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Improving The Operational Efficiency at A Manufacturing Facility by Using Lean Techniques: A Case Study at Shams Cables Factory

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Abstract

The ever-increasing competitive landscape necessitates manufacturers to seek improvements in operational efficiency constantly. This paper explores the integration of various methodologies to enhance operational efficiency at Shams Cables Factory. The proposed approach combines lean techniques, conceptual modeling, and process visualization tools like facility layout, activity relationship chart (ARC), flow process chart (FPC), and VA/NVA analysis to further refine the process by differentiating between value-adding and non-value-adding activities. As a result, these integrations allow for targeted efforts to eliminate NVA activities, streamline VA activities, and maximize overall efficiency.

Keywords
Lean manufacturing, Facility Layout Design, Activity Relationship Chart, Efficiency, VA/NVA Analysis

1. Introduction
Similar to Kaizen or The Toyota Production System, the principle of continuous improvement known as lean manufacturing can be used to describe it. This idea was designed to minimize waste while maximizing resource use. After Japan's defeat in World War II, it extends its roots. After World War II, the Japanese automobile industry was where lean manufacturing was initially implemented due to a lack of materials, funding, and skilled labor. The "Toyota Production System" now known as "Lean Manufacturing" was created by two highly respected individuals at the Toyota Automotive Company, Eiji Toyoda and Taiichi Ohno. Lean management aims to use the process to accomplish the goals of high quality, safety, and worker morale while at the same time lowering costs and cutting lead times (N. Kumar et al. 2022). Industries use lean manufacturing as an approach to cut waste from manufactured goods. The fundamental plan is to reduce the cost of the goods during all phases of production, including designing, fabricating, and manufacturing, with the aid of prior business analyses. When designing, the material and financial resources can be used to the fullest extent possible. In order to reduce waste, the industry must first identify all forms of hidden waste. The engineer will frequently choose the product's well-known, secure, and reliable material over less expensive alternatives. As a result, the organization's profit will drop, the engineer will pay more, and the associated economic risks will rise (N. Kumar et al. 2022).

1.1 Lean thinking

By allowing for more flexibility in manufacturing systems and processes and challenging mass production practices, lean thinking has successfully produced "leaner" (i.e., less wasteful) products and supply chains. The phrase "Industry 4.0" recently became popular. The phrase "fourth industrial revolution" first appeared in use in Germany in 2011. With the numerous prospects and business models that can be consolidated through new technologies, it attempts to connect the real and virtual worlds in industrial production (V. L. Bittencourt et al. 2019). Lean thinking is used to make the most of each step of the project, whether it be group size, raw materials, or inventory as illustrated in Figure 1, and to eliminate any misuse to cut down on time and money wasted (N. Kumar et al. 2022) (Figure 1).

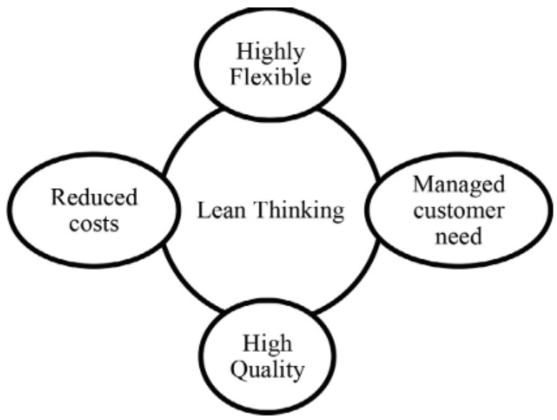


Figure 1. Components of lean

1.2 Lean manufacturing techniques

Lean manufacturing uses a batch of techniques. These techniques aid in defining the goal of lean manufacturing. When examined closely, it will become clear that the techniques outlined below are essential to lean manufacturing. Therefore, we mention some of the techniques as shown in Figure 2.

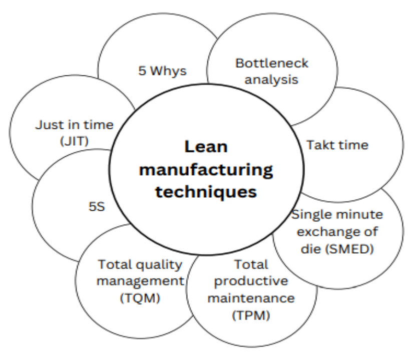


Figure 2. Lean manufacturing techniques

- ❖ Bottleneck analysis: The technique involves calculating the length of time at the peak of the production process. By using bottleneck activity and time measurement, we can determine the line capacity.
- ❖ Takt time: The German word "cycle" is takt. Thus, it aids in figuring out the production cycle.
- ❖ Single Minute Exchange of Die (SMED): Is a technique used to cut the setup time to under 5 minutes. It employs a number of procedures for this (N. Kumar et al. 2022).
- ❖ Total productive maintenance (TPM): For optimal effectiveness, consistency, and process capability, this technique is used. This technique is based on two main concepts which are included in its name.

