KONYA GIDA VE TARIM ÜNİVERSİTESİ 2013

The Journal of Applied Engineering and Agriculture Sciences
https://dergipark.org.tr/en/pub/umtd

RESEARCH ARTICLE

Facility Layout Improvement in Brake Pad Manufacturing Using CRAFT Algorithm

Hüseyin Ali SARIKAYA[1], Hatice YILDIRIM DİNÇ[2], Habibe URGANCI[2]

[1]Mudanya University, Faculty of Engineering, Architecture Design, Industrial Engineering Department
[2]Konya Food and Agriculture University, Engineering and Architectural Faculty, Industrial Engineering Department

Corresponding author:
Hüseyin Ali Sarıkaya,
Mudanya University,
Faculty of Engineering, Architecture Design,
Industrial Engineering Department

E-mail address: huseyin.sarikaya@mudanya.edu.tr

Submitted: 18.07.2024
Revision Requested: 23.07.2024
Last Revision Received: 24.07.2024
Accepted: 24.07.2024

Citation: Sarıkaya, H.A., Yıldırım Dinç, H., Urgancı, H., A. (2024). Facility Layout Improvement in Brake Pad Manufacturing Using CRAFT Algorithm. *The Journal of Applied Engineering and Agriculture Sciences* 1(1), 27-46.

ABSTRACT

Effective facility planning can significantly reduce a company's operating costs. Facility layout problems deal with the location of objects within a particular area and the flow of materials between these objects. Companies must control costs and eliminate activities that do not add value to products to succeed in today's fiercely competitive global environment. There should be no extraneous equipment, products, or personnel involved in the business. The primary goal is to reduce the transportation costs. In this study, a new layout alternative has been proposed for a brake pad production factory operating in Konya Organized Industrial Park using the CRAFT (Computerized Relative Allocation of Facilities Technique) algorithm. Computational results show that the layout plan shortens material flow times by reducing department distances, as assessed by daily total transportation cost. In the new arrangements made using Muther`s Systematic Layout Planning (SLP) approach, interdepartmental transportation costs and the total daily material handling cost has been reduced by 55%.

Keywords: CRAFT, Muther’s Systematic Layout Planning, Material Handling Cost

1. Introduction

Plant layout is the arrangement of all the systems intended to produce a product or provide a service. Examining facility alternatives is an important issue as it will help ensure a working relationship between all units. So, in real life; it has many applications related to the design of facilities such as factories, hospitals, schools, markets, airports, warehouses, water turbines, circuit board problems (Akbilek, 2017).

Facilities planning aims to make things physically easier. The precise layout of departments within the facility will reduce transportation costs and ensure economic development, while also having a positive impact on employee health, motivation, and fitness. It is important that facility planning is done carefully during the initial installation phase to avoid difficult changes in the future. However, planning a one-time installation may not be enough. Facility layout plans must be revised at certain times for reasons such as changes in product variety, capacity increases, and technological developments.

In today's competitive world, companies operating in the manufacturing or service sectors need to work more efficiently and reduce costs as much as possible to survive and increase competitiveness. Companies carry out cost reduction studies at many stages, from determining the most suitable factory location to choosing a production system that minimizes stocks and avoids waste as much as possible as well as optimum placement of machinery/sections and logistics activities.

It is aimed at increasing efficiency and effectiveness while reducing costs. Efficiency is the most important factor increasing profit. The way to increase productivity is to use resources such as machinery, personnel, and equipment more effectively and to reduce expenses. It has become mandatory for companies to research and implement factors that increase profitability to take part in the competition. Material transportation also has an important place among these expenses. Research to date shows that most of the costs in a business are made up of unnecessary activities. The extra flow of materials, information and documents between departments/machines causes unnecessary transportation and therefore increases costs. These unnecessary shipments are often caused by parts/machines not being properly placed inside the factory. Studies of manufacturing systems have found that 35 to 70 percent of product cost can be related to material handling costs. Through research, it has been determined that material handling activities account for 20-50% of a manufacturing company's total operating budget (Tomkins et al., 2010)

Thus, if the firm locates its departments appropriately, it can reduce the production costs, which can increase the competitiveness of the firm. Facility planning determines how tangible assets can best support the business purpose. Facility planning has gained more importance in recent years. It aims to minimize the costs in the material flow, shorten delivery times by eliminating unnecessary movements.

The aim of this study is to highlight the importance of facility layout and propose a more efficient layout by analyzing the current transportation distances of a company operating in Konya Organized Industrial Park, Turkey. The company produces suspension and steering components. It has accelerated the sector with its developing corporate structure and rapidly increasing production power. With an annual production capacity of more than 40 million in passenger, light commercial, heavy vehicle, trailer and agricultural vehicles and a unique product range of more than 40,000, in the world's largest production site in its sector. It continues to be a strong, dynamic, and distinctive company with the production of steering and suspension parts, brake pads, brake discs, air bellows and air tank products. The company where the studies are carried out has just started the production of brake pads. However, there is a high-cost problem caused by some deficiencies and inaccuracies in the location of the pad production facility. In addition, there are some problems because there is no systematic layout in the facility, for example, waiting for machines and jobs in workflow processes, machines, and workers with excessive workload, etc. Furthermore, insufficient arrangements will result in unnecessary transportation costs between departments and machines. Factors such as unnecessary activities in the facility, irregularities in the facility layout plans, loss of time reduce the productivity of this facility. Thereupon, the layout of the brake pad manufacturing plant has been analyzed, and Muther's Strategic Layout Planning (SLP) procedure has been applied using CRAFT algorithm. SLP is a method for organizing and optimizing the layout of a manufacturing facility. The goal of SLP is to improve plant efficiency and productivity by reducing waste, increasing flow rates, and minimizing the distances that materials and products must travel.

The computer-aided layout used for layout design and improvement is Computerized Relative Allocation of Facilities Technique (CRAFT), developed in 1963 by Armour, Buffer and Volkmann. CRAFT is a technique that develops an existing layout by considering data. The inputs used include the size of buildings and departments, material flows, movements and distances between departments, initial frequency layout, site boundaries and required costs. When calculating with the CRAFT program in the OM_IE add-in, an iterative phase was performed, namely the replacement of adjacent areas, the calculation of the distances between areas, the transportation distances and the total distance traveled by material transportation (Febianti, et al., 2020). These methods and their details will be explained in the following sections.

The aim of this study is to increase occupational safety by applying the CRAFT algorithm to Muther's SLP method in the facility discussed here, to shorten the raw material transportation distance, semi-finished and finished product delivery times, and thus to achieve a high level of efficiency compared to similar studies previously conducted in this field.

This study is organized as follows: The first part is an introduction, and the second part is a literature review. Facility planning is discussed in part three, while layout types are explained in part four. The fifth part uses a business to implement Muther's SLP approach. The process to be employed for choosing the alternative layout is described in the sixth part. The seventh part concludes and includes further research.

2. Literature Survey

Considering these workplace layout issues, SLP has been shown in many applications to be the best way to improve workplace layout as it allows for incremental improvements in the assessment of layout and design (Khariwal et al., 2021). There are many studies on the subject in literature. Some of them, which are like the study we have done here, are listed below.

Yurdakul et al. (2009) examined the performance of a production organization and the consequences of moving physical resources such as labor, materials, machinery, and equipment to a location where production takes place in a way that minimizes overall material handling costs in this article. Firstly, the performance of the system was evaluated after modeling using ARENA package application. The LayOPT package program was then used to create a new layout and ARENA was used to model how the new layout would affect performance. The model created with the revised SLP was created so that the effects of additional system changes could be evaluated. According to the research, the new layout and the modifications that need to be made have a noticeable effect on performance.

Wiyaratn et al. (2013) examined the number of tools and equipment used in iron production in this case study. The operation process chart, material flow chart, and activity relationship chart have been extensively studied in conjunction with factory layouts. During the design process, the old facility layout plan and the new facility layout plan were compared. The new plant structure significantly reduces the material flow distance from logging to storage according to the SLP approach.

Zhou et al. (2011) performed the SLP methodology to the new layout of an automobile company. They used relevant graphs to reveal the logistical and non-logistical relationships of the workshops in the facility. After analyzing issues such as logistics efficiency, space utilization, management facilities, and cost, they proposed an improvement plan.

