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Analysis of the impact of the 5S tool and Standardization on the duration of the production process - case study

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Abstract
The high level of competition in the manufacturing industry requires the creation of working conditions that allow for the efficient implementation of production processes. One of the solutions enabling the adaptation of production stations to improve the work performed by employees is the implementation of a management system based on the Lean Manufacturing (LM) philosophy. The purpose of this article was to determine the potential impact of the implemented LM tools, in the form of 5S and standardization, on the efficiency of the production process in specific production conditions. The methodology of the conducted research included: obtaining data before and after the implementation of LM tools (in total 12 months). The data was used to determine the effectiveness of individual operations, and then to conduct a comparative analysis using statistical tests. It was found, among others, that the implementation of LM tools resulted in an increase in the efficiency of the manufacturing process by about 11 percentage points. The obtained results confirm the thesis that a manufacturing company, in order to maintain its position on a competitive market, can improve the efficiency of processes by using tools such as LM. The selection of tools must be adequate to the implemented processes, so that they bring measurable increase in efficiency.

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1. Introduction

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 (Pawlak, 2023).

Lean Manufacturing (LM) is one of the most commonly used methods supported by the organization of the production process (Ghobadian et al., 2020). Proper implementation of the lean management philosophy allows to increase the chances of competition on a highly competitive market (Abreu-Ledon et al., 2018; Galeazzo and Furlan, 2018). One of

the basic goals of the LM philosophy in a production plant is the elimination or reduction of waste (Nordin et al., 2010). There are seven basic groups of waste, which include, among others: overproduction, excessive stocks, errors and quality defects, waiting, excessive processing, unnecessary transport, unnecessary movement, unused potential of employees. The literature on the subject presents the results of the conducted research, indicating the improvement of the company's functioning after the implementation of selected Lean Manufacturing tools in the field of improving the environment (Caldera et al., 2017), social relations and financial results (Thanki et al., 2016). In addition, LM offers methods and tools that bring many benefits resulting from the elimination of errors and deficiencies while increasing productivity (Nguyen et al., 2022). The LM philosophy is universal, which means that it can be implemented in many industries, both manufacturing and service (Hopp, 2018), regardless of their size (Hu et al., 2015).

Due to the numerous benefits of implementing the Lean Manufacturing philosophy, it is implemented all over the world, both in Europe, the United States and Asia (Negrao et al., 2017; Henao et al., 2019). 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 et al., 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 et al., 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 the paper (Mostafa, 2013).

In this article, based on the analysis of data from a production plant dealing with the preparation of packaging for the transport of food products and their loading, an analysis was carried out to present the impact of the implementation of selected LM tools (5S and standardization) on the duration of individual operations and, consequently, the efficiency of the entire production process.

2. Literature review

One of the most frequently implemented Lean Manufacturing tools in manufacturing plants is 5S. The purpose of implementing the 5S tool is to create orderly and properly organized workplaces. As a result of a properly implemented 5S tool, it is possible to improve product quality, increase productivity and improve work safety, which in turn may increase the stability of the manufacturing process (Rewers and Trojanowska, 2008). The process of implementing the 5S tool includes five stages, which include (Bevilacqua et al., 2015; Omogbai and Salanitis, 2017):

- Sort - selecting at the workplace only the necessary tools and materials helpful in the implementation of production works.
- Set in order - marking and placing tools and materials in the right places.
- Shine - tidying up the workplace.
- Standardization - determination of standards for the arrangement of station equipment.
- Sustain – developing habits aimed at adhering to the principles of the 5S methodology.

The effects of implementing the 5S tool for the duration of the production process are described in the literature provided. In the work (Jiménez et al., 2012), an example is described showing the result of the implementation of the 5S tool and Kanban, which allows for the reduction of the total production lead time by 65%. A similar effect of the implementation of the described LM tool was presented in (Sidhu et al., 2013), where the assembly line production process time was reduced from 50 minutes to 41.5 minutes.

