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OPTIMIZATION PRODUCTION FLOOR LAYOUT IN AN ELECTRONIC INDUSTRY USING THE PRODUCT LAYOUT APPROACH

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ABSTRACT: This report aims to present a study on redesigning the production floor layout in an electronic appliance manufacturing company using a product layout approach. The study was initiated to improve the overall efficiency of the production process and reduce production costs. The report provides an in-depth analysis of the existing layout of the production floor, highlighting the key strengths and weaknesses of the current design. The study identifies the areas of the production floor that are causing bottlenecks and delays and recommends potential changes to the layout that could reduce these issues. The report describes the proposed layout design and its potential benefits, including improved flow of materials, reduced handling and transportation time, and increased production process efficiency. The study concludes with a discussion of the potential challenges that may arise while implementing the new layout and recommends strategies for overcoming them. Overall, this study is expected to result in significant improvements in production efficiency, reduced cycle times, and increased throughput, thereby enhancing the company's competitiveness in the market. This study found that batch size changes from 20% to 10%, and 33.3% of space is utilized for external cabinets.

Keywords: Production, floor Layout, simulation, optimization, industry

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INTRODUCTION

Optimizing facility layout is essential for increasing operational effectiveness and cutting expenses in a variety of sectors. To identify the best facility designs, a number of approaches are used, such as mathematical modelling and Systematic Layout Planning (SLP). Genetic algorithms have been successfully used in building site layout design to reduce facility distances, improving operating efficiency [1]. Additionally, iterative heuristics are used by spatial optimization models to evaluate the effectiveness of current layouts and make the required adjustments, guaranteeing improved resource usage [2].

Particle Swarm Optimization (PSO) and other metaheuristic techniques have shown to be successful in resolving intricate layout problems, especially when it comes to double-row facility configurations. PSO's implementation has led to significant material handling cost savings, demonstrating its feasibility in large-scale industrial contexts [3]. Furthermore, heavy equipment repair facilities have effectively used Activity Relationship Charts (ARC), which have been shown to decrease needless movement and improve repair efficiency [4]. The applicability of these methodologies across many industries is further supported by the notable benefits demonstrated by practical implementations of layout optimization in electric two-wheeler conversion workshops, which minimize operational movement distances [5].

In a variety of industries, such as electronics, textiles, and furniture, lean manufacturing (LM) has become a crucial foundation for reducing waste and increasing efficiency. Lead times are shortened and operational efficiency is increased via the use of Lean concepts like Value Stream Mapping (VSM) to help identify and eliminate non-value-adding operations [6] [7]. According to research conducted in the electronic industry, using automated waste management techniques increased output and quality [8]. Similar to this, the furniture business saw an 82.5% decrease in waiting times as a result of implementing Lean Office concepts, which improved customer satisfaction and operational performance [9]. In 2024, Hasegawa *et al*. These results demonstrate how important lean manufacturing is for promoting sustainability and optimizing resource utilization [10] [7].

Optimization strategies based on simulation have become popular as a reliable way to enhance facility architecture. When combined with optimization tools, simulation engines offer a more dynamic depiction of systems, successfully capturing stochastic characteristics like blocking and queuing that are frequently missed in deterministic models [11]. In order to effectively explore viable design spaces, hybrid algorithms—such as simulated annealing and genetic algorithms—have been used to successfully negotiate intricate layout restrictions [12] [13]. Additionally, by mimicking production processes and logistics, reinforcement learning has become a cutting-edge method for improving industrial layouts, resulting in quantifiable gains in overall efficiency [14]. The evaluation procedure is further improved by combining machine learning with data envelopment analysis, which yields more precise predictions and rankings of layout efficiency [15].

To increase productivity and efficiency, a number of important elements need to be taken into account while redesigning a factory floor layout. Optimizing space is essential for maintaining a productive workflow and reducing traffic. In order to comply with lean manufacturing concepts, this entails examining workspace design, safety clearances, and the functional overlap of various regions [16]. By improving logistical movement pathways and using automated guided vehicles (AGVs) to save transportation costs and boost throughput, advanced approaches like production simulation and reinforcement learning can further improve industrial layouts [15]. In order to improve production productivity, inefficiencies in material flow and operator mobility are addressed by systemic layout planning (SLP) in conjunction with techniques such as Bloc plan and FLAP [17].