Tak and Yadav (2012) applied the SLP method in this study to effectively improve the placement of a profitable business. The study describes a case study of a specially built plant to produce steel almirah. The article contains a presentation of a particular product as an example, along with a description of the stages of SLP technique implementation. By comparing the three recognized possibilities, the layout of the productive system that works best is selected.

Watanapa and Wiyaratn (2011) suggested using SLP to help design process locations and areas in the best possible way. After deciding how many machines and how much space is needed in reel manufacturing, investigations were made on the activity relationship chart, material flow chart and operation process chart. They assumed that the relationships between machines, operations departments, and material flow chose the best location for each activity. Two alternative plant layouts were created using the SLP approach and the performance of the new layout in terms of material flow was compared with that of the existing configuration. Handling and surface disassembly significantly reduced the material flow distance in the new factory layout, effectively increasing productivity.

Wang and Kong (2013) created a layout plan for a company that produces recycled rubber using the SLP method in this project. By analyzing material and non-material flows, a relationship graph is produced for each workshop in the company. Then, two viable layout solutions are proposed, considering the current state of the business and its long-term development plan. To determine the goal and optimal design, these two concepts are compared using the comparative law of comparable flow capacity. This layout change optimizes the production system.

Xiao et al. (2012) conducted a study that highlighted the importance of the low-carbon logistics sector as the low-carbon economy grows. At the planning stage, the idea of a low-carbon logistics system was presented to realize a low-carbon economy by enterprises. Their research presents a low-carbon SLP remediation method. It combines the standard SLP layout method with low consumption, low emissions, low pollution, and reduced logistics. The plant layout was reviewed and redesigned using remediation methods as well as the actual plant layout. As a result, the factory's logistics situation has been significantly improved, overall efficiency has increased, the amount of raw materials has been reduced, and energy consumption and waste treatment have also been significantly reduced.

Wiyaratn et al. (2013) changed the current layout of the canned fish plant in this study. The SLP method is used to create an alternative plant layout that considers canned fish locations, activity relationships, ideal process areas and material flow. Problem found with material flow in each operating section. Material flow distance has been greatly reduced by using an alternative plant structure and SLP approach.

Çapraz (2013) evaluated e-waste separation systems and processes in the first stage of the thesis and performed data collection processes. Then, settlement alternatives were created using the fundamental concepts of the settlement planning problem and disassembling systems using the unique circumstances and requirements. Models of developed layout options have been created with the aid of the simulation program ARENA 10.0. Due to the variety and structural ambiguity of e-waste, disassembly times in the models were determined as imprecise. The outcomes of the simulation models are contrasted using various performance indicators, including the quantity of salvageable parts recovered during disassembly operations, the total amount of waste disassembled, the amount of money made from the sale of parts, and the amount of time spent on non-value-added activities. The Kruskal-Wallis H test was used to statistically examine the simulation model findings.

Prasad et al. (2014) used the CRAFT methodology to design an innovative factory layout, which was specifically designed to a typical manufacturing plant that required network connectivity with units that would have required communication facilities in the modern era of industrial technology. The best plant layout can be created using the JAVA application developed to use the STEP file as input.

Lin et al. (2015) proposed a method for planning and perfecting hospital OT facility layouts in this article. The OT layout is first designed using SLP using logistic and non-logistical links. The fuzzy constraint theory is then introduced to fully evaluate the layout schemes. These research findings can assist hospital managers in applying more contemporary management techniques in day-to-day operations.

Doğdubay and Karan (2017) explained the effect of the kitchen plan on the workflow and how the best kitchen planning should be, and the qualitative and quantitative requirements needed for hotel kitchens in general and large hotel businesses in particular. In addition, based on the literature resources, it has been examined whether the kitchen planning activity can be carried out according to the SLP model.

Potadar and Kadam (2018) analyzed the layout of the existing process type and determined the transportation costs. The SLP tool was used to come up with new and improved layouts. As part of the study, they examined the existing plant layout of IWAI Electronics, a loudspeaker manufacturing industry. Computerized Relationship Configuration Planning (CORELAP) was used analytically to examine the Total Closeness Index (TCR) of the existing configuration. Subsequently, a new development plan was proposed, which reduced processing costs by 11.63%.

Mallick et al. (2019) used the Computerized Plant Relative Allocation Technique (CRAFT) to improve the layout of a foundry industry. The findings show that the new layout design created using the CRAFT algorithm can reduce the overall distance traveled by 34.9%.

Suhardi et al. (2019) aimed to redesign the plant layout of a garment company producing women's underwear. They used SLP and ergonomic approaches to minimize the total material handling cost. Two design alternatives were proposed, and the performance of each design was evaluated using ARENA simulation software. Based on the calculation and simulation of the total material handling costs, one of the proposed plant layouts was selected as it could reduce the total material handling cost by 22.92% and the material transport time by 34.01%.

Huang et al. (2019) developed a multi-objective, very constrained optimization model for shop floor layout design. In their study, the optimization layout design of the finishing workshop was discussed using the improved SLP technique, which is a new problem-solving method created by combining the traditional SLP method and the genetic algorithm.

Zhang et al. (2020) improved the traditional method of SLP and combined it with a multi-objective decision optimization model. To make the improved SLP (ISLP) more suitable for research and practice problems, we created a mathematical model. This optimization model was also applied to an existing plant layout problem to realistically verify the effectiveness of ISLP and the model. First, the results of the established model were found, and then the layout of the system was simulated before and after optimization using Flex Sim simulation software. Finally, they analyzed and compared the experimental results.

Khariwal et al. (2021) applied SLP as a solution to the problem of moving wagons along long lines, interrupting the flow and finding unusable areas of the facility, encountered in maintenance, repair and supply activities in the railway workshop, and with this method, it improves the flow between stores and reduces the movement in the workshop. He proposed a new workshop layout that helps.

Haryanto et al. (2021) used the SLP methodology to minimize the material handling costs incurred in the manufacturing process of Tressel parts that they identified in a hard disk drive (HDD) manufacturing company. The proposed layout was able to reduce the material handling costs (OMC) of Tressel's manufacturing process. This saved the company's material handling costs from IDR 5,377,415 per month to IDR 2,971,717 after improvements. OMC was reduced by IDR 2,405,698 per month, resulting in a saving of 44.7%.

Tjusila et al. (2021) focused on finding the best alternative layout solutions with optimal flow movements using the SLP method, CRAFT algorithm, and CORELAP to improve the layout of a company that manufactures different types of packaging made of Styrofoam, blown bottles, PET bottles, and injection caps. The result of the study calculates the flow of material movement to the finished product. Considering the cost of material handling, the distance traveled, the frequency and time of movements, the layout results of the three methods are compared to achieve a more efficient layout design. The most efficient layout is the second design, the SLP method, which reduces the distance by 60. 21% and the material handling cost by 44.29%. The layout implementation was visualized using the simulation software Promodel and Flexsim.

Elkhoja et al. (2022) generally adopted facility planning as a strategy due to intense competition in the global economy and has helped any firm achieve supply chain excellence. The plant layout problem, which tries to optimize the company's production processes by organizing and positioning the production units in any plant, forms the basis of plant design. The method of producing factory layout plans is called systematic layout plan (SLP). Consequently, the tissue paper factory in Libya was chosen as the subject of the case study of this technology. In this study, the distances between plant departments and machines are reduced to save space. The binary swap method resulted in an increase in productivity. As a result, costs associated with material handling were reduced, which lowered overall costs and increased overall profits.

Faishal et al. (2023) aimed to improve the plant layout to reduce the material handling time of a small and medium-sized enterprise (SME) manufacturing sponge slippers in Yogyakarta, Indonesia, which faced material handling difficulties between departments, resulting in increased production time and decreased productivity. In this research, they used Activity Relationship Table (ARC) and CRAFT techniques to redesign the facility layout, followed by analyzing the proposed layout using simulation. The results show that the CRAFT technique reduces distance by 53.76%, reduces material handling time by 37.13%, and improves efficiency by 2.39%. In contrast, the ARC method reduces the distance and material handling time by 34.29% and 25.52% respectively, leading to an efficiency increase of 3.75%. As a result, the new layout obtained from CRAFT methods was proposed for implementation.