An equally frequently implemented tool in production plants that fits into the LM philosophy is the standardization of work. Standardization of work means the creation of conditions ensuring the possibility of carrying out production operations in the same way by different employees (Mor et al., 2019). In order to properly implement work standardization, it is necessary to follow a series of instructions and standardize workplace equipment (e.g. by implementing the 5S tool). The standardization of the production process allows employees performing production operations to be able to carry out activities within the production process without interruption to activities unrelated to the production process (resulting, for example, from a lack of understanding of activities performed during a selected operation). Properly implemented standardization of work makes it possible to perform all activities in the same way, in the same order and time at the same costs, which directly affects the efficiency of the production process.

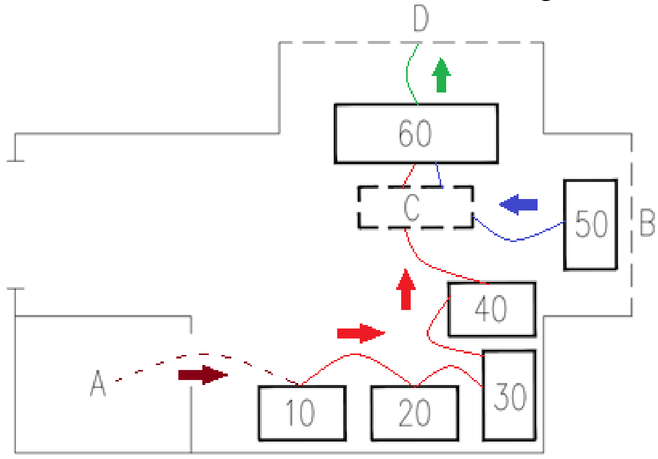
3. Methodology and case study

The purpose of this article was to determine the impact of the implemented LM tools (5S and Standardization) on the efficiency of the manufacturing process in a production plant in the food industry - a case study. The assortment of the production plant included the production of packaging used for the meat industry, used for large-size transport together with the transported goods. The subject of the analysis was the production process consisting of six operations performed on separate, individual production stations (Table 1).

Table 1. Parameters of the production process before the implementation of Lean Manufacturing tools

No. operation	Description of the operation
10	Retrieving components and assembling the base of the structure.
20	Preparing the components and making the frame of the structure.
30	Making screw connections of components.
40	Preliminary preparation for the operation of securing with cling film.
50	Preparation of the transported product for packaging.
60	Packing the finished product in accordance with the production order and securing the product.

The production process of containers for transporting meat products and their loading began with the collection of elements necessary for its implementation from the warehouse of input materials (area A). Then, operations 10 ÷ 40 are performed in turn, according to table 1. At the same time, the second process related to the preparation of a batch of meat, operation 50 (area B), is carried out. The finished packaging made in accordance with the production order, matching in terms of dimensions and dedicated transported goods from operation 50, went to the inter-operational buffer (area C). Then, in operation 60, the operation of proper packaging of the product in the manufactured container is carried out, Figure 1.



Where:

	Flow of the packaging production process,
	Flow of goods for loading,
	Flow of input elements,
	Flow of finisher product,
10 ÷ 60	Production operations.

Fig 1. Production flow spaghetti diagram`

Depending on the order, activities were carried out as part of the production process, including the production of packaging for transporting meat products. The production and packaging of products was carried out in a serial manner, the method of packaging and construction of the packaging for transport depended on the size of the order (different size of dimensions). One employee was responsible for one operation. Due to the high turnover of employees, the level of their skills and experience varied. The production process was characterized by a low degree of automation and high repeatability of the activities carried out. The production process was carried out in three shifts on working days and in two shifts on holidays.

In order to achieve the intended purpose of the work, the following research methodology was adopted: First, LM tools, i.e. Standardization and 5S, were implemented at 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.

The implementation of standardization consisted in creating instructions describing individual production operations and systematizing the sequence of activities carried out at the stage of preparation of the manufacturing process. Since the implementation of the 5S and standardization tools, regular control of the correctness of the implemented procedures has been carried out, confirming the proper implementation of the aforementioned tools.

The introduced changes in the field of 5S and standardization did not change the order of production operations and the arrangement of production stations. However, there were changes at the production stations that allowed limiting the activities carried out by the operator, Table 2.