2. Literature review

Every organization that uses lean manufacturing techniques has an issue with resources, effort, and time waste in the production process. Lean manufacturing has been developed to reduce waste and boost productivity, efficiency, and work quality. We reviewed several research studies, as given below:

Sundar, R et al. concentrated in their study entitled “A review on lean manufacturing implementation techniques” on every aspect of lean manufacturing, such as Value Stream Mapping (VSM), Cellular Manufacturing (CM), U-line system, Line Balancing, Inventory control, Single Minute Exchange of Dies (SMED), Pull System, Kanban, Production Leveling, and so on. The result of the study is to assist the company in implementing the lean manufacturing system to reduce all types of waste at all levels of product manufacturing so as to reduce product costs. In addition, an effort has been made in this work to create a lean road map (R. Sundar et al. 2014). Abdul Rahman, Nor Azian et al. the aim of their research is to better understand how the Kanban system works in multinational firms and to identify the barriers that prohibit Malaysian small and medium-sized businesses (SME) from utilizing Kanban. They suggest that top management commitment, vendor cooperation, inventory control, and quality improvement are essential for implementing Kanban and moving toward lean manufacturing (N. A. A. Rahman et al. 2013). Hodge, George L et al. conducted an article entitled “Adapting lean manufacturing principles to the textile industry” to evaluate which lean concepts can be successfully applied in the textile business. As well, they listed various lean tools and principles in their study. Additionally, they found that case studies, interviews, and visits to production facilities were used to assess the use of lean manufacturing in the textile industry. In a textile context, a model for applying lean tools and principles was created (G. L. Hodge et al. 2011). Rohani, Jafri Mohd et al. studied in their paper one of the most important lean manufacturing methods, Value Stream Mapping (VSM) to upgrade a color industry's production line as a case study. Using team formation, product selection, conceptual design, and time-frame formulation through takt time calculation, lean core principles were applied to develop VSM for waste detection and elimination. Final results demonstrated that the value added time fell from 68 minutes to 37 minutes and the Production Lead-time was reduced from 8.5 days to 6 days by using various lean thinking practices (J. M. Rohani et al. 2015). Widiasih, Wiwin et al. concentrated on creating a risk management model by combining several methods. The House of Risk method was used to classify risk agents and divide hazards into risk occurrences and risk agents. The Delphi method was applied to discover potential risks. Along with this, linkages between risk occurrences were mapped using Interpretive Structural Modeling. The percentages of risk occurrences and risk agents were then determined using the Analytical Network Process in order to calculate the modified Risk Potential Number. The risk management department of an Indonesian manufacturing company that was just beginning to apply Lean Manufacturing is supported by this recommended model. Nineteen risk agents and ten risk events out of nine potential dangers have been discovered. Following the mapping of interrelationships between these risks and the calculation of an updated Risk Priority Number, the following top three risk events should be given priority for mitigation: Key Performance Index objective cannot be met based on SQCDP parameter, Unable to complete the action plan on time, and Employees cannot receive lean manufacturing training materials or expertise. The study made the point that Company X can manage risks across all of its efforts successfully thanks to the integrated methodology. In addition, this integration intends to improve decision-making by providing quantitative analysis at each stage of risk management. (W. Widiasih et al. 2015). Rojasra, P, M et al. discussed how one of the lean manufacturing techniques in Indian companies generates more than 50% of industrial production in terms of value addition and generates one-third of export revenue. Furthermore, lean manufacturing allows to produce high-quality, and low-cost products. This article talks about the 5S methodology's adoption at the Krishna Plastic Company in Udhyognagar, Amreli, and Gujarat. Among the different lean manufacturing techniques accessible, 5S offers good potential for required improvement such as cleaning, sorting, organizing, and laying the framework for workplace improvement. The company conducts a ten-week study. According to the findings of the 5S deployments, the production effectiveness of the system increased from 67% to 88.8% in the following week (P. M. Rojasra et al. 2013). Sharma, Rohan et al. conducted on the 5S application to increase the production rate of the number of screens that are manufactured within one minute. The researchers concluded that the process of producing the screens was inefficient, and the proposed measure was to reorganize the materials to produce the screens more quickly (R. Sharma et al. 2018). Zarrar, Ahmed et al. conducted a study on the relationship between lean manufacturing and the Internet of Things (IoT). The investigators concluded that the Internet of Things (IoT) serves as a support for "lean manufacturing" as it works to improve productivity as well as to simplify the maintenance phase (A. Zarrar et al. 2021).

3. Problem statement

The factory is currently dealing with an issue related to its layout and the high proportion of non-value-added (NVA) tasks. These factors are negatively impacting the factory's efficiency and productivity. The current layout causes the movement of materials and workers resulting in wasted time and effort. Additionally, the presence of NVA activities, like waiting time, transporting work-in-process from one location to another, and setting up materials and equipment, is further making matters worse. All these factors combined are causing production costs longer lead times and a decline, in product quality. To address these challenges effectively the factory needs to implement a strategy that focuses on optimizing the layout to minimize unnecessary movement, identifying and eliminating NVA activities, and implementing lean manufacturing principles.