Li and Penaranda (2024) performed CRAFT analysis of the cost matrix with twenty sections and two conditional (probability weighted) racking routes to show whether a new rack was needed on a particular route on a bakery in Ontario which was experiencing rack disorganization and storage problems due to facility layout issues. CRAFT's revised layout had two racking areas (one near and one far) that optimized flow for all product routes, resulting in a 26% improvement in total movement cost, which can increase production and reduce racking problems in the oven.

Nugraha and Widjajati (2024) applied the SLP methodology to redesign the layout of a bottle storage facility considering factors such as material flow, space requirements, and efficiency. Data was collected through observations, interviews, and literature review and analyzed using SLP software. The study results show that the new layout reduces total costs by 90,439 IDR and increases productivity. Based on the results of the layout proposals generated by CRAFT software, the company can maximize productivity as the cost and distance required are optimized through the methodology of the CRAFT software layout planning system.

3. Muther's SLP and Its Implementation in A Facility

3.1. Overview of Muther's SLP

The SLP approach was developed by Richard Muther in 1961. Staff at all levels can easily detect it. SLP adjusts the existing plant layout to make material handling more efficient. For the implementation of the SLP, first, the necessary information and data are collected, and the relationship between the departments is determined by making flow analysis. The relationship diagram developed by Muther is used to show the relationships between departments. Letter notations are used to show relationships. The flow between departments is shown qualitatively. These notations allow people to perceive the analysis more easily.

Muther's method is one of the most widely used. It allows the researcher to see the relationship of the departments with each other. The use of charts and diagrams increases people's inclination towards the subject by making the analysis easier to understand by people.

SLP recommends a new layout with less material transported. In this way, an improvement in transportation costs is achieved. It enables the researcher to see the relations and needs in production and sheds light on the improvements to be made. As the parts that are strongly related to each other get closer to each other, the time and effort provided for transportation decreases.

<u>Steps of SLP</u>

The approach consists of three main stages as analysis, research, and selection. In the analysis phase, the necessary data is collected, and the relations are examined by considering the flow and the area. In the research phase, alternative options are created, and the most efficient option is used in the selection phase. Aiming at lower transportation costs, the SLP method consists of 10 steps (Figure 1). In the first step, data is collected. By analyzing the collected data, flow charts between departments are created. Based on the flows between departments, the degrees of importance between them are determined. An activity relationship chart is created by using the letters A, E, I, O, U, X for the degree of importance. An activity relation diagram is created by performing activity relation analysis. A relationship diagram is created by showing with bars. Space suitability and space requirement are determined. A field relation diagram is created by adding field data to the relation diagram. If there are any constraints to be added to the model, they are added, and the exception is checked. Based on these analysis, new alternative settlement plans are created. The alternative settlement plans created are evaluated and applied by selecting the most suitable settlement plan for the enterprise.

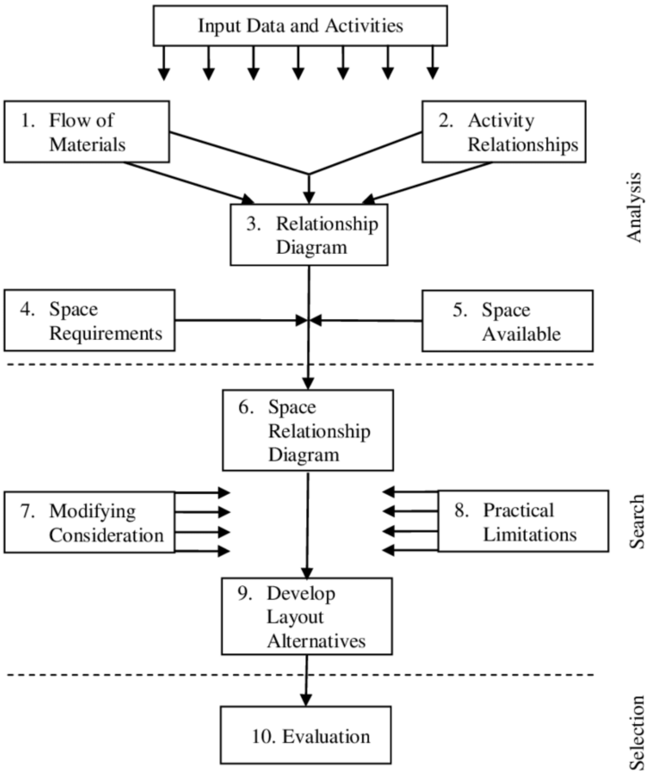

Figure 1. Muther's Systematic Layout Planning Procedure

Input Data and Activities

Information must be gathered and processed to develop relationships between departments. Which kind of criteria will be utilized as data should be decided.

Flow of Materials

Using the flow summary chart, the flow density between the sections is determined. This analysis is required to ensure the lowest cost material flow. The material should reach its destination by circulating in the least possible way. The reasons for the relationship and intimacy can be:

- Material flow amounts.
- Personnel can work in more than one place.
- Multiple departments using the same equipment.
- Joint paperwork, document filling.
- Departments or employees who need to be in contact.

Activity Relationship Chart

At this stage, a qualitative evaluation is made and the degree of closeness between departments is determined. The activity relationship diagram shows the relationship of the departments with others, and the degree of closeness is scored. Qualitative evaluation consists of 6 levels, shown in Table 1. We decide the distance between the departments according to the relationship closeness.

Table 1. Closeness Rating

Value	**Closeness rating**
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness

U	Unimportant
X	Undesirable

Based on the closeness rating, an activity relationship chart is created as in Figure 2.

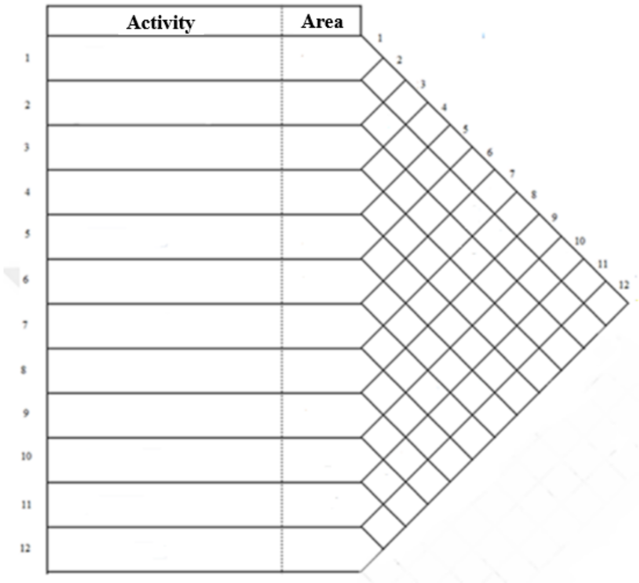

Figure 2. Activity Relationship Chart

Activity Relationship Diagram

In this step, the partitions are positioned. Strong or weak relationships between departments are shown. It is the visual version of the activity relationship diagram on the layout. The relationship between the sections is visually indicated by lines. Each letter in the activity relationship diagram has a linear equivalent. The relationship diagram gives an idea for inter-section spacing arrangements without considering space requirements. The SLP method uses class notations to define the interdepartmental relationship in an easy-to-understand way. In the previous step, the degree of importance has been determined by letters, in this step the linear line equivalent of each letter is determined as in Table 2.

Table 2. Linear Equivalent of Significance Levels

Relationship	**Closeness rating**	**Diagram Lines**
A	Absolutely necessary	
E	Especially important	
I	Important	
O	Ordinary closeness	
U	Unimportant	
X	Undesirable	

Space Relationship Diagram

It is the version of the fields added to the relationship diagram. In this step, the combination of the relationship chart and the activity relationship diagram is analyzed. The analysis of qualitative factors in SLP practice can be easily perceived by anyone. Adjustments are made subjectively.

Modifying Considerations

When creating a new layout, some restrictions may be required. Such as the last section in the flow should be close to the shipping area, the first section should be close to the raw material area, and the sections that should be close to quality control.

