SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 175

ANALYSIS OF THE IMPACT OF SELECTED LEAN MANUFACTURING TOOLS ON THE PARAMETERS OF THE PRODUCTION PROCESS – CASE STUDY

Szymon PAWLAK

Silesian University of Technology, Faculty of Materials Engineering; szymon.pawlak@polsl.pl,
ORCID: 0000-0002-8896-7966

Purpose: The aim of the research was to present the impact of the use of selected Lean Manufacturing tools (5S and Poka Yoke) on the efficiency of the production process and the number of non-conforming products generated during the manufacturing process. The research was carried out on the basis of data from a production plant in the automotive industry.
Design/methodology/approach: The article presents a statistical analysis of the impact of the implementation of Lean Manufacturing tools on the production process - a case study.
Findings: The obtained results allowed to present the scale of changes coming in the manufacturing process, confirming at the same time the positive effect of the implementation of Lean Manufacturing tools on the efficiency of the manufacturing process and the quality of manufactured products. As a result of the implementation of the 5S and Poka Yoke tools, an increase in efficiency was found in all production operations.
Social implications: The analysis carried out can increase awareness of the importance of the impact of Lean Manufacturing on the production process.
Originality/value: In the article, an original statistical analysis was carried out, indicating an increase in the efficiency of the production process due to the implementation of selected Lean Manufacturing tools.

Keywords: Lean Manufacturing, 5S, Poka Yoke.

Category of the paper: Case study.

1. Introduction

The aim of the study is to present the changes taking place in the employment structures of production plants, occurring as a result of the implementation of modern production management and control systems as well as the automation of production processes that fit into the framework of Industry 4.0. The conducted analysis was based on the analysis of data from production plants with a high level of automation and computerization of production processes,

http://dx.doi.org/10.29119/1641-3466.2023.175.24 http://managementpapers.polsl.pl/

in line with the philosophy of Industry 4.0. The collected information will allow to present the current situation on the labor market and the needs of production plants for a strictly defined profile of an employee. In the era of a highly competitive market and the rivalry of companies with similar production capacities, their work organization plays an important role. In many cases, the factor that allows for the increase of competitiveness is the appropriate selection of organizational tools that have an impact on improving the efficiency and/or quality of the manufactured product or the services provided (Rohani, Zahraee, 2015). One of the methods of work organization management is the implementation of the Lean Manufacturing (LM) concept in enterprises. It should be noted, however, that the correct implementation of the LM philosophy is a complex process with many problems. Studies conducted in production plants in Great Britain (Baker, 2002) and in companies from the automotive industry from the United States and India indicate a low level of effectiveness in the results achieved despite the implementation of the Lean concept (Mohanty et. al., 2007). While in the article (Venkat, 2020) based on the analysis of the impact of LM on the efficiency of the assembly line production process in the electrical industry, an increase in productivity of almost 23% was found. Similar conclusions indicating the improvement of the achieved parameters were presented in the paper (Samuel, 2021). The reason for different results in the effectiveness of the impact of the LM concept on the generated parameters of the production process may therefore be the way they are implemented in the enterprise, which was described in (Mostafa et al., 2013).

In research (Pavnaskar et al., 2003), it was found that one of the most important factors affecting the correct implementation of the LM concept is the use of a project approach focusing on the implementation of one Lean tool at a time. It is necessary to constantly control the effects of the implementation of selected LM tools and evaluate the results obtained.

The aim of the research was to present the impact of the use of selected Lean Manufacturing tools (5S and Poka Yoke) on the efficiency of the production process and the number of non-conforming products generated during the manufacturing process. The research was carried out on the basis of data from a production plant in the automotive industry.

2. Lean Manufacturing

The Lean Manufacturing concept, which was initiated by Toyota, allows for quality improvement, cost reduction and an increase in the speed of response to numerous changes resulting from the dynamics of external and internal factors occurring in various types of processes (Mohan Sharma, Lata, 2018). The benefits resulting from the use of tools in accordance with the LM philosophy caused that they were implemented in numerous production plants around the world (Rahman, 2013)**.** High flexibility in the implementation of individual LM tools meant that they were used in many industries and industries such as:

healthcare, construction and pharmaceuticals (Buggy, Nelson, 2005; Aziz, Hafez, 2013). With the use of Integrated Lean Concepts, organizations are able to achieve the assumed quality goals while reducing production documentation (Jewalikar, Shelke, 2017).

