14th Annual International Conference on Industrial Engineering and Operations Management Dubai United Arab Emirates (UAE), February 12-14, 2024

Publisher: IEOM Society International, USA DOI: 10.46254/AN14.20240495
Published: February 12, 2024

Optimizing the Facility Layout and Material Handling System Using the Systematic Layout Planning Method: A Case Study at PT EDS Manufacturing Indonesia

Ahmad Nauval Ariq Ms, Baidilla Anamta Bimasakti, Felix Ferdinand Laureng and Setya Ady Wicaksono
Department of Industrial Engineering
Universitas Indonesia
Depok, 16424, Indonesia
ahmad.nauval@ui.ac.id, baidilla.anamta@ui.ac.id, felix.ferdinand11@ui.ac.id. setya.ady@ui.ac.id

Rahmat Nurcahyo
Professor, Department of Industrial Engineering, Faculty of Engineering
Universitas Indonesia
Depok, West Java 16424, Indonesia
rahmat@eng.ui.ac.id

Arief Nurdini
Doctoral Student, Department of Industrial Engineering, Faculty of Engineering
Universitas Indonesia
Depok, West Java 16424, Indonesia
ariefnurdini@gmail.com

Abstract

P.T. EDS Manufacturing Indonesia is a company that manufactures wire harnesses for vehicles. The outdated layout causes various challenges in the wire harness assembly line, such as excessive material handling costs. The initial step in constructing a new alternative layout is to measure process and layout data, determine time standards, and material handling, and continue in making an alternative layout using SLP methods. From the two alternative layouts created, alternative layout 2 features closeness from the external warehouse to every supply station and allocates every workstation to be sequentially and rotational layout allocation, resulting in an improvement of using 18 workers, 72 unit hourly production, and efficiency of 97.7%. SimPy simulation validates the proposed layout's material handling cost and daily production. The result showed an improvement of a decrease of 13.9% in material handling cost and an increase of 3.92% in daily production.

Keywords:
Facility Layout, Material Handling, Systematic Layout Planning, Wiring Harness.

1. Introduction
Material handling and facility layout planning are vital manufacturing processes that may substantially influence productivity, cost, and overall performance. A layout is the configuration of buildings, equipment, and material handling systems within a manufacturing facility that has a direct impact on production efficiency and cost

(Klausnitzer & Lasch, 2019; Wibowo, Nurcahyo, and Khairunnisa, 2016). On the other hand, a manufacturing plant's general design and organization include the location of equipment, storage rooms, and workstations. Conveyors, automated guided vehicles (AGVs), and warehouse management systems (WMS) are examples of material handling methods and means of delivering, storing, and managing commodities inside a facility.

The manufacturing sector is one of the critical catalysts for Indonesia's economic growth (Nurcahyo and Wibowo, 2015). The automobile industry is a noteworthy sub-segment of Indonesia's manufacturing sector, which has seen substantial expansion in recent years (Nurcahyo and Habiburrahman, 2021). The value of investment realized in the Indonesian automobile sector in 2015 was USD 1,757 million. Expanding the manufacturing sector has created more job possibilities and contributed to the country's overall economic development (Indrawati, Virananda, and Abdi, 2021).

PT EDS Manufacturing Indonesia is a manufacturing company that was established in 1989. This company was a collaboration between PT Astra Otoparts Tbk and Yazaki Corporation. In 2015, Yazaki Corporation became the sole owner of this company. PT EDS Manufacturing Indonesia manufactures wiring harnesses used by automobiles. This company implemented Japanese philosophy and methods in manufacturing, resulting in an efficient and timely process. As a result, a need for improvement is always present and taken care of. Some improvements can be made partly by inefficient material handling caused by the placement of supply racks, the use of electrical equipment, and workers' idle time.

The growing interest in optimizing factory layouts and material handling systems is driven by the need to improve efficiency and productivity and reduce costs in manufacturing facilities. One approach to achieving this is using the Systematic Layout Planning (SLP) method, which is a systematic and rational approach to designing factory layouts based on input data and activities to evaluate the plant layout (Barnwal and Dharmadhikari, 2016). This method has been widely studied and applied in various industries, showing significant potential in optimizing facility layouts and material handling systems and ultimately improving overall performance.

1.1 Objectives

This research paper aims to contribute to the existing literature by providing a comprehensive overview of the SLP method and its application in optimizing factory layouts and material handling systems. The paper will also discuss using SLP to create an existing material handling cost, activity relationship chart, activity relationship diagram, and area allocation diagram to propose a layout recommendation that can optimize material handling costs and movement in Plant 813 of PT EDS Manufacturing Indonesia.

2. Literature Review

2.1 Facility Layout Planning

Facility layout planning (FLP) is a critical aspect of industrial production systems, as it involves a set of design problems related to the arrangement of elements that shape these systems in a physical space (Pablo et al., 2021). As part of business operational strategies, FLP is considered one of the most critical design decisions (Ghassemi Tari and Neghabi 2015; Kheirkhah, Navidi, and Bidgoli 2015; Sun et al. 2018). It also significantly affects the efficiency of production systems and their productivity level (Altuntas and Selim 2012; Navidi, Bashiri, and Messi Bidgoli 2012; Ku, Hu, and Wang 2011). FLP aims to optimize the use of space and resources to improve efficiency and productivity in the storage process (Nurcahyo et al., 2019). The layout planning aims to improve the facility's layout by finding alternatives that have been considered with essential elements in production, storage operations, or other needs.