Develop Layout Alternatives

Creating an alternative layout is suggested in this step. A new layout plan is created according to the needs and relations between the departments. The activity relationship diagram guides the creation of the new layout. The goal is to minimize inter-departmental transport.

Evaluation

In this step, alternative layouts are suggested, and the most suitable layout is applied.

3.2. Application of SLP in a Facility

In the sections that follow, the components that were previously detailed will be used with the brake pad production facility.

Facility Departments

Muther's SLP method operates in Konya Organized Industrial Park. It has been applied in a company showing the improvement and the improvement has been analyzed. The facility consists of 18 departments as shown in the table below.

Table 3. Facility Departments

No	**Departments**
1	Sheet Metal Warehouse
2	Press
3	Sheet Sandblasting
4	Bonding
5	Semi-Finished Goods Warehouse
6	Hot Pressing
7	Chemical Warehouse
8	Furnace
9	Surface Cleaning
10	Assembly
11	Packaging
12	Shipment
13	Recreational area
14	Molding room
15	Offices
16	Brake Pad Accessory Waiting Area
17	Brake Pad Chemical Preparation Area
18	Mold Rack Space

The operation process chart of the production line is detailed in Figure 3 below.

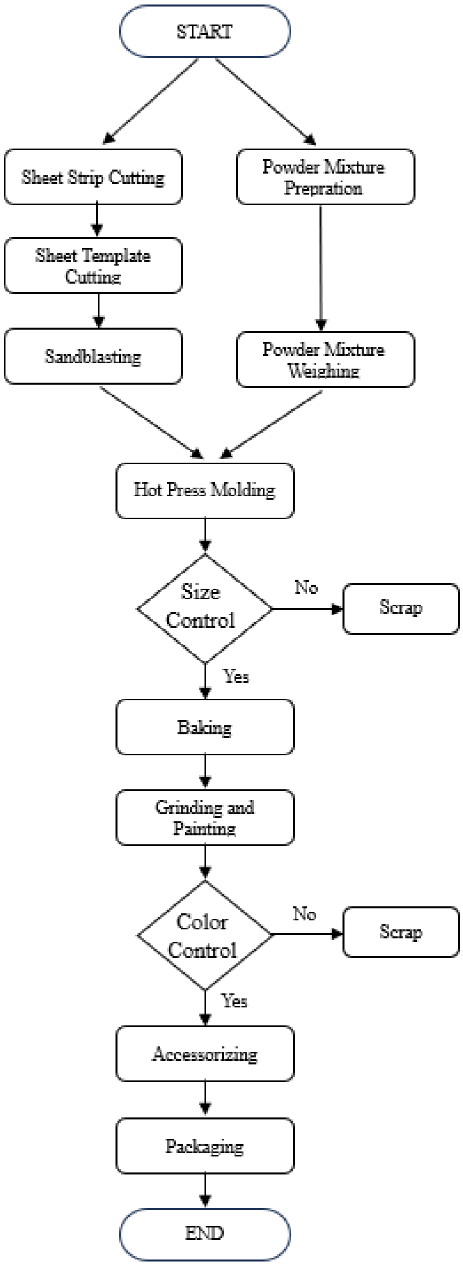

Figure 3. Operation Process Chart of The Brake Pad Manufacturing Plant

From To Charts

The from-to chart created based on the daily flow of materials between work centers is shown in Figure 3.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		3000 units																
2			18000 units															
3				18000 units														
4						18000 units												
5																		
6								30000 units										
7						7200 units												
8									30000 units									
9					30000 units													
10											15000 units							
11												15000 units						
12																		
13																		
14																		
15																		
16					12													
17						9												
18						9												

Figure 3. From-to Chart for Materials

The from-to chart for daily movements between departments is shown in Figure 4.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		30																
2			90															
3				36														
4						36												
5																		
6								30										
7						24												
8									24									
9					60													
10											90							
11												45						
12																		
13																		
14																		
15																		
16					1													
17						9												
18						9												

Figure 4. From-to Chart for Daily Movements.

Departments Space

Space requirements can be equipment area, material area (semi-finished product, finished product), personnel needs areas (cafe, table tennis, rest area). The area occupied by 18 departments is shown in Table 4.

Table 4. Departments Space Information

No	Departments	Space (m^2)
1	Sheet Metal Warehouse	60
2	Press	900

3	Sheet Sandblasting	360
4	Bonding	150
5	Semi-Finished Goods Warehouse	480
6	Hot Pressing	900
7	Chemical Warehouse	440
8	Furnace	150
9	Surface Cleaning	1000
10	Assembly	1100
11	Packaging	300
12	Shipment	600
13	Recreational area	800
14	Molding room	800
15	Offices	600
16	Brake Pad Accessory Waiting Area	500
17	Brake Pad Chemical Preparation Area	400
18	Mold Rack Space	280

Activity Relationship Chart

The brake pad manufacturing plant activity relationship chart is shown in Figure 5 based on the following closeness rating shown in Table 5.

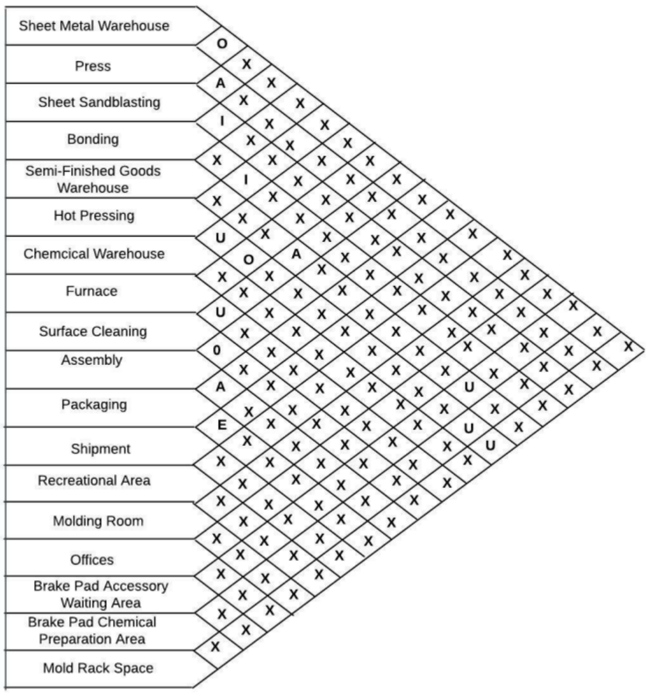

Figure 5. Activity Relationship Chart of The Brake Pad Manufacturing Plant

A qualitative assessment is conducted at this point, and the level of collaboration between departments is established, and the degree of closeness is graded based on number of movements as shown in Table 5.

Table 5. Closeness Rating

Number of movements	Relationship	Closeness rating
60 and above	A	Absolutely necessary
45-55	E	Especially important
36-44	I	Important
30-35	O	Ordinary closeness
0-29	U	Unimportant
0	X	Undesirable

Activity Relationship Diagram

An activity relationship diagram has been created according to the degree of relationship obtained from the number of daily trips. The relationship between the departments is depicted in the activity relationship diagram as shown in Figure 6.

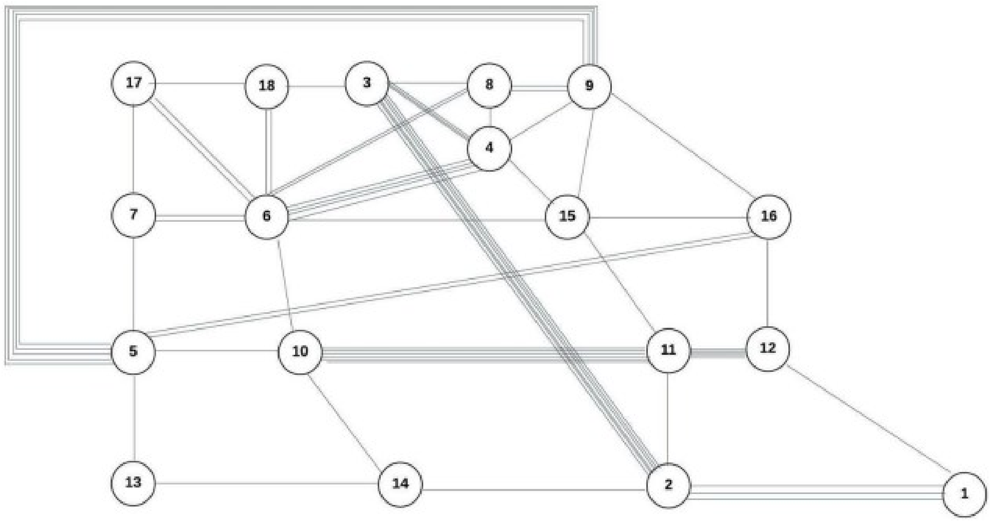

Figure 6. Activity relationship diagram

Space Relationship Diagram

The space relationship diagram drawn according to the activity relationship diagram is as in Figure 7.