Lean Manufacturing allows for the reduction or elimination of waste (Nandakumar et al., 2020; Ghosh, 2013). Waste is understood as all activities that do not bring a positive value to the created product or object being the subject of the ongoing process (Chowdary, George, 2016). The elimination of waste as a result of the implementation of the Lean philosophy is based on the introduction to the existing process of tools characterized by specific features that affect selected aspects of the process, causing previously expected results.

The reduction of waste as a result of the implementation of LM tools leads to an increase in efficiency by shortening the execution times of individual production operations (Wahab, 2013; Abdulmalek, Rajgopal, 2007), improving the quality of manufactured products (Pettersen, 2019) and shortening the delivery time of products to the customer (Ghosh, 2013). There are many LM tools, including: value stream mapping (VSM), kaizen, 5S, Jidoka, SMED, Poka-Yoke, TPM, Heijunka, Just-In-Time (JIT) or Kanban.

Then it is necessary to correctly implement the tool and evaluate the results obtained. It should be noted that the result of the implementation of LM tools is not the same for every process and depends on many factors, which include, among others: the complexity of the process, the technological aspect, the correctness of the implementation of Lean tools or the awareness of employees at every level of the organization (Palange, Dhatrak, 2021). An important role in the proper implementation of Lean Manufacturing tools in the organization is played by the management. The authors of works (Mohammad, Oduoza, 2019; Zargun, Al-Ashhab 2014), defined the key factors determining the effectiveness of the implementation of the Lean philosophy and grouped them into four main areas, two of which are "Leadership and management" and "Strategy". Proper management of the organization allows for the implementation of the Lean culture, which emphasizes relations between employees at every level of the company (Ghodrati, Zulkifli, 2012; Pepper, Spedding, 2010).

3. Methodology and research area

The analysis was based on data collected in the production plant where the manufacturing process of products used for the production of automotive components is carried out. The analyzed process consisted of seven operations carried out on individual, specialized production stations, technologically adapted to the implementation of the tasks - in accordance with the guidelines contained in the technological documentation. Operations carried out as part of the manufacturing process were carried out manually with the use of simple tools adapted to the assumed technology of performed activities. The production process was not automated.

The arrangement of workstations was in the form of a linear form of production organization and was consistent with the order of operations performed. The production process, due to the type of production and the reproducible size of the production batch, was carried out in a series-parallel system. Employees performing production operations had full training and their number was constant throughout the period of the analysis. The average production volume per month was 10,000 units. Transport operations between the stations were carried out using automated conveyor belts and transport trolleys. Before starting the analysis, the LM technique in the form of the Kanban tool was implemented in the production process organization system. Operation execution times were determined using the MTM I method at the process planning stage, Table 1.

Table 1.
Production operations execution times, determined at the production planning stage

Operation number	Description of the operation	Theoretical execution time of the operation [s]
10	Execution of steel connectors with bend	48
20	Production of steel hooks with a hole ⌀ 8	27
30	Making the core insert	54
40	Making soldered connections	17
50	Assembling the sub-assembly from parts of the components	134
60	Mounting the subassembly with bracket	25
70	Pressing	9

The process of implementing LM tools was gradual. First, the 5S tool was implemented on all production stations. The implementation of the 5S tool was carried out in accordance with the accepted standards covering a five-stage procedure, i.e. selection, systematics, cleaning, standardization and self-discipline, Figure 1. Since the implementation of the 5S tool, regular control of the correctness of the implemented procedures was carried out, confirming the correct implementation of the 5S tool.

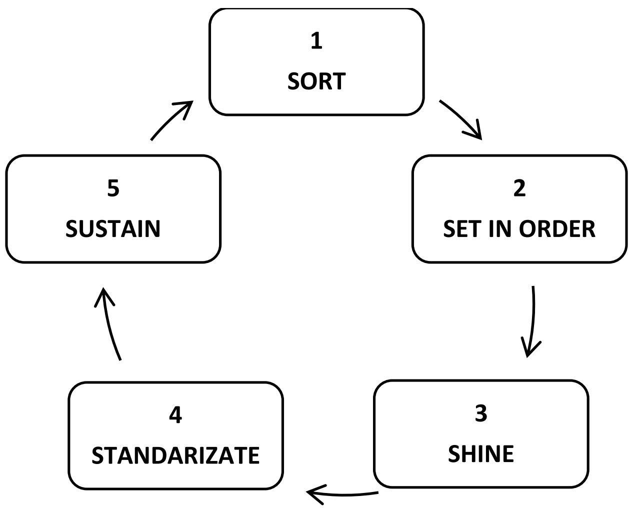

Figure 1. A Scheme of the 5S method.

