

# Case Study on Improvement in Plant Layout Design

Devashri D. Thakre<sup>1\*</sup>, Uday A. Dabade<sup>2</sup>

<sup>1</sup>PG Student, Walchand College of Engg., Sangli, Maharashtra, India

<sup>2</sup>Professor and Head, Department of Mechanical Engineering, Walchand College of Engg, Sangli, Maharashtra, India

**Abstract** – Layout problems are found in every industry with variety of types. They are known for impacting the system performance. So it is important for industries to improve the plant layout design and simultaneously take into consideration to reduce their cost and expenses involved so as to survive in the competitive world. There are number of solution techniques available to optimize plant layout design. Lots of research papers and many of literature reviews exist on these variety of techniques developed by many of researchers till now, but they are restricted to certain specific aspects of the plant layout problems. This paper will give the complete idea about the plant layout design without any specific consideration. The paper includes understanding of plant layout and its types, location problems, formulation methods of those problems, methodologies and simulation techniques. In the end complete process is summarized so that anyone interested in this area can choose best suitable technique that can be implemented to the particular case and start working on it from the basics. This paper will guide at a macro level to understand all aspect of plant layout design.

Case study taken in this paper is of one of the MNC. Systematic Layout Planning (SLP) method has been applied which gives solution in terms of minimized travelling distance and reduced material handling. Analysis of previously designed layout and final layout came out of Systematic Layout Planning (SLP) showed that material flow throughout the plant area is reduced by 38.2% and additional 70 square meters of area is created for kitting.

**Keywords:** Plant Layout Design, Formulation Methods, Methodologies, Simulation Techniques, Systematic Layout planning.

## INTRODUCTION

Patil [1] defined plant layout as a designing best structure to contain facilities which includes operating equipment, storage space, material handling equipment, personnel and other supporting services. Each plant layout design is unique by its particular assumptions, constraints, limitations, and the intrinsic activity of the components said by Vollman and Buffa [2]. Shayan and Chittilappilly [3] 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 [4] 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. Huang [5] states that facility layout design determines to arrange, locate, and distribute the equipment and support services in facility to achieve minimization of overall production time,

maximization of flexibility and maximization of factory output in conformance. There are number of traditional facility layout design procedures. They are developed way back in nineties. Some of the methods are listed chronologically.

- 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)

## LITERATURE REVIEWS: FACILITY LAYOUT DESIGN

### A. Types of Layout

The choice of type of facility layout can have a significant impact on the long-term success of a firm. This decision, therefore, should not be considered lightly, but only after a thorough analysis of the operational requirements has been completed. There are various methods of grouping and production machinery, the common and classical types of the arrangement are fixed position layout, process layout and product layout, but most plants today are laid out using a combination of these classical layouts and are never seen in their pure form. Dixit and Dev focused upon these different layouts and their efficient utilization in the production industries. This is very useful to fetch the best layout for different existing condition of the industries [6].

The efficiency and productivity depends on the type of manufacturing layout is being used for production of goods and services.

	Product layout	Process layout	Fixed layout	Cellular layout
Product layout	Operations immediately adjacent to next			
Process layout	Equipment performing common function are grouped			
Fixed layout	Component is fixed, tools, machines and men move around			
Cellular layout	Grouping into families based on common machining requirement			
	Product layout	Process layout	Fixed layout	Cellular layout
Significance	Continuous flow production	Gap production	Order wise	Cont. production flow
Capital investment	High	Less	Very high	
Material flow cost and time	Low	Higher	Saves cost	Moderate
Inventory and WIP required	Less	High	Very less	Less
Overhead cost	High	Low		Moderate
Flexibility/ expansion scope	Low	Moderate	Higher	Moderate
Applications	Mass production, standardized product, stable demand and continuous supply	Job production, where there is frequent change in product, variable demand	Proceeds for several orders, production of bulky products, variable demand	
Advantages	Optimum use of floor space	Effective supervision	Sequence of process can be altered easily	Advantages of both product and process layout
Disadvantages	Breakdown of a machine hampers whole production	More inspection is needed	Very large space required	

According to Singh [7], not only efficiency is increased directly but indirectly good facility layout also contributes to efficiency by reducing accidents, hazards, by increasing easiness and convenience. Most importantly a better facility design allows smooth function of manufacturing. Based on the literature studied, table 1 describing comparative study of all kind of facility layout is made which will be helpful in identifying given layout and the appropriate type of layout it would have been.

