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Review on Lean & Agile Implementation in Gear Manufacturing Industries

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Abstract*— Ever increasing customer demand and competitive environment among manufacturers across the world has engaged the industry to adapt advanced manufacturing strategies. The combination of both lean and agile manufacturing can be integrated to achieve customer demand and satisfaction. The integration of lean and agile manufacturing concepts would meet complete and qualitative manufacturing system. The main purpose of Lean and agile manufacturing is the customer satisfaction with a cost-effective price. The integration of Lean and agile manufacturing has been adopted in most of the manufacturing enterprises. Lean mainly leads to eliminating the non-value-added activities while agility focuses on rapid response to market demand. Some of the industries use Lean concept and lean tools to improve the productivity, but few manufacturing industries use Agile concept to rapid response to customer demand. The integration of Lean & Agile concepts meets customer requirements and also increases the productivity which in turn increases profit of the industry. The main aim of this paper is to increase profit, productivity and meeting customer demand by integration of Lean & Agile implementation in Gear manufacturing industry.

***Index Terms*— 5S, Kaizen, Just in Time (JIT), Kanban**

I. INTRODUCTION

The market has grown more cost-conscious and demanding in recent years. Any business that wants to thrive in the fast-paced market environment of today must have strong quality processes. In order to provide the best-in-class goods and services in this scenario, it is imperative to review the manufacturing procedures and systems in order to increase operational efficiency. Historically, the key to making money was bulk output and full plant utilization. The drawbacks of the conventional manufacturing approach include increased inventories of work-in-process and finished goods, as well as excessive raw material usage. This manufacturing method produced rigid plants that are extremely challenging to reorganize. Lean and agile manufacturing techniques have been implemented by organizations to cut inventory, maintain short product lead times, and improve system flow reliability. Lean removes low-value tasks from the process and makes full use of all available resources, including people, machines, and money. The lean manufacturing improves competitiveness by inventory reduction and lead-time reduction also improves overall quality of the process [1].

Lean manufacturing is focused on maximizing customer value by minimizing waste, or any activity that doesn't add value, through continuous improvement. Lean manufacturing which mainly focuses on improving the efficiency of operations by eliminating and reducing wastes.

Agile manufacturing is a production methodology focused on achieving rapid, flexible, and innovative responses to quickly changing customer demands and market conditions. Key principles include speed, responsiveness, adaptability, quality, customization, and cost control, often leveraging technology and modular design to quickly pivot production without significant expense or delay.

II. OVERVIEW OF LEAN TOOLS

Lean manufacturing

The Lean technique eliminates all the process that removes non-value-added activities. Eliminating waste entails getting rid of pointless meetings, tasks, and paperwork as well as ineffective working methods. In manufacturing organizations, there are seven main categories of waste: overproduction, excess inventory, waiting (lost time), unnecessary motion, unnecessary transportation, rework, and over-processing/over-engineering. It is acknowledged that even small changes can help an organization become more efficient and save money.

Some of Lean tools used in manufacturing are:

5s: 5S is a lean tool used to improve efficiency in work by reducing waste. It helps keep the workplace clean and in more efficient manner, which in turn helps to increase productivity. It has a five stage of the improvement of the process. It has five “S” all “S” gives the different meaning and activity. Seiri, Seiton, Seiso, Seiketsu, and Shitsuke. Is a Japanese word and translate into English These 5S is: Sort, Set (in place), Shine, Standardize, and Sustain [17].

- P. Rewers and J. Trojanowska et, al. suggests that 5S is one of the basic tools of Lean Manufacturing, from which the enterprise starts. 5S is the first step to improve production and it can be adapted to both in production and in the office. The aim of the 5S is to arrange and well-organized workplace. The implementation of this tool can

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improve the quality of the products and services provided, raise productivity, improve safety and hygiene of work, and as a result increase the stability of processes and reduce operating costs of the enterprise [31].

