

APPLYING LEAN MANUFACTURING PRINCIPLES TO ENTERPRISES: TOWARDS SYSTEMIC DIGITALIZATION DEVELOPMENT IN THE CONTEXT OF INDUSTRY 4.0.

Tashkinov Aleksei

Associate Professor, Department of Economics and Management of Industrial Production, Perm National Research Polytechnic University, Russia.

Abstract: The successful evolution of a production system through the integration of lean manufacturing and digital technology initiatives, along with their subsequent rollout within an enterprise, demands that managers develop new competencies in project management, particularly those involving information technologies. This paper presents a conceptual framework for applying contemporary project management techniques grounded in the principles of lean and digital production. This framework includes key aspects of digital technology implementation, illustrated through a case study of a civilian product manufacturer in the chemical industry. Adopting this new approach to organizing the production system necessitates a fundamental shift in the project management mindset and overall enterprise management philosophy first and foremost among leadership, followed by all shop-floor personnel. The study details a specific lean manufacturing project: the implementation of a 5S system enhanced by digital technologies in shop-floor environments, carried out with the active participation of site foremen. The significant results achieved through this integration of digital tools into the 5S methodology, as measured within the actual production process, empower shop-floor managers to make more informed decisions at their level when executing management directives.

Keywords: Industry 4.0, lean manufacturing, digital production, efficiency, lean project, 5S system, production system.

1. Introduction

The development of scientific theories in the socio-economic sphere and the dynamism of economic relations in the era of the digital economy have led to the need for high-quality research into the theory and practice of project management in the context of digitalization. In today's competitive business landscape, project quality is of utmost importance as organizations strive to meet the ever-evolving needs of their clients [1]. Quality is achieved thanks to people, their attitudes, and their commitment [2]. The tools and technical skills are necessary. However, studies show that soft skills are more important for the project's success [3]. The starting

point for digitalization development work is to understand the overall current digitalization status of the organization and thus, create an overall picture of its strengths and weaknesses and possible improvement actions for the future [4]. Thus, digitalization can mean enhancing existing processes, finding new opportunities within existing business domains, or finding new opportunities outside existing business domains [5]. The term project management approach is the “highest level of abstraction used when describing how a project will be designed” [6], whereas a project management methodology is more granular and provides specific guidance about how to manage a project [7], [8], [9].

The ubiquity and evolutionary pace of the development of digital technologies has 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. Following the relentless movement of the next great technological era, businesses must navigate economic and geopolitical uncertainty. The natural tendency of many organizations is to step back. The tipping point is whether businesses should place digital in their core business logic, rather than simply as a proponent of business processes, may have passed. The process of digital transformation covers absolutely all enterprises, regardless of their industry affiliation, since digitalization is both a vital need and a factor of competitiveness. Lean management is successfully used to improve the efficiency of production system processes. With the development and implementation of Industry 4.0, there is an increase in digitalization activities aimed at improving business results and productivity. The main organizations are focused on implementing Industry 4.0 initiatives in processes to improve efficiency and productivity. At the same time, there are currently some pockets of Industry 4.0 application in enterprises, without coordination. It is unclear whether this implementation is consistent with existing continuous improvement methods such as lean management, which are known to have advantages in achieving business goals. Therefore, this study is important for further exploring the synergies and practical implementation of both Industry 4.0 and lean management in order to increase enterprise efficiency, as well as to avoid multidirectional actions in the implementation of lean management and Industry 4.0 initiatives for this process. The main purpose of this study is to study the current efficiency of the enterprise and offer solutions that increase productivity using an integrative approach covering industry 4.0 and lean management. These recommendations are based on the integration models of lean management and industry 4.0, as well as on the practical application of theoretical constructs in both management approaches. In this way, research seeks to contribute by proving a plan that an organization can follow to investigate the effectiveness of the production system, identify areas of improvement, propose solutions, provide an implementation plan, and provide a tracking mechanism.