Table 2. Improvements made on individual operations as part of the implementation of LM tools

No. operation	Improvements introduced as part of 5S and Standardization
10	Limiting the number of structural elements used during operations at the production station to only those used during the production order.
20	Preparation of construction instructions for a specific (implemented at the moment) production order.
30	The use of a shadow table and the limitation of tools at the production station.
40	Changing the structure of the station allowing for easier execution of operations and marking the place of transfer of the finished product.
50	Preparation of work instructions defining unified standards for product preparation for transport to the interoperational buffer.
60	Implementation of structural changes to the station facilitating the implementation of operations. Standardized work activities - workplace instructions.

The period of implementation of LM tools was 3 months. The measurement of the analyzed parameters, i.e. the duration of the production process, was carried out for a total of 12 months and covered the time before the introduction of Lean Manufacturing tools (6 months), and after the implementation of 5S and standardization (during the implementation of the tools, measurements were not carried out). Operation time measurements were carried out each day using the working day photography method. Personnel performing production operations was characterized by frequent rotation between production positions.

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. Then, the same action was performed after implementing the LM tools.

The productivity of the production process was determined on the basis of the analysis of real operation times 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 equation. 1 (Golińska, Goliński 2011).

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

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

Then, for the obtained data on the duration of the production process, a statistical analysis was carried out in order to determine the statistical significance of the observed differences in the duration of production operations before and after the implementation of LM tools. For statistical analysis, among many tests, such as: Wilcoxon Signed-Rank Test (for paired data), Kruskal-Wallis Test Post hoc Kruskal-Wallis or Tests Median Test, the Mann-Whitney U test was selected because the distribution of the analyzed data in an interval scale was different from normal. The non-parametric Mann-Whitney U test is used to verify the hypothesis that the differences between the medians of the examined variable in two populations are insignificant, assuming that the distributions of the variable are close to each other (Więckowska 2018). The basic conditions for using the test are:

- measurement on an ordinal or interval scale,
- independent model.

The hypotheses concern the mean ranks for the compared populations or are simplified to the medians:

$$H_0 : \theta 1 = \theta 2,\ H_1 : \theta 1 \neq \theta 2 \quad (2)$$

Where:
θ1, θ2 - medians of the examined variable in the first and second population. The value of the test statistic is determined, and on its basis the p-value is compared with the significance level α:

$$\text{if } p \leq \alpha \Longrightarrow \text{ we reject } H_0 \text{ accepting } H_1,$$
$$\text{if } p > \alpha \Longrightarrow \text{ there is no reason to reject } H_0.$$

Depending on the sample size, the test statistic takes the form: for a small sample size

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \quad (3)$$

or

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 \quad (4)$$

Where:
n_1, n_2- number of samples,
R_1, R_2 – sum of ranks for the sample.

for a large sample size

$$Z = \frac{U - \frac{n_1 n_2}{2}}{\sqrt{\frac{n_1 n_2 (n1+n_2+1)}{12} - \frac{n_1 n_2 \sum(t^3 - t)}{12(n_1+n_2)(n_1+n_2-1)}}} \quad (5)$$

Where:
t – the number of cases included in the tied rank.

The assumed confidence level α for each of the conducted analyzes was 0.05.

4. Research results and discussion

As a result of the analysis of the production process carried out over a period of 6 months, the actual duration of individual production operations was determined, Table 3.

Table 3. Parameters of the production process before the implementation of Lean Manufacturing tools

Operation number	**10**	**20**	**30**	**40**	**50**	**60**
Average time [s]	45	60	16	35	69	11
Median [s]	45	59	17	36	70	11
MAX time [s]	57	71	22	39	80	14
MIN time [s]	31	50	10	28	60	8

Operation number 50 is characterized by the longest duration, which was 69 seconds, and together with operation 20, they are characterized by the greatest level of complexity. The shortest time was recorded on operation 60 equal to 11 seconds. As part of operation 60, activities related to the final inspection of the product and its packaging are performed, which are characterized by the smallest number of activities necessary to perform it. The total duration of all production operations was 236 seconds.

