Optimizing Facility Layout for Enhanced Productivity using Pro Model: A Case Study of a Shoe Manufacturing Company in Marikina, Philippines

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Abstract

Through the optimization of business operations and the fulfillment of employee needs, an effective facility layout is essential to the success of manufacturing industrial output. It guarantees a smooth system operation, reduces wasted space, and maximizes resource efficiency. The goal of this study is to identify and address problems that lead to waste and reduce productivity by examining the facility layout of a shoe manufacturing company in Marikina. To accomplish this goal, the main causes of issues with the current facility design were found using the Ishikawa Diagram. Pro Model simulation software was likewise employed to examine and recommend a creative facility layout design that maximizes output and eliminates waste in the company's production process. The findings of the study indicated that lower output levels were significantly attributed to the current facility layout. As a result, a new facility plan was suggested, which led to a significant increase in production output of 16.67%. The shoe factory's manufacturing processes might be optimized, waste reduced, and efficiency increased by putting the suggested facility layout concept into practice. By highlighting the significance of facility layout optimization in boosting efficiency and overall operational performance, this work makes a significant contribution to the field of facility layout optimization.

Keywords
Facility Layout, Production Inefficiencies, Product Layout, ProModel Simulation, Time and Motion Study

1. Introduction
Through the use of tools, equipment, and labor, the manufacturing sector plays a critical part in converting raw materials into completed goods. Implementing a suitable facility layout becomes essential given the wide range of manufacturing operations involved. Ishak et al. (2020) claim that the facility architecture is a key component of the manufacturing sector and includes a range of tactics for allocating factory resources to support a smooth production process. It also plays a crucial role in overall business operations, helping to meet staff needs and maximize production efficiency (Jones 2022).

Manufacturing footwear is a labor-intensive industry that involves the separate production of various parts such as soles, toe caps, heels, and welts, which are later assembled by workers on an assembly line. The shoe manufacturing process consists of multiple phases to bring together all the components. The specific equipment and processes used in shoe production vary depending on the type of shoes being manufactured. However, this process can be time-consuming and complex, particularly for companies involved in large-scale shoe production. Therefore, having an effective facility layout is crucial in organizing the manufacturing operations efficiently, optimizing the production process, and meeting the needs of employees.

Marikina City in the Philippines is widely recognized as the Shoe Capital of the country due to its thriving shoe industry (Angeles 2023.). The shoe manufacturing company being studied in this paper is one of the prominent shoe manufacturers in Marikina City. With over fourteen years of experience, the company has gained a reputation for delivering high-quality shoes to its customers. Initially, the company supplied shoes to other brands but eventually transitioned to selling shoes under its own brand name. Moreover, the company is well-regarded for producing affordable yet durable shoes. However, manufacturing companies often encounter production bottlenecks, particularly when engaged in mass production. The shoe manufacturing company experienced difficulties with facility layout planning as it evolved over the years due to space limitations, employee expansion, and machinery inclusion.

This paper focuses on the various processes used by the shoe manufacturing business. It points out that the facility's design was inadequately planned out, which caused delays and inefficient resource consumption. These problems were caused by the organization of the job, employee movement, and the placement of the materials for processing. The manufacturing processes lacked organization , with some processes requiring workers to go back to a prior station because one person was tasked with many jobs at once. Issues with facility layout have significant impacts on production costs, work in progress, lead times, and productivity (Drira et al. 2006). Inadequate workspace arrangement can lead to challenges in handling and mobility between workstations, generating delays, unnecessary processing, and overall system performance issues.

Poor planning for the facility's layout can also raise operational costs for the business, especially for material handling costs, which make up 20 to 50 percent of all factory operating costs (Tompkins and White 1997; Sharma and Sing, 2005). This paper intends to address the issue of facility layout and explore any possible repercussions of inadequate facility layout planning. It also seeks to provide an enhanced facility architecture that meets the requirements of the workforce while maximizing manufacturing process efficiency.