2.2 Time Study

Time study is a systematic observation, analysis, and measurement of the separate steps in the performance of a specific job for the purpose of improving procedures and increasing productivity (Barnes et al., 1990). Main components of time study are observation, measurement, analysis, and improvement.

2.2.1 Worker Measurement

Worker quantity measurement emphasizes the importance of working time measurement in the manufacturing industry to increase company productivity (Manaruzzaki et al., 2022). Total number of workers could be measured using the equation below.

$$Total\ number\ of\ workers\ needed = Daily\ Demand/Number\ of\ Shift$$

2.2.2 Efficiency
Efficiency is a metric in optimizing the utilization of available resources in the industry, and it is also a key performance indicator for measuring the performance of a company (Nurcahyo et al., 2019). Efficiency can be determined using the following formula.

$$Efficiency\ Production\ Line = Output/Input$$

2.3 Systematic Layout Planning
The systematic layout planning (SLP) is a procedure used to set the layout of the workplace in a plant notice to the logical relationship between workplaces with high frequency that are placed close to each other (Suhardini et al., 2017). The SLP method uses both quantitative and qualitative inputs. Quantitative inputs such as distance and frequency of displacement, while qualitative inputs include the degree of activity relationship. (Heragu, 1997).

2.3.1 Operation Process Chart (OPC)
Operation Process Charts are graphical representations that show the transformation of raw material into a final product. Operation Process Chart describes the process steps to be experienced raw materials regarding the sequence of operations and inspections from the initial stage to the final product or component, and contains the information needed for further analysis such as time, materials, space, tools, and machines used (Hakim, 2020).

2.3.2 Activity Relationship Chart
The Activity Relationship Chart (ARC) is a facility layout planning method that involves a relatively straightforward approach to organizing and designing the layout of a facility. ARC primarily relies on assessing and expressing qualitative relationships between different activities or workstations within the facility. ARC will provide consideration regarding the degree of proximity between workstations with: absolute or not absolute, must be close together, important enough to be placed close together and others (Wignjosoebroto, 2009).

2.3.3 Activity Relationship Diagram
The Activity Relationship Diagram (ARD) displays the relationships between the activities of departments and machines depending on the priority degree of closeness to achieve the shortest possible movement distance. (Wignjosoebroto, 2003)

2.3.4 Area Allocation Diagram
Area Allocation Diagram (AAD) or commonly known as Space Relationship Diagram (SRD) is a method of combination of ARC, ARD, and spatial related requirements in order to to provide a clear overview of how the available space will be utilized to meet the functional requirements of a facility (Siahaan et al, 2018).

2.4 Material Handling
Material handling is defined as a series of multidisciplinary activities involving parts of information and technical, administrative, and managerial equipment, carried out during the life cycle of an item, workplace, work equipment, or transportation device, to maintain the value of an asset which includes the reliability, availability, and productivity (Nurcahyo, 2019). The main objective of material handling is to ensure the timely delivery of the desired quantity of material at the desired location with minimum cost and maximum safety.

3. Methods
The research was conducted using the SLP method. The research begins with conducting a literature review about the plant layout, collecting necessary data, and analyzing the data using the SLP method to create the best alternative to improve the efficiency of the research object. RULA assessment is also used to analyze the ergonomics factor of Plant 813. The detailed flowchart for creating a new Layout can be seen in Figure 1.

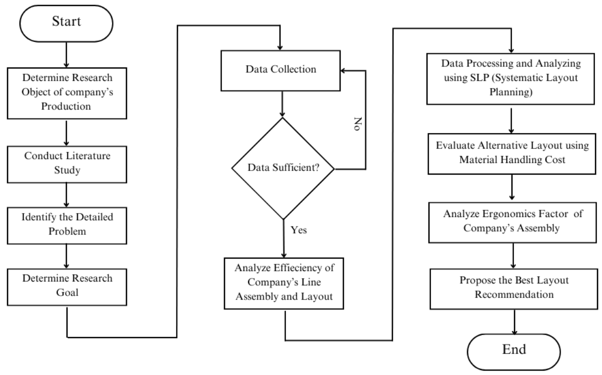

Figure 1. Methodology Flowchart

4. Data Collection

4.1 Research Location

The overall layout of the PT EDS Manufacturing Indonesia factory can be seen in Figure 2. The figure shows the scalable view of the factory at an area of 30.54 hectares. The production plant is focused in the center of the factory, which is the most important place to produce wiring harnesses. Supporting places for the logistic activity are the warehouse, receiving area, and finish good area. Other places are used for supporting activities for all officers and operators at the factory, such as the office area and canteen. Shown also in Figure 3, Plant 813 is the main object of research in systematic layout planning.

Figure 2. The whole layout of PT EDS Manufacturing Indonesia Factory

4.2 Existing Layout

The object of our research is plant 813, one of several plants in the production area. Plant 813 is divided into the pre-assembly area and the final assembly area. Since plant 813 has a unique line production with two outputs simultaneously, we decided to investigate the layout of this plant further. The initial layout of Plant 813, with a total area of 205 m^2, is shown in the scalable view in Figure 3 below.