4. Methodology

The framework of this project has conducted based on the methodology used. The framework of this project includes five steps which are shown in Figure 3

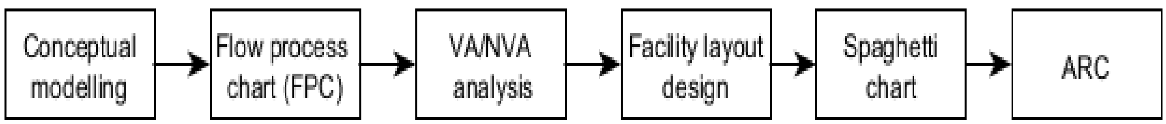


Figure 3. Suggested Framework

4.1 Conceptual modelling

Conceptual models play a crucial role in facilitating the effective application of lean industry concepts. They serve as a foundational framework that guides organizations in understanding, implementing, and sustaining lean principles and practices. YEd Graph is a free, cross-platform diagramming tool that allows you to create flowcharts, UML diagrams, mind maps, and other types of diagrams. So, we use Yed Graph software to create the conceptual model below in Figure 4:

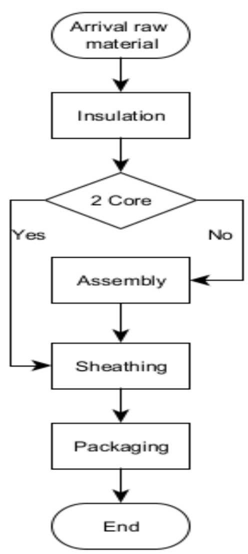


Figure 4. Conceptual modeling for the two journey using YEd Graph

4.2 Flow process chart (FPC)

The Flow Process Chart (FPC) is a traditional data-gathering tool utilized by Industrial engineers to document every operation, storage, transport, delay, and inspection step in a product's flow path. Hence, we can use the approach of Value Stream Mapping (VSM) which is distinguished by its ability to capture information flows in line with material movements within a single map. For our project, Table 1 shows the Flow Process Chart (FPC) for the product (V. Chopra et al. 2019).

4.3 Value and non-value added (VA/NVA) analysis

Value-added and non-value-added (VA/NVA) analysis can assist in identifying the work components that can be removed, merged, reorganized, and/or simplified. Any activity that improves the end product is referred to be VA, and any that doesn't are referred to as NVA. Waste created from production activities can also be taken into account in the VA / NVA analysis (D. Sahija et al. 2021).

4.4 Facility layout design

A well-designed layout can streamline the production process, reducing unnecessary movement of materials and people. The facility distribution form of a production line depends on the type of the enterprise and the production organizational mode. So, this project uses a qualitative approach that aims at maximizing closeness rating scores between departments based on a closeness function. This can lead to faster production times, lower costs, and increased output. So, we use Solidwork software to create the facility layout (Figure 5, Figure 6 and Figure 7).