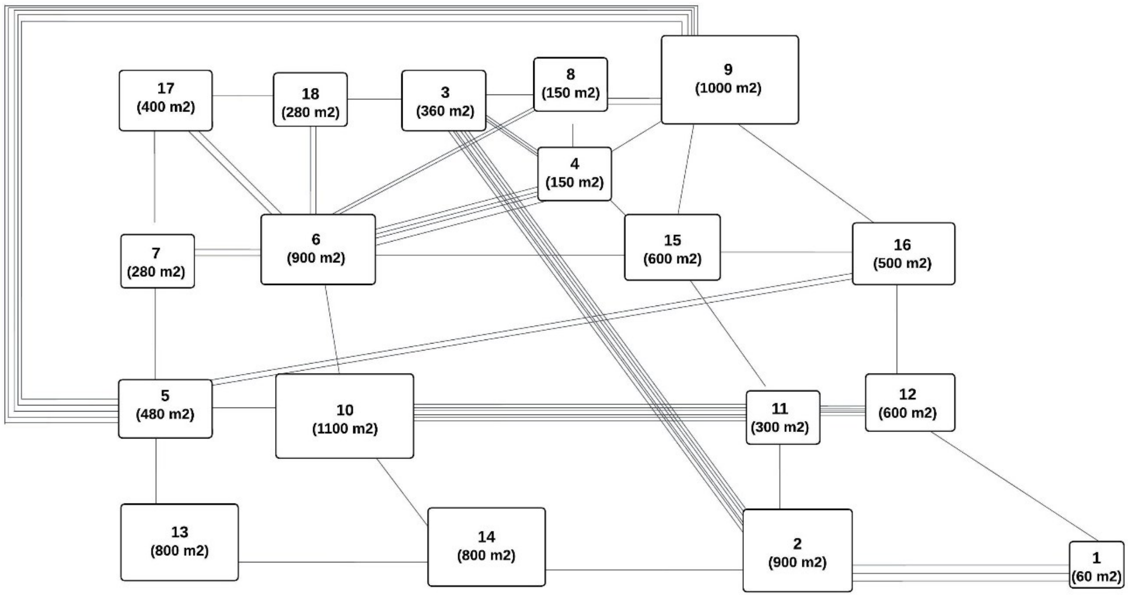

Figure 7. Space relationship diagram

<u>Initial Layouts</u>

Below (Figure 8) is an overview of the brake pad production facility's initial layout.

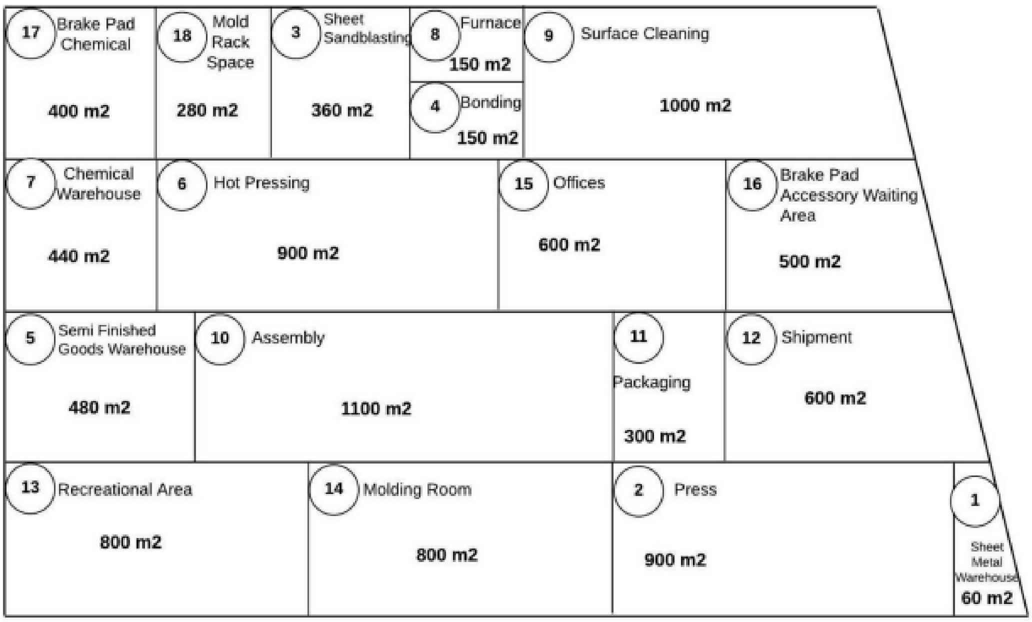

Figure 8. Initial layout

Below is an overview of the initial layout of the brake pad manufacturing plant drawn with AutoCAD (Figure 9).

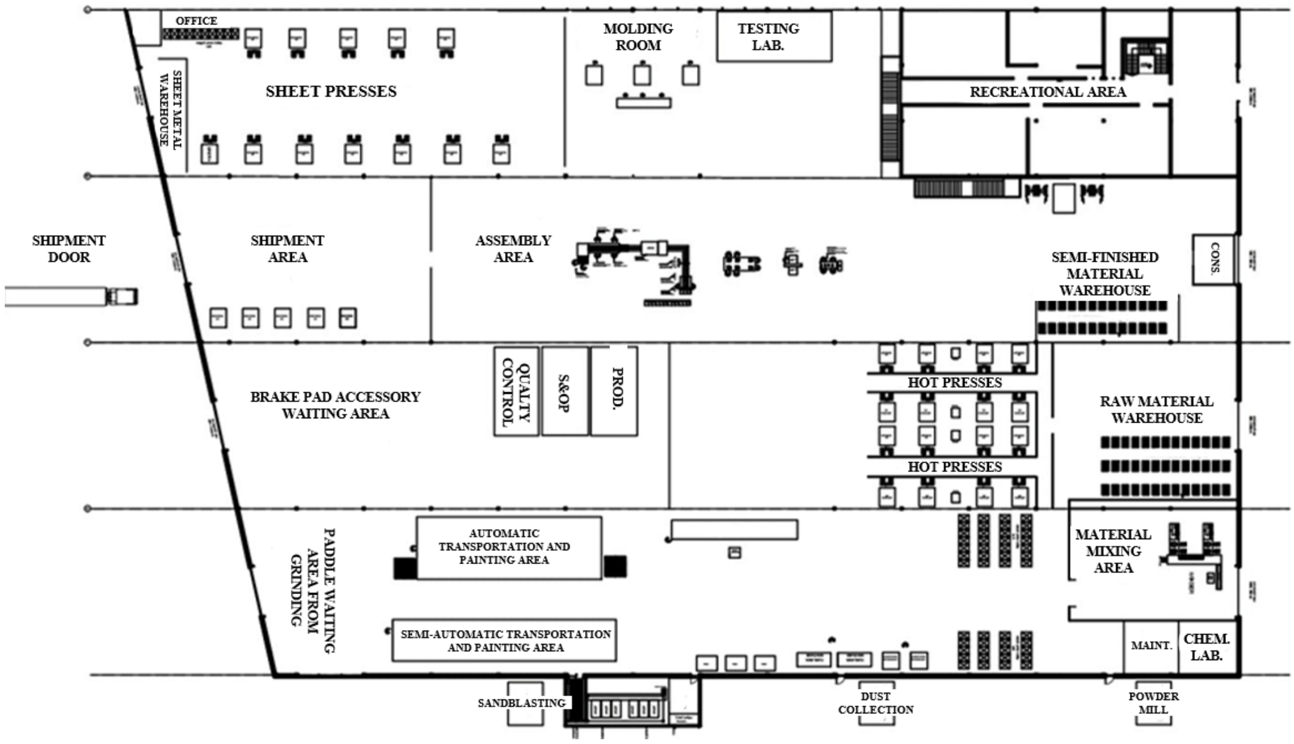

Figure 9. Initial Layout by AutoCAD

<u>Route Sheet</u>

A list of the manufacturing steps and the order in which they must be completed is provided below. The necessary times are also provided in addition.

