Garment Production Management

Week 5 Quantitative approaches to layout analysis

Lecturer: ***Dr. Shalemu Sharew (Associate Prof.)***

Bahir Dar University
Bahir Dar, Ethiopia

Recap-previous week

- Process selection and capacity planning
- Plant layout and facility design
- Layout planning concepts
- Types of layouts

Lecture learning outcomes

1. Identify various quantitative layout analysis techniques
2. Analyze performance of layouts
3. Understand computer aided layout planning techniques
4. Compare effectiveness of various quantitative techniques

Session outline

- Quantitative approaches to layout analysis
- Tools and techniques used in layout analysis
- Computer aided layout planning
- Quantitative layout analysis and evaluation techniques

Quantitative layout analysis

- Process of using mathematical models and numerical data to evaluate and optimize the physical arrangement of departments, workstations, or equipment
- Mathematical and statistical methods used to evaluate and improve efficiency of production layouts
- Minimize measurable metrics (transportation and material handling costs)
- Helps to identify bottlenecks, optimize material flow and enhance overall productivity
- Qualitative layout analysis focus on closeness ratings

Quantitative layout analysis

Facility layout planning

- Systematic layout planning (SLP) is a classic qualitative method [1]
  - Uses relationship charts to arrange departments by desired proximity
  - Provide an initial layout based on qualitative workflow relationships before quantitative optimization
- Depends on heuristic algorithms that iteratively construct or improve layouts
- Inter-department relationship data is used

Quantitative layout analysis

Mathematical techniques

- Load-Distance (LD) method: Calculates the score of a layout by multiplying the load (number of trips or volume) by the distance traveled
    - LD=load (number of trips*distance travelled)
- Travel chart (Cross chart): A matrix that records the number of movements (or costs) between various departments
- Center of gravity method: Locate a new department or facility to find the coordinates (x,y) to minimize weighted distance to all existing connection points
- Linear programming: allocate limited resources to reach an optimal output with constraints

Mathematical models and algorithms

- Optimize travel distance and costs (find local or global minimums) using algorithms
- Algorithms commonly used in garment production layout analysis are:

1. Automated Layout Design Program (ALDEP)- Construction type
2. Computerized Relationship Layout Planning (CORELAP)- Construction type
3. Computerized Relative Allocation of Facilities Technique (CRAFT)- Improvement type
4. Computer-Aided Layout Planning (CALP)- Construction and improvement
5. Block Layout Overview with Computerized Planning (BLOCPLAN)- Block layout
   - Minimize (material flow *distance) between centroid of the departments
   - Improvement from ALDEP and CORELAP
   - It is a software tool focusing on block layout not detail workstation

Automated layout design program (ALDEP)

- A construction-type algorithm
- Qualitative approach (REL-Chart)
- Starts with an empty layout and adds departments one by one
- Uses a random selection process to pick the first department and then places subsequent departments based on their Relationship Chart (REL-Chart) scores
- Generate many different layout alternatives quickly, especially when there are no predefined locations
- Application in garment industry:
  - Relationship is less critical than flow quantity
  - Sewing must be next to cutting; finishing next to sewing
  - Does not consider material flow volume (pieces/hour)

Computerized relationship layout planning (CORELAP)

- A construction-type algorithm
- More systematic than ALDEP
- Calculates a Total Closeness Rating (TCR) for each department
- Department with the highest TCR is placed in the center
- Others are added around it based on their relationship significance.
- Focuses on qualitative data (how important it is for Department A to be near Department B) rather than floor space or flow costs
- Used for preliminary block layout of major sections in a garment factory (e.g., cutting room next to fabric store).

Computerized relationship layout planning (CORELAP)

Implementation steps

Data collection:

- Gather information on workstations, material flow, and interactions

Relationship identification:

- Assign prioritization to workstation adjacency based on material flow frequency

Computer model generation:

- Integrate collected data into a simulation model
- Generate various layout configurations

Computerized relationship layout planning (CORELAP)

Implementation steps

Simulation and evaluation:

- Simulate different layouts and assess efficiency on material handling and workflow metrics

Optimal Layout Selection:

- Choose the most efficient configuration based on simulation results and cost-effectiveness

Implementation and monitoring:

- Deploy the new layout
- Continuously monitoring performance to make necessary adjustments

Computerized related allocation of facilities technique (CRAFT)