The efficiency of the production process for the entire process was 66%. The lowest level of efficiency was recorded in operation number 40 and amounted to 55 %, while the highest in operation number 50 and equaled 72 %.

After the implementation of the 5S tool and standardization, production data was collected over the next 6 months, which was used to determine the times of the operations, which are presented in Table 4, Figures 2 and 3.

Table 4. Parameters of the production process after the implementation of the 5S tool and standaryzation (S).

Operation number	**10**	**20**	**30**	**40**	**50**	**60**
Average time [s]	37	46	12	27	56	9
Median [s]	37	46	13	27	56	9
MAX time [s]	44	56	16	29	65	10
MIN time [s]	28	39	8	24	52	7

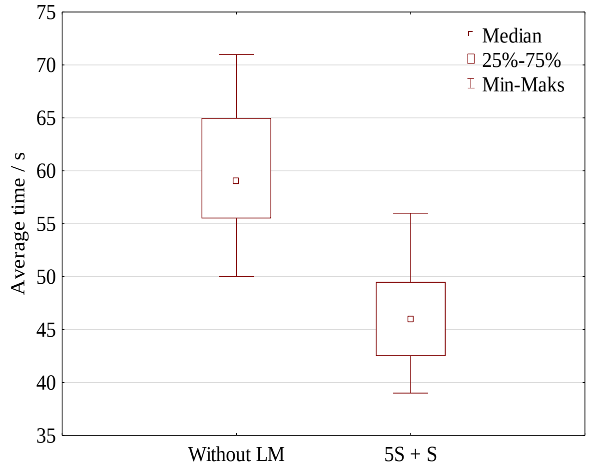


Fig 2. Duration of the production operation before and after the implementation of 5S and standaryzation (S) (operation 20)

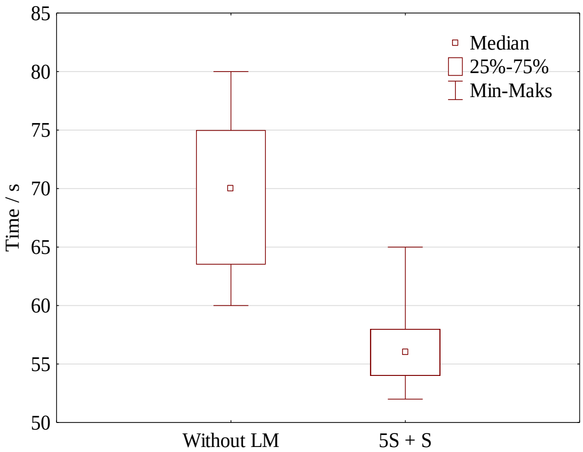


Fig 3. Duration of the production operation before and after the implementation of 5S and standaryzation (S) (operation 50)

The obtained results indicate a reduction in the duration of individual operations as a result of the implementation of the 5S tool and standardization, thus confirming the observations presented in the article (Venkat et al., 2020) and (Samuel et al., 2021) or (Mor et al., 2019). After implementing the LM tools, the greatest time reduction was observed for operations 20 and 50, which amounted to 14 seconds and 13 seconds, respectively. The greatest decrease in time in the implementation of operations 20 and 50 results from the fact of their complexity and the number of activities necessary to perform as part of the operation. As a result of the implementation of work standardization and the 5S tool, the workstation and the sequence of activities performed as part of the operation were systematized, which directly reduced the duration of the operation.

As a result of the implementation of Lean Manufacturing tools, there was a change in the efficiency of the manufacturing process analyzed, Figure 4. The largest difference in the efficiency of individual operations was identified on operation number 20 and amounted to 20 percentage points. The total efficiency of the production process was 83%.