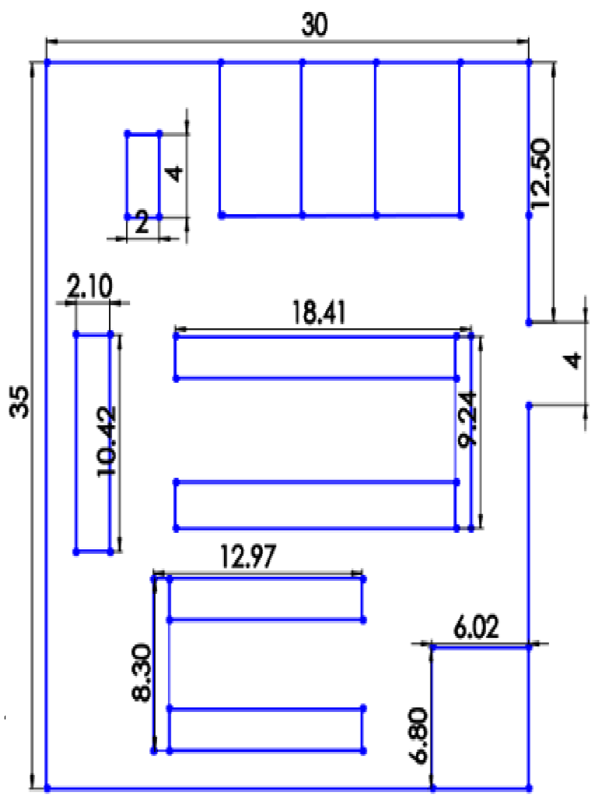


Figure 4 Facility layout using Solidwork

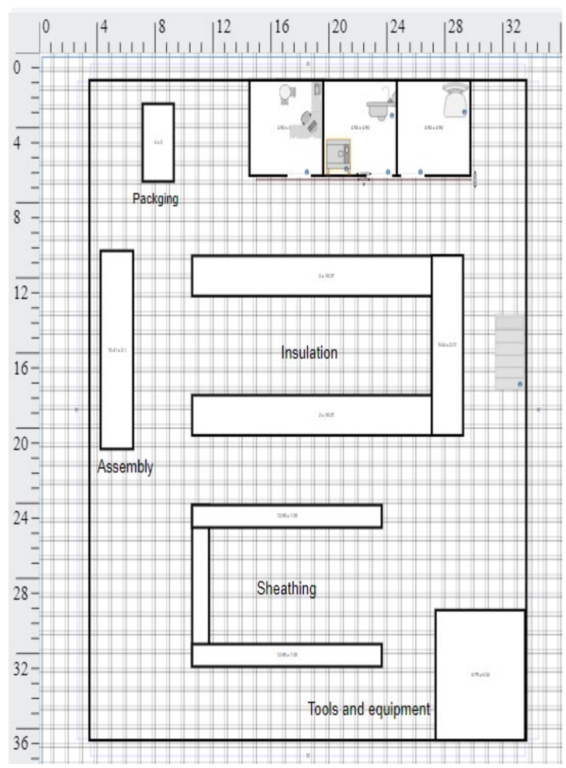
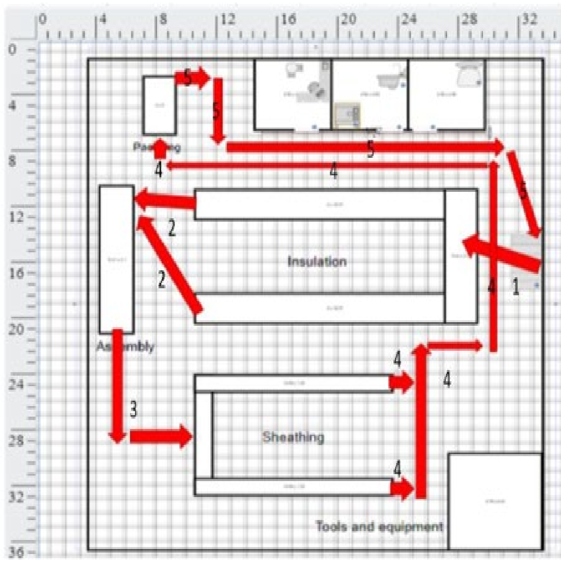


Figure 6. Facility layout using Smartdraw



Number of trip	Description of trip
1	From door to Insulation
2	From Insulation to Assembly
3	From Assembly to Sheathing
4	From Sheathing to Packaging
5	From Packaging to Shipping

Figure 7. Spaghetti chart

4.6 Activity relationship chart (ARC)

An activity relationship chart (ARC) is a valuable tool for optimizing facility layout and improving operational efficiency. It provides a visual representation of the relationships between different activities or departments within a facility, by identifying the relationships between activities, ARCs help to group closely related activities together, minimizing unnecessary movement of materials, personnel, or information. This can significantly reduce cycle times, improve productivity, and lower overall operational costs. ARCs are essential tools for planning and designing new facilities or reconfiguring existing ones. By considering the relationships between activities, ARCs can help to create layouts that minimize travel distances and optimize workflow patterns. We use the activity relationship chart (ARC) to arrange the facility layout based on the priority level and to clarify the relationship between processes (Figure 8 and Figure 9, Figure 10, Figure 11).

5.

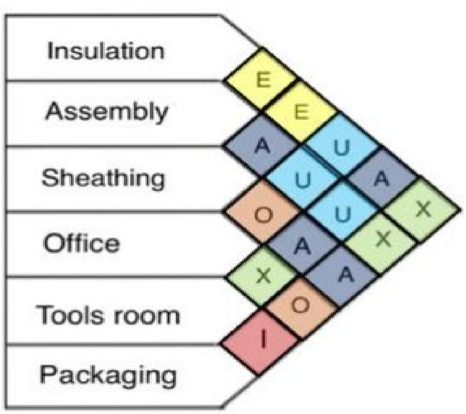


Figure 8. Activity Relationship Chart (ARC)

A	Absolute
E	Especially
I	Important
O	Ordinary
U	Unimportant
X	Prohibited

Figure 9. Relationships

By gathering all the data we create FPC the we analyze the VA and NVA activity ass shown Table 1.