The efficiency of CRAFT in drastically cutting material handling expenses and operational inefficiencies is demonstrated by a comparison of layout optimization approaches like CRAFT and SLP [18]. Last but not least, it has been demonstrated that incorporating lean manufacturing concepts into layout redesign initiatives can cut lead times, eliminate non-value-added tasks, and lower material handling expenses, all of which increase overall process efficiency [19].

Considering all the approaches, optimizing facility layouts requires a comprehensive strategy that incorporates simulation-based models, lean manufacturing concepts, metaheuristic optimization methodologies, and systematic layout planning. By combining these techniques, industries can solve operational and spatial inefficiencies, which eventually boosts sustainability and productivity.

In the company under study, the existing production floor layout exhibited several inefficiencies, including excessive travel times between workstations, unbalanced workloads, and poorly utilized space. These issues resulted in production delays and increased operational costs.

Objectives: The primary objective of this study is to redesign the production floor layout for external cabinet of refrigerator using the product layout approach. Specific objectives include:

1. Reducing travel time between workstations.
2. Balancing workloads across the production floor.
3. Improving space utilization.
4. Enhancing overall production efficiency.

Addressing the inefficiencies in the current layout through a well-planned redesign is expected to bring substantial benefits to the company. By reducing travel times, balancing workloads, and improving space utilization, the redesigned layout aims to lower production costs and boost productivity. These improvements will not only enhance operational efficiency but also contribute to the company's competitiveness in the market. Additionally, the findings from this study could serve as a valuable reference for best practices in facility layout design within the manufacturing industry, providing insights and strategies that other companies can adopt to optimize their own production layouts.

METHODOLOGY

A mixed-methods approach was employed, combining qualitative observations of the production floor with quantitative data analysis. This approach provided a comprehensive understanding of the existing layout's inefficiencies and facilitated the development of optimized layouts.

Data collection involved conducting a stopwatch-based time study of various production processes, capturing the time taken for each operation and the travel time between workstations. Additionally, qualitative observations were made to identify workflow bottlenecks and underutilized space.

Data were analyzed using simulation models to evaluate the performance of the current and proposed layouts. Key performance indicators (KPIs) such as cycle time, travel time, and space utilization were measured and compared.

The layout of any department/system or any organization consists following theories – Space Utilization Theory, Storage Systems, Cold Storage Principles, Inventory Management, Ergonomics, Materials Handling, Quality Assurance, Lean Manufacturing or Lean Principles, Safety Regulations, Supply Chain Management, Maintenance and Reliability, Energy Efficiency.

Here we will see different processes related to Deep freezer manufacturing. It is a series of actions and steps taken to achieve a completely manufactured Deep Freezer. Many different sequences are used to manufacture one piece of Deep Freezer. For this purpose, external and internal process were studied in details. The outer body is made of a steel sheet that is used to protect the external body of the deep freezer. Different processes are used to manufacture the outer body of the sheet. Total time of each process was calculated by taking average of measurement taken multiple time as given in Table 1. The total time for each process, includes loading, operation, and unloading and time of all activities taken place to complete process.

External Cabinet: Total time consumed by each process in the manufacturing of external cabinet is given below:
The total area of the Internal Layout is 16830 ft.
The total area used for different Internal Cabinet layouts is 5197.69 ft
The total area left for the Internal Cabinet after placing all the machines is 11632.31.
The formula of Utilization is:
Utilization = Space Used / Space Available
So, the total space used by different machines in the External Cabinet is **35%.**

Total Distance: The total distance a single part travels for the complete processing of the External Cabinet is 127 ft it can be notice from Table 2. Furthermore, it has been found that total number of visits made by workers to complete a batch of 10 parts are 452.

Table 1: Time of different process involved in manufacturing of Internal Cabinet.