### B. Facility Layout Problems (FLP)

The placement of the facilities in the plant area, often referred to as “facility layout problem”, is known to have a significant impact upon manufacturing costs, work in process, lead times and productivity. Drira et al proposed rough tree representation of layout problems and different factors taken into account in their literature [8].

A plant layout problem may be associated with either a single objective or a multiple objective. However, real-life plant layout problems are often associated with multiple objectives, such as minimization of total flow cost, maximization of total closeness rating (TCR), etc. A multiple-objective facilities layout problem can therefore be defined mathematically as the optimum assignment of facilities to locations so as to achieve the objectives stated for the layout problem. These objectives can be classified into following two categories: Conflicting objectives, such as minimization of TFC and maximization of TCR and safety, and congruent objectives, such as minimization of distance-weighted cost of several attributes, viz. flow, closeness rating, etc. [9].

### C. Formulations

Once the problem is identified and the type of layout to be designed is decided, formulation of problem comes into the picture. Formulation is done generally in terms of objectives such as minimization of cost associated or time, maximizing the closeness between the departments, etc.

Different models that are developed to formulate layout designs are:

#### 1) Quadratic assignment problem (QAP 1957):

The name was so given because the objective function is a second degree function of the variables and the constraints are linear functions of the variables. Required parameters are number of locations, flow of material from one location to other, cost associated with this transportation. QAP is of two kinds, linear assignment problem and travelling salesman problem [10].

#### 2) Linear integer programming problem (LIP 1963):

Integer programming problem and the QAP are equivalent. The difference is that this type requires more memory for formulation i.e. more variables and constraints are involved than that of QAP model [10].

#### 3) Quadratic set covering problem (1975)

In this formulation, the total area occupied by all the facilities is divided into a number of blocks. The distance between the locations is to be taken from centroids of the locations. Disadvantage is that the

problem size increases with the total area occupied by all the facilities is divided into smaller blocks. It is not suitable for problems with nine or more facilities [10].

**4) Graph theoretic problem (1976)**

This model is based on a predefined desirable adjacency of each pair of facilities. Used mostly for the construction type layout design process [11].

**5) Mixed integer programming problem (1978)**

Linear mixed integer program has the smallest number of variables and constraints amongst all integer programming formulations of the QAP. This type of model is applicable to evaluate the performance of solutions for the problem having more than one objective [10].

**D. Methodologies**

In this section various solution methodologies, e.g. exact procedures, heuristics and meta-heuristics available to solve facility layout problems optimally or near to optimal are explained.

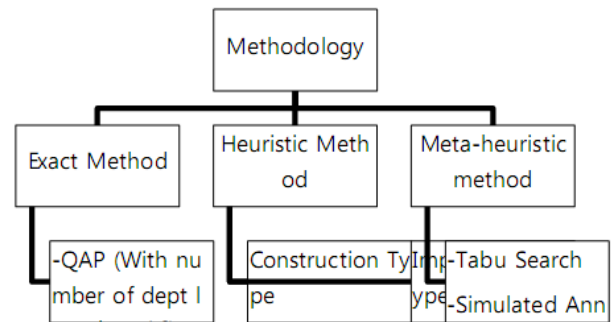
Exact method is used to find an optimum solution of quadratic assignment formulated Facility Layout Problem (FLP). QAP involves only binary variables. Only optimal solutions up to a problem size of 16 are reported in literature. Beyond  $n=16$  it becomes intractable for a computer to solve it and, consequently, even a powerful computer cannot handle a large instance of the problem.

A heuristic is a technique designed for solving a problem more quickly and finding an approximate solution when classic methods fail to find any exact solution. Heuristic algorithms can be classified as construction type and improvement type. Construction based methods are considered to be the simplest and oldest heuristic approaches to solve the QAP. Improvement based methods start with a feasible solution and try to improve it by interchanges of single assignments. Improvement methods can easily be combined with construction methods [11 - 12].