- An improvement-type algorithm and most popularly used
- Requires an initial starting layout
- Calculates the transportation costs (Load *Distance) and attempts to swap adjacent departments to see if the total cost decreases
- Quantitative approach (flow matrix)
- Focuses on minimizing the total material handling cost
- Unlike construction algorithms, rearrange the layout until no further cost reduction can be found (reaching a local optimum)
- Improves existing layout by **exchanging departments** to reduce material handling cost (distance × flow)

Computerized related allocation of facilities technique (CRAFT)

- Garment industry has high flow volume between operations
  - (e.g., Cutting → Sewing → trimming/finishing → Inspection/Quality → Ironning/pressing → packing)
- Minimizes travel distance and works best when flow pattern is known
- In garment lines, balanced flow is important
- Helps rearrange sewing machine groups to reduce backtracking
- Assumes rectangular departments & fixed shapes but sewing lines are often U-shaped or straight
- But with multiple runs, CRAFT still improves over manual layout
- Useful for large-scale, repetitive garment production (e.g., T-shirts, jeans)

CRAFT algorithms

- Reduce transport distances and costs in real factories
- Minimize total traveling cost of the layout by:
  - TC$= min \sum_{i=1}^{n} \sum_{j=1}^{n} D_{ij} W_{ij} C_{ij}(x)$
  - W_{ij} = The inter-departmental traffic from department i to j (flow matrix)
  - D_{ij} = The distance from department i to j
  - C_{ij} = The handling cost between department i and j

Inputs for CRAFT algorithms

The main inputs to CRAFT algorithm are:

- Number of departments (n)
- Existing or initial layout of the department (e.g. AutoCAD diagram)
- Cost matrix (C_{ij})-handling cost between departments
- Flow matrix (W_{ij}) between departments

Steps in CRAFT algorithms

The main steps in CRAFT algorithm

1. Initial layout identification:

- Map the current layout of machines and workstations

2. Transportation cost calculation:

- Determine distance-based transportation costs for material flow between workstations

***3.* Optimization model construction:**

- Optimize layout by a mathematical model using:
    - Linear and Integer programming

Steps in CRAFT algorithms

The main steps in CRAFT algorithm

4. Evaluation of initial layout:

- Analyze workflow efficiency
- Transportation cost metrics to identify inefficiencies

***5.* Layout adjustment alternatives:**

- Suggest modifications (relocate machines & reconfigure workstation layouts)

***6.* Iteration and optimization:**

- Repeat the process until no further cost reductions
- Workflow improvements possible

Computer Aided layout planning (CALP)

- Modern and integrated (qualitative and quantitative) approach
- Combines features of both construction and improvement algorithms
- Uses interactive graphics to allow a designer to manually adjust layouts while the computer calculates the efficiency metrics in real-time
- Bridges the gap between manual drafting and pure algorithmic generation
- Incorporate 3D modeling and constraints like fixed walls or heavy machinery locations

Block Layout Overview with Computerized Planning (BLOCPLAN)

- Decision-support system for industrial engineers
- Simplify the complex task of arranging departments within a fixed rectangular space

Block Layout:

- Treats departments as "blocks" of space not individual machines
- Focuses on high-level arrangement of the facilities

Overview:

- Provides a macro-view of the floor plan
- Allows to see interaction of different zones (like production, shipping, and administration)

Computerized Planning:

- Uses algorithms to automate the trial-and-error process
- Generating dozens of possible layouts in seconds using **REL-Chart** or **Travel Chart** data

Block Layout Overview with Computerized Planning (BLOCPLAN)

BLOCPLAN algorithm steps

1. **Initialization**: start by initializing the layout with a random or user-defined configuration
2. **Evaluation**: evaluate the current layout performance minimizing material handling costs
3. **Improvement**: apply a series of improvement procedures to generate new layouts
4. **Selection**: Select best layout by evaluating results & repeats 3 & 4 until a stopping criterion is met.

Minimize the product of material flow and distance between centroid of the departments

- C= $min \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij} d_{ij}(x)$
- f_{ij} = the material flow between departments i and j, and
- d_{ij} =represents the distance between the centroids of departments i and j

Block Layout Overview with Computerized Planning (BLOCPLAN)

Performance depends on:

Problem size:

- Number of departments
- Complexity of the material flow matrix

Area of the department:

- The size and shape of departments affect feasibility and optimality of layout

Material flow:

- The accuracy and completeness of the material flow data can significantly impact the algorithm's ability to generate optimal layouts