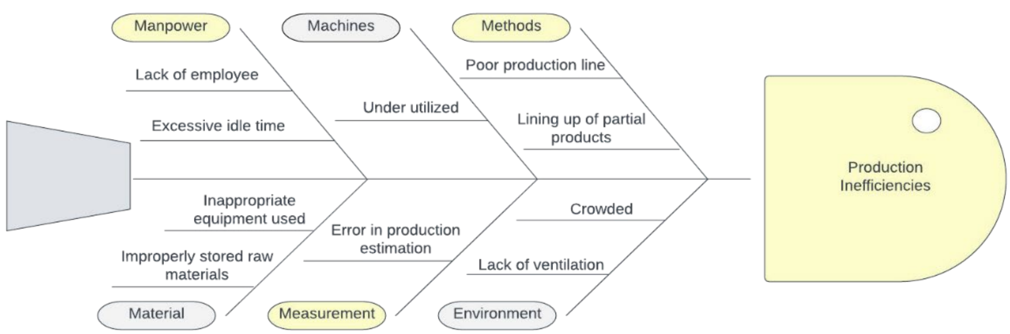

Figure 1. Cause and Effect Analysis of a shoe manufacturing company

The Ishikawa Diagram in Figure 1 depicts the primary problem related to inefficient manufacturing, which restricts the efficient flow of processes. Several aspects, including labor, machines, processes, materials, measurement, and environment, are blamed for the main issue. These elements work together to exacerbate the fundamental problem, which is ultimately the outcome of an inadequate facility plan.

1.1 Objectives

This paper seeks to examine and fix the production inefficiencies brought on by underlying issues connected to a subpar facility layout. The negative impacts of an insufficient facility layout on the performance of the organization in numerous areas have been acknowledged as being considerable. In light of these conclusions, the research concentrates on a number of primary goals. Its initial goal is to review and assess the company's current facility layout. Second, it looks for bottlenecks or choke points in the production processes. Third, the research conducts a thorough examination of the core causes of production inefficiencies due to the subpar facility layout using tools like the fishbone diagram, TMS (Time and Motion research), and ProModel. Lastly, this paper aims to implement targeted improvements in the production system, with the goal of achieving a 15% increase in overall efficiency.

2. Literature Review

The layout of facilities or departments create a facility layout problem (FLP) that firms run into throughout their operational processes. This is true for both the manufacturing and service industries. By figuring out the best way to distribute facilities to places, FLP aims to minimize a particular function. Planning a facility's layout well is crucial to the production process and has a big impact on how profitable a business is. Material handling costs, which include unit material flow, unit material handling cost, and the rectilinear distance between the centroids of equipment locations, account for a sizable amount of the overall operational cost.

Material handling expenses typically account for 20% to 50% of total operating expenses, while production expenses as a whole range from 10% to 80%, according to Tompkins and White (1996). By carefully laying out the facility, it is feasible to reduce material handling expenses by 10% to 30%. Therefore, even a little reduction in material handling costs can have a significant impact on overall operating costs. In addition to ensuring safe and effective operations, a proper facility layout is essential for reducing trip time, cutting down on material handling costs, and removing barriers that could restrict material and facility mobility. Numerous studies have been done over time to address facility layout challenges. A comprehensive summary of approaches to facility layout issues was published by Drira et al. in 2007. The strategy used to overcome these obstacles differs depending on the particulars of the workshop, the nature of the issue, and other important factors. Aleisha and Lin (2005) emphasized the frequent application of simulation methods to evaluate the efficacy of various layout configurations.

Numerous heuristic methods have been used in the literature to solve the facility layout problem. The FLP has been addressed using metaheuristic techniques as Tabu Search, Simulated Annealing, Ant Colony, and Genetic Algorithm. A neighborhood-based Tabu Search method was put forth by Chiang and Kouvelis in 1996. A Simulated Annealing approach was also created by Chwif et al. (1998) expressly to deal with the aspect ratio issue in facility planning. They used paired exchanges between facilities and ad hoc moves on the planar site. McKendall et al. (2006) used two Simulated Annealing techniques to find a different approach to the dynamic facility layout issue. To improve the efficiency of Simulated Annealing, they used a "look-ahead and look-back strategy" and the pairwise exchange method. An ant colony algorithm was developed by Solimanpur et al. (2005) to address the sequence-dependent single-row machine layout problem. Both limited and unconstrained dynamic layout concerns were addressed by Baykasoglu and Gindy (2001) using the ant colony technique. Numerous approaches for solving the facility layout problem and optimization have been presented in the literature, including studies by Roslin et al. (2009), Zhou et al. (2020), Marcelo et al. (2016), Mohamadi et al. (2019), Kromer et al. (2020), Matai and Singh (2021), Siregal et al. (2020), and Molla et al. (2020), Lin et al. (2015), Marcelo et al. (2016), Misola and Navarro (2013), Navarro and Navarro (2016), Navarro and Navarro (2022), Navarro et al. (2023). Additionally, several studies in the literature seek to maximize production employing a pertinent Design Trade-Off Duque et al. (2016), Sison et al. (2018), Palisoc et al. (2019), and Navarro et al. (2022) with the use of Pro Model simulation, Navarro et al. (2015) and Bangayan et al.(2016)