A metaheuristic is a higher-level procedure or heuristic designed to find a sufficiently good solution to an optimization problem, especially with incomplete data available. Metaheuristics sample a set of solutions which is too large to be completely sampled. Metaheuristics may make a few assumptions about the optimization problem being solved, and so they may be usable for a variety of problems. Arostegui, et al. classify heuristics methods into tailored and general. While tailored heuristics have a limited applicability to a specific problem, general algorithms define a

strategy for obtaining approximate solutions and thus are widely applicable to various forms of combinatorial optimization problems [13-14]. From the literature methodology is summarized in figure 1.

Levary and Kalchik [15] have characterized most used solution procedures for facility layout problems. Characteristics include input required, type of output obtained, advantages features and limitations. All the techniques are tabulated according to their characteristic very systematically. This survey paper will guide to adopt the appropriate method for a given layout.



**Fig. 1 Methodology**

**E. Simulation Techniques**

Application of a simulation model is to assist decision making on expanding capacity and plant layout design and planning. The plant layout design concept is performed first to create the physical layouts then the simulation model used to test the capability of plant to meet various demand. Table 2 shows the various software packages and their applications as per requirement of results [16].

**Table 2 Simulation Software Packages [16]**

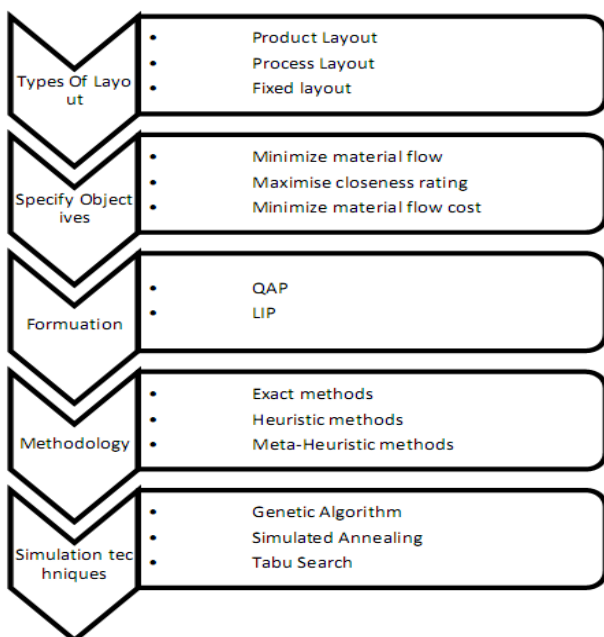
Type of analysis	Simulation software
Block Layout	-FACTORYOPT -WINSABA -SPIRAL -CRIMFLO -MALAGA -MATFLOW PLAN OPT STORM
Group Technology	-PROFILER MINITAB SAS PDM Products
Material Flow Analysis	-FACTORYFLOW PFATS
Process Flow Mapping	-VISIO -OPTIMA -SIMULB -ARENA
Visualization and Performance Evaluation	-PROMODEL -WITNESS -MPX -TAYLOR II -QUEST

	-FACTORYPLAN
Multi-criterion Evaluation of Layout Alternatives	-EXPERT CHOICE -SUPERTREE
Economic Analysis of Layout Alternatives	-EASY ABC
Capacity Planning and Sizing of Layout Alternatives	-LINDO -GAMS -CPLEX -MPX -FACTORY MODELLER

**F. Summary**

From the literature studied the process that should be followed for plant layout design is summarized in the figure 2.

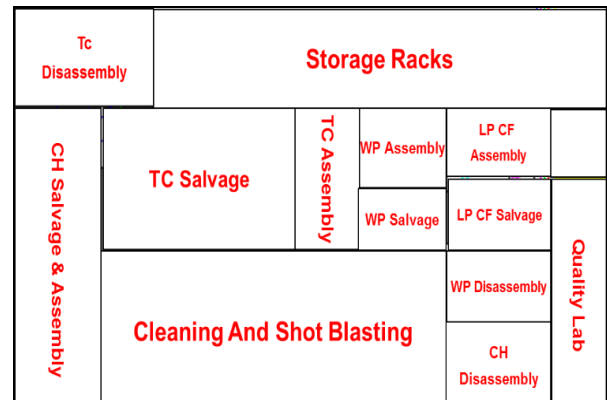
1. Select suitable type of layout for given plant according to the requirement. For example for Mass production or batch production select type of layout by referring table 1 accordingly.
2. Specify objectives as per the company's requirement. That may be minimization of cost or maximization of closeness rating.
3. Formulate the objective according to the goal set.
4. Whether the data collected is small or large decides the method to be applied to design the layout. The quality of the solution i.e. exact solution or near to optimal solution is taken into consideration as well.
5. For the verification of solution we have got, implementation of simulation technique is necessary.



