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THE IMPACT OF SELECTED LEAN MANUFACTURING TOOLS ON THE LEVEL OF DELAYS IN THE PRODUCTION PROCESS. A CASE STUDY

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Abstract:
Organizing manufacturing work in a way that minimizes delays in individual production operations is a key factor in a highly competitive market. One of the key factors to prevent delays is their correct identification and proper definition of methods to reduce their impact on selected parameters of the production process. The study presents the impact of Lean Manufacturing tools (5S, standardization and Total Productive Maintenance) on delays in the manufacturing process. A statistical analysis of the level of delays was performed, which was aimed at showing the essence of using Lean Manufacturing tools to improve the efficiency of the production process. In the example analyzed, the implementation of selected LM tools allowed for a reduction of delays related to failures by approximately 18 hours.

Key words: *Lean Manufacturing, 5S, standardization, Total Productive Maintenance*

INTRODUCTION

Production plants strive to implement solutions that improve the production process and reduce waste. The environment in which organizations operate is very dynamic and in many cases forces them to constantly adapt to new requirements in order to maintain sustainable development [1]. In a highly competitive market, an important factor is the implementation and systematization of the operating process, which enables increasing the efficiency of production work while ensuring the appropriate quality of products [2]. The means to achieve the goals is the appropriate selection of organizational tools, production management techniques or, in selected cases, a complete change related to, for example, the automation of the manufacturing process.

The increasingly widely used solutions in the field of Industry 4.0 allow for automation and remote supervision of processes, ensuring basic goals. necessary for entrepreneurs, which is to increase efficiency, eliminate errors and long-term reduction of production costs [3]. Due to the scale of changes taking place in the employment structure in the production plant and the role of humans in the light of the implementation of the assumptions of Industry 4.0, many works have been written describing the potential consequences that directly result from increasing the level of automation and reorienting the method of production management [4-8]. Industry 4.0 and its benefits clearly support activities in the area of the production process and, together with other well-known management techniques such as Lean Manufacturing, allow for comprehensive process management [9,10].

This article analyzes the production process to determine the impact of implementing Lean Manufacturing tools such as Standardization, 5S and TPM on the level of delays occurring in the process.

REVIEW OF THE LITERATURE

The Lean Manufacturing (LM) concept, which was initiated by Toyota, allows for quality improvement, cost reduction and increased reaction speed to numerous changes resulting from the dynamics of external and internal factors occurring in various types of processes [11]. The benefits of using tools consistent with the LM philosophy have resulted in them being implemented in many production plants around the world [12]. Lean Manufacturing allows for the reduction or elimination of waste [13,14]. Waste is understood as any activity that does not add positive value to the resulting product or the subject of an ongoing process [15].

The literature on the subject presents the results of conducted research, indicating an improvement in the functioning of the enterprise after the implementation of selected Lean Manufacturing tools in terms of improving the environment [16], social relations and financial results

[17]. Moreover, LM offers methods and tools that bring many benefits resulting from the elimination of errors and omissions while increasing productivity [18]. There are many LM tools, including: value stream mapping (VSM), kaizen, 5S, Jidoka, SMED, PokaYoke, Heijunka, Just-In-Time (JIT) and Kanban. The most frequently used ones include Standardization, 5S and Total Productive Maintenance.

Standardization of work means creating conditions that ensure that different employees can carry out production activities in the same way [19]. To properly implement work standardization, it is necessary to follow a number of instructions and standardize the workplace equipment (e.g. by implementing the 5S tool). Standardization of the production process allows employees performing production operations to perform activities within the production process without interrupting unnecessary activities (e.g. resulting from a lack of understanding of the activities performed during a selected operation). Standardization of the production process aims to precisely define the sequence and method of carrying out production works at each production station. Standardization activities therefore allow for the unification of the level of process efficiency and product quality regardless of the level of human resources involvement [20]. In order to implement production standardization, it is first necessary to carry out activities to determine the parameters of the processes carried out in selected operations in such a way that they constitute the foundation that guarantees the production of a finished product that meets the requirements set for it.

The Lean Manufacturing tool, 5S, aims 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 can increase the stability of the production process. The process of implementing the 5S tool consists of five stages, which include: sorting, cleaning, standardization, and self-discipline. The available literature describes the effects of implementing the 5S tool on the production process. The work [21] describes an example illustrating the effect of implementing the 5S tool and Kanban, which allows to shorten the total production lead time by 65%. A similar effect of implementing the described LM tool was presented in [22] and [23]. In the literature, the 5S tool is considered an essential element enabling the implementation of TPM (Total Productive Maintenance).

Total Productive Maintenance is defined in the literature on the subject as the concept of maintaining appropriate productivity of the production process by eliminating failures, aimed at achieving comprehensive system effectiveness as a result of the involvement of all people in the organization [24]. The important role of humans as a factor necessary for the proper functioning of the TPM tool was emphasized in [25]. The TPM tool includes a number of activities necessary to organize the environment in such a way that it meets its purpose. These activities are usually presented in the form of pillars, which include: autonomous maintenance, continuous improvement, maintenance planning, quality control planning, interdepartmental communication, staff development and training, safety and environment.