External Cabinet	
Processes	**Time (Sec)**
Process 01	55.46
Process 02	35.08
Process 03	39.48
Process 04	83.63
Process 05	14.96
Process 06	49.25
Process 07	69.48
Process 08	108.03
Process 09	69.19
Process 10	257.33

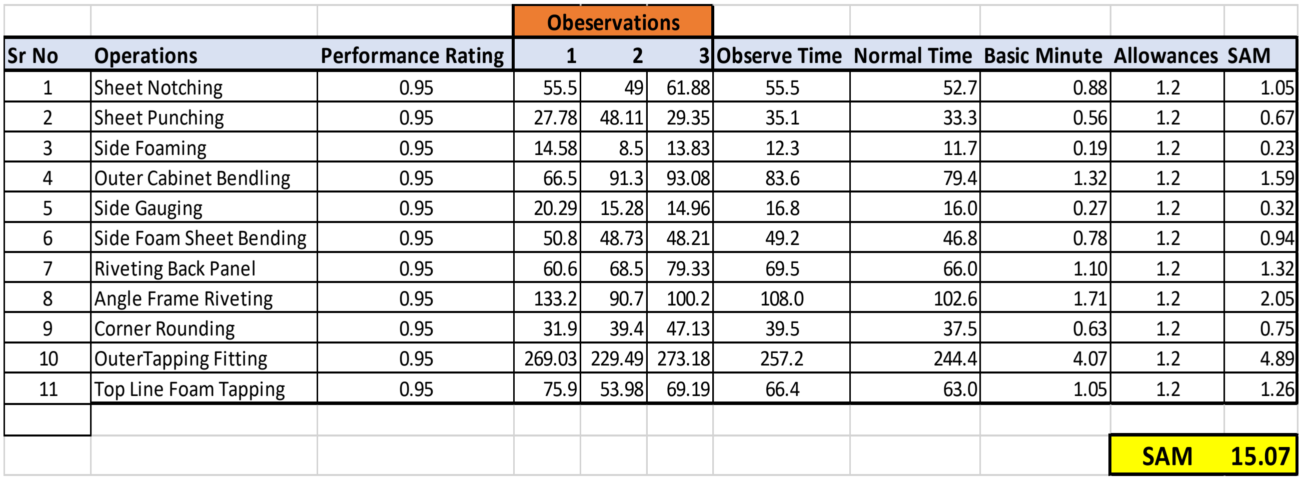
Table 2: From-To Chart of External Cabinet of a 10-batch size in an 8-hour shift is shown below:

		TO														
		Process 1	**Process 2**	**Process 3**	**Process 4**	**Process 5**	**Process 6**	**Process 7**	**Process 8**	**Process 9**	**Process 10**	**Process 11**	**Process 12**	**Total-Dist**	**Visits**	
FROM	**Process 1**		D = 6 F = 10	-	-	-	-	-	-	-	-	-	-	6	50	
	Process 2	-		D = 11.6 F = 10	-	-	-	-	-	-	-	-	-	11.6	50	
	Process 3	-	-		D = 12 F = 10	-	-	-	-	-	-	-	-	12	50	
	Process 4	-	-	-		D = 5.7 F = 10	-	-	-	-	-	-	-	5.7	50	
	Process 5	-	-	-	-		D = 9.2 F = 10	-	-	-	-	-	-	9.2	38	
	Process 6	-	-	-	-	-		D = 20.10 F = 10	-	-	-	-	-	20.1	38	
	Process 7	-	-	-	-	-	-		D = 6.7 F = 10	-	-	-	-	6.7	38	
	Process 8	-	-	-	-	-	-	-		D = 6.7 F = 10	-	-	-	6.7	38	
	Process 9	-	-	-	-	-	-	-	-		D = 9.1 F = 10	-	-	9.1	33	
	Process 10	-	-	-	-	-	-	-	-	-		D = 20.8 F = 10	-	20.8	31	
	Process 11	-	-	-	-	-	-	-	-	-	-		D = 19.10 F = 10	19.1	18	
	Process 12	-	-	-	-	-	-	-	-	-	-	-			18	
	Total	0	6	11.6	12	5.7	9.2	20.1	6.7	6.7	9.1	20.8	19.1	127	otal Visit	452