**Fig. 2 Summarized methodology of layout design**

**CASE STUDY: IMPROVEMENT IN FACILITY LAYOUT**

Plant remanufacturing 5 types of products is taken as a case study to redesign the layout. 5 products are Cylinder Head (CH), Turbocharger (TC), Water Pump (WP), Lube Pump (LP) and Cam Follower (CF). Accommodation of new product line in TC is one of the major reasons for redesigning layout, General process for remanufacturing these products starts with core to disassemble and then dismantled parts sent for cleaning followed by various salvaging processes and finally product gets assembled. Material flow in the current layout is complex which results in higher throughput time for all the lines. Current layout of the plant is shown in figure 3.



**Fig. 3 Current layout**

**A. Objectives**

Most of the times there is a case in plants that, current plant space is fully occupied and it was designed according to previously required production and now in future it is required to change as the business grew. So in such cases making space available is tough task. So according to the requirement of the company following objectives are taken into consideration.

- i. Minimize material flow
- ii. Maximize adjacency score/ closeness rating between the cells where there is requirement

**B. Systematic Layout Planning (SLP)**

Systematic Layout Planning (SLP) shown in figure 4, is widely used for layout design. It is constructive type of method used to design new layout for the plant which will have higher productivity at less material flow throughout the plant. SLP consist of 10 steps which are divided into three phases, viz., Analysis, Search and Evaluation.

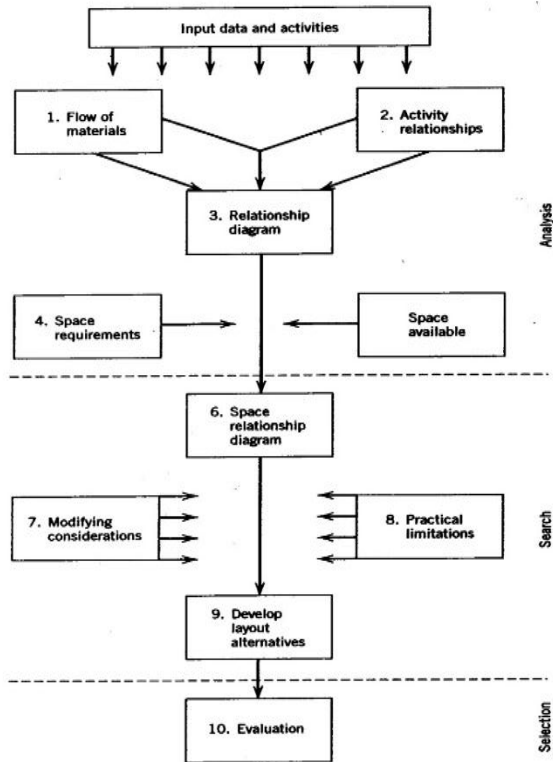


Fig. 4 Systematic Layout Planning

**Tools required:**

- i. *Activity relation diagram:* Activity relation diagram shows closeness required between every two departments. Input required for this tool is activity relation chart. It is nothing but chart showing all the closeness ratings and reason behind that closeness rating as shown in figure 5.
- ii. *Constraints:* Cleaning cell includes section for dirt removal, rust removal, paint removal etc. it's a module of 5 sections having large tank for filling up the chemical required. So cleaning cell will be constraint during redesigning whole plant.
- iii. *Detailed information about process flow and cells:* Table 3 includes all the product line cells and the area occupied by them in square meters.