Layout planning techniques

Algorithm	Advantage	Disadvantage
BLOCPLAN	Efficient in handling large problems, flexible in accommodating various objective functions	Computationally intensive/slow, requires careful tuning of parameters
CORELAP	Easy to implement, effective in handling small to medium-sized problems, efficient placement of workstations through adjacency-based optimization	Limited in handling large problems, relies heavily on user input
ALDEP	Fast and efficient, effective in handling simple layout problems	Limited in handling complex problems, lacks flexibility for various objective functions
CRAFT	Refine existing facility layouts through iterative improvements	Dependent on existing layout; low computational speed
CALP	Handles style changes; graphic interaction for sewing lines	

Layout planning techniques for garment industry

Techniques	Type	Importance	Justifications
ALDEP	Construction	Limited	Good for relationships, ignores flow volume
CORELAP	Construction	Moderate	Good for major departments, too coarse for sewing lines
CRAFT	Improvement	High	Minimizes material handling cost; ideal for high-flow repetitive garment making
CALP	Construction + Improvement	Very high	Handles style changes; graphic interaction for sewing lines
BLOCPLAN	Block layout	Low–Moderate	Only for high-level zoning; not for detailed workstation layout

Multiple-Criteria Decision Analysis (MCDA)

- Traditional layout planning considers single objective (e.g.minimize distance * flow)
- Compare multiple layout alternatives based on conflicting goals like maximum production vs. minimum cost
- MCDA optimizes many criteria
- Powerful extension to traditional layout planning techniques
- Real-world layout decisions involve conflicting objectives not just minimizing material handling cost
- MCDA provide a structured way to compare alternative layouts across many criteria simultaneously

Criteria in MCDA

Criterion	Examples in garment industry
Material handling cost	Transportation of cut fabric to sewing
Space utilization	Aisles and machine density
Flexibility	Capability to changing styles (e.g., shirts → jackets)
Safety	Emergency exits, fire hazards, etc.
Employee morale and comfort	Ergonomic design (comfortable seats,lighting, ventilation and noise)
Expansion potential	Future machine additions
Work-in-process (WIP)	Buffer space between operations
Supervision ease	Line-of-sight across sewing floor

Multiple-Criteria Decision Analysis (MCDA)

Common MCDA techniques are [4]:

- Analytic Hierarchy Process (AHP)-Ranking of criteria
  - Break problem into hierarchy: Goal → Criteria → Sub-criteria → Alternatives (layouts)
  - Pairwise comparisons (e.g., material handling cost vs flexibility) which is more important?
  - Calculate weights and score each layout
  - Strongly suitable for garment industry
  - Garment layout involves subjective (hard to quantify) factors (e.g. workers comfort, ease of supervision)
  - Handles qualitative and quantitative criteria together

Multiple-Criteria Decision Analysis (MCDA)

Common MCDA techniques are:

- Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)
    - Identify ideal solution (best on all criteria) and worst solution (worst on all criteria)
    - Identify Choose layout closest to best and farthest from worst
- Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)
    - Applied for complex cases in garment industry
- Data Envelopment Analysis (DEA)
    - Requires many similar layout alternatives but garment layouts are often fewer
    - Better for comparing multiple factories, not multiple layouts

Multiple-Criteria Decision Analysis (MCDA)

Common MCDA techniques are:

- Simple Additive Weighting (SAW)
  - Very easy to explain to factory managers.
  - Requires careful normalization (e.g., handling cost vs. safety)
- Geographic Information Systems (GIS) analysis
  - Benchmark city layouts by deriving figures from spatial geographic characteristics
- Simulation & Regression:
  - Multiple linear regression to find correlations between layout parameters

Summary

- Quantitative and qualitative layout analysis techniques improve efficiency of the production layout
- Various computer aided layout planning methods and algorithms are used
- Multiple-Criteria Decision Analysis (MCDA) based models are better than conventional layout planning techniques
- MCDA techniques consider multiple criteria and develop optimized layout
- Some layout planning techniques focus on block layout for designing departments
- Others focus on detail layout at workstation level
- Convectional techniques (CRAFT or CALP) generate layout alternatives and MCDA (e.g. AHP + TOPSIS) to select the best overall layout

References

1. Nguyen, V. T., et al. (2026). Optimizing Factory Layout Through Systematic Layout Planning and Multi-Criteria Decision-Making Approaches: A Case Study at Textile Company. *Engineering Proceedings*, 128(1), 3.
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3. Hsiao, M. H. (2005). A Grouping Genetic Algorithm for the Assembly Line Design Problem of Sewing Lines in Garment Industry (Master's thesis). Chung Yuan Christian University.
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Thank You !

Contact email: shalemu14@gmail.com