Table 1. VA/NVA analysis

Opn. No.	Description	Distance (m)	Time (min)	Symbol					VA/NVA
				○	⇨	D	▭	▽	
1	Move the wheel from the truck to the insulation machine.	6.37			●				NVA
2	Close the valve to secure the wheel.		0.50			●			NVA
3	Pulling the copper wire to the entrance of the machine.		0.10			●			NVA
4	Cut the head of the copper wire and tight it to the existing copper wire in the machine.		2.10	●					NVA
5	Heating the machine.		1.5	●					NVA
6	Some dirt comes out of the machine after heating it.		1.08			●			NVA
7	Starting the insulation process.		60	●					VA
8	Copper wire insulation.			●					VA
9	Crossing the copper wire into a basin of water for cooling.			●					VA
10	The wire is then dried.			●					VA
11	The wire passes through a wheel to adjust its path and stabilize it.						●		VA

12	End of the insulation process.							●	VA
13	Move the wheel from the forklift to the assembly machine.	10.42			●				NVA
14	Close the valve to secure the wheel.		0.50			●			NVA
15	Starting the assembly process.		80	●					VA
16	The wire passes through a wheel to adjust its path and stabilize it.						●		VA
17	End of the assembly process.							●	VA
18	Move the wheel from the forklift to the sheathing machine.	14.57			●				NVA
19	Close the valve to secure the wheel.		0.50			●			NVA
20	Prepare the sheath material.					●			NVA
21	Tight the core to the existing sheath wire in the machine.		1.5	●					NVA
22	Prepare the wheel that exist at the end of the machine.		0.40			●			NVA
23	Applies the sheath material.		2	●					NVA
24	Cool the sheath.			●					NVA
25	Starting the sheathing machine.		140	●					VA

26	The wire passes through a wheel to adjust its path and stabilize it.						●		VA
27	Cut the wire to the desired size.		2	●					NVA
28	End of sheathing process.							●	VA
29	Move the wheel from the forklift to the packaging machine.	27.6			●				NVA
30	Preparing packaging materials.		1			●			NVA
31	Place the packaging materials inside the machine.		0.50	●					NVA
32	Preparing the logo at the end of the packaging machine.		0.40			●			NVA
33	Place the wire inside the packaging machine.			●					VA
34	Starting the packaging machine.		40	●					VA
35	Place the logo when packaging is finished.			●					VA
36	Shipping.				●				VA