The period of implementation of the mentioned tool was 3 months. Then, 14 months after the implementation of the 5S tool, systems preventing errors by employees (Poka Yoke) were implemented at two production stations (operations 10 and 50). On the remaining stations, the implementation of the Poka-Yoke tool was not possible due to technological reasons. During the analysis, data was collected on: the time of execution of operations and the number of production shortages. The measurement of the analyzed parameters was carried out for a total of 37 months and covered the time before the introduction of Lean Manufacturing tools (9 months), after the implementation of the 5S method (14 months) and after the implementation of Poka-Yoke (14 months).

The analysis of the impact of Lean Manufacturing tools on the efficiency of the production process and the level of generated defects was carried out in the order described below. First, an analysis of data on the parameters characterizing individual operations and their performance was carried out before the implementation of techniques in accordance with the LM concept. The efficiency of the production process was determined on the basis of the analysis of the actual times of the operation in relation to the theoretical time determined at the planning stage of the production process. The real-time measurement was carried out in accordance with the principles of working day photography. The efficiency of the production process was determined on the basis of the Eq. 1.

$$E = \frac{t_r}{t_n} * 100\% \quad (1)$$

where:
E – actual performance index [%],
t_r – real time of operation execution [s],
t_n – normative time to perform the operation [s].

Then, an analysis of data on the number of non-conforming products (deficiencies) occurring after the implementation of the 5S method and Poka Yoke, Eq. 1 was carried out.

$$D = \frac{n_d}{s} * 100\% \quad (2)$$

where:
D – defects [%],
n_d – number of defects in the process [pcs],
s – size of the production batch [pcs].

Then, for the obtained data on the efficiency of the process and the number of errors on individual operations, a statistical analysis was carried out in order to determine the statistical significance of the observed differences in individual scales. Kruskal-Wallis ANOVA, Mann Withney U and POST-HOC tests with Dunn Bonferroni correction were used for statistical analyses. The assumed confidence level α for each of the conducted analyzes was 0.05.

4. Research results

In order to carry out the analysis, first, production plants were selected, characterized by a high level of automation of production processes and an extensive IT network allowing for remote control of production processes and information flow. Then, the current state was compared with the historical state recorded in each of the production plants. Due to the different date of establishment of the analyzed plants, the period of historical data was between 5 and 10 years. For the purposes of the research, nine production plants with various levels of employment were analyzed (Figure 1). As a result of the conducted analysis, data on the actual execution times of production operations obtained in the period of 9 months were determined. On the basis of the obtained data, the actual performance index and the percentage share of non-conforming products generated by individual production operations were determined. These data, presented in Table 2 was taken as reference data.

Table 2.
Parameters of the production process before the implementation of Lean Manufacturing tools

Operation number	**10**	**20**	**30**	**40**	**50**	**60**	**70**
Theoretical time [s]	48	27	54	17	134	25	9
Average real time [s]	61	43	63	22	209	36	10
Median	72	65	80	28	263	47	12
MAX operation execution time [s]	51	27	55	18	158	28	9
MIN operation execution time [s]	60	41,5	62	21	205	34	10
Actual performance index [%]	80	68	86	78	66	72	89
Non-compliant products [%]	11	4	5	4	17	5	2

Based on the analysis of the parameters of the production process before the implementation of Lean Manufacturing tools, it was found that the highest level of efficiency was characterized by operation 30 and 70 and were 86% and 89%, respectively. The lowest level of efficiency was recorded in operation 50 and amounted to 66%, such a low level of efficiency in operation 50 was related, among others, to its level of complexity and the number of activities that must be performed. In the case of the analysis of the level of deficiencies in individual production operations, the highest percentage of non-conforming product occurred in operations 10 and 50 and amounted to 11% and 17%, respectively.

