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The impact of Lean Manufacturing and Industry 4.0 on the Efficient Operation of an Enterprise

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Abstract: ***The advantages and opportunities that the digital world opens up do not free enterprises from problems that require scientific and practical justification and the search for management solutions. Such challenges at the strategic level include changes in the industrial business model, the transition to new ways of working against the background of the accelerated development of Industry 4.0, digital technologies, and the subsequent implementation of the enterprise. The study proposes a concept that includes the main sections of the application of lean manufacturing using digital technologies at the Perm Chemical Equipment Plant, which produces civilian products. The introduction of a new concept and methods of organizing a production system requires a restructuring of the way of thinking and approach to business, first of all, of managers, and then of all workshop workers. The article describes the implementation of the 5S system using digital technologies at workplaces in workshops with the participation of site foremen. Thanks to the great results obtained from the integration of digital technologies in lean manufacturing, such as 5S, the results obtained by measurement methods in the real production process make it possible to stimulate shop managers to make decisions at the shop level in the implementation of management decisions.***

Keywords**: Industry 4.0; Lean Production; Lean project; 5S tool**

I. INTRODUCTION

The ubiquity and evolutionary pace of the development of digital technologies have led to relentless changes in customer preferences and market structures, and these changes, in turn, raise new requirements for organizations. Today, an increasing number of organizations are improving the customer experience through the use of digital technologies, and they are expanding their processes for creating a value proposition through analysis obtained from data on current product use. Since the mid-1950s, Toyota has been well-known for its efficiency, quality, and employee involvement. Today, lean has become the standard for efficiency and excellence in the manufacturing industry [1].

The fourth industrial revolution, often referred to as Industry 4.0 [2], is characterized by the integration of digital technologies into various aspects of manufacturing and industry. Industry 4.0 refers to the fourth industrial revolution, characterized by the integration of smart technologies, automation, and data exchange in various industries [3]. However, today's business ever-changing environment has been experiencing unprecedented transformation and many firms are constantly in search of new avenues to stand out by maintaining their competitive advantage, these firms are constantly compelled to find new channels to create, interact, and deliver values to the customers and stakeholders [4, 5].

Therefore, in this journey of introducing Industry 4.0 technologies, it is needed to preserve the practices already implemented in the company, such as the Lean Philosophy [6]. Customers are pushing businesses above and beyond to meet their changing demands. In 2019, Savić said, “The pace of change will never be this slow again,” and emphasized how businesses must find ways to adapt, react, and remain resilient to the coming disruptive changes [7]. Organizations are forced to be agile and stay one step ahead to keep their competitive position and outperform new market entrants. At the same time, technology is raising the bar, increasing customer expectations even further. For organizations to remain competitive, the literature suggests that it is necessary to incorporate digital technologies and sustainability into the business model to meet the customers' needs and wants. Argues that digital transformation projects can increase organizational resilience, improving their ability to recover and grow under uncertain conditions and in a dynamic environment by implementing digital technologies and sustainable objectives into the organizational culture, strategy, and business model (Hajishirzi et al., 2022) [8].

Digital transformation is talked about by company executives, politicians, and scientists. Some call it the fourth industrial revolution, while others offer a combined approach when considering a digital transformation strategy [9].

II. STUDY DESIGN AND METHODOLOGY

The new concept was called «Toyota Production System» (TPS). In 1988 John Krafcik coined the term «Lean Production». The term LEAN («Lean Manufacturing») appeared in American management.

[10, 11]. The basic goal of the LM philosophy in a production plant is the elimination or reduction of waste [12, 13]. Taking this into account, we will present the main conceptual provisions of the full-scale LEAN concept deployment at the Plant. A detailed description of the LEAN concept and several main stages in the lean manufacturing implementation tools are discussed by the author in the article [14]. 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.

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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 [15][47][48][49].

The process of implementing the 5S tool includes five stages, which include Sort - selecting at the workplace only the necessary tools and materials helpful in the implementation of production works [16, 17].

- 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 [18], 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 [19], 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 [20]. 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). Taking into account the presented literary review, and against the background of increased pressure from clients and governments on more sustainable digital solutions, the issue of implementing a conceptual approach to managing the development of the enterprise's integration of LP and digital technologies is becoming more and more urgent [12, 21, 22, 23, 24].

But it should be admitted that in this case, the transition of enterprises to digital transformation does not pay enough attention to such issues that are directly related to effective methods of enterprise management, including enterprise management in the context of digital transformation.

Following this thesis, companies need to change the nature of their existing work, and change their strategy and plans for new requirements dictated by new challenges and trends in the digital economy.