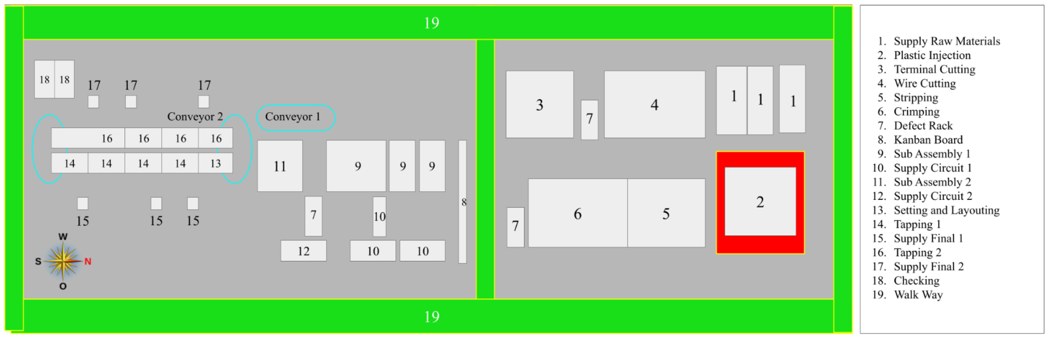

Figure 3. The initial layout of Plant 813

4.3 Floor Area

Researchers gathered data from the production floor at Plant 813 and determined that the total area of the production floor is 33.4167 m^2. The subsequent table presents the floor area data for each process, as per the initial layout of Plant 813 (Table 2).

Table 1. Floor Area Dimension of Plant 813

Work Area	Total	Dimensions		Area (m²)
		Length (m)	Width (m)	
Wire Cutting	1	3.88	1.3	5.044
Terminal Cutting	1	2.6	1.3	3.38
Plastic Injection	1	2.75	1.32	3.63
Stripping	1	3	1.33	3.99
Crimping	1	3.82	1.33	5.0806
Sub-Assembly Type 1	1	4.3	1	4.3
Sub-Assembly Type 2	1	1.75	1	1.75
Setting, Layouting, and Tapping	10	1.42	0.4	5.68
Checking	2	0.77	0.73	0.5621
Total Area				33.4167 m²

4.4 Production Flow

The flow of the production wiring harness can be seen in Figure 4. In the production area, the starting point is from supplying all materials for the pre-assy until the final assy and checking process. We can use this figure to understand the process flow, the main activity in Plant 813.

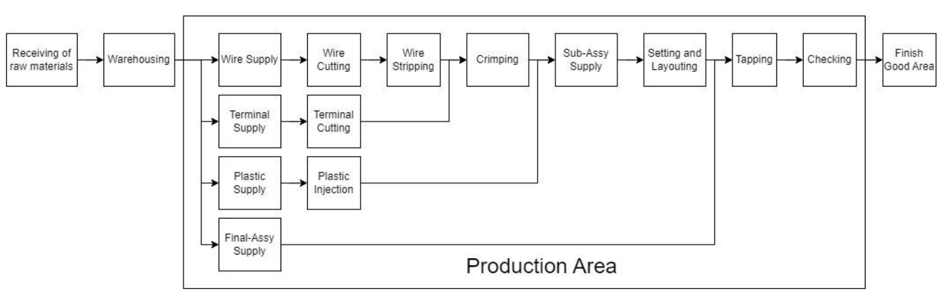

Figure 4. Wiring Harness Production Flow in PT EDS Manufacturing Indonesia

4.5 Product Demand

The actual wiring harness demand of PT EDS Manufacturing Indonesia from July-October 2023 is listed in table 3. Monthly and daily average demand is calculated based on the data in the table.

Table 2. The demand of Wiring Harness

Number	Month	Demand Total (Pieces)
1	July (2023)	18,480
2	August (2023)	23,760
3	September (2023)	23,760
4	October (2023)	23,760
Monthly Average Demand		**22,440**
Daily Average Demand		**1,020**

4.6 Operation Process Chart

The Operation Process Chart in Figure 5 is made to show the operations done in creating a wiring harness in Plant 813 (Type 1 left, and Type 2 right). The difference between Type 1 and Type 2 is from the sub-assembly process. This Type 1 has three workstations due to the complexity of the product, while Type 2 has a more straightforward design with only one workstation in the sub-assembly process. The time standard is shown beside every operation.