After the implementation of the 5S method, in the next 14 months, production data was collected, which was used to determine the values of operation execution times and their efficiency, which are presented in Table 3. After another period of implementation of the Poka Yoke tool on operations 10 and 50, analogous data were collected and determined for the next 14 months, which are presented in Table 4.

Table 3.
Parameters of the production process after the implementation of the 5S tool

Operation number	10	20	30	40	50	60	70
Average real time [s]	54	37	63	21	179	32	10
Median	54	36,5	62,5	20,5	172	32,5	10
MAX operation execution time [s]	58	43	69	23	223	35	11
MIN operation execution time [s]	49	28	57	18	158	26	9
Actual performance index [%]	89	75	86	82	76	79	92
Non-compliant products [%]	10	5	6	4	16	5	2

Table 4.
Parametry procesu rodukcyjnego po wdrożeniu narzędzia Poka Yoke (5S + Poka Yoke)

Operation number	10	50
Average real time [s]	51	176
Median	51	168
MAX operation execution time [s]	52	211
MIN operation execution time [s]	48	152
Actual performance index [%]	95	77
Non-compliant products [%]	2	6

As a result of the implementation of the Poka Yoke tool, the efficiency of operations 10 was increased to 95%. There was also a decrease in the level of deficiencies in operations from 10 to 2%, and in the case of operations from 50 to 6%.

A comparative analysis was carried out for the real efficiency index and the share of defects. The results did not confirm statistically significant differences for each of the operations (p > a) after the implementation of 5S. Then, in order to determine the statistical significance of each of the above-mentioned indicators after the introduction of Poka Yoke on operations 10 and 50, the POT-HOC test was performed, the results of which are presented in Tab. 5 and 6. It was found that there were significant differences in efficiency and the number of deficiencies after the implementation of the 5S and POKA YOKE tools in relation to the state before the implementation of the above mentioned tools.

Table 5.
POST-HOC results for operation 10

P Value	Without LM	5S Tool	5S Tool+POKA YOKE
Actual performance			
Without LM		0,255	<0,001
5S Tool			0,028
5S Tool+POKA YOKE			
Share of deficiencies			
Without LM		1	0,001
5S Tool			0,001
5S Tool+POKA YOKE			

Table 6.
POST-HOC results for operation 50

P Value	Without LM	5S Method	5S Tool+POKA YOKE
Actual performance			
Without LM		0,070	0,019
5S Tool			1
5S Tool+POKA YOKE			
Share of deficiences			
Without LM		1	0,001
5S Tool			0,001
5S Tool+POKA YOKE			

5. Research results

The results obtained, indicating an increase in the efficiency of the production process as a result of the implementation of the 5S tool, confirm the observations presented in the article (Sharma, Singh, 2015) and (Fernandes et al., 2018). After the implementation of the 5S tool, an increase in efficiency was recorded on six production operations, the highest increase in efficiency was recorded on the 50th operation and reached 76%. The increase in efficiency resulted from tidying up the workplace, but also from the introduction of standards for cleaning the workplace after its completion. The implemented solutions in the form of a shadow table and formalized instructions for cleaning the stations ensured their order and, consequently, eliminated time delays in the implementation of production operations. In the analyzed case, the statistical difference between the generated process parameters before and after the implementation of 5S using the Mann Withney U test did not confirm the statistically significant differences, however, the downward trend of the obtained results was noticeable. The above results indicate the need for the production plant to consider the possibility of implementing further LM tools, which will contribute to further improvement of process efficiency in individual operations. This thesis is confirmed by the results described below for operations 10 and 50, on which the Poka Yoke tool was implemented.

As a result of the analysis of efficiency and generated deficiencies for operations 10 and 50 after the implementation of 5S and Poka Yoke, the value of the p statistic was less than the adopted confidence level α. The results obtained in the analysis of the level of efficiency for operation 10 indicated that in the case of comparing the process efficiency parameters before the implementation of the Lean Manufacturing tools and the 5S tool with the implementation of the Poka Yoke technique, there is a statistically significant difference, which is graphically presented in Fig. 2-5. In the case of operation 50, a statistically significant difference was found only in the case of comparing the parameters generated by the production process before the implementation of the 5S tool with the implementation of the Poka Yoke tool.