III. DATA ANALYSIS AND RESULTS

The advent of advanced digital technologies, typified by Industry 4.0, opens up new and innovative opportunities for manufacturing companies to enhance their production systems through connectivity and intelligence [25, 26, 27, 28]. Therefore, to leverage the potential of digital technologies into existing Lean-based production systems (LPSs) [29, 30, 31, 32], manufacturing companies need to redefine and reconfigure organizational strategy, structures, infrastructure, resources, and culture [33, 34, 35].

More specifically, two research questions are posed:

RQ1. What problems and organizational features arise when integrating digital technologies into a lean manufacturing system?

RQ2. How do managers develop appropriate lean manufacturing projects and cope with the integration of digital technologies in the enterprise?

For instance, separating LPS and SP teams manages the performance but this triggers an internal drift rendering a belonging paradox. Lean manufacturing is a concept that aims to eliminate waste, to increase productivity and quality, producing "greater quantity in less time, with fewer resources and reduced inventories and capital" [36, 37, 38]. Resolutions are as such context-sensitive and system-dependent [39]. Our study confirms the complementary effects of LP and digital technologies. In addition to the new opportunities, that are provided by dynamic technological progress, the way we live, work, and relate to each other is also changing [40, 41, 42]. The challenges enterprise specialists face in project design and implementation are more complex and time-dynamic than ever before. This section is divided according to the two stages defined above in section. On the one hand, in the first section, the pilot project and the tasks set will be described, and the implementation of the 5C tool will answer the first question mentioned above (RQ1). On the other hand, the second section will describe the project, and the main results of the implementation of 5C, obtained as a result of the integration of digital technologies, which allows answering the second question presented above (RQ2).

A. Implementation of the 5C Tool as Pilot

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. 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) [15, 20].

First, an analysis of data on the parameters characterizing individual operations and their performance was carried out before the implementation of techniques by the LM concept.

Then, the same action was performed after implementing the LM tools. As a result of the implementation of work standardization and the 5S tool visualization system, the integration of digital technologies the workstation, and the sequence of activities performed as part of the operation were systematized, which directly reduced the duration of the operation.

B. Implementation of the Lean Manufacturing Method using the 5S, Visualization System the Integration of Digital Technologies

The procedure at workplaces shall comply with the standard of the 5S system.

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The standard for compliance with the shop 5S system. In the first step (Sort), it was necessary to determine what employees need in the production process, and what needs to be disposed of or used in other departments of the plant. Sorting, according to workshop workers, turned out to be a rather laborious and difficult process. This process was because, according to the instructions for implementing the 5S system, during this first step, employees must identify unused materials, materials, equipment, equipment and other items that have accumulated in the workshop over the many years of the plant. It turned out that some of these items are significantly outdated and are not used in the workflow Figure 1.

These items were not dismantled or marked, and none of the workshop workers knew exactly what it was necessary for and what of it would be used in the process of work. According to reports, of the first step, a total of 24 unused items were not involved in the production process. This completely expensive "dead cargo" pulled back valuable production resources - useful areas that can be used to store really necessary tools and equipment for the placement and installation of truly demanded equipment. In addition, all this "superfluous" and "unnecessary" is a distraction that dissipates the attention of workers. The factor stealing one of the most expensive resources is time. Currently, at workplaces, all the necessary tool is arranged in an orderly manner in drawers and on special racks, which makes the process of finding it as convenient and fast as possible Fig. 1"

Fig.1. After Implementation of the "Sorting" Step in a Workshop in the Mechanical Area

The assortment of the production plant included the production of packaging used for the chemical 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- I: Description of the Operation

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.
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 products and their loading began with the collection of elements necessary for its implementation from the warehouse of input materials. 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 operation 50, is carried out. The finished packaging made by the production order, matching in terms of dimensions and dedicated transported goods from operation 50, went to the inter-operational buffer. Then, in operation 60, the operation of proper packaging of the product in the manufactured container is carried out.

The implementation of standardization consisted of 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 Table 2.

Table- II: Improvements Introduced as Part of 5S and Standardization

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 interoperation buffer.
60	Implementation of structural changes to the station facilitating the implementation of operations. Standardized work activities - workplace instructions.

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. Another important principle of the 5S system is the use of visualization and associated notation. It also allows you to save time, quickly receive the necessary information, and act strictly according to the instructions. For example, workshops in recent years have been staffed with a large number of new equipment. Now each piece of such equipment contains information about the persons responsible and working on it. In addition, the cost of the equipment is indicated. It would seem, why? What does this have to do with lean manufacturing? But it turns out to have. We have already said that lean production is designed to protect resources. And the machine, is all the more expensive, isn't it a resource? In this case, we are talking about increasing the employee's responsibility, about preventing them from frivolity or negligence of equipment failure. This measure is also aimed in the most direct way at involving personnel in the overall process of reducing costs and losses, increasing production efficiency.