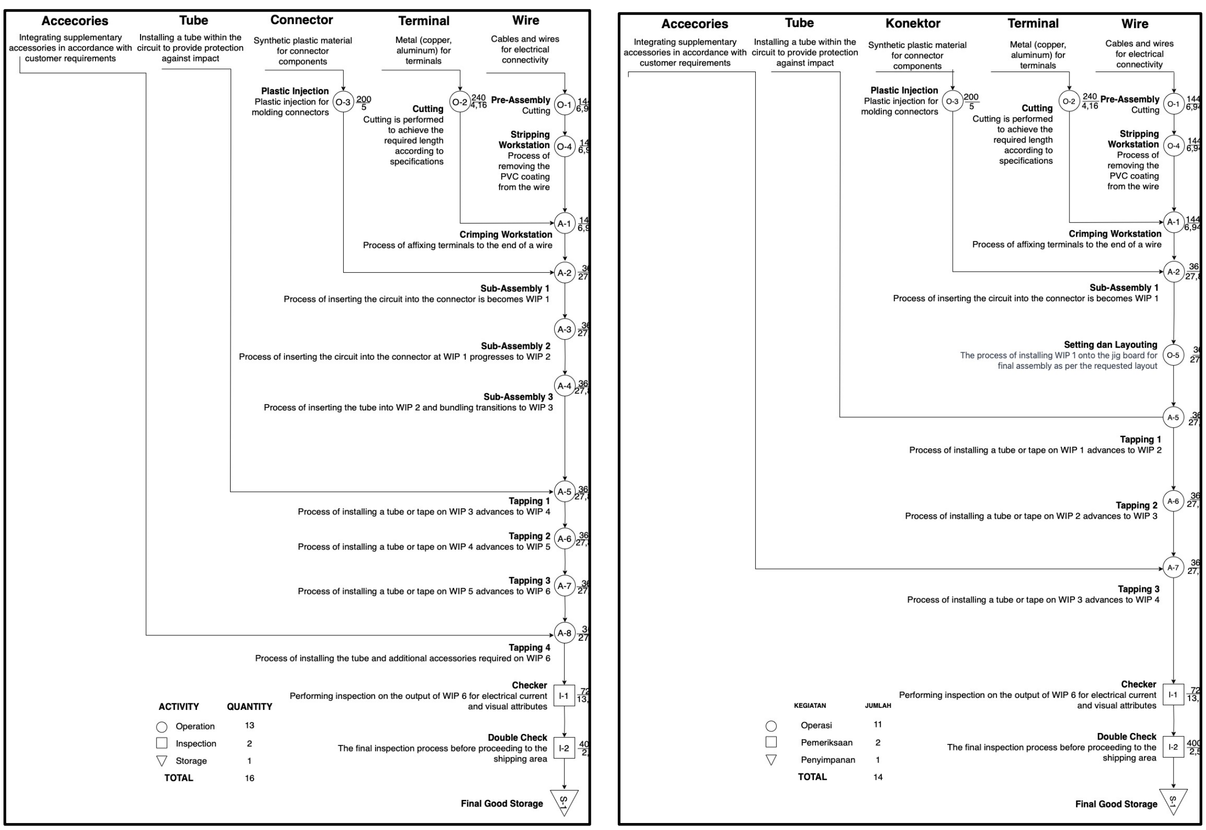

Figure 5. Operation Process Chart Type 1 and Type 2 of PT EDS Manufacturing Indonesia

5. Results and Discussion
5.1 Numerical Results
In creating a new Layout for the wiring harness production line, it is necessary to calculate the number of machines needed based on time study analysis and product demand data from Table 1. In calculating the number of machines, researchers used a routing sheet. The routing sheet of wiring harness production can be seen in Table 3.

5.1.1 Routing Sheet
A route sheet lists production operations and their sequence. It shows the sequence of steps required for customers to acquire a single finished product. PT EDS Manufacturing Indonesia route sheet consists of operation description, takt time, and wiring harness production cycle time. From the routing sheet, the number of workers that needed to meet daily demands is 19 workers.

Table 3. Routing Sheet of Wiring Harness Production

No	Operation	Operation Description	Takt Time (min/pc)	Average Cycle time (pc/sec)	Average Cycle Time (min)	Pcs/Hr	Hr/1000 Pcs	Allowances	Pcs/Hr
1	O-1	Wire Cutting	0.42	0.04	2.40	144	6.94	5%	136.8
2	O-2	Terminal Cutting	0.25	0.07	4.00	240	4.17	5%	228
3	O-3	Plastic Injection	0.30	0.06	3.33	200	5.00	5%	190
4	O-4	Stripping	0.42	0.04	2.40	144	6.94	5%	136.8
5	A-1	Crimping	0.42	0.04	2.40	144	6.94	5%	136.8
6	A-2	Sub-Assembly 1	1.67	0.01	0.60	36	27.78	5%	34.2
7	A-3	Sub-Assembly 2	1.67	0.01	0.60	36	27.78	5%	34.2
8	A-4	Sub-Assembly 3	1.67	0.01	0.60	36	27.78	5%	34.2
9	O-5	Setting and Layouting	1.67	0.01	0.60	36	27.78	5%	34.2
10	A-5	Tapping 1	1.67	0.01	0.60	36	27.78	5%	34.2
11	A-6	Tapping 2	1.67	0.01	0.60	36	27.78	5%	34.2
12	A-7	Tapping 3	1.67	0.01	0.60	36	27.78	5%	34.2
13	A-8	Tapping 4	1.67	0.01	0.60	36	27.78	5%	34.2
14	I-1	Inspection/Checking	0.83	0.02	1.20	72	13.89	5%	68.4
15	I-2	Double Checking	0.83	0.02	1.20	72	13.89	5%	68.4

5.1.2 Total Number of Machines
From time standard calculation, the total number of machines could be determined using assembly line balancing as shown in Table 4.