RESULTS AND DISCUSSION

SAM Calculation: For each operation, first of all takes the readings of the cycle times. Here, three number of the cycle time reading has been used. Then, taking the average for of these cycle time. This called Observed Time. In this current time study, we take the Performance rating factor for each operator at 95%. Multiply each rating factor to the observed time to get Normal Time. Converting this normal time into basic minute by simply divided by 60. Finally adding the allowance factor of the machine delay & personal fatigue to get the SAM for each operation. At the end, taking sum of all of these operations SAM to get the total SAM for making the inner body of Deep Freezer. SAM calculation is shown of internal cabinet in Table 3.

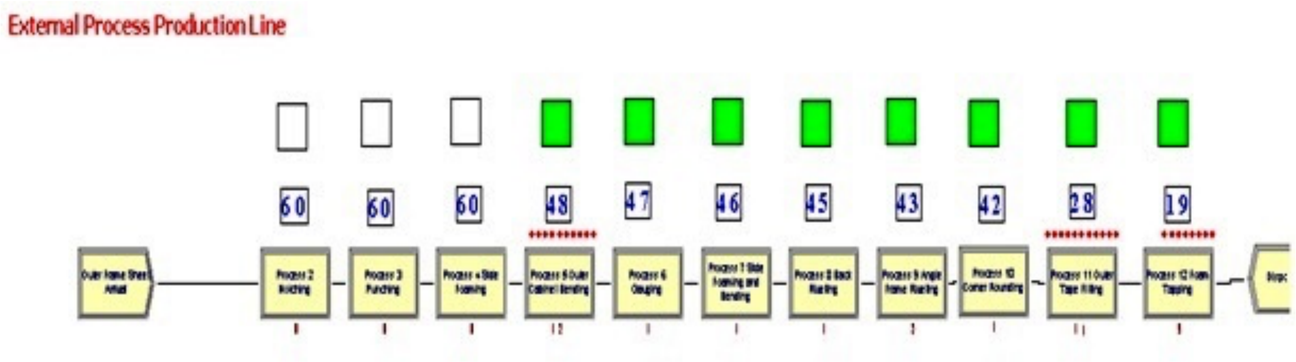
Table 3: External Body SAM Calculation.