**Table 3 Area Occupied By The Cells**

Sr. No	Process	Area Occupied (M <sup>2</sup> )
1	Disassembly	185
2	Pre cleaning	25
3	Primary cleaning	200
4	Shot Blasting	200

5	Post cleaning	25
6	CH Salvage	720
7	Quality	100
8	CH Assembly	520
9	FG	168
10	Storage	140

iv. *Space relation diagram:* Space relation diagram is extension of the activity relation diagram. It is to allocating area required to each cell in activity relation diagram as shown in figure 6.

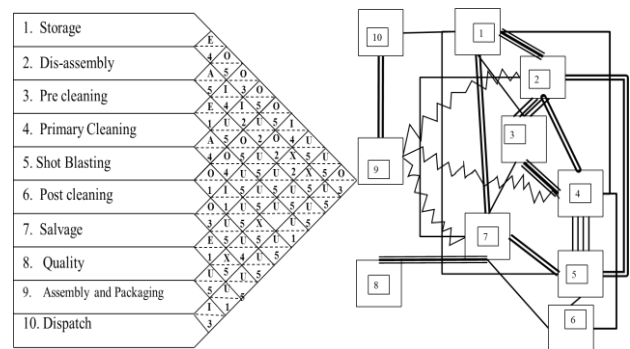


Fig. 5 Activity relation chart

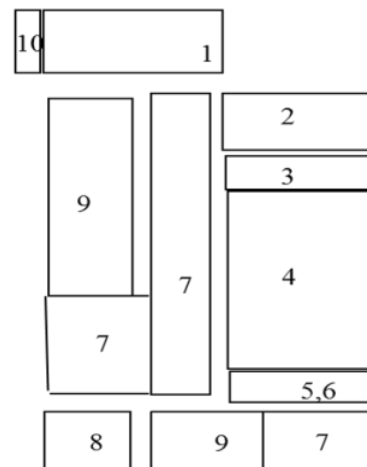


Fig. 6 Space Relation Chart

Final layout obtained from Systematic Layout Planning (SLP) is as shown in figure 7.

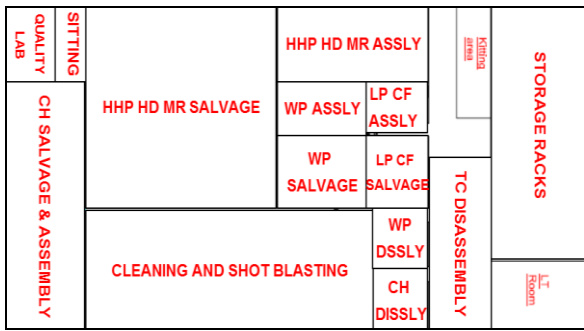


Fig. 7 Proposed layouts

**B. Result**

Comparative analysis between current layout and final layout is done and results are as shown in table 4. Material flow is calculated from tool named string diagram. Total closeness distance between the departments is calculated from AutoCAD.

**Table 4 Results Comparing Current and Proposed Layout**

Parameters	Current Layout	Proposed Layout
Material Flow (centroid to centroid distance between cells) in meters	1091	1010
Space Utilization (Area in M <sup>2</sup> )	Kitting	NA
	OE/Meeting room	25
	TBWS Area	50
	Sitting place for Line managers	NA
Overall Weight(Kg)*Distance(Feet)	486873	300886
Parameters	Current Layout	Proposed Layout

**CONCLUSIONS**

Systematic Layout Planning (SLP) is widely used for layout design method. Although Muther’s systematic layout planning is traditional approach, and is derived way back in 1961; still many of the automated layout design techniques still use same procedure for solving facility layout problems. Additionally, SLP is a powerful approach and at the same time is easy to use. Improving the plant layout using SLP method will decrease the material flow considerably. It is very useful method for low and medium capacity plants.

Improvement in proposed layout with respect to current layout is computed and conclusions to the new layout obtained by using Systematic Layout Planning are:

- i. Total closeness rating between the departments is improved by 7.9%
- ii. Total material flow in terms of weight\*distance flow minimized by 38.2%
- iii. Space utilization: 70 square meters of extra space created for kitting, sitting place shop managers on floor area is created.

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#### **Corresponding Author**

**Devashri D. Thakre\***

PG Student, Walchand College of Engg, Sangli, Maharashtra, India

**E-Mail – [devashri\\_thakre@yahoo.com](mailto:devashri_thakre@yahoo.com)**