Table 4. Total Number of Machines Needed Each Operation

No	Operation	Wire	Terminal	Connector	Tube	Accessories	Total Machines	Rounds Up
1	Cutting	0.942	0.566	-	-	-	1.508	2
2	Plastic Injection	-	-	0.680	-	-	0.68	1
3	Striping	0.942	-	-	-	-	0.942	1
4	Scrimping	-	0.942	-	-	-	0.942	1
5	Sub Assembly	-	-	3.770	-	-	3.77	4
6	Layouting	-	-	-	1.988	-	1.988	2
7	Tapping	-	-	-	-	3.770	3.77	4
8	Checker	-	-	-	-	1.988	1.988	2

5.1.3 Production Line Capacity

With efficiency of 95%, total number of hours production line capacity could be determined. The detail of operation capacity is shown in Table 5

Table 5. Operation Capacity of Production Line

No	Operation	Number of machines	Hours per day	Historical Performances	Hours Capacity
1	Cutting	2	8	95%	7.6
2	Plastic Injection	1	15	95%	14.25
3	Striping	1	15	95%	14.25
4	Scrimping	1	15	95%	14.25
5	Sub Assembly	4	60	95%	57
6	Layouting	2	60	95%	57
7	Tapping	4	60	95%	57

5.1.4 Efficiency

To meet daily the demand, the input assumption is figured out by multiplying the required 19 workers with working hours per day, 15 hours and production demand each day 1020 pieces. So, the total efficiency in this production process for Plant 813 is 90.4%

5.1.5 Material Handling Cost

Material handling costs is one of the metrics to select the new Layout with minimum material handling costs and moving moments. From the existing layout, the daily material handling equipment cost is $73.80, divided by a number of working hours to be $4.92 (Table 6).

Table 6. Material Handling Cost

Material Handling Areas	Cost/Day	Cost/Hour
External Plant	$23.18	$1.55
Pre Assembly	$7.99	$0.53
Sub Assembly	$16.44	$1.10
Final Assembly	$24.76	$1.65
Final Check	$6.58	$0.44
Total Material Handling Cost	$73.80	$4.92

5.2 Graphical Results

5.2.1 Activity Relationship Chart

The SLP method was used to develop a new alternative layout, which involved using ARC to assess the level of proximity of a place or workstation. Focusing on the scale of Plant 813 that we studied, the ARC is shown in Figure 6.

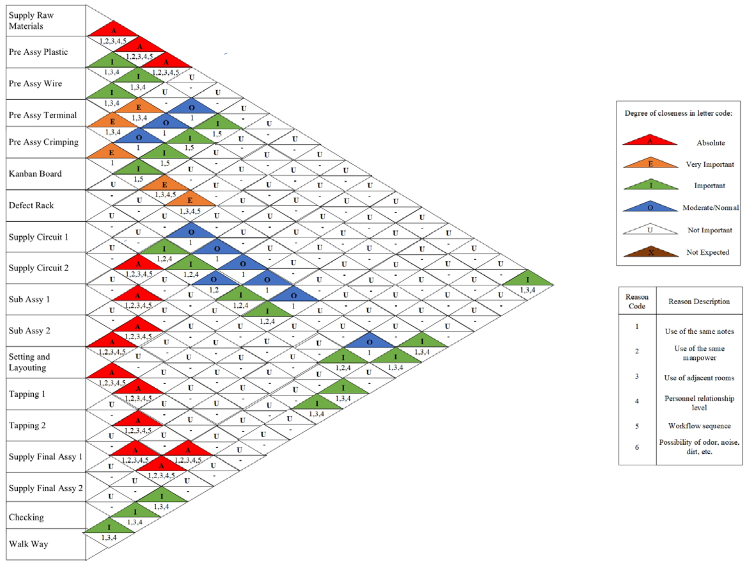

Figure 6. ARC of Plant 813

The ARC shows that the closeness of every workstation depends on the production flow order. The ARC also shows that Walk Way must be close to all supply areas to ease and minimize handling frequency. Defect racks must also be closed into each workstation to mitigate the defect WIP to be stored directly when needed.

5.2.2 Activity Relationship Diagram

We found that the optimized layout from ARD can be made with the two options for improving the layout. The first ARD shown in Figure 7 (left) has good quality since it has a close relation between the walkway and the whole supply station, a close relation between the final assy with the checking station, and a close relation between the defect rack and workstations. The second ARD shown in Figure 7 (right) has excellent quality since it has a close relation to the walkway and all supply stations, rotating closeness in the pre-assy stations, and rotating closeness in the final assy station.

