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A LITERATURE REVIEW OF FACILITY PLANNING AND PLANT LAYOUTS

M. H. Kulkarni [*], S. G. Bhatwadekar, H. M. Thakur

[*] Asst. Prof., Department of Mechanical Engineering, KIT's College of Engineering, India
[*] Asso. Prof., Department of Production Engineering, KIT's College of Engineering, India
[*] Asst. Prof., Department of Production Engineering, KIT's College of Engineering, India

ABSTRACT

Facility planning is a broad area to work. Many activities are carried out in facility planning. In broader terms, the decisions regarding plant locations, plant design which consists of structural, layout and handling systems design. The brief review of selected literature in the area of facility layout problem, types and methodologies used to solve facility layout problems is presented in the article. In order to conduct further studies in the case of dynamics of facility layout problems and based on available gaps in the literature scope for further research is suggested. There is large scope for improvement for reduction in risks and accidents in industry by considering risk as objective for deciding location as usual objectives like costs and profits etc and also for developing new methodologies for large scale dynamic problems.

KEYWORDS: Facility planning, systematic layout planning (SLP), simulated annealing (SA), dynamic layout

INTRODUCTION

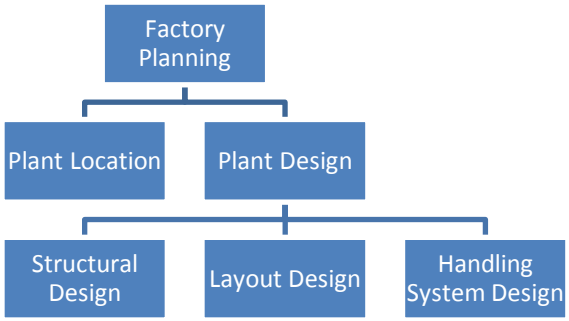
Facility layout means planning:
Placement of required facilities in specified area of plant is called as facility layout problem.

A facility layout is an arrangement of everything needed for production of goods or delivery of services. A facility is an entity that facilitates the performance of any job. It may be a machine tool, a work centre, a manufacturing cell, a machine shop, a department, a warehouse, etc. (Heragu, 1997).

Shayan and Chittilappilly (2004) defined the facility layout problem as an optimization problem that tries to make layouts more efficient by taking into account various interactions between facilities and material handling systems while designing layouts.

Azadivar and Wang (2000) defined that the facility layout problem as the determination of the relative locations for, and allocation of, the available space among a given number of facilities.

Hierarchy of Facility Planning:
Facility planning is a broad area to work. Many activities are carried out in facility planning; same is classified below:



Plant Location: Location is the placement of a facility with respect to customers, suppliers, and other facilities with which it interfaces. Decision regarding plant location is taken by considering various factors. Facility location is generally first step in facility planning.
Structure: Structure consists of the buildings and utilities (e.g., gas, water, power, heat, light, air, sewage).
Layout: Layout consists relative placements of all equipment, machinery, and furnishings within the structure.
Handling System: Handling System consists of the mechanism by which all interactions required by the

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layout are satisfied (e.g., materials, personnel, information, and equipment handling systems).

Need for layout decision:

- Inefficient operations:
  - High Cost
  - Bottlenecks
- Changes in the design of products or services
- The introduction of new products or services
- Changes in environmental or other legal requirements
- Changes in volume of output or mix of products
- Changes in methods and equipment
- Accidents
- Ambience

Inputs required for facility layout and plant design:

- Marketing: demand forecast → product mix → production rate → Capacity
- Aggregate Production Plan
- Mode of Production: continuous/intermittent
- Logistics: where to produce, how much
- Types and number of machines

Procedures for Facility Layout Design:

There are number of traditional facility layout design procedures-

- Naddler's Ideal System Approach (1961)
- Immer's Basic Steps (1950)
- Apple's Plant Layout Procedure (1977)
- Reed's Plant Layout Procedure (1961)
- Muther's Systematic Layout Planning (1961)

Although Muther's systematic layout planning (SLP) is traditional approach, and is derived way back in 1961; still SLP is widely used for layout design. Many of the automated layout design techniques and techniques like CRAFT (Computer Relative Allocation of Facility Techniques) uses same procedure for solving facility layout problems.