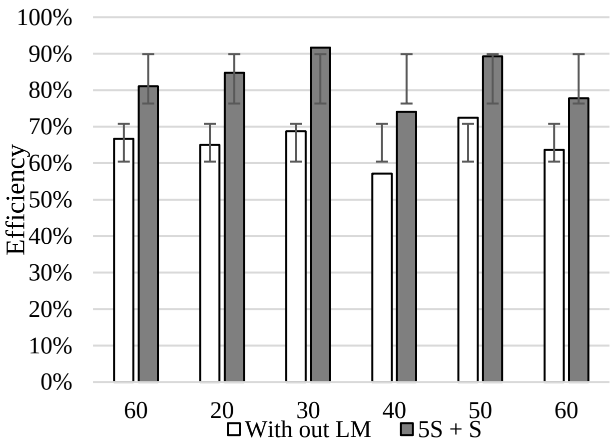


Fig 4. Efficiency of the production process on individual units operations before and after the implementation of 5S and standardization (S)

Then, in order to determine the statistical significance of differences in the time of individual operations before and after the implementation of the LM tools, the Mann Withney U test was performed, Table 5.

Table 5. Mann-Whitney U test results for all operations

Operation	p - value	without LM	5S + S
10	without LM		0.0001
	5S + S	0.0001	
20	without LM		0.0001
	5S + S	0.0001	
30	without LM		0.0001
	5S + S	0.0014	
40	without LM		0.0001
	5S + S	0.0001	
50	without LM		0.0001
	5S + S	0.0001	
60	without LM		0.0001
	5S + S	0.0001	

As a result of the test, it was found that there were significant differences in the duration of production operations for each operation analyzed in relation to the state before the implementation of the abovementioned tools (p>a).

Obtained results in the analyzed case indicate a significant reduction in the time of individual operations, thus confirming the effectiveness of the implemented LM methods, the effect of which directly affects the final parameters of the production process. Obtaining such a large difference in the duration of the production process may indicate the correct implementation of LM tools.

5. Summary and conclusion

This article presents the results regarding changes in the duration of individual production operations as a result of the implementation of LM tools. The obtained results allowed to present the scale of changes taking place 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 5S tools and standardization, time reductions were found in all production operations. As a result of the Mann Withney U test it was found that there were significant differences in the duration of production operations for each operation analyzed in relation to the state before the implementation of the abovementioned tools (p>a) (table 3). The sum of the execution time of individual production operations after the implementation of LM tools was reduced by approximately 23%, process efficiency increased by 11 percentage points.

In view of the above, it can be concluded that the changes resulting from the implementation of LM tools in the production plant significantly affected the duration of individual operations included in the production process, which was confirmed by ststistical methods.

Due to the great popularity of LM tools, such as 5S and Standardization, the results obtained by measurement methods on the actual production process may encourage decision makers in other production plants to implement solutions in accordance with the LM philosophy. However, it should be noted 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. The results are consistent with data from other manufacturing processes cited in scientific publications (Venkat et al., 2020) and (Samuel et al., 2021) or (Mor et al., 2019). 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.

In further research, in addition to comparing the parameters generated by the production process before and after the implementation of Lean Manufacturing tools, the factor of assessing the correctness of their implementation and functioning during data acquisition can also be taken into account. Such action will allow to assess not only the impact of the implementation of LM tools on the parameters of the development process, but also the quality and durability of this implementation as a function of time.

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5S 工具和标准化对生产过程持续时间的影响分析——案例研究

關鍵詞
精益制造
5S 工具
标准化
效率。

摘要
制造业的高水平竞争需要创造能够高效实施生产流程的工作条件。 能够调整生产站以改善员工工作的解决方案之一是实施基于精益制造 (LM) 理念的管理系统。 本文的目的是确定以 5S 和标准化形式实施的 LM 工具对特定生产条件下生产过程效率的潜在影响。 所进行的研究方法包括：获取 LM 工具实施前后的数据（总共 12 个月）。 这些数据用于确定单个操作的有效性，然后使用统计测试进行比较分析。 结果发现，LM 工具的实施使制造过程的效率提高了约 11 个百分点。 获得的结果证实了这样的论点：制造公司为了保持其在竞争市场中的地位，可以通过使用 LM 等工具来提高流程效率。 工具的选择必须适合所实施的流程，这样才能显着提高效率。