The shoe industry is highly competitive due to globalization in production and the presence of numerous large companies competing for market share. In this context, shoemakers strive for a high level of competitiveness by meticulously analyzing every detail to achieve optimal results and maximize productivity. Key areas of focus include layout design, machinery, and human resources. Various techniques are employed to analyze these factors, with notable examples discussed below. One relevant case study (Eryilmaz et al. 2010) aims to determine the optimal production policy for daily working schedules by considering combinations of men's shoe models. The study employs Arena, a simulation tool, to evaluate the impact of model variations on throughput rate. Another study (Covas 2014) focuses on production line balancing in the footwear industry, addressing custom requests from customers. The document examines three simulation options, namely Arena, Flexsim, and Simio, ultimately selecting Simio for implementation and analysis. Another aspect explored involves determining the quantity of units to schedule per shift, calculating the required number of operators, setting conveyor speed, coordinating the main line with sub-assembly lines, assigning work elements to operators, and establishing the sequence of models (Thomopoulos 2014). Accurate determination of the amount of lasts per model is crucial for plant management (Bangsow 2012). Nisanci (1980) conducts a simulation study of a shoe manufacturing plant with seven departments, aiming to understand the production system's characteristics and assess its behavior under alternative operating policies. Additionally, alternative approaches such as an Adaptive Large Neighbourhood Search (ALNS) heuristic simulation model demonstrate their effectiveness in designing plant layouts without relying on queue theory (Dang & Pham 2016). In another work, a scheduling module is proposed, focusing on short-term responsiveness to market needs and changes. This module integrates a finite capacity scheduler with a new software based on the Analytical Hierarchy Process (AHP) decision support system, assigning priorities to orders based on aspects like complexity and urgency (Zangiacomi, Zhijian, and Boer 2004). It is important to note that different simulation software options have their own advantages and limitations, and the choice depends on the specific application (ProModel 2020).

The study aims to optimize facility layout to enhance productivity. The research gap could lie in the limited research available on the specific strategies, techniques, or factors that can effectively enhance productivity in the shoe manufacturing industry. The above existing studies might not adequately address the relationship between facility layout optimization and productivity improvement in this particular context. Also, there are limited or not specific to the challenges and requirements faced by shoe manufacturers in Marikina, Philippines.

3. Methodology

This paper used mixed-methods - both qualitative and quantitative studies to evaluate the shoe manufacturing company. In line with this, this paper conducted an observation of the manufacturing company's process, which was used to identify the company's operational problems. Also, the Time and Motion Study (TMS) was used in the study to further analyze the observation. TMS gave an analysis of the specific tasks required as well as a standard time to complete the specific process of making a shoe. In addition, with the standard computed time and identified unnecessary tasks present, the researchers will integrate the application of ProModel — which allows the study to test procedures that can maximize the production process by proposing a new layout for the company's facility design. The methodology chart shown in Figure 2 demonstrates the processes included in the study. It incorporates a series of steps .

This study took place in Brgy. Concepcion, 1807 Marikina City, Philippines, focusing on a fashion industry company specialized in producing high-quality footwear, handbags, sandals, and belts. The choice of this specific factory was motivated by the recognition that facility layout plays a significant role in generating lead time within a manufacturing organization. By selecting this shoe manufacturing company, this paper aimed to gain deeper insights into the challenges and complexities present in the workplace. An inefficient facility layout can result in waste, delays, and unnecessary additional processing. Recognizing this, the analysis of the facility layout will be conducted following the completion of the time and motion study and the observation of the manufacturing process. This sequential approach ensures a comprehensive understanding of the existing workflow and operational dynamics before addressing the specific inefficiencies related to facility layout. Equation 1-3 are used to get the mean and standard deviation on the given observations.