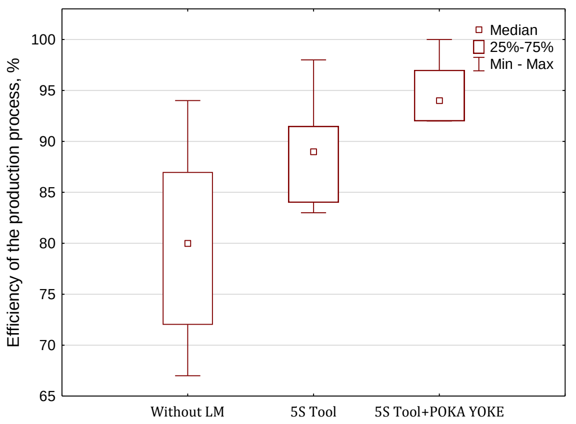

Figure 2. Efficiency of the production process - operation 10.

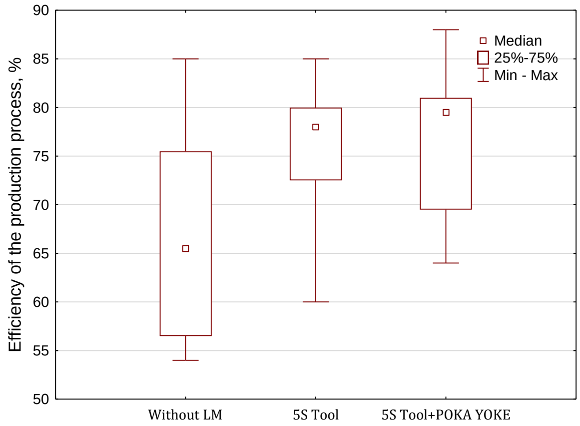

Figure 3. Efficiency of the production process - operation 50.

The results obtained in the analysis of the level of deficiencies generated on operations 10 and 50 indicated that in the case of comparing the parameters of deficiencies generated before the implementation of the Lean Manufacturing tools and the 5S tool with the implementation of the Poka Yoke technique, there is a statistically significant difference.

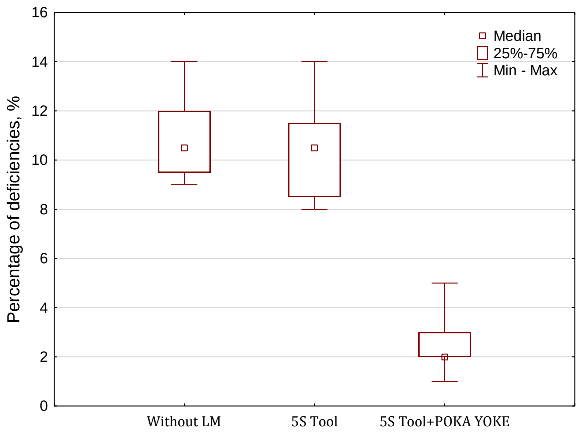

Figure 4. Percentage of deficiencies-operation 10.

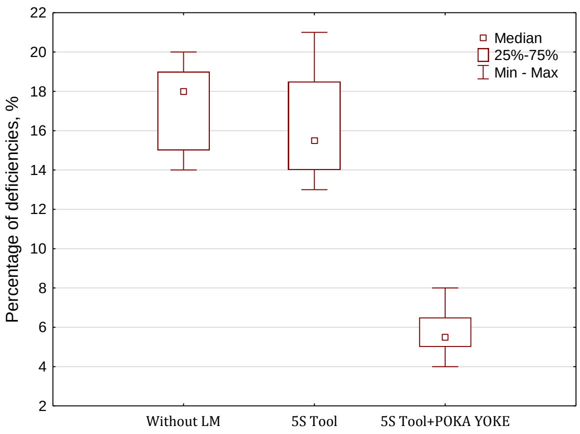

Figure 5. Percentage of deficiencies-operation 50.

In the case of the analysis of the parameters obtained as a result of the implementation of Poka-Yoke, a decrease in the level was noted, which is confirmed by the studies described in the articles (Sonil, Yadav, 2018) and (Fatah, 2022). The large decrease in the level of rejects on operations 10 and 50 is due to the introduction of safeguards to avoid error by the employee. A large number of parts used during the operation caused numerous errors of employees, which had a direct impact on the level of process efficiency, and in the absence of identifying a defect in the product, it generated deficiencies analyzed in this article and the need to perform the operation again.