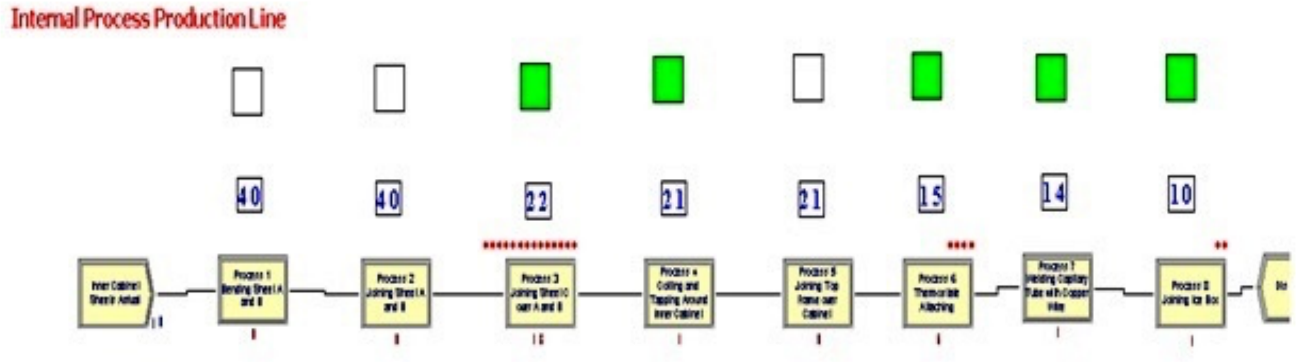


			Obeservations							
Sr No	Operations	Performance Rating	1	2	3	Observe Time	Normal Time	Basic Minute	Allowances	SAM
1	Sheet Notching	0.95	55.5	49	61.88	55.5	52.7	0.88	1.2	1.05
2	Sheet Punching	0.95	27.78	48.11	29.35	35.1	33.3	0.56	1.2	0.67
3	Side Foaming	0.95	14.58	8.5	13.83	12.3	11.7	0.19	1.2	0.23
4	Outer Cabinet Bendling	0.95	66.5	91.3	93.08	83.6	79.4	1.32	1.2	1.59
5	Side Gauging	0.95	20.29	15.28	14.96	16.8	16.0	0.27	1.2	0.32
6	Side Foam Sheet Bending	0.95	50.8	48.73	48.21	49.2	46.8	0.78	1.2	0.94
7	Riveting Back Panel	0.95	60.6	68.5	79.33	69.5	66.0	1.10	1.2	1.32
8	Angle Frame Riveting	0.95	133.2	90.7	100.2	108.0	102.6	1.71	1.2	2.05
9	Corner Rounding	0.95	31.9	39.4	47.13	39.5	37.5	0.63	1.2	0.75
10	OuterTapping Fitting	0.95	269.03	229.49	273.18	257.2	244.4	4.07	1.2	4.89
11	Top Line Foam Tapping	0.95	75.9	53.98	69.19	66.4	63.0	1.05	1.2	1.26
									SAM	15.07

From SAM calculation by Table 3, the Standard Allowed Minute for external body is 15.07 min.

Simulation of internal & external processes: Simulation modelling is used to tackle real-world issues in a safe and effective manner. It gives a significant approach of analysis that is simple to verify, discuss, and comprehend. Simulation modelling delivers important solutions across sectors and disciplines by providing clear insights into complicated systems.so the simulation of internal and external line is gives below as:





According to calculated operation time of each operation we make the simulation of both internal and external body line and run this simulation for 8 hours. We consider the batch size of 10 no of parts. According to this measured time total output of external body is 18 batch (190 products) and internal body output is 10 batch (100 parts).so according to existing time motion study the output in 8-hour shift is

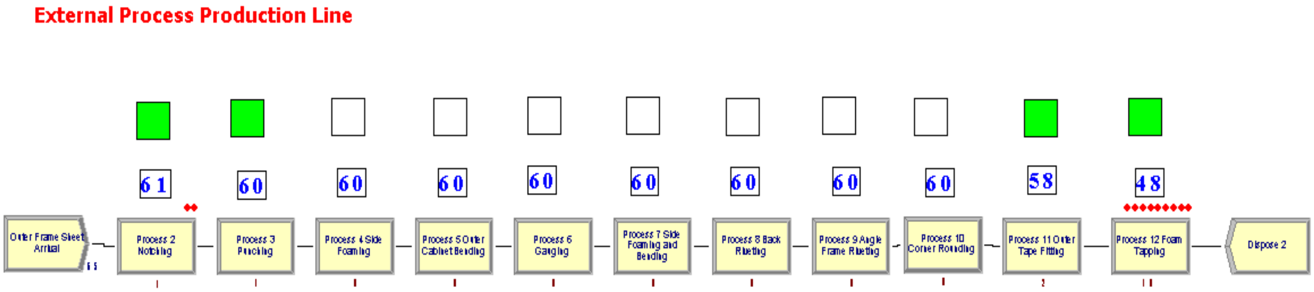
- 190 external parts

Table 4: External Body SAM Calculation with Improvement:

			Obeservations							
Sr No	Operations	Performance Rating	1	2	3	Observe Time	Normal Time	Basic Minute	Allowances	SAM
1	Sheet Notching	0.95	55.5	49	61.88	55.5	52.7	0.88	1.1	0.97
2	Sheet Punching	1	27.78	48.11	29.35	35.1	35.1	0.58	1.1	0.64
3	Side Foaming	1	14.58	8.5	13.83	12.3	12.3	0.21	1.1	0.23
4	Outer Cabinet Bendling	1	66.5	91.3	93.08	83.6	83.6	1.39	1.1	1.53
5	Side Gauging	0.95	20.29	15.28	14.96	16.8	16.0	0.27	1.1	0.29
6	Side Foam Sheet Bending	0.95	50.8	48.73	48.21	49.2	46.8	0.78	1.1	0.86
7	Riveting Back Panel	0.95	60.6	68.5	79.33	69.5	66.0	1.10	1.1	1.21
8	Angle Frame Riveting	1	133.2	90.7	100.2	108.0	108.0	1.80	1.1	1.98
9	Corner Rounding	0.95	31.9	39.4	47.13	39.5	37.5	0.63	1.1	0.69
10	OuterTapping Fitting	1	269.03	229.49	273.18	257.2	257.2	4.29	1.1	4.72
11	Top Line Foam Tapping	0.95	75.9	53.98	69.19	66.4	63.0	1.05	1.1	1.16
									SAM	14.27

Simulation of Internal Cabinet: Simulation modelling is used to tackle real-world issues in a safe and effective manner. It gives a significant approach of analysis that is simple to verify, discuss, and comprehend. Simulation modelling delivers important solutions across sectors and disciplines by providing clear insights into complicated systems.so the simulation of internal line is gives below as:

External Body Improvement



We add the following changes in simulation of the external body line

- we have changed the batch size from 10 to 5.
- we add 3 more workers on process 10 (outer tape fitting) from 3 worker to 6 that was bottleneck.
- In improved line total output is 48 batch's (240 body's).
- So, by using this improvement we can manufacture 50 more products in same 8 hours of shift.

SAM RESULTS

Improvements in External Body line:

- Change batch size from 10 to 5 parts
- After changing batch size allowance change from 20% to 10%.
- Change some worker performance rating from 95% to 100%.

After making these changes Internal body line SAM value is changed from 15.07 To 14.27 min because when we change the batch size then bundle allowance basic and personal allowance value also changed.so overall internal body SAM value is decreased to 0.8 min.

Utilization:

	Utilization
Existing-External	33.30%
Improved-External	51.60%

Conclusion: This study demonstrates the effectiveness of using a product layout approach to redesign the production floor, leading to significant efficiency gains. The optimized layouts reduced travel time, balanced workloads, and improved space utilization, resulting in enhanced productivity and cost savings. Study has found 20% reduction in cycle time and 15% utilization of space. Future research could explore the broader application of these findings and incorporate advanced technologies to further optimize production layouts.

REFERENCES

1) M. L. A. E. Borges, G. M. Araújo, A. Monteiro, A. D. Granja, and F. A. Picchi, "Decision-making optimization method for construction site layout planning," *PARC*, vol. 15, p. e024015, Nov. 2024, doi: 10.20396/parc.v15i00.8674145.