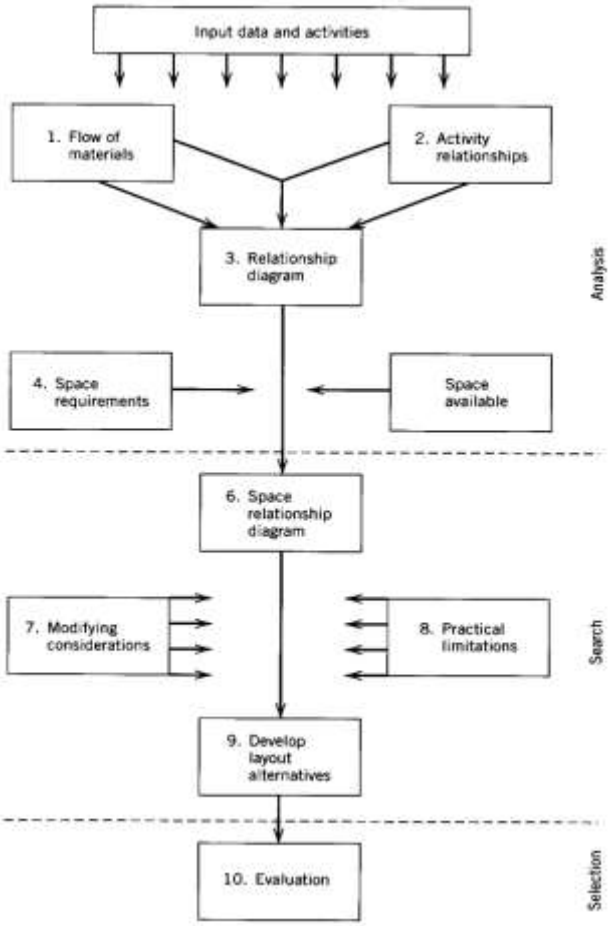

Figure 1: Muther's Systematic Layout Planning (1961)

LITERATURE SURVEY

Placement of required facilities in specified area of plant is called as facility layout problem. Facility layout problem has significant, major and long term impact on material handling inside the plant, total lead time of product to manufacture, work in progress and operating efficiency. A good placement of facilities contributes to the overall efficiency of operations and can reduce up to 50% the total operating expenses (Tompkins et al., 1996). Many researchers have published their research work in this area for specific objectives or covering specific aspect of problem. Also many reviews are not recent (Hassan, 1994; Kusiak and Heragu, 1987; Levary and Kalchik, 1985). Review of existing research work in particular area helps researchers to identify research gaps and future scope for work or research to be carried out. Hence review of the researches is important.

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Amine Drira, (2007) defines in his review, different types of facility layout problems and has discussed various problem formulation methods. The authors also discussed different facility problem solving techniques with more emphasis on dynamic facility layout problems. He has derived a rough tree structure to present an idea of different considerations while developing a plant layout.

Robin S. Liggett (2000) reviewed about techniques that are used to optimize single objective functions and evaluated various variety of space allocation problems and uses of different algorithm to solve these space allocation problems with detailed review of facility problems/space allocation problem. The authors also discussed limitations of different algorithms and research gaps in automation of facility layout solving tools which are commercially available.

Reza Zanjirani Farahani(2009) provides review in multi criterion facility location problems and has categorized multi criterion facility problems in to three categories, which are bi-objective, multi-objective and multi-attribute. The authors also discussed about methodology to be used to solve these categories problems and briefly mentioned about criteria's that are used in literature to solve facility location problems.

As per changing market, product mix and quantities, changes in plant layout are essential. These types of facility layout problems are called as dynamic layout problems. Alireza and Reza (2011) reviewed different dynamic layout problems in literature and suggested uncertainty of future parameters must be considered while developing the model for solution of dynamic layout problems. The Authors have given brief overview of mathematical models formations for solving dynamic facility layout problems with number of case studies.

Different Facility layout Scenarios:
Products variety and volume:

- Fixed position layout: In Fixed product layout, the products generally circulate within the production facilities (machines, workers, etc.); in this particular type of layout, the product does not move, it is the different resources that are moved to perform the operations on the product. This type of layout is commonly found in industries that manufacture large size products, such as ships or aircrafts. (Amine Drira,2007)
- Process layout: Process layout groups facilities with similar functions together (resources of the same type). This organization is often reported to be suited when there is a wide variety of product. (Amine Drira,2007)
- Product layout: Product layout is used for systems with high production volumes and a low variety of products. Facilities are organized according to the sequence of the successive manufacturing operations. (Amine Drira,2007)
- Cellular layout: In a cellular layout, machines are grouped into cells, to process families of similar parts. These cells also need to be placed on the factory floor. Therefore, one is also generally concerned with so called intra cells machine layout problems, as mentioned for example in (Proth, 1992, ch. 3) and (Hamann & Vernadat, 1992). Here, one is concerned with finding the best arrangement of machines in each cell.

