A study to improve plant layout design for minimizing production costs

I I Al-Bayati¹ and S S Al-Zubaidy²

¹ Mechanical Engineering Department, Kerbala University
² Production and Metallurgy Department, University of Technology
E-mail: israa.i@uokerbala.edu.iq.

Abstract: Plant allocation and the costs of moving between workstations in production and manufacturing lines are among the most prominent factors affecting the total cost of production. Selecting appropriate work locations and distances between workstations is thus a key factor affecting the efficiency and productivity of a production line and thus the quality and cost of the final product. In this research, problems with a current plant layout are assessed with an eye to increasing productivity with minimum additional outlay. The aim is to improve the work flow in a pulley plant based on consequential planning of the plant layout, based on the assumption that the improved plant layout can reduce material flow distances, resulted in reduced costs of operation by about 5 to 10%.

Key words: Plant layout, Design plant layout, SPL.

1. Introduction

Productivity is generally believed to have a direct relationship with what is produced and what resources are used for that production, offering a ratio of output to input. Productivity has multiple implications for departmental effectiveness, particularly for areas such as production in industry. Productivity improvement requires assessment of many factors, including workers, machines, materials, and money. Plant layout can also be improved to increase industrial productivity, as plant design can influence multiple drivers of work efficiency. In the last decade, the problem of plant layout has received significant consideration in terms of facilities layout on factory floors and related situations based on locating facilities in a simple plane area. This has led to the development of various methods and heuristic techniques for designing effective plant layouts to reduce waste and increase productivity rather than firms being dependent on conventional systems and processes [1]. Many researchers have applied the Systematic Layouts Planning methodology and Annealing Simulations to select and evaluate alternative layouts, and Tabu Search and Genetic Algorithms have been found to be among the best techniques for productivity improvement by reducing unnecessary action time in the production process, which is a major factor in reducing production costs and increasing annual profitability. The first step in plant layout improvement should thus be identifying and selecting a suitable procedure for the work.

2. Proposed Methodology

The methodology applied in this research to optimise the plant layout was systematic layout planning, which aims to provide an easier flow of materials at the lowest cost based on reduced material handling.

2.1 Systematic Plant Layout
As a technique to locate workplace layout effectively in a plant, the systematic planning method provides machine layouts which improve plant space utilisation. The method offers a step by step planning procedure which allows the user to define, monitor, and rate the various activities, relationships, and alternate steps in the plant layout based on input data and material flow [2], as shown in figure 1:

1. Studying the plant layout fundamentals and previous design.
2. Collecting the necessary machines.
3. Analysing the product production process.
4. Analysing the current plant layout to define the problems with current processes and material flows.
5. Writing a report after collecting suggestions and making rearrangement decisions with regard to the plant layout [3].

![Systematic plant layout procedure](image)

**Figure 1.** Systematic plant layout procedure [4,5]

2.2 *Original Plant Layout* (*Case study*)

A pulley factory with a shop production system was selected as the case for this study. The pulleys consist of three rings of 6 inches diameter, and the daily production is 500 pieces. These pulley systems are widely used for lifting large parts or other masses, being constructed essentially of rope and a wheel. The plant layout of the factory is based on the process layout. For the initial production of the pulley, as shown in figure 2, metals, as a raw material, are melted in a furnace to create a core and then moved to the sand mould; after setting, moulds are disassembled, and then finishing occurs in the surfacing
department. Pieces then move to the inspection department to be investigated by inspectors and those that pass go to the stock room to be packaged and stored. Each department’s details are described in the following steps and in Table 1.

1. The sand plant: This department has an approximately 300 metre working area; it is also the process start point.
2. Making the core: The cores are produced in this department based on moving the sand in to make them.
3. Storing the core: Cores are stored in this department for use in the manufacturing process [6].
4. The sand mould department: Employees place the sand into the mould and use a jolt squeeze machine to compress the sand. A core is inserted in each mould and all moulds are positioned to wait for molten metal [7, 8].
5. Furnace department: In this department, a cupola furnace is used to produce molten metal, which is added to the moulds metal and left over night before the transportation to the disassembly and surface finish department.
6. Disassembly and surface finish department: In this department, the moulds are disassembled and surface work is completed on the pieces before they are sent for quality inspection.
7. Inspection: Here, the work is inspected for defects; defects are sent back for rework, while work with no defects is stored until it is delivered to customers.

The total distance that each sample moves until it becomes an end product is 95 metres, from the raw material department to the packaging department. The distance for returning defective samples from the inspection department to the furnace is 40 metres.

**Figure 2.** Pulley production layout process
3. Plant Layout Analysis

1. Core stock: This is a rectangular room bordered by a metal fence with a single door; inside this room, all cores are placed on the floor, causing inconvenience in uploading them for use. Additional shelves should be added to make core storage more orderly.

2. The sand moulds: The moulds are made using a jolt squeeze machine, which is located at the east of the plant. This area holds the mould making departments and is also where the finished moulds wait for the molten metal. Each department is separated clearly, though the sand plant is in-between the sand mould and the furnace, obstructing the path between the two departments and increasing the potential for accidents while transporting molten metal from the furnace or sand from the plant to the sand mould. Where extra care is taken to prevent this, delays in transferring the molten metal are likely to be increased. One solution would be to change the sand location the other side of the sand mould department, thus placing the mould department in the middle of the plant. This would reduce the distance that the molten metal must move as well as allowing its transportation in a more direct path, helping prevent accidents and saving time.

3. Disassembly and surface finishing: The indirect path and distance from the sand mould department to the disassembly and finishing department causes delays in transferring work. The disassembly and finishing departments should be rearranged to come between the inspection department and the sand mould area, creating a more direct and shorter path, reducing the time and distance for transferring work.

4. Inspection department: All work is inspected in this department, which is the last step of the process before pieces are stored in the warehouse or delivered to customers. The single inspection machine causes delays in the work in this department, causing an accumulation of products and potential mix ups. The inspection department should thus be improved by adding another inspection machine to avoid delays to the work or mixing up of the products.

5. Packaging department: In order to utilise the factory area more effectively, this section should be moved to the left-hand side to ensure that there are no unused empty spaces and that the work can be stacked to one side as shown in figure 3.

Table 1. Working areas, size and numbers machines and equipment

| The departments                  | Work area (m²) | Machines and equipment | Material handling |
|----------------------------------|----------------|------------------------|-------------------|
| The plant of the sand            | 300            | 2                      | 2                 |
| Machinery for sand moulds        | 400.5          | 17                     | -                 |
| Core storing                     | 26             | -                      | -                 |
| Core making                      | 31             | 11                     | -                 |
| Inspection and check up          | 98             | 1                      | -                 |
| Disassembly and surface finishing| 20             | 2                      | 1                 |
| Melting process                  | 110            | 2                      | 6                 |
| Warehousing                      | 10             | -                      | 1                 |
| Manual sand moulds               | 50             | -                      | -                 |
| The raw material                 | 65             | -                      | -                 |
4. Conclusion

After analysing the workflow in the factory departments throughout the production process and noting the layout obstacles, it is apparent that work flow could be improved by modifying the layout design. The new design, shown in figure 3, reduces the work flow distance for parts between departments, causing the total moved distance for any part, from raw material to the packaging department, to be reduced to 60 metres; similarly, the distance from the inspection department for defective pieces to return to the furnace becomes just 30 metres. The new proposed path also helps to prevent accidents during material transportation by avoiding indirect routes. The layout rearrangement should thus decrease both time and distance in the flow of work, reducing workers’ effort and generating productivity improvement.

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