Applying a Systematic Layout Planning Method for Factory Layout Design

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Abstract

Plant layout is the process of systematically planning and allocating space within a factory, considering the relationships between activities, production flow, and space constraints to maximize operational efficiency. This research aims to improve the production plant layout of an engine and agricultural machinery manufacturing by applying a systematic layout planning method (SLP) to increase space utilization efficiency, reduce redundant material handling, and lower production costs. Research operations using the SLP method start with (1) collecting data on plant layouts and production processes (PQRST), (2) analyzing production process activities, (3) analyzing relationships between activities, (4) calculating usable area, and (5) design alternative plant layouts. The tools used include flow charts, flow process charts, P-Q charts, from-to charts, activity relationship charts (ARC), and activity relationship diagrams (ARD). The data providers were 6 people, including the factory manager, production manager, human resources staff, and production line staff. Applying the systematic layout planning approach (SLP) to data analysis and factory layout design resulted in a factory layout that reduced material handling distances in the production process. Research findings showed that production line A reduced handling distance by 77.1 meters (from 362.7 meters to 285.6 meters for alternative layout 2), and production line B reduced handling distance by 45.3 meters (from 197.5 meters to 152.2 meters for alternative layout 2). Reduce the number of path intersections in the production process, finding that the number of intersections decreased by 2 points (from 5 points to 3 points for alternative layout 2).

Keywords: factory layout design, relation diagram, systematic layout planning (SLP)

1. Introduction

Businesses in both the manufacturing and service sectors, including government agencies, private companies, and state-owned enterprises, face intense competition and rapid change in all aspects. Therefore, operational efficiency is a crucial factor for organizational survival and growth. Entrepreneurs need to produce high-quality goods and services, deliver them on time, and control costs appropriately to gain a sustainable competitive advantage. (Heizer et al., 2020; Slack et al., 2019)

One of the key factors in production efficiency is maximizing the use of space within the factory building. Proper factory layout helps ensure the rapid and systematic movement of materials and labor, reducing time and resource waste, and positively impacting overall quality, cost, and operational lead time. (Tompkins et al., 2010) Therefore, the concept of factory layout planning is used to manage and optimize production areas to suit the nature of the work process, focusing on increasing efficiency, reducing waste, and enhancing flexibility. (Muther, 1973; Apple, 1977)

Engines and agricultural machinery are labor-saving tools for farming. Thailand is the 21st largest exporter of agricultural machinery in the world. In 2022, Thailand was the 20th largest importer globally, with a share of 1.2%. (Chaiwat Sowcharoensuk, 2024) The research facility has been in operation for over 19 years, producing a total of more than 50,000 diesel and gasoline engines. Despite the company's advanced production technology and skilled workforce, issues were found with the unsystematic layout of the factory, leading to bottlenecks in material handling, underutilized space, and redundant material movements. This impacted production efficiency, costs, and customer satisfaction. Therefore, it was necessary to improve the factory layout using the Systematic Layout Planning (SLP) approach to increase efficiency and accommodate future growth. (Liberatore & Nydick, 2003)

To address the factory layout issues, the SLP method was adopted as a guideline for improving the factory layout. This helped to improve the continuity of the production process flow, reduce redundancy in material and labor movement, increase space utilization efficiency, lower production costs per unit, promote employee collaboration, boost morale, reduce conflict, and enhance the company's long-term competitiveness.

1.1 Research Objective

To design the factory layout using a systematic layout planning method (SLP).

2. Research Methodology

1. Key Informant Groups

The six informants regarding the factory layout improvement were: one factory manager, one production manager, two human resources employees, and two production line employees.

2. Research Instrument

Research tools include: flow chart, flow process chart, P-Q chart, from-to chart, activity relationship chart (ARC), and activity relationship diagram (ARD).

3. Research Procedures

3.1 Collect data on plant layout and production processes, including product, quantity, routing, supporting services, and time (PQRST), as well as workstation layout and distances between workstations.

3.2 Analyze production process activities and create product-quantity (P-Q) charts and from-to charts to show workload and material flow.

3.3 Analyze the relationship between activities using an activity relationship chart (ARC) to assess the necessity of placing activities close together based on usage frequency and task connections, and create an activity relationship diagram (ARD) to show the optimal placement of activities.

3.4 Calculate the usable area for each activity to support the design of alternative plant layouts.

3.5 Design alternative plant layouts by positioning machinery, workstations, and support areas to align with the production process.