- Sirkku Muotka, Amir Togiani, Juha Varis et, al. suggests the 5S method is used to organize and maintain work areas to enable a smooth and efficient flow of work. By minimizing waste in the production cell and establishing and upholding an organized work environment, 5S seeks to maximize productivity. The five steps in the 5S process are used to organize the workplace, design a course of action utilizing standardization to facilitate future development and improvements, and generate visual reminders to assist maintain the established order. One typical visual result of 5S implementation is that all tools on the pegboards have organized, labelled, and color-coded storage locations. [34]
- Sirkku Muotka, Amir Togiani, Juha Varis et, al. suggests that these findings demonstrated that the Design Thinking methodology and its cycle of empathy, definition, ideation, prototype, and testing aligns with the 5S implementation and supports its procedures. The study showed that these two approaches may be effectively used to the upkeep and arrangement of secure and comfortable workspaces, which is a prerequisite for improved quality by 12% and more effective productivity optimization. It was also demonstrated that the applied design thinking methods were sufficient to address the underlying causes of complicated issues. [34]
- Rizkya et al [4] presented a 5S implementation process preceded by observation, interviews, and documentation, reporting the 18,75% reduction in search activity and the minimizing of the total area used up to 11, 20%. Karthik et Silksonjohn [5] report time savings, improved safety, and effective workplace organization gained by following the 5S principles.

Just in time (JIT):

Just-in-Time (JIT) is an inventory management and production strategy where materials, components, and finished goods are delivered and produced only when they are needed in the manufacturing process. By reducing waste and inventory. JIT seeks to boost productivity, cut expenses, and enhance product quality. A key component of lean manufacturing is just-in-time. It is linked to lean methodologies. The right part arrives at the right location at the right time thanks to just-in-time manufacture. By producing things just when needed, the just-in-time (JIT) manufacturing technique seeks to boost efficiency and decrease waste.

- Santosh Kumar et, al. (2014) applies the lean tool such 5S, Kaizen, JIT, VSM by method time measurement and line balance efficiency and reduce the cycle time in a truck body assembly line and improve efficiency in that product line. Also says that lean manufacturing is a business philosophy that continuously improves the process involve in manufacturing [16].
- P. Rewers and J. Trojanowska et, al. suggests the main goal of the Just in Time concept is to minimize inventory while guaranteeing on-time production and delivery. Just in Time necessitates minimizing inventory, identifying and removing faulty parts and materials promptly, and avoiding inappropriate operation. Using the pull system and continuous flow, JIT enables you to synchronize every step of the production process. This approach makes use of Kanban, which establishes the appropriate time to start the production process. This shows the production lead time has been reduced by 25% which increases the productivity. [31].
- S. Neha, M. G. Singh, K. Simran, and G. Pramod et, al. suggests when lean management was first used outside of Japan, it was known as JIT. The lean management method provides provision of high-quality products and services in perfect synchronization to customer needs with no waste. a production philosophy founded on the deliberate removal of all waste and ongoing productivity enhancement. It includes the effective completion of every manufacturing task necessary to create a finished good. The productivity is increased by 156% which increases the sales and inturn increases the profit of the industry. [32] [33].

Kanban

Kanban is a subsystem of the Lean manufacturing system which was created to control inventory levels, the production and supply of components.

Junior et al. [18] suggest that the implementer can categorize and analyze the Kanban variants using the knowledge gained from the development and accumulation of the Kanban system. Sipper and associates. Make a distinction between the dual card Kanban system for production signalling and the transportation Kanban system for signalling. Buffer maintenance smoothes the production flow and reconfigures the Kanban System to reduce inventory during demand uncertainty. Therefore, the Kanban system offers mixed model production and the ideal inventory level, which reduces lead time for product delivery and makes efficient use of resources like people, machines, etc. [17].

- Junior et al. suggests that the Japanese word kanban refers to the pulling of a product through a production process. Kanban aims to notify a previous process when parts or materials are needed for the subsequent process. A workstation process that generates few faults can be significantly enhanced by kanban. However, the system may become "starved" for parts if there are workstations with high defect rates (a hidden factory). By combining kanban with an IEE measurement and improvement system, this issue could be prevented. Between a supplier and a client, kanban might serve as a relay signal. Lights, color balls down a tube, or a computer network can all

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produce kanban signals. By using a barcode system to measure product quantities sold, a food market can determine when to stock. Lights, color balls down a tube, or a computer network can all produce kanban signals. By using a barcode system to measure product quantities sold, a food market can determine when to stock. When a product pull occurs, a stockperson uses first-in, first-out product restocking to supply the designated quantity. The kanban system allows the provider to know how much merchandise to supply a strategy to keep the material flowing in an ordered fashion. Material order points, the amount of material required, and when it should be delivered are all indicated on kanban cards. The output of materials gradually increased from 40% to 55% by using Kanban and JIT. The wastage also reduced by13%. [18], [21].