6. Conclusion

The key element in the timely implementation of production is to create such conditions that the operations included in the production process are carried out with the least number of time disruptions and the highest quality of manufactured products. Due to the high level of competition in the manufacturing industry, the creation of working conditions that allow for smooth implementation of production processes is one of the conditions determining the proper functioning of the company. All production processes are exposed to the threat of delays and quality problems. However, the effects of delays and shortages are most burdensome in the case of variable production with a small degree of automation. One of the solutions to reduce or eliminate the negative impact on the production process is the implementation of a management system based on the Lean Manufacturing philosophy. As mentioned in the introduction of the article, the control of the generated parameters of the production process at the stage of implementing Lean Manufacturing tools and after their implementation is a key element that allows you to assess the effectiveness of the actions taken.

This article presents the results of changes in the level of generated parameters resulting from the implementation of the 5S and Poka Yoke tools. The obtained results allowed to present the scale of changes coming in the manufacturing process, confirming at the same time the positive effect of the implementation of Lean Manufacturing tools on the efficiency of the manufacturing process and the quality of manufactured products. As a result of the implementation of the 5S and Poka Yoke tools, an increase in efficiency was found in all production operations. In the case of the implementation of the 5S tool, an increase in efficiency was recorded on six production operations, the highest increase in efficiency was recorded on the 50th operation and reached 76%. As a result of the implementation of the Poka Yoke tool, the efficiency of operations 10 was increased to 95%. There was also a decrease in the level of deficiencies in operations from 10 to 2%, and in the case of operations from 50 to 6%. As a result of the statistical analysis, statistically significant differences were confirmed before and after the implementation of the Poka-Yoke tool.

The data on the basis of which the analysis was carried out come from one production plant (case study), which does not allow defining an unambiguous rule describing the impact of LM tools on production processes. The obtained results, however, allow to confirm the assumptions of the legitimacy of the implementation of selected LM tools for individual parameters of the manufacturing process. Conducting analyzes of the impact of selected LM tools on the manufacturing process seems to be a legitimate activity. A detailed analysis of the results obtained and comparison of the results from other production plants may allow to identify the reasons for better adaptation of LM tools and their impact on the production process.

Acknowledgements

Silesian University of Technology (Faculty of Materials Engineering), supported this work as a part of Statutory Research BK-218/RM1/2023 (11/010/BK_23/0045).

References

1. Abdulmalek, F.A., Rajgopal, J. (2007) Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. *Int. J. Production Economic, No. 107,* pp. 223-236.
2. Ahmed, T., Ali, S.M., Allama, M.M., Parvez, M.S (2010). A Total Productive Maintenance (TPM) Approach to Improve Production Efficiency and Development of Loss Structure in a Pharmaceutical Industry. *Global Journal of Management and Business Research*. *Vol. 10,* pp. 186-190.
3. Aziz, R.F., Hafez, S.M. (2013). Applying lean thinking in construction and performance improvement. *Eng. Journal*, *Vol. 52,* pp. 679- 695.
4. Baker, P. (2002). Why is lean so far off? If lean manufacturing has been around for decades, why haven't more manufacturers got further with it? *Works Management -London then Horton Kirby then Swanley*, *Vol. 55, No. 10,* pp. 26-29.
5. Buggy, J.M., Nelson, J. (2005). *Applying Lean Production in Healthcare Facilities, Vol. 6, No. 5.* www.informedesign.umn.edu, October 12.
6. Chowdary, B.V., George, D. (2012). Improvement of manufacturing operations at a pharmaceutical company. *Journal of Tech Management, No. 23*, pp. 6-75.
7. Fatah K.M.A. (2022). Eliminating customer complaints by using simple and Low-Cost Poka-Yoke technique. *Jurnal Teknik Industri*, *Vol. 17, No. 3*, pp. 168-173.
8. Fernandes, J.P., Godina, R., Matias, J.C. (2018). Evaluating the impact of 5S implementation on occupational safety in an automotive industrial unit. *Springer Proceedings in Mathematics and Statistics*, *Vol. 281,* pp. 139-148.
9. Ghodrati, A., Zulkifli, N. (2012). A review on 5S Implementation in Industrial and Business Organizations. *IOSR Journal of Business and Management*, *Vol. 5,* pp. 11-13.
10. Ghosh, M. (2013). Lean Manufacturing performance in Indian Manufacturing Plan. *Journal of Manufacturing Tech Management, No. 24,* pp. 113-122.
11. Jewalikar, A.D., Shelke, A. (2017), Lean Integrated Management Systems in MSME Reasons, Advantages and Barriers on Implementation. *Materials Today: Proceedings*, *No. 4*, pp. 1037-1044.