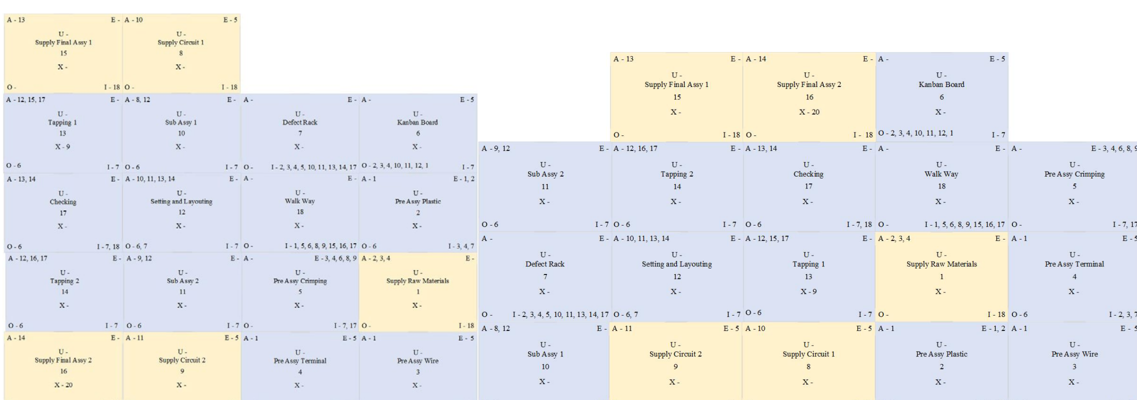

Figure 7. Alternatives of ARD

5.2.3 Area Allocation Diagram

The Area allocation diagram from two alternative ARDs allocates the area allocated in Plant 813. Figure 8 (top figure) shows the first alternative layout that has the closeness area of every sequential workstation from pre-assy until final assy. The location for the checking area is closer to the final-assy workstation, which indicates a better layout for improvement. Figure 8 (bottom figure) also shows the second alternative layout with the closeness area from the external warehouse to spread for every supply station in the plant. The closeness is allocated for storing the finished goods away from Plant 813. This AAD allocates every workstation to be sequentially and rotational layout allocation.

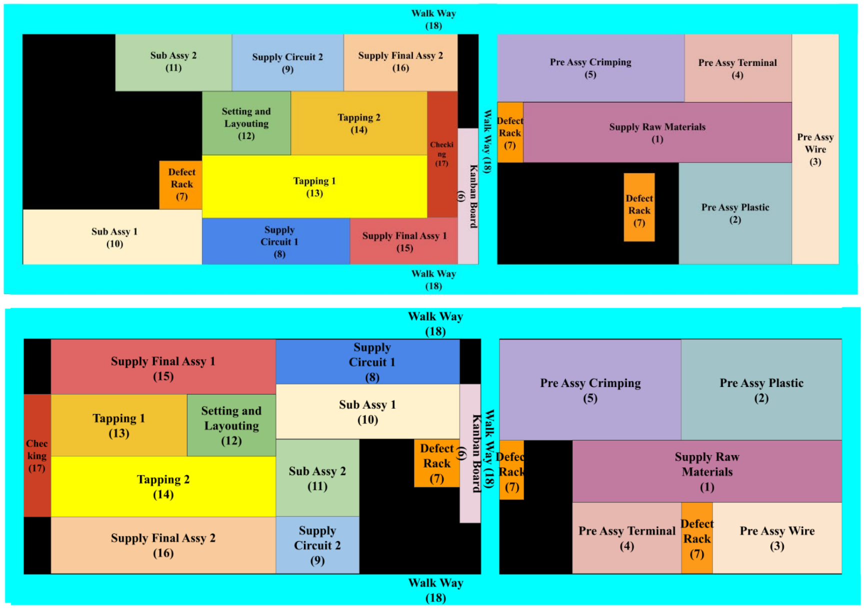

Figure 8. AAD of Alternative Layouts

5.3 RULA Assessment

Physical and ergonomic factors resulted in a RULA score of 3, indicating that changes or improvements in task design or working posture are necessary.The proposed improvement employs fewer machine-based systems, thus requiring a higher utilization of manpower, which may require adjustments to reduce the potential for injury, such as breaks between shifts or slight changes in posture to make it more ergonomic. The work that requires human labor is in WS-Sub Assembly and WS Final Assembly, where the working posture can be depicted in Figure 9 below.

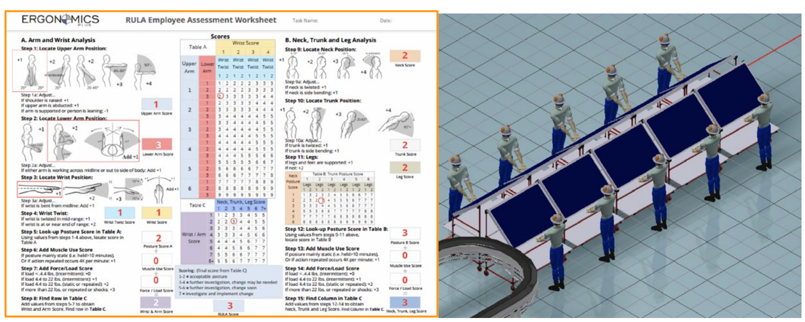

Figure 9. RULA Assessment

5.4 Proposed Improvements

The proposed improvement for the first and second alternatives is shown in Figure 10 and 11, respectively.