- Vikash Sharma, Shashank Kumar, Rakesh D. Raut et, al. suggests there are numerous varieties of kanban that can be employed, and the system is highly adaptable. Similarly, they can be applied in a wide range of ways as long as the business complies with the fundamental kanban guidelines. Because it uses direct communications to generate material—that is, to supply and the customer—this system is an effective tool for cutting waste during manufacturing. Producing it is the pull signal. When the customer withdraws output, the kanban shows exactly what the customer is utilizing and, consequently, what they will require in the future. This paper shows that inventory and work in process is reduced by 18%, which increases the productivity. [27].

Continuous Improvement (CI)/Kaizen

Kaizen: Kaizen is a Japanese word kai means continuous and zen means improvement. Its main focus on completely improves the product and satisfy the customer. Continuous improvement is the small incremental improvement in overall efficiency. It increases the productivity, profit and overall effectiveness of the company. Kaizen and 5s are the component of continuous improvement Continuous Improvement (CI) is inventories exposes waste such as the idle time, waiting time, inventory and resource problem [17].

- Lean production means continuous improvement; we must keep on changing the future state into current state for getting the better results. Kaizen tool has greatly proved to be a effective tool for eliminating waste in cycle time. This powerful tool only highlights process inefficiencies, transactional and communication mismatches but also guides about the improvement areas. On the shop floor time is money. If the time is wasted money is wasted. By applying the Kaizen and value stream mapping tool in a small-scale automobile industry, a current state map is developed. By eliminating non-value-added activities. This shows marked improvement in the process inventory, production lead time and processing time. In this study process inventory time reduced from 3 to 1 days resulting in improvement of 33.33%. Process lead time was reduced by 52.94% and the processing time was reduced by 80.69%.
- The Japanese term for constant improvement is kaizen. All employees are involved in this attitude of constant quality and productivity improvement at work, which enables quick efficiency gains without requiring costly investments. When considering the organization of business and supply chain activities, production efficiency is a critical issue. Thus, increasing a production process's efficiency is a crucial component of action control. Kaizen should be applied among the staff members who directly create products as well as at the tactical and operational levels of management. Top management, whose job it is to establish a suitable workplace culture that supports ongoing development, should support the entire process. [31].

Agile manufacturing

Agile Manufacturing is the technique used to meet customer demand rapidly. It helps to rapidly response to customer requirement. Agile manufacturing aims to satisfy customer demands. Accurate data analysis and study are essential for making industrial modifications in order to make the most efficient and wise use of important resources, such as labour, equipment, materials, and money. An organization can improve its production by being flexible or agile. Agile looks at how quickly and efficiently an organization reacts to management information and/or business intelligence, as well as the caliber and applicability of the decisions that are taken afterward.Some of the papers on both lean and agile implementation in manufacturing industries.

- C. Hemalatha, K. Sankaranarayanasamy, N. Durairaaj [1] suggested that it reduces the overall time needed to create the assembly by implementing both Lean and Agile manufacturing for work-in-process. Lean and agile strategy execution calls for fundamentally novel ideas in terms of people, organizations, technology, and strategies. One of the most effective strategies for lowering WIP is the application of Lean and Six Sigma concepts. The process's setup and cycle times have been shortened by 13% which was ealier much higher than 30% by incorporating lean and agile manufacturing, which has decreased overall time by 11%.
- Dharmendra Hariyani, Sanjeev Mishra, Milind Kumar Sharma, Poonam Hariyani, ISGLSAMS is a fast, adaptable, sustainable manufacturing system that can react swiftly to shifts in consumer demand in the marketplace. ISGLSAMS combines lean, agile, six sigma, green, and sustainable practices all at once under one manufacturing facility. To position itself for the ISGLSAMS competition, the organization must plan at the strategic level, taking into account both its strengths and shortcomings. Planning at the tactical level aids the business in developing the resources necessary to achieve

long-term strategic objectives. Operational-level planning helps the company carry out its operations in an ISGLSA way to satisfy market performance targets and business sustainability standards [19]. Organizations can create a new business model for competitiveness and business benchmarking with the use of an integrated strategic approach [12].