12. Mohammad, I.S., Oduoza, C.F. (2019), Interactions of Lean enablers in Manufacturing SMEs using Interpretive Structural Modelling Approach – a case study of KRI. *Procedia Manufacturing, Vol. 38,* pp. 900-907.
13. Mohan Sharma, K., Lata, S. (2018**).** Effectuation of Lean Tool "5S". *Materials and Work Space Efficiency in a Copper Wire Drawing Micro-Scale Industry, Vol. 5,* pp. 4678-4683.
14. Mohanty, R., Yadav, O., Jain, R. (2007). Implementation of lean manufacturing principles in auto industry. *Vilakshan-XIMB Journal of Management, Vol. 1, No. 1,* pp. 1-32.
15. Mostafa, S., Dumrak, J., Soltan, H. (2013). A framework for lean manufacturing implementation. *Production & Manufacturing Research, Vol. 1, No. 1,* pp. 44-64.
16. Nandakumar, N., Saleeshya, P.G., Harikumar, P. (2020). Bottleneck Identification And Process Improvement By Lean Six Sigma DMAIC Methodology. *Materials Today: Proceedings, No. 24,* pp. 1217-1224.
17. Palange, A., Dhatrak, P. (2021). Lean manufacturing a vital tool to enhance productivity in manufacturing. *Materials Today: Proceedings, Vol. 46,* pp. 729-736.
18. Pavnaskar, S.J., Gershenson, J.K., Jambekar, A.B. (2003). Classification scheme for lean manufacturing tools. *International Journal of Production Research, Vol. 41, No. 13,* pp. 3075-3090.
19. Pepper, M.P.J., Spedding, T.A. (2010). The Evolution of Lean Six Sigma. *Journal of Quality & Reliability Management*, pp. 138-155.
20. Pettersen, J (2009). Defining lean production: some conceptual and practical issues. *The TQM Journal, No. 22,* 238-142.
21. Rahman, N.A.A., Sharif, S.M., Esa, M.M. (2013). Lean Manufacturing Case Study with Kanban System Implementation. *Procedia Economics and Finance, Vol. 7,* pp. 174-180.
22. Rohani, J.M., Zahraee, S.M. (2015). Production line analysis via value stream mapping: a lean manufacturing process of color industry. *Procedia Manufacturing, No. 2,* pp. 6-10.
23. Samuel, R., Rajesh, M., Rajanna, S. (2021). Implementation of lean manufacturing with the notion of quality improvement in electronics repair industry. *Materials Today: Proceedings, Vol. 44, No. 10,* pp. 2253-2257.
24. Sharma, R., Singh, J. (2015). Impact of implementing Japanese 5S practices on total productive maintenance. *Intenational Journal of Current Engineering and Technology, Vol. 5(2),* pp. 818-825.
25. Sonil, P., Yadav, T. (2018). Productivity Improvement by using Poka-Yoke. *International Research Journal of Engineering and Technology, Vol. 5*, pp. 761-763.
26. Venkat, B., Jayanth, P., Prathap, P., Sivaraman, S., Yogesh, S. (2020). Implementation of lean manufacturing in electronics industry. *Materials Today: Proceedings, Vol. 33,* pp. 23-28.

27. Wahab, A.N.A., Mukhtar, M., Sulaiman, R. (2013). A Conceptual Model of Lean Manufacturing Dimension. *The 4th Int. Conference on Electrical Eng. and Informatics*. *Procedia, No. 11*, pp. 1292-1298.
28. Zargun, S., Al-Ashhab, A. (2014), Critical Success Factors for Lean Manufacturing: A Systematic Literature Review – An International Comparison between Developing and Developed Countries. *Advanced Materials Research*, *Vol. 845*, pp. 668-681.