The topic discussed in this article is an important aspect enabling verification of the effectiveness of the implementation of selected Lean Manufacturing tools and their impact on the production process based on a case study. Verifying the effectiveness of selected LM tools on real examples can be a guide for other companies struggling with similar problems.

METHODOLOGY AND RESEARCH AREA

The aim of the article was to determine the impact of the implemented LM tools (5S, Standardization and TPM) on the level of delays occurring in the production process in a plant specializing in mass production of products used in the metal industry. The production process consists of seven operations carried out at individual, specialized production stations, technologically adapted to perform the given work - in accordance with the guidelines included in the technological documentation, Table 1.

Table 1
Description of production operations

Operation number	Operation description
10	Production of steel connectors with a bend
20	Production of steel hooks with a hole
30	Milling of the front surface
40	Making holes
50	Assembly of a subassembly from parts of the components
60	Assembly of the component with the handle
70	Ironing the protective film

The arrangement of workstations takes the form of a linear form of production organization and is consistent with the sequence of operations performed. The production process, due to the type of production and the repeatable size of the production batch, is carried out in a parallel and series-parallel system. The number of production employees is variable and determined by the number of orders in a given period of time.

The choice of the described production process for analysis is justified by the fact that production is carried out on a mass scale, the possibility of using the system to keep a register of occurring delays and information from production managers about problems related to the high level of delays. The data obtained as part of the analysis covered a six-month period of production work.

To achieve the intended goal of the work, the following research methodology was adopted: The First stage was to measure the level of delays occurring in the production process. As part of the measurement, an analysis was carried out in the area of five types of delays defined by technologists, which included: human errors (A), machine failures (B), excessive repair time (C), defective material (D) and excessive inter-operation transport time (E), Table 2.

Table 2
Characteristics of delays occurring in the production proces

Cause of delays	Characteristics of delays
A	Delays related to incorrect performance of the operation, use of the wrong material, use of the wrong tool, too slow performance of the operation, incorrect performance of the operation resulting in the need to repeat it (delays resulting from the regulations of activities within the operation).
B	Machine failures caused by random or human factors that prevent the operation from being performed.
C	Carrying out repairs or planned maintenance on production equipment inconsistently or too slowly.
D	Receiving material that does not meet the requirements
E	Waiting for material, i.e. semi-finished products and delays in internal transport between operations.

In the second stage, LM tools were implemented, i.e. standardization and 5S were implemented at all production stations, and solutions were created in accordance with the TPM philosophy for the entire production line. The 5S tool was implemented in accordance with the adopted standards, including a five-stage procedure, i.e. selection, systematics, cleaning, standardization and self-discipline. The changes introduced in the area of 5S, standardization and TPM did not change the sequence of production activities and the arrangement of production stations in the hall. The implementation period of LM tools was 8 weeks.

The third stage was to analyze data on delay times before and after the implementation of LM tools. The measurement of the analyzed parameters, i.e. the duration of delays in the production process, lasted a total of 25 weeks and included the time before the introduction of Lean Manufacturing tools (11 weeks) and 14 weeks after the implementation of 5S, standardization and TPM (no measurements were carried out during the implementation of the tools). Measurements of delay times were reported by people managing the production process.

The last stage of the research was to conduct a statistical analysis aimed at determining the statistical significance of the observed differences in machine and equipment failure times before and after the implementation of the TPM tool. In order to determine the statistical significance of differences between failure times before and after the implementation of the TPM tool, the Mann Withney U test was performed. The assumed confidence level α for each of the analyzes performed was 0.05.

RESULTS AND DISCUSSION

As a result of carrying out an analysis of the production process before the implementation of LM tools over eleven weeks, the average time of delays was determined on a weekly basis in the production process, taking into account the reasons for their occurrence, Table 3.

Table 3
Average weekly delays before LM implementation

Type of delay	A	B	C	D	E
MAX [h]	45	18	6.5	3	26.5
MIN [h]	29	7	1.5	0.5	7.5
Average [h]	38.5	12.2	3.3	1.5	16.5

The total delay time identified in the production process was over 71.5 hours. The greatest delay time was due to human errors (A), which resulted in an average of 38.5 hours of delays per week. This fact confirms the problems reported by the company's management, related to the lack of standardization of the production process at individual production operations. Human errors account for over 53% of all delays identified in the production process. Then, in accordance with the methodology, solutions included in the LM philosophy were implemented, including standardization, 5S and TPM. Table 4 describes the activities carried out in the mentioned areas.