A. **Time and Motion Study**

Time and Motion Study (TMS) is a method that could improve overall production and identify inefficient processes. The TMS breaks down processes into components and calculates how much time is needed to complete each step to evaluate and optimize work processes. TMS is used to calculate normal and standard time, to improve the production rate of the company

B**. AutoCAD Software**

This paper utilized AutoCAD software for the current and proposed layouts. The incorporation of AutoCAD allows the researchers to plan and establish a new layout suitable for the company, with a design that avoids potentially dangerous errors and mistakes.

C. Pro-Model

ProModel is software made to quickly and precisely simulate various production systems (Marcelo et al. 2016). For the study, ProModel was used to simulate the current layout of the company and assess its performance through identifying the presence of blockage and idle times of entities, workers and locations. The total number of products produced using the layout was also identified using the software.

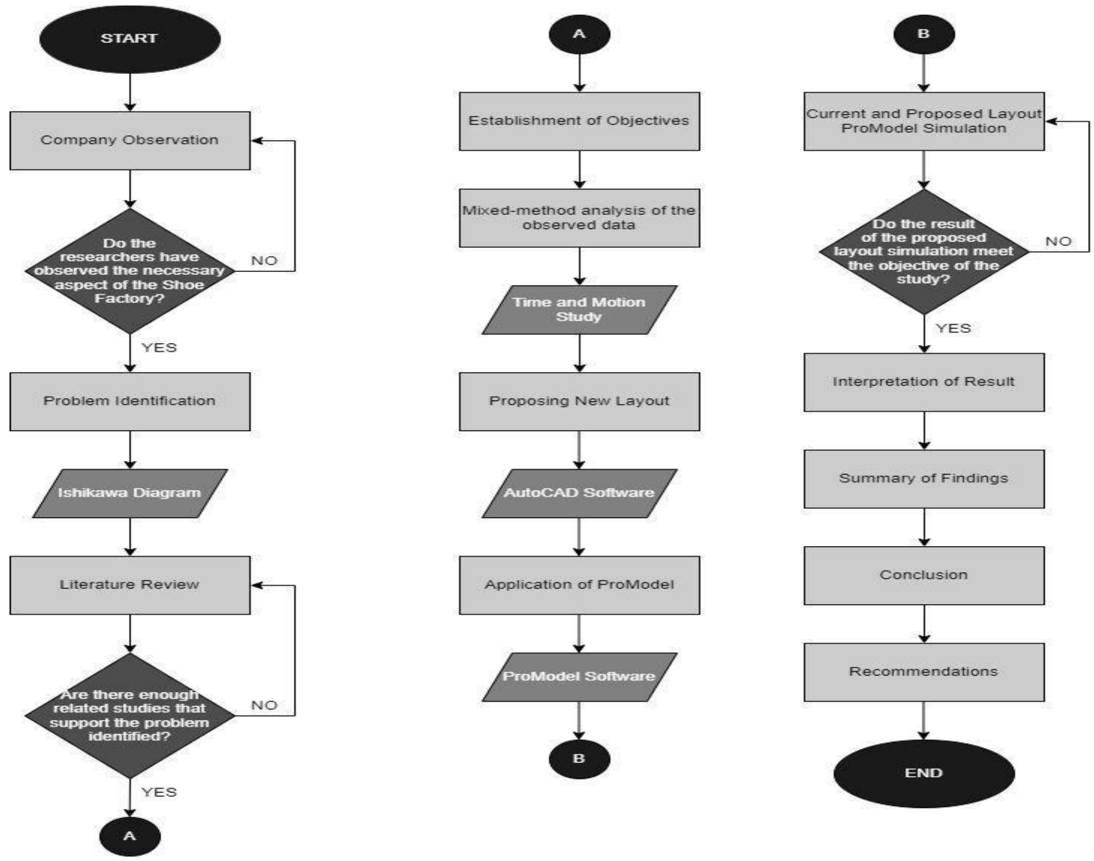

Figure 2. Methodology of the Study

$$\underline{X} = \frac{\Sigma X}{N} \tag{1}$$

Where;
X̄ = mean
X = individual value (TMS data)
N = total number of values

The sample standard deviation is represented by the formula:

$$s = \sqrt{\frac{(X_i - \underline{X})^2}{N-1}} \tag{2}$$

Where;
s = sample standard deviation
Xi= individual value (TMS data)
N = total number of values

The normal distribution is represented by the following formula:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \tag{3}$$

Where;

$\sigma\sigma$ = standard deviation (s from the standard deviations formula)
$\mu\mu$ = mean ($\bar{X}$ from the mean formula)

To simulate the processing time in the model, these parameters were estimated using data from the time and motion study and entered as input into the ProModel software.