- Dilupa Nakandala, Arun Elias, Hilal Hurriyet suggested that Lean and agile implementations lead to continuous process improvements, with the continuous improvement of existing processes and systems by developing existing knowledge and skills identified as a requirement for Industry 4.0 technology challenges [13]. Lean as a platform for Industry 4.0 adoptions has been the primary focus of several studies [22] [23] but agility, the twin strategic approach to lean, has not received much attention in Industry 4.0 technology research [24]. Several studies have taken the deductive research approach and investigated the integration of lean and Industry 4.0 technologies for the sustainability performance of firms, such as in lean automation [25]. Hence, this study takes an explanatory approach and empirically investigates the effects of lean and agile practices on Industry 4.0 implementations and the role of leadership and innovation in the relationships between lean, agility and Industry 4.0 technology adoptions [13]. Both exploratory and exploitative learning are investigated as distinct constructs to assess their effects on the relationships between lean and Industry 4.0 technology implementation and agility and Industry 4.0 implementations. The uniqueness of this study lies in the fact that it empirically links lean, agility and contextual ambidexterity with Industry 4.0 implementations. The findings extend the industry 4.0 literature by providing empirical evidence for the important role of lean implementations in Industry 4.0 implementations and the role of exploitative learning in fully translating organisational agility and partially translating lean effects on Industry 4.0 implementations. The findings are relevant and current and inform practitioners of how their investments in lean and exploitative learning enable their Industry 4.0 technology implementations.[14]
- According to K. Venkataraman (2014) [30] claims that in order to reduce and eliminate waste, a number of firms have been implementing lean manufacturing in recent years. Value stream mapping is used in this article to shorten the crank shaft's cycle time. There is a three-assembly available for creating a crank shaft, and it improves the process and reduces waste. A variety of tools are used and have advantages. They build a current state map of the crank shaft assembly line and a future state map for enhancing the crank shaft assembly process. This shows the by elimintating waste the industry increases the productivity by 15% and also response to customer requirement.
- Nitin Upadhye et al, (2010) descried significant steps the business has taken to use the lean mindset in order to increase its efficacy and efficiency. In order to use lean manufacturing processes in MSME, this study tried to identify a number of wastes and problems. Lean Manufacturing Systems (LMS) have been found to assist in identifying and reducing waste. To identify and remove waste in an MSME, lean tools such as kaizen, JIT, VSM, 5S, SQC, preventive maintenance, total employee involvement, and SMED were employed. MSMEs will be able to leverage their strengths and overcome their deficiencies with the aid of lean tools and methodologies. It is advised that any organization, regardless of rank, use the lean concept as a method for improvement. The best improvement approach for all manufacturing sectors, including OEMs and component production, is lean management.

III. CONCLUSION

Some of the research paper uses lean tools such as 5S, Kaizen, VSM, JIT, TQM and many other Lean tools, which helps to reduce setup time, production lead time, inventory and wastages. But lean tools are not sufficient in the present competitive world, we should also satisfy customer demand very quickly. Therefore, Lean and Agile implementation in manufacturing industry research help us to know how integration of Lean and Agile will contribute to this competitive world. Some of the papers adapted lean concepts to improve productivity. Many research suggests that combining lean and agile increases the organization benefits. The review papers suggest to use some lean tools to reduce setup time and agile to meet customer requirement.

Lean concept focuses on eliminating non-value-added activities while agile detecting and responding to uncertain changes of the market. Challenges for competing in the business environment makes lean and agile as vital capabilities of a manufacturing organization. Both concepts are able to achieve strategic objectives through improving the overall performance. Many research suggests that combining lean and agile via decoupling point increases the organization benefits. This paper redefines lean and agile, and describes a comprehensive methodology for performance analysis at enterprise level based on both concepts [2].

Lean tools such as 5S, Kaizen, JIT are used in the machine shop and Agile is implemented to the gear box manufacturing process to reduce production lead time, setup time to increase Productivity, which in turn increases Profit of the company.

REFERENCES

[1] C. Hemalatha, K. Sankaranarayanasamy, N. Durairaaj, Lean and agile manufacturing for work in-process (WIP) control, Materials Today: Proceedings, Volume 46, Part 20, 2021, Pages 10334-10338, ISSN 2214-7853.

[2] Hassan Soltan, Sherif Mostafa, Lean and Agile Performance Framework for Manufacturing Enterprises, Procedia Manufacturing, Volume 2, 2015, Pages 476-484, ISSN 2351-9789.

[3] Varinder Kumar Mittal, Rahul Sindhwani, Vivek Kalsariya, Faizan Salroo, Kuldip Singh Sangwan, Punj Lata Singh, Adoption of Integrated Lean-Green-Agile Strategies for Modern Manufacturing Systems, Procedia CIRP, Volume 61, 2017, Pages 463-468, ISSN 2212-8271.