2) E. Zhou and A. T. Murray, "Facility Layout and Spatial Configuration Efficiency Assessment," *Networks and Spatial Economics*, Jul. 2024, doi: 10.1007/s11067-024-09637-z.
3) W. Isnaini, A. P. Rifai, N. M. E. Nurmasari, N. A. Masruroh, I. B. Dharma, and V. E. Andriani, "Sequential use of blocplan, solver, and particle swarm optimization (PSO) to optimize the double row facility layout," *International journal of production management and engineering*, May 2024, doi: 10.4995/ijpme.2024.20061.
4) M. A. W. Prediansyah and A. S. Cahyana, "Innovation in Facility Layout Optimization through Heavy Equipment Repair revolution," *Indonesian Journal of Innovation Studies*, vol. 25, no. 3, Jun. 2024, doi: 10.21070/ijins.v25i3.1167.
5) C. I. H. Simanjuntak, M. H. F. Putra, N. A. Zaky, R. Dewandono, R. Nurcahyo, and A. Lazuardy, "Facility Layout Optimization for Electric Two-Wheeler Conversion Workshop in Indonesia: A Systematic Layout Planning Approach," Feb. 2024, doi: 10.46254/an14.20240493.
6) A. Jessani, R. Kumar, and A. Gul, "Reduction of Lean Wastes by Using Value Stream Mapping: A Case Study of Textile Company in Pakistan," *International Journal of Supply Chain Management*, Mar. 2024, doi: 10.47604/ijscm.2399.
7) Y. Silambi and R. Indiyanto, "Lean Manufacturing Analysis to Minimize Waste on The Production Process," *Indonesian Journal of Computer Science*, Feb. 2024, doi: 10.33022/ijcs.v13i1.3768.
8) Sánchez Corona, A. L., Navarro González, C. R., Arrendondo Robledo, V., Mendoza-Muñoz, I., Sauceda Meza, I., Cárdenas Robles, A., Marquez Gonzalez, J., González Toxqui, C., Lopez Badilla, G. G. L., & Valenzuela Martínez, E. T. (2024). Application of Basic Strategies of Lean-Sustainable Manufacturing Relation to Reduce Industrial Waste in an Electronic Industry of Mexicali, Baja California. *Advances in Business Strategy and Competitive Advantage Book Series*, 41–64. https://doi.org/10.4018/979-8-3693-5293-9.ch003
9) Hasegawa, H. L., Vaz, C. M. de P., & Teixeira, R. L. P. (2024). Identification and waste reduction in the furniture industry through lean office. *International Journal of Professional Business Review*. https://doi.org/10.26668/businessreview/2024.v9i3.4472
10) J. T. Gutiérrez Villegas, M. L. Silva Ríos, A. E. Valles Ramírez, and E. O. Gutiérrez Villegas, "Manufactura esbelta en mejoramiento de procesos productivos," 2024, pp. 1–11. doi: 10.22533/at.ed.2012407031.
11) H. Pierreval, "Integrated Simulation Optimization for Layout Problems," *Industrial Engineering and Engineering Management*, pp. 1486–1490, Dec. 2018, doi: 10.1109/IEEM.2018.8607591.
12) Song, X., Poirson, E., Ravaut, Y., & Bennis, F. (2021). Efficient multi-objective simulated annealing algorithm for interactive layout problems. *International Journal on Interactive Design and Manufacturing (Ijidem)*, *15*(4), 441–451. https://doi.org/10.1007/S12008-021-00773-1
13) P. Azimi and P. Soofi, "An ANN-based optimization model for facility layout problem using simulation Technique," *Scientia Iranica*, vol. 24, no. 1, pp. 364–377, Feb. 2017, doi: 10.24200/SCI.2017.4040.
14) H. Choi *et al.*, "Optimization of the Factory Layout and Production Flow Using Production-Simulation-Based Reinforcement Learning," *Machines*, Jun. 2024, doi: 10.3390/machines12060390.
15) A. Tayal, U. Kose, A. Solanki, A. Nayyar, and J. A. Marmolejo Saucedo, "Efficiency analysis for stochastic dynamic facility layout problem using meta-heuristic, data envelopment analysis and machine learning," vol. 36, no. 1, pp. 172–202, Feb. 2020, doi: 10.1111/COIN.12251.
16) S. A. Gangurde, "Assembly Line Integration as a Lever for Efficiency and Space Utilization in Automotive Parts Production," *International Journal For Multidisciplinary Research*, vol. 6, no. 4, Aug. 2024, doi: 10.36948/ijfmr.2024.v06i04.26758.
17) G. Halim, L. Gozali, H. J. Kristina, and C. Robin, "Perancangan tata letak relokasi lantai produksi dengan metode systematic layout planning, blocplan, dan flap," *Jurnal Ilmiah Teknik Industri : Jurnal Keilmuan Teknik dan Manajemen Industri*, vol. 12, no. 1, May 2024, doi: 10.24912/jitiuntar.v12i1.29641.
18) M. M. Auliyak and A. S. Cahyana, "Efficiency Comparison CRAFT vs. SLP Methods in Production Optimization," *Indonesian Journal of Innovation Studies*, Apr. 2024, doi: 10.21070/ijins.v25i2.1124.
19) M. I. Amal and N. A. Mahbubah, "Integrating Lean Implementation and Relayout Design for Efficiency Improvement," *Jurnal Ilmiah Teknik Industri*, vol. 21, no. 2, pp. 240–252, Dec. 2022, doi: 10.23917/jiti.v21i2.19748.