4. Data Collection

This paper use primary sources by conducting observations and interviewing workers and took pictures and videos of the layout, process, and production of shoes in Marikina City. This paper utilizes secondary sources to understand and explain the current layout of the factory. Likewise, it was implemented to help identify problems present in the manufacturing process and provide solutions to maximize the production time and cost of the company.
The method used in collecting data for this study was through observation and time and motion study of the procedures done in making shoes located at 678 Bagong Silang, Concepcion Uno, Marikina, Metro Manila. The procedure for collecting data are as follows: This paper focused on each part of Shoe manufacturing process layout: cutting, skiving, marking, painting, upper making, sewing, lasting, soling, finishing, and packaging. In addition, there were recorded five job cycles on each process to help determine standard times. Through observation, irregularities and problems that impede production efficiency were identified. Another method used to collect data was an Interview. Through Interviews, the researchers were able to identify the production number of the company and the estimated quota they have throughout the year. Furthermore, the demand mentioned by the company is used to understand the trend and the forecasting of the business and its future demand. With the data gathered through interviews were analyzed to improve the factory's system and allow the workers to work efficiently and effectively while maximizing profit and eliminating waste in the company's production

5. Results and Discussion

5.1 Numerical Results

Table 1. Observation of Manufacturing a Pair Shoe

Elements	1	2	3	4	5	6	7	8	9	10	Total Observed Time (Seconds)
E1. Cutting	51.73	55.42	52.47	53.49	52.79	51.97	57.44	54.87	56.17	56.48	542.83
E2. Skiving	188.43	191.63	190.42	188.78	190.5	191.48	189.49	190.05	187.4	188.13	1896.31
E3. Marking	39.4	28.7	31	46.2	38.4	28.8	33.3	35.9	9.6	59.7	411
E4. Painting of Logos	120.4	97	133.1	163	134.3	148	162.2	172	150.5	186.5	1467
E5. Upper Making	215.5	262.95	214.17	238.12	222.62	226.74	226.78	222.68	215.96	233.7	2279.22
E6. Sewing	105.83	105.19	114.93	105.11	106.18	100.46	112.42	108.88	106.79	107.54	1073.33
E7. Lasting	77.52	69.64	62.41	72.88	66.59	75.74	74.8	70.09	76.62	77.68	723.97
E8. Soling	502.52	509.73	599.85	479.67	600.22	514.9	490.27	574.69	471.43	523.89	267.17
E9. Finishing	363.43	470.53	326.51	514.48	372.58	319.13	476.59	338.1	363.19	386.33	3930.87

Table 2 . Normal Time of Each Element (In Seconds)

Elements	tal Observed Cycle Time	Average Time Consumed	Rating Factor	Normal Time
E1	542.83	54.283	95%	51.57
E2	1896.31	189.631	90%	170.67
E3	411	41.1	85%	34.94
E4	1467	146.7	90%	132.03
E5	2279.22	227.922	100%	227.92
E6	1073.33	107.333	100%	107.33
E7	723.97	72.397	110%	79.64
E8	5267.17	526.717	100%	526.72
E9	3930.87	393.087	90%	353.78

$$\text{Normal Time (In Minutes)} = \left(\frac{A_{oc}}{P_{rf}}\right) = 28.08 \tag{4}$$

$$\text{Standard Time (In Minutes)} \left(\frac{Nt}{1-A}\right) \; 32.01 \tag{5}$$

Where;

A_{oc} = Average observed cycle time

P_{rf} = Performance Rating Factor

Nt = Total Normal Time

A =Allowance Factor

Table 3. Allotted Allowance Factor

Allowance Factor					
	Personal	**Variable**	**Fatigue**	**Unavoidable Delays**	**Total Allowance Factor**
Men	5%	2%	4%	3%	14%
Women	7%		4%	3%	14%