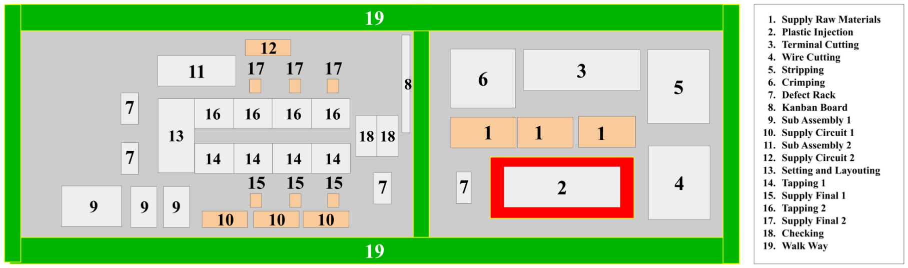

Figure 10. Proposed Improvement Alternative Layout 1

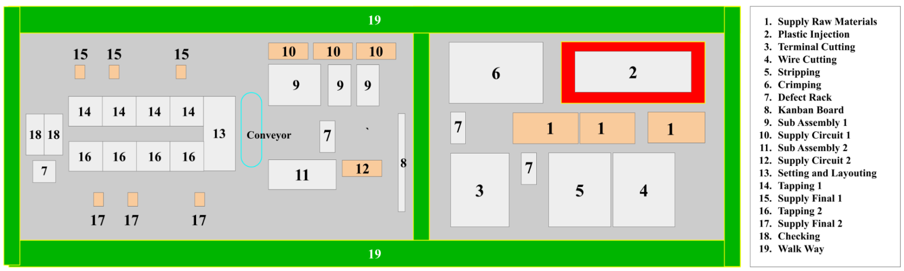

Figure 11. Proposed Improvement Alternative Layout 2

Based on this research, the purpose of a new layout to produce a wiring harness is to have less material handling cost by using the alternative layout at PT EDS Manufacturing Indonesia. This new alternative Layout can decrease the material handling costs and also reduce the moving moments during the production process. The summary of the layout design calculation can be seen in Table 7.

Table 7. Summary of Layout Design Calculation

Layout Design	Number of Workers	Hourly Production	Efficiency
Existing Layout	19	68	90.4%
Alternative Layout 1	19	70	94.0%
Alternative Layout 2	18	72	97.7%

Implementing Alternative Layouts 1 and 2 effectively reduced the number of workers, hour production output, and the efficiency. Comparing the two alternatives, Alternative Layout 2 demonstrated superior outcomes in reducing the number of workers, hourly production, and efficiency. The number of workers is the same as the existing layout with a one-line system but can make less one manpower by rotational layout. Total production per hour also increased because of the lesser distance in material handling inside Plant 813, causing an increase in efficiency. Consequently, Alternative Layout 2 was chosen as the optimal layout for the wiring harness production line, ensuring enhanced efficiency and cost-effectiveness.

5.5 Validation

The validation was done using the SimPy library in the Python programming language. SimPy is designed to facilitate the modeling and simulation of complex systems by providing a framework for representing entities, events, and processes. From the SimPy simulation, the chosen alternative layout reduces the material handling costs and increases the production efficiency by reducing movements and decreasing average production time (Table 8).

Table 8. Summary of Layout Design

Layout Design	Material Handling Cost (day)	Average Production Takt Time (min)	Average Time in System	Daily Production
Existing Layout	$78.96	0.838	24.57	1020
Proposed Layout	$69.30	0.806	23.72	1060
Percentage Increase/Decrease	**-13.9%**	**-3.97%**	**-3.46%**	**+3.92%**

By implementing the proposed layout, material handling cost can be reduced from $78.96 to $69.30, showing a decrease of 13.9%. Average production takt time decreased by 3.97% from 0.838 minute to 0.806 minute and average time in the system also decreased by 3.46%. The total daily production that can be made is increased from 24216 units to 25524 units monthly.

6. Conclusion

From the new alternative layouts made by using the Systematic Layout Planning (S.L.P.) method, two alternatives was created, called alternative layout one and alternative layout 2. The new layouts effectively reduced the number of workers, hour production output, and efficiency. Comparing the two alternatives, Alternative Layout 2 demonstrated superior outcomes with 18 workers, an hourly production of 72 units, and an efficiency of 97.7%. Validation was done using SimPy simulation in Python to analyze the material handling cost and production efficiency. The results showed that the chosen alternative layout reduces material handling cost by 13.9% from $78.96 to $69.30, average production takt time by 3.97% from 0.838 minutes to 0.806 minutes, and daily production increased by 3.92% from 1020 to 1060. An alternative layout can increase monthly production from 24216 units to 25524 units.

References

Apple, J., Plant Layout and Material Handling, 3, 1997.

Barnes, R. M. (1991). Motion and time study: design and measurement of work. John Wiley & Sons.

Barnwal, S., & Dharmadhikari, P. (2016). Optimization of plant layout using SLP method. International Journal of Innovative Research in Science, engineering and technology, 5(3).

Indrawati, S. M., Virananda, I., & Abdi, Z. (2021). The Productivity and Future Growth Potential of Indonesia. Economics and Finance in Indonesia, 67(2), 6.Klausnitzer, A., & Lasch, R. (2019). Optimal facility layout and material handling network design. Computers & Operations Research, 103, 237-251.

Manaruzzaki, A., Suhardi, B., Andriyani, H.T. and Tyastuti, N.U., Literature Review: The Importance of Working Time Measurement in the Manufacturing Industry to Increase Company Productivity (Case in Indonesia).