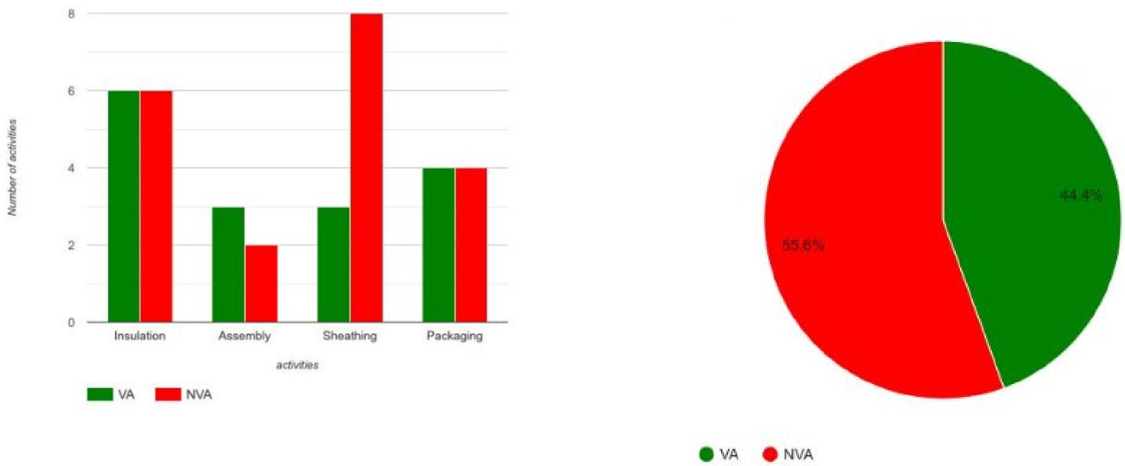


Figure 10. Comparison of VA/NVA activities

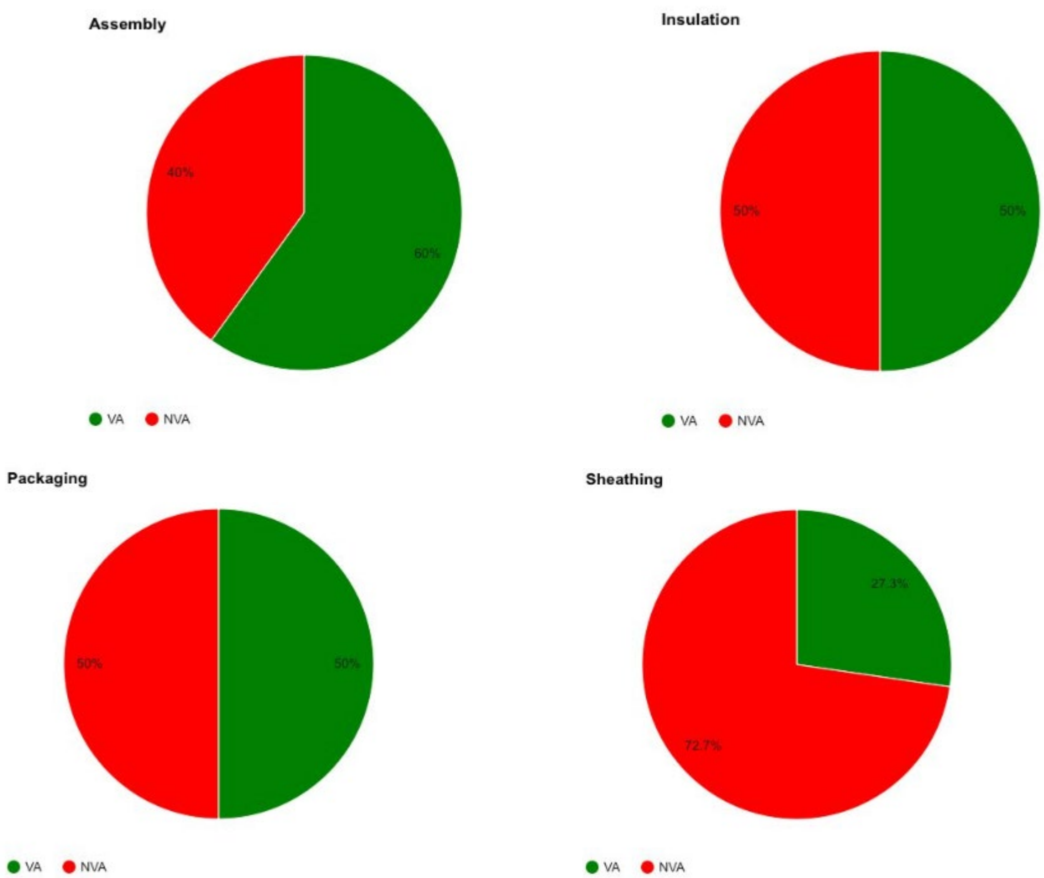


Figure 5 VA / NVA activities for all processes

6. Conclusions
After analyzing the data, it is clear that the Shams factory has real problems related to the high percentage of NVA activities and poor facility layout. In this paper, we apply lean concepts and methodologies to achieve the expected results and outcomes. We can significantly improve our operational effectiveness by applying lean concepts and analytical instruments. Non-value-added activities (NVA) such as excessive handling, waiting, and rework are the goals for removal in lean methodologies. We used a spaghetti chart to provide a clear picture of the flow of materials and persons, showing inefficient flow and encouraging layout optimization. Also, the activity relationship chart helped us build a streamlined facility layout that reduces distance and needless interactions between processes, resulting in a seamless, value-driven operation. By addressing both internal and external flow obstacles, this combined strategy enables significant performance benefits that save costs, increase customer satisfaction, and shorten lead times. Keep in mind that achieving lean requires continual monitoring and modification. Using these techniques can help you maintain optimal operational efficiency.

References
Agrahari, R. S., P. A. Dangle, and K. V Chandratre, “Implementation of 5S methodology in the small scale industry: a case study,” Int. J. Sci. Technol. Res., vol. 4, no. 4, pp. 180–187, 2015.

Bittencourt, V.L., A. C. Alves, and C. P. Leão, “Lean Thinking contributions for Industry 4.0: a Systematic Literature Review,” IFAC-PapersOnLine, vol. 52, no. 13, pp. 904–909, 2019, doi: https://doi.org/10.1016/j.ifacol.2019.11.310.

Castillo, G., L. F. Alarcón, and V. A. González, “Implementing lean production in copper mining development projects: Case study,” J. Constr. Eng. Manag., vol. 141, no. 1, p. 5014013, 2015.

Chambi Quiroz, J, N. E., Chacón, and P. Prada, “Proposal to Improve the Consolidated Copper Mineral in a Warehouse, Using Lean Manufacturing Tools BT - Production and Operations Management,” J. Vargas Florez, I. de Brito Junior, A. Leiras, S. A. Paz Collado, M. D. González Alvarez, C. A. González-Calderón, S. Villa Betancur, M. Rodriguez, and D. Ramirez-Rios, Eds., Cham: Springer International Publishing, 2022, pp. 229–244.

Darsini, D., “Production Process Waste Analysis With Lean Manufacturing Approach in Copper Crafts Industry,” J. Ind. Eng. Halal Ind., vol. 2, no. 2, pp. 59–65, 2022, doi: 10.14421/jiehis.3471.

Dianto, C., F. Widiandoko, D. Rahmanasari, Yuniaristanto, and W. Sutopo, “Redesign Production Layout Using Dedicated Storage Method: Case Study of PT.Solo Grafika Utama,” IOP Conf. Ser. Mater. Sci. Eng., vol. 943, no. 1, p. 12042, 2020, doi: 10.1088/1757-899X/943/1/012042.