Table 6. Route Sheet

Company Produce		Part Name		Prepared by	
		Part No.	221022-0824	Date	24.06.23
Operation No.	Operation Description	Operation Time		Operation Amount	# of workers
FB. MOPR000	Assembly first confirmation		0.16 sec	200	1
FB. MOPR002	Manual shim assembly		104 sec	200	1
FB. MOPR004	Add brand		34.67 sec	200	2
FB. MOPR008	Attaching an indicator		65 sec	200	1
FB. MOPR009	Last check		0.16 sec	200	1
FB. MOPR011	Packaging		34.67 sec	200	7

<u>Machine Fraction</u>

The amount of equipment required for an operation is called the machine fraction. Equipment requirements are based on the following factors:

- Number of changes (The same machine can work in more than one shift).
- Setup times (If computers are not committed, the longer the setup, the more machines are needed).

- Degree of flexibility (Customers may request small batches of different sizes. Products are delivered frequently - additional machine capacity will be needed to meet these demands).
- Layout (separation of production cells or directed factories into machines).
- Fully efficient maintenance (increases machine uptime and improves machine uptime).

The machine fraction is calculated by dividing the total time required to perform the operation by the times during which the operation will be performed, as shown in Equation (1).

$$F = \frac{SQ}{EHR} \tag{1}$$

where

F = Number of machines required per shift

S = Standard time per unit produced (minutes)

Q = Number of units to be produced per shift

E = Actual performance expressed as a percentage of standard time

H = Available time per machine (minutes)

R = Reliability of the machine, expressed as a percentage of uptime

The results of machine fraction calculations using the formula mentioned earlier are shown in Table 7.

Table 7. Machine Fractions

Machines	**Calculations**
Press	S: 0.067 minutes H: 450 minutes Q: 6000 units E: %88=0.88 R: %100=1 F: 1,015=2
Sheet Sandblasting	S: 0.01 minutes H: 450 minutes Q: 6000 units E: %93=0.93 R: %85=0.85 F:0.16=1
Bonding	S: 0.0076 minutes H: 450 minutes Q: 6000 units E: %82=0.82 R: %90=0.90 F:0.13=1
Hot Pressing	S: 0.25 minutes H: 450 minutes Q: 6000 units E: %90=0.90 R: %85=0.85 F:4.35=5
Surface Cleaning	S: 0.05minutes H: 450 minutes Q: 6000 units E: %90=0.90 R: %90=0.90 F:0.823=1
Assembly	S: 0.05 minutes H: 450 minutes Q: 6000 units E: %80=0.80 R: %100=1 F:0.83=1
Packaging	S: 0.025 minutes H: 450 minutes Q: 6000 units E: %80=0.80 R: %100=1 F:0.41=1

4. Method Used for Alternative Layout: CRAFT

The CRAFT algorithm was originally developed by Armour and Buffa in 1963. CRAFT, one of the earliest layout algorithms to be described in the literature, is an innovative program that optimizes design by gradually improving the layout. CRAFT evaluates facilities with interchangeable departmental locations. The algorithm continues until no more changes can be made to reduce transportation costs. The results given by CRAFT are not optimal in terms of minimum transportation costs. However, in most applications the results will be good and close to optimal.

The flow is fed data from a from-to chart. Equation's distance-based objective function calculates the "cost" of a layout.

Think about the distance-based objective first. Let m represent the total number of departments, f_{ij} the flow from department i to department j (measured in the quantity of unit loads transported per unit of time), and $c_{ij}$the price associated with transporting a unit load one distance unit from department i to department j. The goal is to reduce the price per unit of time for departmental transportation. The goal can be expressed mathematically as the following:

$$Min\ Z = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij}\, c_{ij} d_{ij} \qquad (2)$$

where d_{ij} denotes the separation between departments i and j. d_{ij} is typically measured rectilinearly between department centroids in layout algorithms, although it can alternatively be measured in accordance with a specific aisle structure (if one is given).

It should be noted that the c_{ij} values in Equation (2) are linearly connected to the length of the transfer and implicitly considered to be independent of how the handling equipment is used. If the c_{ij}values do not agree with the premises, one may set c_{ij} 1 for all i and j and concentrate only on the facility's overall unit load travel (i.e., the product of the $f_{ij}$and the d_{ij}values).

Since CRAFT is an improvement-type layout algorithm, it starts with an initial layout, which typically represents the layout of an existing facility but can also represent a potential layout created using other methods. The basic layout of departments' centroids is first determined using CRAFT. The rectilinear distance between adjacent department centroids is then calculated, with the results being stored in a distance matrix. Each entry in the from-to chart is multiplied by the corresponding entries in the unit cost matrix (i.e., the c_{ij} values) and distance matrix to obtain the initial layout cost.

After weighing all feasible two-way (pairwise) or three-way department exchanges, CRAFT chooses the exchange that will result in the biggest decrease in the layout cost as the ideal exchange. (A two-way or three-way exchange cannot result in the division of any department.) To finish the first iteration, CRAFT determines the best exchange, modifies the layout in accordance with the best exchange, and calculates the new department centroids as well as the new layout cost. In the following iteration, CRAFT once more chooses the optimal trade from among all potential two-way or three-way exchanges in the (updated) layout. The procedure is repeated until there is no more room for cost savings in the layout. Since no more two-way (three-way) exchanges can lower the layout cost, the final layout obtained in this way is also referred to as a two-opt (three-opt) layout.

Initial Layout

The first layout of the parts of the factory related to brake pad production has been created using the CRAFT algorithm with the help of the excel plugin. One of the reasons for using CRAFT as an algorithm in this study is that it is a user-friendly algorithm that can reduce costs when considering inter-departmental and inter-departmental flows. The second is the easy and fast definition of fields in the computer environment. There are 18 departments with their associated fields, as visible on the Excel display. To utilize the CRAFT application more effectively, the area of the lining production plant has been proportionately reduced. A 40x54 unit area has been covered with CRAFT. There are many colors displayed for each department. The first layout is applied to CRAFT in the following figure (Figure 10). The price is 44,346.57 units, as is evident.