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The introduction of new methods for organizing the production system requires a restructuring of the way of thinking and approach to business, first all, managers, and then through the involvement of all shop workers. Sorting activities were carried out not only in the common places of storage of the unit equipment but also at each workplace. So, after the sorting was implemented, a rack was installed on mechanical section No. 1, and systematization was carried out with the designation of large-sized equipment in the workshop. The implementation of the 5S system at workplaces is carried out on an ongoing basis by site foremen. Every day, before the start of the work shift, when issuing a shift-day task, they carry out operational control with the site operators, set tasks, and check the schedule of measures. The new approach in production assumes that the operator knows exactly the goals and tasks of his site, and the master can monitor the fulfillment of the tasks, determine deviations and take corrective actions in real-time.

As a result of the implementation of the Lean project, it became possible to receive real-time data on the availability and location of any unit of tools and technological equipment. Generate a forecast of the tool demand with an accuracy of 5%. Maintain tool safety stock at work centers, warehouses, and tool storerooms - 10% of tool demand. Reduce losses for preparation and final time for tool search within a month due to timely and complete provision with both tooling and tools [43].

IV. DISCUSSION

To conclude, it is important to point out that this work presents two distinct contributions: to the scientific community (theoretical) and the industrial world in practice (practical). The famous LEAN principles include the 5S system, Kanban, Kaizen, TPN, JIT, SMED, VSM, Poka-yoke, U-shaped cells, and visualization [10, 11].

Previous studies have demonstrated the advantages of incorporating digital technologies into existing LP-management models, and further studies have perspective when investigating the implementation of I4.0 [12, 15, 16, 17]. The solution to this is to ensure the existence of regular communication meetings at all levels of the organization, for those who lead the transformation, as well as for those who deal with the program on a day-to-day basis. This method of regular communication and team engagement also reflects a different way of working for many organizations. Nevertheless, cooperation is one of the desired outcomes of any digital transformation framework [41]. The stated conceptual and methodological provisions have not yet been reflected in the management literature and have been explicitly systematized, contain elements of scientific novelty and include a certain scientific increment as an expanded management toolkit. The developed author's concept based on integration cooperation allows us to systematize the theoretical and methodological principles of enterprise management, as well as improve organizational changes aimed at developing management decisions.

The results are consistent with data from other manufacturing processes cited in scientific publications [14, 15, 19], or [20]. A detailed analysis of the results obtained and a comparison of the results from other production plants may allow us to identify the reasons for better adaptation of LM tools and their impact on the production process. 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 by the LM philosophy.

V. CONCLUSION

In conclusion, it is important to note that our research has allowed us to identify existing gaps in science and answer the questions posed, which is scientifically sound since it includes two key aspects. The first aspect is related to the expansion of theory and a new. Integrated approach in this field for the scientific community. The second aspect of the study contributes to existing practice, as it suggests using new management approaches and ways to achieve goals when implementing industry 4.0 lean management in an enterprise to solve problems. Summing up the results of the study, we can talk about the implementation of the conducted scientific experiment, which allowed, with the help of argumentation and practical solutions, to consider the approach to managing the production system in the context of an integrated approach [43]. When enterprises approach Industry 4.0 in lean manufacturing, they often review the organization of work within the enterprise. We are talking about the structure of the enterprise, its relations with employees, its relations with the customer/client and even demonstrating to the market new digital models, and digital transformation projects that force others to react [44]. The focus is on gaining an advantage in the competitive landscape. But enterprises that look at digital technologies, from the standpoint of making only profit, do not take into account such important aspects that are inextricably linked with the interaction of all elements of the production and economic system, with the strategic core of the enterprise, may soon lose competitive superiority in the market. The goal is not gradual improvement, but a step-by-step change to total rethinking using a conceptual approach. Due to the large results obtained from the integration of digital technologies into lean manufacturing, such as 5S and Standardization, the results obtained by measurement methods in a real production process, allow us to encourage shop managers who make operational decisions at the shop level and other industries to implement management decisions by the work we present [43]. Taking into account the above advantages, the concept under consideration "Digital Technology Industry 4.0 in lean manufacturing" is actively developing at Perm Chemical Equipment Plant and has successfully proven itself in project management in this work [45, 46].

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