The data in Table 1 with ten (10) observations of individual elements were used to determine the observed time per element, the normal and standard time, each employee of Shoe Manufacturing Company consumes in manufacturing a pair of shoes. This paper selected the rating factors shown in Table 2 based on the observations the made during the observation. A rating factor is a percentage-based assessment of a work's speed relative to what is perceived to be the typical pace and has been proven to be it. For this study, the researchers assigned a rating factor of 110% for element 7, 100% for elements 5, 6, and 7, 95% for element 1, 90% for elements 2, 4, and 9, and 85% rating factor for element 3. The assigned rating factors were based on the observations for each element the researchers have conducted. The computation shown in (3) is for normal time. The normal time was computed by multiplying the average time for each element by their respective rating factors. The normal time for manufacturing a pair of shoe is calculated to be 28.08 minutes and shown in (4). Having computed the normal time for each element, the researchers proceeded to determine the allowances that needed to be considered in completing a task. Also, when establishing a standard time, it is necessary to consider any necessary allowances. Employees of manufacturing companies require leeway and breathing room in the workplace, particularly where employees are in a high-frequency and repetitive step in a production process. This paper decided to allot a 14% total allowance factor. 7% is a personal allowance for women and 5% for men. It was stated in the study that the common personnel allowance for male workers and female workers is 5% and 7%, respectively. In addition to that, since men are mostly in a section that requires a standing position, an additional 2% allowance factor, as suggested by Farhad (2022), is allotted for variable factors. On the other hand, 4% is for fatigue allowance, which is a percentage commonly used (Jana, 2014). In line with this, as delays and mistakes in tasks such as the manufacturing industry are inevitable, the researchers allotted 3% for unavoidable delays such as assembling the pattern, positioning properly the machine, and the delays in holding the materials. Using the allotted allowance factor indicated in Table 3, the standard time can be calculated by multiplying the calculated normal time by 1 plus the allowance factor. With the identified 14% allowance factor, the standard time computed by the researchers in manufacturing a pair of shoes is 32.01 minutes, depicting that it will take an hour to produce one (1) pair of shoes if only one (1) employee is assigned to a certain section.

5.2 Proposed Improvement

The Pro-Model Simulation presents the overall performance of the current production process present in the factory. Through the simulation, the effectiveness and efficiency of the system can be seen. With this, the simulation is beneficial since the problems and possible improvements can be identified and addressed by proposing new layout and making changes on the system. The proposed layout Shoe Manufacturing company to increase production efficiency is shown in Figure 3.