[4] Hajar soleymanizadeh, Qiang Qu, Seyed Mojtaba Hosseini Bamakan, Seyed Mahmoud Zanjirchi, Digital Twin Empowering Manufacturing Paradigms: Lean, Agile, Just-in-Time (Jit), Flexible, Resilience, Sustainable, Procedia Computer Science, Volume 221, 2023, Pages 1258-1267, ISSN 1877-0509.

[5] Alexander Kurt Moldner, Jose Arturo Garza-Reyes, Vikas Kumar, Exploring lean manufacturing practices' influence on process innovation performance, J. Business Res. 106 (2020) 233–249.

[6] Jose Arturo Garza-Reyes, Vikas Kumar, Sariya Chaikittisilp, Kim Hua Tan, The effect of lean methods and tools on the environmental performance of manufacturing organisations, Int. J. Prod. Econ. 200 (2018) 170–180.

[7] N. Mundra, P. Rajesh, Mishra, Impediments to lean six sigma and agile implementation: an interpretive structural modelling, Mater. Today: Proc. 28 (Part 4) (2020) 2156–2160.

[8] M. Mohan Prasad, J.M. Dhiyaneswari, J. Ridzwanul Jamaan, S. Mythreyan, S.M. Sutharsan, A framework for lean manufacturing implementation in Indian textile industry, Mater. Today:. Proc. (2020), https://doi.org/10.1016/j.matpr.2020.02.979.

[9] Gunjan Yadav, Sunil Luthra, Donald Huisingh, Sachin Kumar Mangla, Balkrishna Eknath Narkhede, Yang Liu, Development of a lean manufacturing framework to enhance its adoption within manufacturing companies in developing economies, J. Cleaner Prod. 245 (2020) 118726.

[10] Luana Marques Souza Farias, Luciano Costa Santos, Cláudia Fabiana Gohr, Lenilson Olinto Rocha, An ANP-based approach for lean and green performance assessment, Resour. Conserv. Recycl. 143 (2019) 77–89.

[11] Jose Arturo Garza-Reyes, Lean and green– a systematic review of the state of the art literature, J. Cleaner Prod. 102 (2015) 18–29

[12] Dharmendra Hariyani, Sanjeev Mishra, Milind Kumar Sharma, Poonam Hariyani, A study of the barriers to the adoption of integrated sustainable-green-lean-six sigma-agile manufacturing system (ISGLSAMS) in Indian manufacturing organizations, Cleaner Waste Systems, Volume 5, 2023, 100098, ISSN 2772-9125

[13] Dilupa Nakandala, Arun Elias, Hilal Hurriyet, The role of lean, agility and learning ambidexterity in Industry 4.0 implementations, Technological Forecasting and Social Change, Volume 206,2024,123533,ISSN 0040-1625.

[14] Dixit, A., Jakhar, S.K., Kumar, P., 2022. Does lean and sustainable manufacturing lead to Industry 4.0 adoption: the mediating role of ambidextrous innovation capabilities. Technol. Forecast. Soc. Chang. 175, 121328.

[15] Ranteshwar Singh, Ashish M Gohil, Dhaval B Shah, Sanjay Desai Procedia Engineering 51 (2013) 592 – 599 1877-7058 © 2013 The Authors. Published by Elsevier Ltd.

[16] S. santosh kumar, M. pradeep kumar. Procedia Materials Science 5 (2014) 1853 – 1862 international conference on advance materials and engineering AMME 2014

[17] R. Sundar, A.N. Balaji, R.M. Satheesh Kumar, A Review on Lean Manufacturing Implementation Techniques, Procedia Engineering, Volume 97,2014,Pages 1875-1885,ISSN 1877-7058.

[18] Muris Lage Junior, Moacir Godinho Filho, Variations of the kanban system: Literature review and classification, Int. J. Production Economics 125 (2010) 13–21.

[19] Mittal, V.K., Sindhwani, R., Kalsariya, V., Salroo, F., Sangwan, K.S., Singh, P.L., 2017. Adoption of integrated lean-green-agile strategies for modern manufacturing systems. Procedia CIRP 61, 463–468. https://doi.org/10.1016/j.procir.2016.11.189.