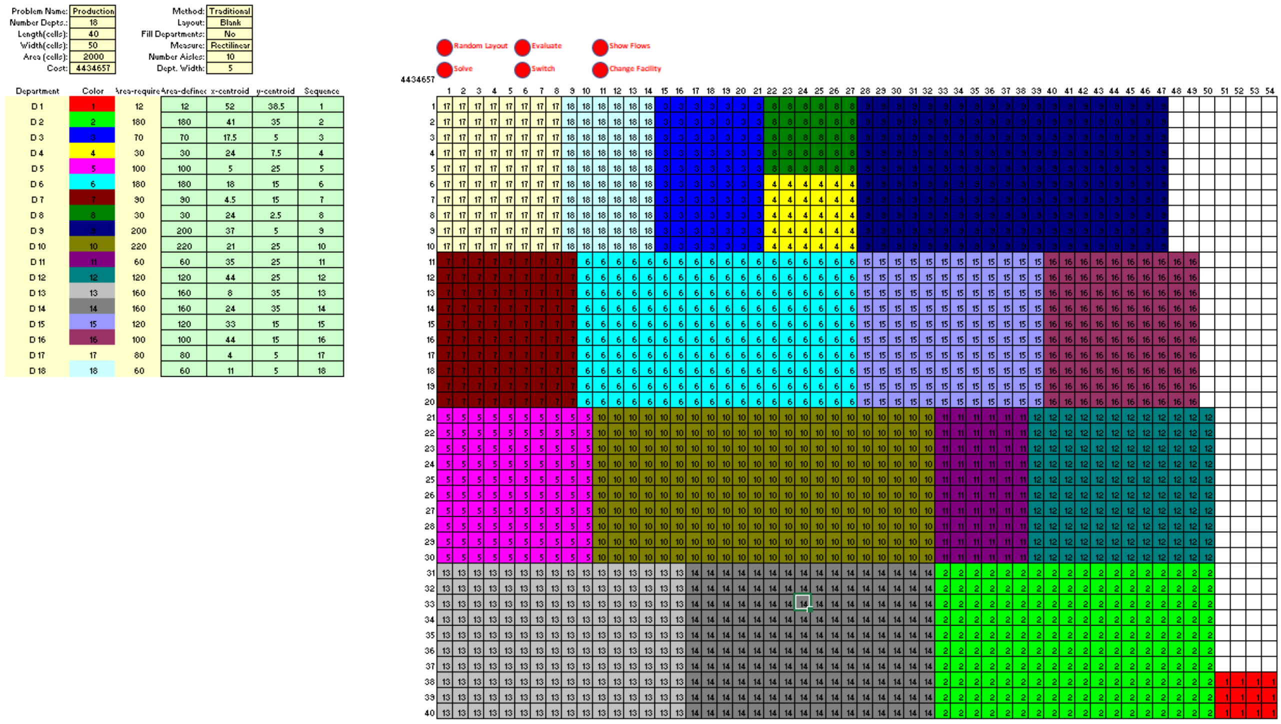

Figure 10. Initial Layout CRAFT

Alternative Layout

Making use of the CRAFT, the layout has been improved. The other approach was abandoned by CRAFT because it was unable to obtain a cheaper price. Figure 11, which is shown below, shows an alternate configuration. The departments have been organized most effectively after 10 iterations. Cost decreased to 24,701.57 units.

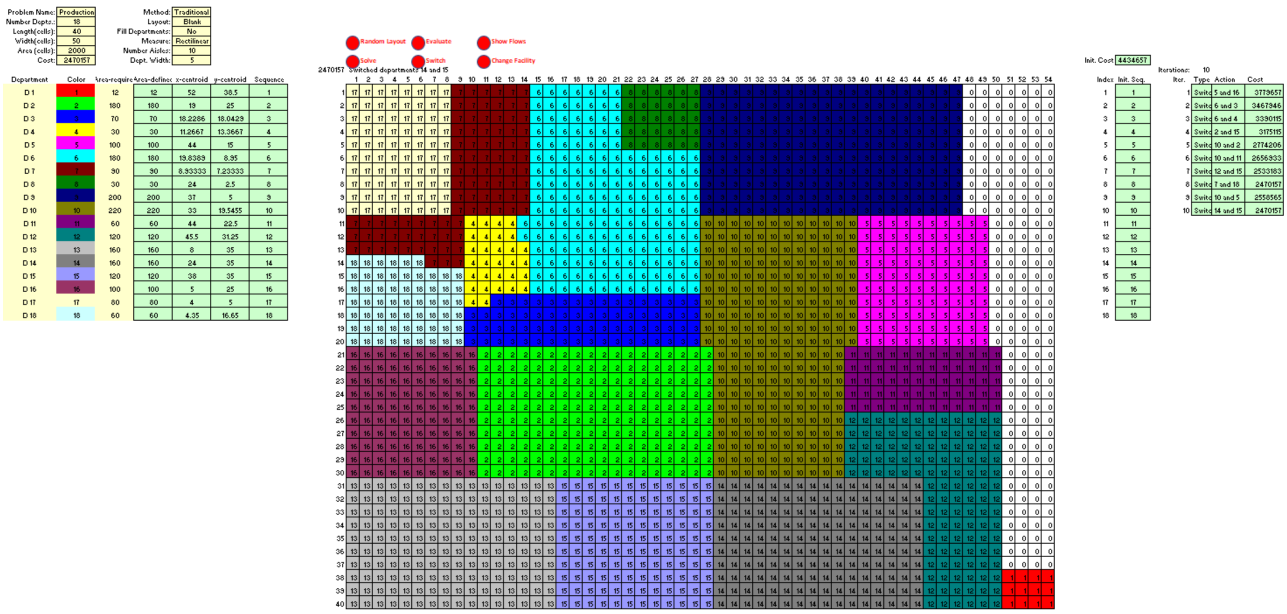

Figure 11. Alternative Layout CRAFT

Analysis of Alternative Layout Proposal

The proposed layout based on the SLP method is shown in Figure 12.

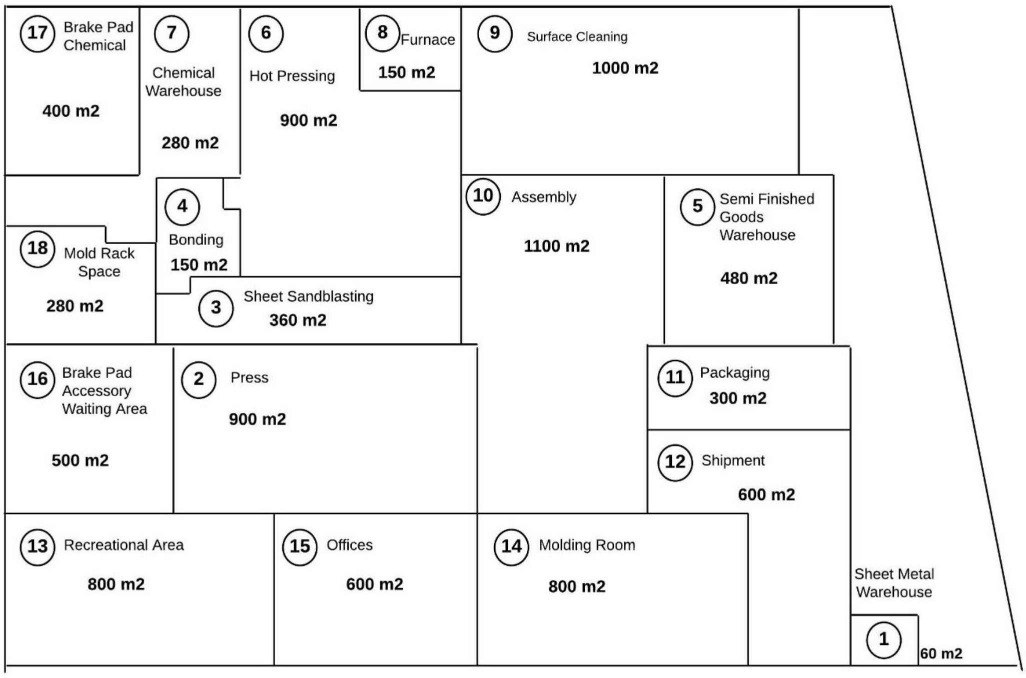

Figure 12. Alternative Layout by AutoCAD

Results and Discussion

For a brake pad manufacturing plant operating in the Konya Organized Industrial Park, using the CRAFT algorithm and Muther's SLP method, a new layout design has been proposed, and improvements have been noted. Furthermore, improvements are supported by calculations. As a benchmark for comparison, the daily total transportation cost has been utilized. There are now 44,346.57 units spent on material handling every day. The transportation expense between the departments in the layout plan has been decreased to 24,701.57 units in the revised arrangements produced utilizing Muther's systematic layout design methodology. The price of material handling is cut by 55%.

5. Conclusion and Further Research

Facilities planning aims to make things physically easier. The precise location of components within the facility will reduce transportation costs and ensure economic development, while also having a positive impact on employee health, motivation and fitness. It is important that facility planning is done carefully during the initial installation phase to avoid difficult changes in the future. However, one-time facility planning may not be enough. Facility layout plans must be revised at certain times for reasons such as changes in product variety, capacity increases, and technological developments.

In this study, information has been provided about the importance and purpose of facility layout planning, facility types and layout techniques, and a new layout plan has been proposed for a brake pad manufacturing facility operating in Konya Organized Industrial Zone and improvements have been observed. A new layout scheme has been proposed by applying the CRAFT algorithm to Muther's SLP method.