Fadlil, I. N. and C. N. Rosyidi, “Improvement of work processes and methods to achieve production targets using VA/NVA analysis, ECRS and line balancing,” in AIP Conference Proceedings, AIP Publishing, 2020.

Guzel D. and A. S. Asiabi, “Increasing productivity of furniture factory with lean manufacturing techniques (Case Study),” Teh. Glas., vol. 16, no. 1, pp. 82–92, 2022.

Hodge, G. L. , K. Goforth Ross, J. A. Joines, and K. Thoney, “Adapting lean manufacturing principles to the textile industry,” Prod. Plan. Control, vol. 22, no. 3, pp. 237–247, Apr. 2011, doi: 10.1080/09537287.2010.498577.

Htun, A., T. T. Maw, and C. Khaing, “Lean manufacturing, just in time and Kanban of Toyota production system (TPS),” Int. J. Sci. Eng. Technol. Res., vol. 8, no. 1, pp. 469–474, 2019.

Huang, C.-Y. , D. Lee, S.-C. Chen, and W. Tang, “A Lean Manufacturing Progress Model and Implementation for SMEs in the Metal Products Industry,” Processes, vol. 10, no. 5, p. 835, 2022.

Kelendar, H., “Lean Thinking from Toyota Manufacturing to the Healthcare Sector,” Res. Med. Eng. Sci., vol. 8, no. 5, 2020, doi: 10.31031/rmes.2020.08.000697.

Ketkamon, K. and J. Teeravaraprug, “Value and Non-value added analysis of incoming order process,” in Proceedings of the International MultiConference of Engineers and Computer Scientists, , pp. 18–20, 2009.

Khaswala, Z. N. and S. A. Irani, “Value network mapping (VNM): visualization and analysis of multiple flows in value stream maps,” in Proceedings of the Lean Management Solutions Conference, 2001, pp. 1–18.

Kumar, N. et al., “Lean manufacturing techniques and its implementation: A review,” Mater. Today Proc., vol. 64, no. April, pp. 1188–1192, 2022, doi: 10.1016/j.matpr.2022.03.481.

Kumaş, A., “Evaluation of logger pro innovative technology supported applications in the scope of stem,” Probl. Educ. 21st Century, vol. 79, no. 5, pp. 751–766, 2021.

Lee, K.-L., C.-C. Wei, and H.-H. Lee, “Reducing exposed copper on annular rings in a PCB factory through implementation of a Six Sigma project,” Total Qual. Manag., vol. 20, no. 8, pp. 863–876, 2009.

Lora-Soto, A., C. Morales-Silva, J. Llontop-Jesus, and N. Mamani, "Process improvement proposal for the reduction of machine setup time in a copper transformation company using lean manufacturing tools," Adv. Intell. Syst. Comput., vol. 1253 AISC, pp. 585–591, 2021, doi: 10.1007/978-3-030-55307-4_89.

Madanhire, I. and C. Mbohwa, "Enterprise Resource Planning (ERP) in Improving Operational Efficiency: Case Study," Procedia CIRP, vol. 40, pp. 225–229, 2016, doi: https://doi.org/10.1016/j.procir.2016.01.108.

Martins, R., M. T. Pereira, L. P. Ferreira, J. C. Sá, and F. J. G. Silva, "Warehouse operations logistics improvement in a cork stopper factory," Procedia Manuf., vol. 51, pp. 1723–1729, 2020, doi: https://doi.org/10.1016/j.promfg.2020.10.240.

Mistry, D. and V. Shah, "Application of Lean Manufacturing Tools and Techniques: A Case Study in a Manufacturing Industry," Int. J. Res. Appl. Sci. Eng. Technol., vol. 8, no. 6, pp. 1260–1267, 2020.

Nabila, A., M. I. H. Umam, A. Suherman, V. Devani, and M. R. Nazaruddin, "Computerized Relative Allocation of Facilities Techniques (CRAFT) Algorithm Method for Redesign Production Layout (Case Study: PCL Company)," 2022.

Palange, A., and P. Dhatrak, "Lean manufacturing a vital tool to enhance productivity in manufacturing," Mater. Today Proc., vol. 46, pp. 729–736, 2021, doi: https://doi.org/10.1016/j.matpr.2020.12.193.

Pazek, K. T. A.-T. T., "Lean Manufacturing." IntechOpen [Erscheinungsort nicht ermittelbar], [Erscheinungsort nicht ermittelbar], 2021. doi: LK - https://worldcat.org/title/1302664883.

Perera, H. A. D., "Productivity improvement through lean tools in a Sri Lankan small and medium enterprise: A case study," in 2016 Manufacturing & Industrial Engineering Symposium (MIES), , pp. 1–6. 2016. doi: 10.1109/MIES.2016.7779988.

Pranav, D. and M. Vivaan, "Impact of 5S and lean manufacturing techniques in various organisations to enhance the productivity," Int. J. Adv. Eng. Manag. (IJAEM, vol. 2, no. 4, pp. 421–436, 2020, doi: 10.35629/5252-0204421436.