[20] Rahul Sindhwani, Varinder Kumar Mittal, Punj Lata Singh, Ankur Aggarwal, Nishant Gautam; Modelling and analysis of barriers affecting the implementation of lean green agile manufacturing system (LGAMS). *Benchmarking: An International Journal* 22 February 2019; 26 (2): 498–529. https://doi.org/10.1108/BIJ-09-2017-0245

[21] Rossini, M., Powell, D.J., Kundu, K., 2023. Lean supply chain management and Industry 4.0: a systematic literature review. Int. J. Lean Six Sigma 14 (2), 253–276. Saabye, H., Kristensen, T.B., Wæhrens, B.V., 2022. Developing a learning-to-learn.

[22] Ciano, M.P., Dallasega, P., Orzes, G., Rossi, T., 2021. One-to-one relationships between Industry 4.0 technologies and lean production techniques: a multiple case study. Int. J. Prod. Res. 59 (5), 1386–1410.

[23] Kamble, S., Gunasekaran, A., Arha, H., 2019. Understanding the Blockchain technology adoption in supply chains-Indian context. Int. J. Prod. Res. 57 (7), 2009–2033

[24] Marcucci, G., Antomarioni, S., Ciarapica, F.E., Bevilacqua, M., 2022. The impact of operations and IT-related Industry 4.0 key technologies on organizational resilience. Prod. Plan. Control 33 (15), 1417–1431.

[25] Tortorella, G.L., Rossini, M., Costa, F., Portioli Staudacher, A., Sawhney, R., 2021. A comparison on Industry 4.0 and lean production between manufacturers from emerging and developed economies. Total Qual. Manag. Bus. Excell. 32 (11 12), 1249–1270.

[26] Mattias Hallgren, Jan Olhager; Lean and agile manufacturing: external and internal drivers and performance outcomes. *International Journal of Operations & Production Management* 18 September 2009; 29 (10): 976–999.

[27] Vikash Sharma, Shashank Kumar, Rakesh D. Raut, Maciel M. Queiroz, Balkrishna E. Narkhede & Ravindra Gokhale. (2025) Barriers to integrated lean management-industry 4.0 technologies. *Production Planning & Control* 36:12, pages 1637-1648.

[28] Bouchra Abdelilah, Akram El Korchi & Mohammed Amine Balambo. (2023) Agility as a combination of lean and supply chain integration: how to achieve a better performance. *International Journal of Logistics Research and Applications* 26:6, pages 633-661.

[29] Amir Qamar, Mark A. Hall, Daniel Chicksand & Simon Collinson. (2020) Quality and flexibility performance trade-offs between lean and agile manufacturing firms in the automotive industry. *Production Planning & Control* 31:9, pages 723-738.

[30] K. Venkataraman *et al.*, B.Vijaya Ramnathb, V.Muthu Kumarc, C.Elanchezhiand,3rd International Conference on Materials Processing and Characterisation (ICMPC 2014) *Procedia Materials Science 6 (2014) 1187 – 1196.*

[31] P. Rewers and J. Trojanowska, "Production Management By Using Tools of Lean Manufacturing," Logist. Manag. Dev. trends, vol. 2008, pp. 43–56, 2016.

[32] S. Neha, M. G. Singh, K. Simran, and G. Pramod, "Lean Manufacturing Tool and Techniques in Process Industry," Int. J. Sci. Res. Rev., vol. 2, no. 1, pp. 54–63, 2013.

[33] E. A. A. Ibrahim, "Implementation of Lean Tools and Techniques to the Production Operational Process at INS Plant By: Emad Abdalla Atwa Ibrahim Head of Contracts & Procurement Communications Regulatory Authority State of Qatar," Head Contract. Procure. Commun. Regul. Auth., no. July, pp. 1–18, 2014.

[34] Sirkku Muotka, Amir Togiani, Juha Varis, A Design Thinking Approach: Applying 5S Methodology Effectively in an Industrial Work Environment, Procedia CIRP, Volume 119, 2023, Pages 363-370, ISSN 2212-8271.

[35] Rizkya, I et al. "5S Implementation in Welding Workshop A Lean Tool in Waste Minimization." IOP conference series. *Materials Science and Engineering* 505.1 (2019): 12018–. Web.

[36] Karthik, S; Silksonjohn, J."A Case Study of 5S Implementation in Inspection Process." *International Journal of Mechanical and Production Engineering Research and Development* (2019): 1469-1476. Web.