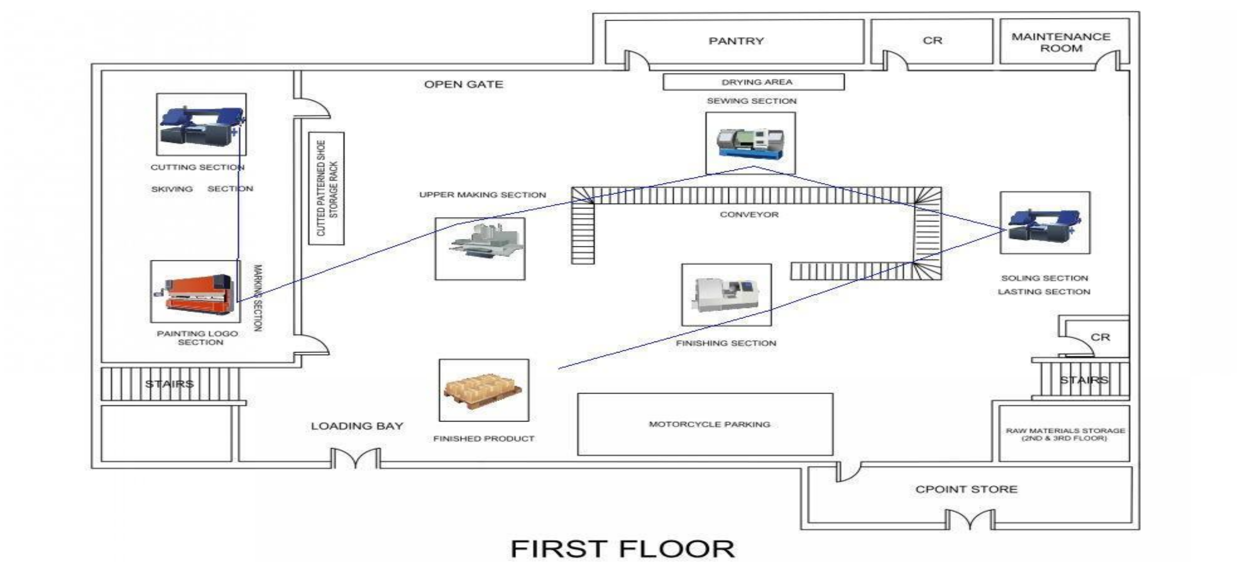

Figure 3. Proposed Layout in ProModel

Figure 4. Single Capacity Location States - Baseline Results Proposed Layout

The Proposed Layout of the Factory has seven sections: the Cutting and Skiving Section, Painting and Marking Section, Packaging, Upper Making Section, Sewing Section, Soling and Lasting Section, and Finishing Section. In Figure 4, the Seven Section is in operation for 46.78%, 34.50%, 63.60%, 34.00%, 11.39%, 98.10%, and 96.60%, respectively. In line with this, the Cutting and Skiving, Painting and Marking, Upper Making, and Sewing are blocked by 48.07%, 60.33%, 64.41%, 86.37%, correspondingly. Finally, all seven sections are idle by 5.15%, 5.17%, 36.40%, 1.59%, 2.24%, 1.90%, and 3.40%.

Scoreboard

Name	Total Exits	Average Time In System (Hr)	Average Time In Operation (Hr)	Average Cost
Gear	63.00	0.97	0.58	0.00

Figure 5. Scoreboard of the proposed layout

In Figure 5 shows the number of exits the factory had per day when the proposed layout was implemented is identified, and that was 63 shoes per day. In line with this, it shows the amount of time the shoes will be produced, which is less than an hour. In addition, the number of times the shoes will last in the production process is also in the scoreboard, which is 0.97 hours. Hence, the shoes in the factory will take less than an hour to make and will be able to produce 63 shoes in a day.

6. Conclusion

In this paper, the manufacturing facility observed had inefficient ergonomic design. Many workers were either standing without proper support or sitting on low chairs with nothing to lean on. This design flaw resulted in a longer production time and decreased productivity. Another issue identified was the high quantity of unused machines in the facility. On a typical production day, a conveyor, sewing machines, and skiving machines were among the unutilized equipment. Missed chances to produce more goods resulted from this underutilization of resources. Another issue was the lack of competent labor. The facility had plenty of staff, but there weren't enough who could handle the bigger machines. Due to the scarcity, there was a lot of downtime in the manufacturing facility's various departments, which reduced output rates. In several operations, such soling and lasting, the facility also lacked significant machinery. There was obvious idle time and a buildup of materials from other processes because there was only one labor and machine assigned to these functions. As a result, the output of the production decreased. The results showed that the suggested layout's operational duration was slightly higher (60%) than that of the existing arrangement (58.32%). But the issue of blocking and moving logic persisted. When resource statuses are taken into account, it is found that workers in the suggested layout were idle for 91.72% of the time and just 4.14% of the time were productive because of delays caused on by location unavailability. The activity analysis revealed each machine's level of operation, blocking, and idle time for the recommended setup. The total number of exits increased from 54 in the existing configuration to 63 in the suggested structure. The shoes' production was anticipated to take 0.97 hours.

The Pro Model simulation also demonstrated how frequently the Upper Making Machine and the Sewing Section's machines were blocked. This shows that in order to increase output production and decrease downtime, it may be necessary to consider strategies other than facility layout. The proposed layout's total number of exits increased significantly, according to the scoreboard analysis. The number increased by 16.67% from 54 in the existing arrangement to 63 in the proposed layout. This suggests that the suggested structure improved the efficiency and speed of product completion within the production facility. Additionally, compared to the current layout, less time was spent on average in the system and during operation. This decrease in time denotes increased effectiveness and output. Shorter production cycles and quicker turnaround times for each product were achieved thanks to the manufacturing process optimization in the suggested layout. With a noticeable increase of exits and a reduction in system and operation's average time, the suggested plan clearly outperformed the current arrangement. These enhancements demonstrate how the suggested architecture can improve the manufacturing facility's overall performance. The proposed facility layout in terms of enhanced output production, ultimately exhibited positive results. However, the operation's high levels of idle time point to a need for development and the necessity to take into account extra tactics, such adding more machinery, to boost worker productivity. These results offer insightful information for further manufacturing facility optimization.

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