Table 4
Improvements in the production process as part of the implementation of LM tools

Improvements introduced as part of 5S and Standardization	Improvements introduced as part of TPM
- Implementation of workplace instructions. - Creating instructions for carrying out the operation. - Limitation of tools and devices on work sites. - Introducing the shadow board. - Changing the structure of the station enabling easier execution of the operation and marking the place of transfer of the finished product. - Development of work instructions specifying uniform standards for product preparation from transport to the inter-operation buffer. - Introduction of a number of training sessions for production employees in the field of production processes.	- Implementation of an electronic monitoring system and device failures in real time. - Introduction of a spare parts catalog (after prior assessment of the quality of the spare element). - Preparation of unified maintenance instructions for equipment included in the production line, along with a checklist. - Introduction of a number of training courses standardizing activities related to the maintenance and repair of devices. - Introduction of a detailed repair reporting method and their periodic analysis, allowing for more accurate identification of potential failure areas and methods of their removal.

The introduced improvements were implemented in accordance with the implementation philosophy of the described LM tools. The company's employees took an active part in the work related to the implementation of activities included in Lean techniques. After the tools were implemented, regular audits were conducted to confirm the effectiveness of the implementation of the mentioned LM tools.

Then, in accordance with the procedure, regular measurements of delay data were carried out, allowing for the assessment of the effects of implementing LM tools. The period of data acquisition was 14 weeks. Table 5 presents the data obtained regarding the average weekly delay time, while Figure 1 shows the differences between the average delay time before and after the implementation of LM tools over 25 weeks.

Table 5
Average weekly delays after LM implementation

Type of delay	A	B	C	D	E
MAX [h]	29.5	9.5	1.5	1.5	16.0
MIN [h]	16.5	4.5	0.0	0.0	7.5
Average [h]	26.2	6.2	0.5	0.8	10.5

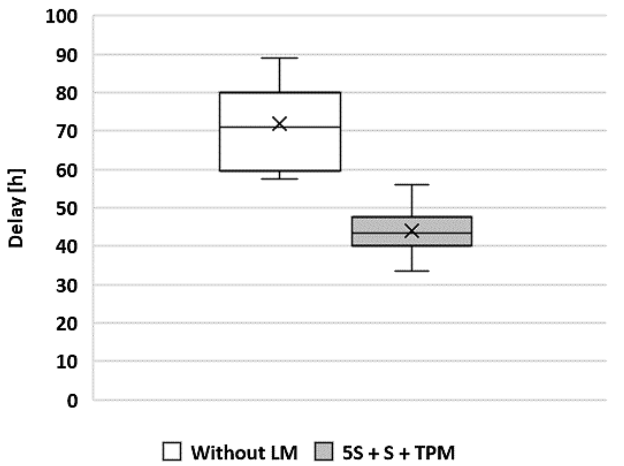

Fig. 1 Duration of the production operation before and after the implementation of 5S, standardization (S) and TPM

The total delay time identified in the production process was 44 hours. The cause of the biggest delays, as before the implementation of LM, was human errors (A). However, the average delay time has been reduced to just over 26 hours. Such a significant decrease in the level of delays could be caused by the implementation of the 5S tool and standardization. A similar effect was presented in the works [22, 23, 26] where a significant decrease in the duration of the production process and an increase in the level of efficiency due to the implementation of the mentioned LM tools were noted. The analysis also paid attention to the reduction of delays related to machine failures (B) and excessive repair times (C). The decrease in the level of delays may be caused by the implementation of TPM activities described in Table 4. The obtained results seem to confirm the conclusions contained in the works [25, 27], where a significant increase in efficiency was observed due to a reduction in the level of failures as a result of the implementation of solutions included in the TPM tool. For example, in [28] a reduction in failure time and an increase in product quality was observed, which allowed for an increase in production efficiency by 16 percentage points.

Then, after obtaining all the information, the Mann Withney U test was performed to determine the statistical significance of differences in delays before and after the implementation of LM tools. As a result of the research, it was found that there are significant differences in the duration of production operations for each analyzed operation in relation to the state before implementing the above-mentioned LM tools (p > a). The results obtained in the analyzed case indicate a reduction in delay times, the effect of which directly affects the final parameters of the production process. Obtaining such a large difference in the generated delays proves the correct selection of tools implemented in the process and their correct implementation.

CONCLUSIONS

The article presents an analysis of the level of delays in the production process before and after the implementation of 5S, Standardization and TPM tools. The results made it possible to present the scale of changes, i.e. reductions in delay times, while confirming the positive impact of the implementation of LM techniques on the production environment.

Moreover, as a result of the Mann Withney U test, it was found that there are significant differences in delay times compared to the state before the implementation of LM tools (p > a). The results obtained showed an average reduction in latency levels of approximately 26 hours. Due to the great popularity of the LM tool and the results obtained using measurement methods in the actual production process, they may encourage decision-makers in other production plants to implement solutions consistent with the Lean philosophy. It should be noted, however, that the data on the basis of which the analysis was carried out comes from one production plant (case study), which does not allow defining a clear rule describing the impact of LM tools on production processes. However, the results obtained allow us to confirm the assumptions about the validity of implementing the TPM tool for individual parameters related to maintenance.

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