Available space, equipment shapes and accessibility needs :

- Regular shapes: Two different facility shapes are often distinguished regular, i.e., generally rectangular (Kim & Kim, 2000).
  - Fixed dimensions
  - Aspect ratios
- Irregular shape: Irregular, i.e., generally polygons containing at least a 27^0 angle (Lee & Kim, 2000).
- Gangways or clearances for movement of operators and material.

Layout configurations:

- Single row: The single row layout problem occurs when facilities have to be placed along a line (Djellab & Gourgand, 2001; Ficko, Brezocnick, & Balic, 2004; Kim, Kim, & Bobbie, 1996; Kumar, Hadjinicola, & Lin, 1995). Several shapes may be considered from this basic situation, such as straight line, semicircular or U-shape (Hassan, 1994).
  - Linear
  - Semi-Circular
  - U-Shape
- Multi Rows: The multi-rows layout involves several rows of facilities (Hassan, 1994).

Loop layout: The loop layout incorporates a Load/Unload (L/U) station, i.e., location from which a part enters and leaves the loop. This station is unique and it is assumed to be located between position m and 1.

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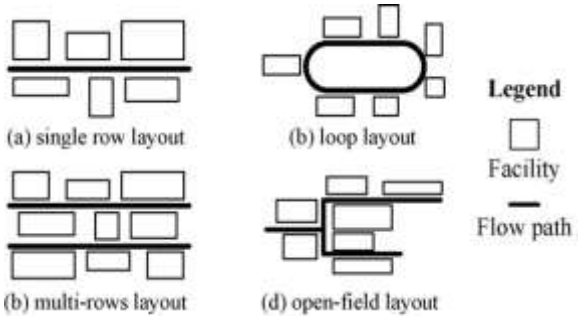

Figure 2: Layout configuration

- Open field: The open field layout corresponds to situations where facilities can be placed without the restrictions or constraints that would be induced by such Arrangements as single row or loop layout (Yang et al.,2005).
- Multi floor:

Now days, when it comes to construct a factory in urban area, land supply is generally insufficient and expensive. The limitation of available horizontal space creates a need to use a vertical dimension of the workshop. Then, it can be relevant to locate the facilities on several floors, as depicted in This figure shows that parts can move horizontally on a given floor (horizontal flow direction), but also from one floor to another floors located at a different level (vertical flow direction). The vertical movement of parts requires a vertical transportation device: elevator. In such situations, both the position on the floor and the levels has to be determined for each facility, so that the related problems are referred to as multi-floor layout problems (Kochhar & Heragu, 1998).

LAYOUT EVOLUTION

In today's competitive world, manufacturing system needs to quickly adapt to the changing market conditions. Page (1991) reported that, on average, 40% of a company's sales come from new products. Due to changes in demands, product mix needs to change in product flow or machine utilization which further tends to need for change in plant layout. Gupta and Seifoddini (1990) stated that 1/3 of USA companies undergo major reorganization of the production facilities every 2 years. A good number of authors have tried to take such an important issue into account when designing the layout. Most articles dealing with layout problems are implicitly considered as static; in other words they assume that the key data about the workshop and what it is intended to produce will remain constant enough over a long period of time. Recently the idea of dynamic layout problems has been introduced by several researchers. Dynamic layout problems take into account possible changes in the material handling flow over multiple periods (Balakrishnan, Cheng, Conway, & Lau, 2003; Braglia, Zanoni, & Zavanella, 2003; Kouvelis, Kurawarwala, & Gutierrez, 1992; Meng, Heragu, & Zijm, 2004). In this respect, the planning horizon is generally divided into periods that may be defined in weeks, months, or years. For each period, the estimated flow data remains constant. There are two main types of layouts that are considered as follows:

- **Static layout :**When the demand is more or less constant with time, Static Plant Layout Problem approach is a suitable method for obtaining a good facility layout.
- **Dynamic layout :**

When demand is varying frequently with time, static layout generation approaches may not be efficient in various periods of the planning horizon. Fluctuations in product demand, changes in product mix, introduction of new products, and discontinuation of existing products are all factors that render the current facility layout inefficient and can increase material handling costs, which might necessitate a change in the layout (Afentakis, Millen, & Solomon, 1990). Maintaining a good facility layout requires a continuous assessment of the variations in product demands and flow between departments, and the need for Dynamic Plant Layout Problems approaches for the development of layouts. A layout plan for the dynamic layout problem consists of series of layouts, each layout being associated with a period. According to Baykasoglu & Gindy, (2001) rearrangement cost should be considered as important factor while modifying or planning plant layout.