Computational results have proven that the developed layout plan shortens material flow times due to the reduction of the distance between departments. Daily total transportation cost has been used as a comparison criterion. The current total daily transportation cost is 44,346.57 units. In the new arrangements made using Muther's systematic development planning approach, interdepartmental transportation costs have been reduced to 24,701.57 units in the layout proposal. Material handling costs have been reduced by 55%.

When the results of similar studies in the literature are examined in terms of material transportation costs, it has been seen that the 55% improvement obtained in the study conducted here is quite good compared to the reduction in material transportation costs in similar studies. This shows that the improvements obtained as a result of applying the CRAFT algorithm to Muther's SLP method are quite satisfactory.

The physical layout of the company has been rearranged and incompatibilities between business units have been reduced. Implementation of the new layout in the enterprise will increase occupational safety, raw material transportation distance, semi-finished and finished product delivery times will decrease, thereby increasing productivity.

For further research, computer-aided simulation software can be used to perform comprehensive “before and after” comparisons. This simulation software provides data on capacity utilization, machine downtime, worker productivity, and more. It will show the impact of variables in real time. Since material flow increases costs, the inclusion of lean manufacturing methods (5S, etc.) in this research framework will significantly contribute to the creation of an efficient facility layout mechanism.

Acknowledgements

In this study, Hüseyin Ali SARIKAYA contributed to the article creation, review of scientific literature, supervision. conclusions and recommendations, Hatice YILDIRIM DİNÇ contributed to data collection, methodology, conceptualization, resources, investigation, writing – review, Habibe URGANCI contributed to the data collection, methodology, application, and numerical analysis.

Conflict of Interest

No conflict of interest is declared by the authors.

References

Akbilek, N. (2017). A flow-focused facility layout application in food machine industry. Sakarya University Journal of Science, 21(5), 951-960. https://doi.org/10.16984/saufenbilder.283221

Çapraz, O. & Aşkıner, Ö. (2013). E-atık geri kazanım sistemlerinde demontaj tesis yerleşim planlaması (Master's thesis, Pamukkale Üniversitesi Fen Bilimleri Enstitüsü).

Doğdubay, M. & Karan, İ. (2017). Otel mutfaklarında sistematik işyeri düzenleme planı (SİDP) modelinin uygulanması. Aydın Gastronomy, 1(1), 9-23.

Faishal, M., Mohamad, E., Pratama, M. A., Rahman, A. A. & Adiyanto, O. (2023). Application of Lean Layout Planning To Reduce Waste in Slippers Manufacturing: a Case Study. Journal of Advanced Manufacturing Technology (JAMT), 17(3).

Febianti, E., Kulsum, K. & Pradifta, D. (2020). Relayout Gudang Bahan Baku dengan Menggunakan Metode CORELAP dan CRAFT di PT. XYZ. Journal Industrial Servicess. 6(1):78. doi: 10.36055/jiss.v6i1.9481.

Haryanto, A. T., Hisjam, M. & Yew, W. K. (2021, March). Redesign of facilities layout using Systematic Layout Planning (SLP) on manufacturing company: a case study. In IOP Conference Series: Materials Science and Engineering, 1096, 012026. doi: 10.1088/1757-899X/1096/1/012026

Huang, L., Yi, Y., Du, Q. & Mo, C. C. (2019). Comparison of Factory Layout Based on Traditional SLP Method and Improved SLP Method. In Proceeding of the 24th International Conference on Industrial Engineering and Engineering Management 2018 (pp. 499-513). Springer Singapore, doi: 10.1007/978-981-13-3402-3_53

Khariwal, S., Kumar, P. & Bhandari, M. (2021). Layout improvement of railway workshop using systematic layout planning (SLP) – A case study, Materials Today: Proceedings, 44(6), 4065-4071. https://doi.org/10.1016/j.matpr.2020.10.444.

Li, J. & Penaranda, K. (2024). Resolving Facility Layout Issues in an Ontario Bakery Using CRAFT with Numerous Departments and Probabilistic Rack Movement, 2024 IEEE 4th International Conference on Human-Machine Systems (ICHMS), Toronto, ON, Canada, 1-7, doi: 10.1109/ICHMS59971.2024.10555632.

Mallick, P., Muduli, K., Biswal, J. N., Pumwa, J. & Oyekola, P. (2019). Development of a suitable plant layout using computerised relative allocation of facility techniques. Int. J. Recent Technol. Eng, 8, 4956-4961.

Naqvi S. A. A., Fahad, M., Atir, M., Zubair, M. & Shehzad, M. M. Wenjun Xu (Reviewing Editor) (2016). Productivity improvement of a manufacturing facility using systematic layout planning, Cogent Engineering, 3:1. https://doi.org/10.1080/23311916.2016.1207296

Nugraha, N. A. & Widjajati, E. P. (2024). The Analysis of Bottle Warehouse Facility Layout Design Using the System Layout Planning Method (SLP) Using Software Craft in PT. XYZ. Advance Sustainable Science, Engineering and Technology (ASSET), 6(3), 0240309-0240309. https://doi.org/10.26877/asset.v6i3.628

Potadar, O. V. & Kadam, G. S. (2019). Development of Facility Layout for Medium-Scale Industry Using Systematic Layout Planning. In: Vasudevan, H., Kottur, V., Raina, A. (eds) Proceedings of International Conference on Intelligent Manufacturing and Automation. Lecture Notes in Mechanical Engineering, Springer, Singapore. doi: 10.1007/978-981-13-2490-1_43

Prasad, N. H., Rajyalakshmi, G. & Reddy, A. S. (2014). A typical manufacturing plant layout design using CRAFT algorithm. Procedia engineering, 97, 1808-1814. https://doi.org/10.1016/j.proeng.2014.12.334

Suhardi, B., Juwita, E. & Astuti, R. D. (2019). Facility layout improvement in sewing department with Systematic Layout planning and ergonomics approach. Cogent Engineering, 6(1), 1597412. https://doi.org/10.1080/23311916.2019.1597412

Tak, C. S. & Yadav, L. (2012). Improvement in Layout Design using SLP of a small size manufacturing unit: A case study. IOSR Journal of Engineering, 2(10), 1-7. doi: 10.9790/3021-021030107

Tjusila, A. K., Gozali, L. & Doaly, C. O. (2021). Factory Re-Layout with SLP, CRAFT, CORELAP, Promodel, and FlexSim for Optimization of Material Flow Movement. Proceedings of the Second Asia Pacific International Conference on Industrial Engineering and Operations Management, Surakarta, Indonesia, 14-16.

Tompkins, J. A., White, J. A., Bozer, Y. A. & Tanchoco, J. M. A. (2010). Facilities Planning. John Wiley & Sons.

Xiao, Y., Cheng, Y. K. & Jia, Q. H. (2012). Application of SLP in Plant Layout Based on Low Carbon Logistics. Advanced Materials Research, 424–425, 314–317. https://doi.org/10.4028/www.scientific.net/amr.424-425.314

Watanapa, A. & Wiyaratn, W. (2011). Systematic Layout Planning to Assist Plant Layout: Case Study Pulley Factory. Applied Mechanics and Materials, 110–116, 3952–3956. https://doi.org/10.4028/www.scientific.net/amm.110-116.3952

Wiyaratn, W., Watanapa, A. & Atir, M. (2013). Productivity improvement of a manufacturing facility using systematic layout planning. doi: 10.7763/IJET. 2013.V5.515

Yurdakul, M., Eşkin, S. & Yusuf, İ. Ç. (2009). Bir İmalat Sisteminin Yerleşim Düzeninin İyileştirilmesi. TÜBAV Bilim Dergisi, 2(4), 399-411.

Zhang, B. & Wang, X. (2020). Modelling and Simulation of Facility Planning Problem Based on Improved SLP Method. IOP Conf. Ser.: Mater. Sci. Eng. 806 012034. doi: 10.1088/1757-899X/806/1/012034

Zhou, K. Q., Li, X., Xie, B. & Yao, C. X. (2011). Study on the Design of Layout of an Automobile Factory Based on SLP. Advanced Materials Research, 314–316, 2306–2311. https://doi.org/10.4028/www.scientific.net/amr.314-316.2306