Rahman, C. and S. U. Sabuj, "Process flow improvement proposal of a batch manufacturing system using arena simulation modeling," Rev. Gen. Manag., vol. 21, no. 1, pp. 63–77, 2015.

Rahman, N. A. A. , S. M. Sharif, and M. M. Esa, "Lean Manufacturing Case Study with Kanban System Implementation," Procedia Econ. Financ., vol. 7, no. Icebr, pp. 174–180, 2013, doi: 10.1016/s2212-5671(13)00232-3.

Rajak, A. K. and S. D. Kore, "Experimental investigation of aluminium–copper wire crimping with electromagnetic process: Its advantages over conventional process," J. Manuf. Process., vol. 26, pp. 57–66, 2017.

Razee, S. M., "Redesigning of a warehouse facility layout for improving the inventory management system: a case study." IUT, MCE, 2016.

Riezebos, J., and W. Klingenberg, "Advancing lean manufacturing, the role of IT," Comput. Ind., vol. 60, no. 4, pp. 235–236, 2009, doi: https://doi.org/10.1016/j.compind.2009.01.005.

Rohani, J. M., and S. M. Zahraee, "Production Line Analysis via Value Stream Mapping: A Lean Manufacturing Process of Color Industry," Procedia Manuf., vol. 2, pp. 6–10, 2015, doi: https://doi.org/10.1016/j.promfg.2015.07.002.

Rojasra , P. M., and M. N. Qureshi, "Performance improvement through 5S in small scale industry: a case study," Int. J. Mod. Eng. Res., vol. 3, no. 3, pp. 1654–1660, 2013.

Rossini, M., F. Costa, G. L. Tortorella, and A. Portioli-Staudacher, "The interrelation between Industry 4.0 and lean production: an empirical study on European manufacturers," Int. J. Adv. Manuf. Technol., vol. 102, no. 9–12, pp. 3963–3976, 2019, doi: 10.1007/s00170-019-03441-7.

Said, M. A. B. M. and N. B. Ismail, "Improvement of production line layout using arena simulation software," Appl. Mech. Mater., vol. 446, pp. 1340–1346, 2014.

Sharma, R., M. Kasher, L. Zhang, N. Mani, and B. Lai, "Application of Lean Manufacturing Principles in Optimizing Factory Production," in 2018 IEEE MIT Undergraduate Research Technology Conference (URTC), , pp. 1–4. 2018. doi: 10.1109/URTC45901.2018.9244796.

Sharma, S. S. , D. D. Shukla, and B. P. Sharma, "Analysis of lean manufacturing implementation in SMEs: a '5S' technique," in Advances in Industrial and Production Engineering: Select Proceedings of FLAME 2018, Springer, , pp. 469–476. 2019

Shokri, A., "Reducing the scrap rate in manufacturing SMEs through Lean Six Sigma methodology: an action research," IEEE Eng. Manag. Rev., vol. 47, no. 3, pp. 104–117, 2019.

Singh, J. , H. Singh, D. Singh, and K. Singh, "Evaluating lean thinking using value stream mapping in manufacturing industry-a case study," Int. J. Product. Qual. Manag., vol. 22, no. 1, pp. 101–116, 2017.

Sundar, R., A. N. Balaji, and R. M. Satheesh Kumar, "A review on lean manufacturing implementation techniques," Procedia Eng., vol. 97, pp. 1875–1885, 2014, doi: 10.1016/j.proeng.2014.12.341.

Ulewicz, R. and L. V Lazar, “The effect of lean tools on the safety level in manufacturing organisations,” Syst. Saf. Human-Technical Facil., vol. 1, no. 1, 2019.
Venugopal, V., and P. G. Saleeshya, “Productivity improvement through the development of sustainability metrics in wire manufacturing industry,” Int. J. Product. Qual. Manag., vol. 39, no. 1, pp. 1–19, 2023.
Widiasih, W., P. D. Karningsih, and U. Ciptomulyono, “Development of Integrated Model for Managing Risk in Lean Manufacturing Implementation: A Case Study in an Indonesian Manufacturing Company,” Procedia Manuf., vol. 4, pp. 282–290, 2015, doi: https://doi.org/10.1016/j.promfg.2015.11.042.
Yang, M. G., P. Hong, and S. B. Modi, “Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms,” Int. J. Prod. Econ., vol. 129, no. 2, pp. 251–261, 2011, doi: https://doi.org/10.1016/j.ijpe.2010.10.017.
Zarrar, A., M. H. Rasool, S. M. M. Raza, and A. Rasheed, “IoT-Enabled Lean Manufacturing: Use of IoT as a Support Tool for Lean Manufacturing,” in 2021 International Conference on Artificial Intelligence of Things (ICAIoT), , pp. 15–20. 2021. doi: 10.1109/ICAIoT53762.2021.00010.