Ming Dong et al (2009) have discussed a new kind of dynamic multi-stage facility layout problem under dynamic business environment, in which new machines may be added into, or old machines may be removed from the plant. This problem can first classify on the basis of unequal area machines and continual presentation of layouts.

V. Madhusudanan Pillai et al (2011) have proposed design for robust facility layout under the dynamic demand environment in this research paper. They considered production interruption costs along with general considered costs (total material handling cost and re-arrangement cost) for solving dynamic layout problems. Robust layout approach which is used to solve dynamic layout problems, assumes that rearrangement and production interruption costs are

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too high and hence, this approach tries to minimize the total material handling costs in all periods using a single layout. The authors have used data presented by Yaman et al. (1993) and compared results of simulated annealing method (SA) with results available in literature and shown that Material handling costs for the layouts from the robust method are not significantly different from the best results for the adaptive approach. The robust approach has the advantage of no relocation of facilities in the periods of planning horizon and hence no disruptions of the operations.

If positions and placement of the departments and machines need to be find for multiple time horizons (For example weeks, months or years) then this problem is called as dynamic plant layout problem. Need of the dynamic plant layout is generated due to change in material flows with respect to time horizon. According to Alan and Artak (2010) some factors which may change material flows are as follows:

i. Changes in the design of an existing product.
ii. The addition or deletion of products.
iii. Replacement of existing production equipment.
iv. Shorter product life cycles.

Changes in the production quantities and associated production schedules.

Different types of Facility Layout Problem formulations:

- Discrete layout/Discrete assignment problem: The simplest layout problem is the assignment of a set of discrete activities to a set of discrete locations in such a way that each activity is assigned to a single location. This is called a one-to-one assignment problem _also known as an equal area layout problem. Assignment of predefined or existing facilities in space available is an example of these kinds of problems.
- Continual layout problems
- Fuzzy assignment layout problems
- Multi objective layout problems

OBJECTIVE, CONSTRAINTS AND RESOLUTION APPROACHES OF FACILITY LAYOUT PROBLEM

- **General objectives for facility layout design:**
  - Minimum Space costs
  - Minimum handling costs
  - Minimum re-arrangement costs
  - Minimum backtracking and bypassing
  - Minimum traffic congestion
  - Minimum shape irregularities
  - Facilitate objective:
    - ✓ Organization structure
    - ✓ Communication and interaction between workers
    - ✓ Manufacturing process
    - ✓ Visual control
- **Constraints in designing facility layout:**

Area constraints	Positioning constraints	Budget Constraints
Space allocation	Clearance between facilities	
Facility location	Orientation	
	Non overlapping	

- **Resolution approaches for facility layout problems:**

Exact Methods	Heuristic Methods	Hybrid Approaches
Branch and bound	Construction and improvement Heuristics	
Dynamic Programming	Meta heuristics: 1. Simulated annealing 2. Tabu Search 3. Generic algorithms 4. Ant Colony	

Apart from these approaches hybrid approaches, intelligence approaches, quadratic assignment problem: desecrate representation, mixed integer programming: continual representation, neural network, and graph theoretic approaches are used to solve facility layout problems.

FUTURE SCOPE FOR RESEARCH

In order to conduct further studies in the case of dynamics of facility location problems and based on

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available gaps in the literature, this section delivers some research trends.

1. One of the areas of challenge is combining continuous models with dynamic location problems. As discussed in literature by Fleischer and Tardos (1998), Klose and Drexl (2005), and Suzuki and Drezner (2009); interaction of dynamic problems with continuous models can produce significant and useful results.
2. There is large scope for improvement for reduction in risks and accidents in industry by considering risk as objective for deciding location as usual objectives like costs and profits etc.
3. Most important in dynamic problems, main variables are generally getting changed time to time. Hence considering these changing variables, more reliable and robust plant layout can be generated. Additional risk variable can be considered for these kinds of problems so as to adjust as per future changes in input variables of the system. (For additional information refer (multi-objective facility location optimization problem, Farahani, SteadieSeifi, and Asgari (2010)).
4. Also approaches which are giving exact solutions like linear programming; different traditional algorithms are not being modified from long time. Hence it is difficult to use these methods to solve dynamic problems. Even though in some cases it is possible to solve dynamic problems by these methods, the complexity of this solution method is very high. Hence for solving specifically large scale dynamic problems heuristics and Meta heuristics methods are used. Hence large scope is present in this area for developing new methodologies for large scale dynamic problems.

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