  - Construction Algorithms
    » Start with basic SLP data and build a block layout by iteratively adding activities to a partial layout until all activities have been placed.
    - Improvement Algorithms
      » Require an initial block layout which they then attempt to improve.
Texas A&M Industrial Engineering
Computer-Aided Layout Techniques

- Computer-aided layout techniques are classified by:
  - Method of recording flows between departments
    - Quantitatively in a from-to chart
    - Qualitatively in a relationship chart
  - Method of generating layouts
    - Construction of a layout
    - Improvement of an existing layout

| Quantitative Input | PLANET | CRAFT
|--------------------|--------|-------
| Improvement Routine | CORELAP | COFAD |

<table>
<thead>
<tr>
<th>Qualitative Input</th>
<th>ALDEP</th>
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CRAFT

- Attempts to minimize transportation cost, where
  Transportation cost = flow * distance * unit cost
- Requires the assumptions that:
  - Move costs are independent of the equipment utilization.
  - Move costs are linearly related to the length of the move.
- Distance metric used is the rectilinear distance between department centroids.

CRAFT Example

- CRAFT is a path-oriented method so the final layout is dependent on the initial layout.
- Therefore, a number of different initial layouts should be used as input to the CRAFT procedure.
- CRAFT allows the use of dummy departments to represent fixed areas in the layout.

CRAFT Example

- Initial Layout

```plaintext
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
A A A A A A A A A A A A A A A A
C C C C C C C C C C C C C C C C
D D D D D D D D D D D D D D D D
E E E E E E E E E E E E E E E E
F F F F F F F F F F F F F F F F
G G G G G G G G G G G G G G G G
H H H H H H H H H H H H H H H H
```

- Dummy Department

- Shipping Department

- Initial Layout
INEN 416 Facility Location, Layout, and Material Handling

**CRAFT Example**

- **Distance Matrix**
  
- **Cost Matrix**

**CRAFT Example**

- **Trial Distance Matrix**
  
- **Trial Cost Matrix**

**CRAFT Example**

- **New Layout**
  
- **Final Layout**

**COFAD**

- A modification of CRAFT to allow for a variety of material handling equipment alternatives.
- It attempts to select both the layout and the material handling system.
- A special version, COFAD-F, allows the evaluation of varying the product volumes and mixes to analyze the flexibility of the design.

**PLANET**

- PLANET is a construction routine with the same basic input requirements as CRAFT.
- Material Flow Input Methods
  - Specify a route or production sequence for each part.
  - From-to Chart.
  - Penalty Matrix -- quantitative representation of a relationship chart.
- Construction Algorithm Selection Methods
  - Choose based on individual flow-between costs.
  - Choose based on the sum of the flow-between costs with previously placed departments.
  - Choose based on the sum of the flow-between costs with all other departments.

**CORELAP**

- Constructs a layout for a facility by calculating the total closeness rating (TCR) for each department.
- The total closeness rating is the sum of numerical values assigned to the closeness relationships from the relationship chart.
  - \(A = 6, E = 5, I = 4, O = 3, U = 2, X = 1\)
- Procedure (similar to one of the procedures for relationship diagramming)
  - Place department with the highest TCR in the center of the layout.
  - Scan the relationship chart for a department with an A (if none, then E, I, and so on) relationship with the selected department. Highest TCR is tie-breaker.
  - Continue until all departments are in the layout.
• Same basic input requirements and objectives as CORELAP.
• Selection Procedure
  – Randomly select first department in the layout.
  – Scan the relationship chart for an A (then E, etc.) relationship with the selected department. Break ties randomly.
  – Repeat procedure until all departments are selected.
• Placement Procedure
  – Place first department in upper left corner and extend it downward. Width of the extension is determined by the sweep width.
  – Next department begins where the previous department ended and follows the serpentine sweep pattern.

ALDEP Example
• Layout Construction

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• Scoring Procedure

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<td>7-3 and 3-7</td>
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Total: 240

Spiral
• Graph based algorithm which attempts to create a structured adjacency graph.
  – The objective is to maximize the adjacency score.
  – The selection and location decisions are made simultaneously, using a greedy approach on a hexagonal grid.
• Procedure
  – Convert the flow matrix to a symmetric matrix.
  – Sort the pairwise relationships by decreasing value.
  – Place the first two departments in the layout.
  – Add the departments by order in the list from step 2, such that the adjacency with already placed departments is maximized. Use a random tie breaker.
Spiral Example

- Sorted Flow List

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- Graph Construction

1. 2. 7
2. 1. 2. 7
3. 5. 6. 3. 4. 5. 6

- Graph Evaluation

- Adjacency Matrix × Symmetrical Flow Matrix

- Score is 385
- Maximum score is 435
- Efficiency is 385/435 = 88%

- Alternative Adjacency Graph

- Score is 405
- Efficiency is 93%

Spiral

- Creating a Layout

- Can use a sweep pattern similar to ALDEP to sweep through the adjacency graph and create a block layout

Excel Layout Tool

- Uses CRAFT-type flow*distance objective
- Layout is specified by a department sequence
- User-specified and random sequences can be used
- ALDEP placement procedure based on a vertical sweep pattern is used to place departments in layout
- Sweep width parameter can be changed
- Grid size and facility shape can also be adjusted
- Pairwise exchange is performed on the sequence position of departments
  - Not restricted to adjacent or equal size departments
  - Due to using the sweep method to create a layout
- Additional add-ins to generate and improve sequences are available
- Software also solves “traditional CRAFT”
M-Craft

- Layout is specified by a sequence of departments
- Horizontal sweep patterns are used to place departments in layout
  - Number of bays controls sweep width
- Pairwise exchange is performed on the sequence position of departments
  - Not restricted to adjacent or equal size departments
    - Due to using the sweep method to create a layout

MULTIPLE / LayOpt

- Layout is specified by a sequence of departments
- Sweep patterns are used to place departments in layout
  - Sweep pattern is based on space filling curve (SFC) concept
  - Many alternative SFCs can be created
- Pairwise exchange is performed on the sequence position of departments
  - Not restricted to adjacent or equal size departments
    - Due to using the sweep method to create a layout

Factory CAD/Flow/Plan

- AutoCAD based add-on
- Has multiple applications
  - CAD: drawing templates
  - FLOW: evaluation of material flow; manual SLP-type manipulation
  - PLAN: layout alternative generation
- FactoryPLAN
  - Uses Spiral-type algorithm to generate alternative layout options

Computerized Layout Planning

Conclusion

- Does not provide an absolute best model for finding the optimal layout.
- Does provide algorithms for evaluating a large number of alternative layouts.
- It is important to understand the underlying assumptions and scoring models of each procedure in order to correctly interpret the results.