3. Results

1. Collect Data

From the study of data on plant layouts and production processes, it was found that the current arrangement of machines and workstations is a functional layout with semi-continuous production, two production lines: the diesel engine production line (line A) with 7 workstations (A1-A7), producing 6 models at an average of 29 units per day, with a production time of 40.5 minutes per process cycle, and a total movement distance of 362.7 meters. And the generator production line (line B) with 6 workstations (B1-B6), producing 4 models at an average of 94 units per day, with a production time of 25.4 minutes per process cycle, a total movement distance of 197.5 meter. The total working area is 326 square meters. Inside the production building, there is an area of 1,766 square meters, including a raw material warehouse, tool warehouse, maintenance department, quality control department, and finished goods warehouse, which are supporting services for production.

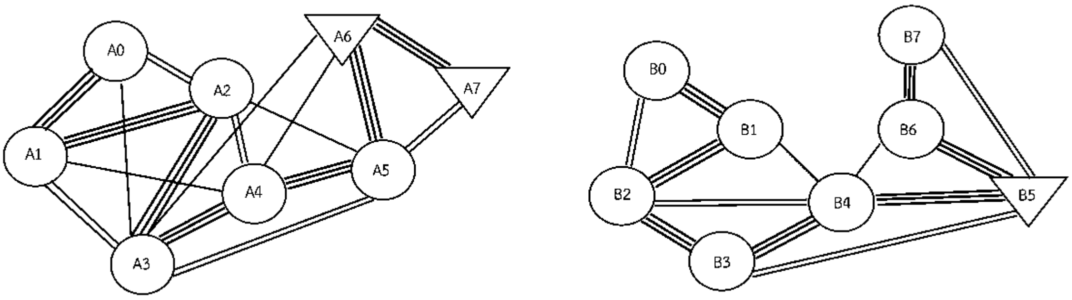
2. Analyze Production Process Activities

The results of the product-quantity chart (P-Q chart) and from-to chart show that there is repetitive material movement between workstations and the raw material warehouse. In production line A, there is movement from the raw material warehouse to workstations A1-A7 for all pairs, totaling 7 repetitive pairs. Each pair has a movement frequency of 34 times per day, resulting in a total movement distance of 362.7 meters per production cycle. In production line B, there is movement from the raw material warehouse to workstations B1-B6 for all pairs, totaling 6 repetitive pairs. Each pair has a movement frequency of 100 times per day, resulting in a total movement distance of 197.5 meters per production cycle.

3. Analyze the Relationship between Activities

The results of the relationship analysis between activities in the production building using the Activity Relationship Chart (ARC) showed that production line A had 7 pairs of A-level (absolute importance), 1 pair of E-level (special importance), 5 pairs of I-level (important), 4 pairs of O-level (ordinary), 11 pairs of U-level (unimportant), and no X-level (undesirable) activity pairs. Production Line B had 7 pairs of A-level, 2 pairs of E-level, 4 pairs of I-level, and 23 pairs of U-level activity pairs, with no O-level or X-level activity pairs. The results of the activity relationship analysis using the Activity Relationship Chart (ARC) are shown in Fig. 1.

Figure 1: Activity Relationship Diagram (ARD)
Production line A Production line B



4. Calculate the Usable Area

Determining the area for each activity in production lines A and B, considering factors such as the nature of the work, specific requirements of each activity, machine size, space for operators, safety and maintenance buffer space, work-in-process (WIP) space, and internal station movement, was done. After evaluating the results, production line A required a total area of 96 square meters, and production line B required a total area of 98 square meters. The combined area for both lines was approximately 194 square meters.

5. Design alternative plant layouts

Design two alternative factory plant layouts as follows:

Alternative plant layout 1: Arranges production line A and production line B in a straight-line flow according to the production process sequence, with merging at the quality control point before entering the testing room, and then proceeding to the painting and baking processes in sequence, up to the finished goods storage. The movement distance for production line A is 317.3 meters, and for production line B it is 165.5 meters, totaling 428.8 meters. There are 5 path intersections.

Alternative plant layout 2: U-cell layout with product testing (A6 and B5) placed adjacent to the final assembly steps (A5 and B4) before leaving the cell and combined at a common quality control point. Then, it enters the testing room, the painting and baking processes in sequence. This layout has a production line A travel distance of 285.6 meters and a production line B of 152.2 meters, totaling 437.8 meters. There are 3 path intersections.

4. Conclusion and Discussion

Applying the Systematic Layout Planning (SLP) approach to factory design and layout allows for the concrete identification of the most suitable factory layout. This can make factory layout improvements more systematic. The improved factory layout can reduce material handling distances, increase production flexibility, use space more efficiently, and balance quality and cost objectives. Similar to the research by Sittichai Pintuma et al. (2024) which applied the principles of systematic layout planning (SLP) to optimize the layout of grass stockpiling in Thailand. The study used relationship diagrams to illustrate the proximity of departments based on their level of relationship, with departments of higher relational importance being placed closer together. The study results helped improve operational efficiency, reduce costs, and enhance workplace safety.

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