Nurcahyo, R., & Habiburrahman, M. (2021). Relationship between ISO 9001: 2015 and operational and business performance of manufacturing industries in a developing country (Indonesia). Heliyon, 7(1).

Nurcahyo, R., & Wibowo, A. D. (2015). Manufacturing capability, manufacturing strategy and performance of Indonesia automotive component manufacturer. Procedia Cirp, 26, 653-657.

Nurcahyo, R., Kristiningrum, E., & Sumaedi, S. (2020). ISO 9001-certified public healthcare center's efficiency and re-certification. International Journal of Productivity and Performance Management, 69(4), 794-812.

Pérez-Gosende, P., Mula, J., Díaz-Madroñero, M., Facility layout planning. An extended literature review, International Journal of Production Research, vol. 59, pp. 3777-3816, 2021.

Rahayu, A.P. and Nurcahyo, R., December. Hazards from the Maintenance Outsource Operation of Container Material Handling Equipment in Port. In 2019 IEEE 6th International Conference on Engineering Technologies and Applied Sciences (ICETAS) (pp. 1-4). IEEE, 2019.

Rahman, M. A., Sarker, B. R. and Escobar, L. A., Peak demand forecasting for a seasonal product using Bayesian approach, Journal of the Operational Research Society, vol. 62, pp. 1019-1028, 2011.

Reimer, D., Entrepreneurship and Innovation, Available: http://www.ieomsociet.org/ieom/newsletters/, July 2020.

Reimer, D., Engineering education and the entrepreneurial mindset at Lawrence Tech, Proceedings of the 3rd Annual International Conference on Industrial Engineering and Operations Management, vol. xx, pp. xx-xx, Istanbul, Turkey, July 3 – 6, 2012.

Reimer, D., Title of the paper, Proceedings of the 5th North American International Conference on Industrial Engineering and Operations Management, pp. xx-xx, Detroit, Michigan, USA, August 10-14, 2020.

Reimer, D., Islam, T. and Ali, A., Engineering education and the entrepreneurial mindset at Lawrence Tech, Proceedings of the 12th Annual International Conference on Industrial Engineering and Operations Management, vol. xx, pp. xx-xx, Istanbul, Turkey, July 3-6, 2012, https://doi.org/10.46254/AN4.12.202201.

Shetty, D., Ali, A. and Cummings, R., A model to assess lean thinking manufacturing initiatives, International Journal of Lean Six Sigma, vol. 1, no. 4, pp. 310-334, 2010.

Siahaan, R.C. and Oktiarso, T., Perancangan Tata Letak Lantai Produksi Baru dengan Metode Systematic Layout Planning, Journal of Integrated System, vol 1, no. 2, pp. 161-179, 2018.

Stehens, M., and Meyers, F., Manufacturing Facilities Design and Material Handling, 5th Edition, Purdue University Press West Lafayette, Indiana, 2013.

Suhardini, D., Septiani, W. and Fauziah, S., 2017, December. Design and simulation plant layout using systematic layout planning. In IOP Conference Series: Materials Science and Engineering (Vol. 277, No. 1, p. 012051). IOP Publishing.

Tompkins JA. Facilities Planning. fourth edition ed. (California: John Willey & Sons), 2010.

Wibowo, A. D., Nurcahyo, R., & Khairunnisa, C. (2016, November). Warehouse layout design using shared storage method. In Proceeding of 9th International Seminar on Industrial Engineering and Management.

Wignjosoebroto, S., Tata Letak Pabrik dan Pemindahan Bahan, Edisi Ketiga. Surabaya: Guna Widya., 2009.

Wignjosoebroto, S., Pengantar Teknik dan Manajemen Industri. Surabaya: Guna Widya., 2003.

Xu, X. (2020, February). SLP-based technical plant layout planning and simulation analysis. In IOP Conference Series: Materials Science and Engineering (Vol. 772, No. 1, p. 012020). IOP Publishing.

Biographies

Ahmad Nauval Ariq MS is a third-year industrial engineering student at the University of Indonesia (UI) Bachelor of Engineering. Born in Pasuruan in April 2003, he is active as a Manufacturing Systems Laboratory Assistant. He has an interest in research in the fields of manufacturing systems, quality systems, and economics.

Baidilla Anamta Bimasakti is a third-year industrial engineering student at the University of Indonesia (UI). Born in Magelang on February 9th, 2003, he is currently exploring his interests in graphic design, photography, and product design.

Felix Ferdinand Laureng is an ordinary third-year student at the University of Indonesia (UI) majoring industrial engineering. Born in Makassar on April 25th, 2003. He is currently responsible for being laboratory assistant of the Statistics and Quality Engineering Laboratory. His research interests are mostly related to machine learning, data science, time-series forecasting, system modeling, and algorithmic trading.

Setya Ady Wicaksono is a third-year industrial engineering student pursuing a Bachelor of Engineering degree at the University of Indonesia, born on October 29, 2003, in Jakarta. Currently serves as the head of the Social Community division at the Association of Industrial Engineering Students and is a Laboratory assistant in the Statistics and Quality Engineering Laboratory. Passionate in data analysis, ergonomics, and information systems, and streamline processes through innovative solutions.