The manuscript includes key sections. The main section is an introduction reflecting the relevance of scientific research and the formulation of the problem. The next part of the manuscript is devoted to the disclosure of theoretical and methodological principles of research and the identification of scientific gaps in the field under study. The terminological base is disclosed, the concepts of lean manufacturing are considered, a critical review of the literature from the point of view of lean manufacturing, Industry 4.0 and the introduction of digital technologies into lean manufacturing is presented. The third part of the manuscript describes the main approaches that we have presented in the process of studying specific examples. The practical section is devoted to the results obtained as a result of the introduction of a cycle of improvement of a production system based on the principles of lean digital production. The cases in the field of digital production application are analyzed with an emphasis on the integration of industry 4.0. This part of the manuscript provides a practical example of the application of the proposed model, taking into account the specifics of the enterprise. The cycle of implementation of the methodological approach proposed in the study is described and recommendations are given. In the conclusion of the part of the manuscript, the results of the study are summarized and the main conclusions are drawn.

2. Literature Review

2. 1. The concept of Lean management

The concept of Lean management (LM) was a response to the emergence of strong competition with severe resource restrictions [10]. LM is a generic term that was coined by Massachusetts Institute of Technology's (MIT) research program titled the „International Motor Vehicle Programme“ (IMVP) which was launched in 1979 and delivered groundbreaking results 11 years later when James P. Womack et al. published their findings in “The Machine that Changed the World” [11]. The founder of the concept of LEAN is Taiichi Ono, who created the production system of Toyota Corporation since the 1950s.[12]. Their research focused on the performance gap between Japanese automotive industries and Western ones. The basis of their data was an analysis of 52 assembly plants in 14 countries. The five-year, five-million-dollar program found that Japanese plants were significantly more productive, because of their production and management style, which the authors called “Lean”. Most notably, still today, the car manufacturer Toyota was at the center of attention, as they have, arguably, contributed the most to what we know today as Lean. Initially, Lean only referred to the manufacturing part, but later the term Lean also included the management style. Today, there is a multitude of Lean derivatives, such as lean enterprise, Lean Leadership, Lean Logistics, Lean Production, Lean Organization, Lean Thinking, Lean Service, Lean Planning [13].

Thus, the works Dennis P. Hobbs, J. Womack, Liker J.K. Morgan J, Taiichi Ono, Rother M., Tanaka T, consider various aspects of the introduction of the concept of LEAN in enterprises [10], [11],[12]. Womack, Jones, and Roos coined the term “lean

production” in their 1990 book “The Machine that Changed the World”[11]. to describe the manufacturing paradigm established by the Toyota Production System.

There is also criticism around “The Machine that Changed the World”. Womack et al. claimed that the cultural and societal context was not the decisive factor for the superior performance of Japanese manufacturers: Thus we devote our attention in the pages ahead to a careful explanation of the logic and techniques of Lean production [13]. This is thought-provoking, as the researchers already knew about Taiichi Ohno’s book, who is said to be the co-inventor of the Toyota Production System (which stands for LEAN more than any other system), where he stresses that everything depends on the will and wanting of the employees [13, pp. 91-92). On the other hand, it is understandable that it is a lot easier to research on and describe the hard facts, than it is to grasp the complex human aspect. Mike Rother boiled it down to the essence. This is because an organization’s collection of practices and principles at any point in time is an outcome that springs from its members’ routines of thinking and behavior. Any organization’s competitiveness, ability to adapt, and culture arise from the routines and habits by which the people in the organization conduct themselves every day. It is an issue of human behavior [14, p. 16].

LEAN is therefore called lean, which allows you to do more and more, and spend less and less - less human effort, less equipment, less time and less production space - while at the same time approaching to provide the consumer with exactly what he wants [15, p. 33].

It is believed that LEAN ideas came to Russia in 2004, together with foreign companies that opened their factories and branches in the country, or organized joint production with Russian enterprises on the basis of industrial cooperation. And each company brought to our practice those approaches to the implementation of LEAN, which are accepted in her country (Toyota, Nissan, Ford, etc.). Studying the experience of foreign colleagues, Russian enterprises began to create their production systems on the basis of common approaches to LEAN, introducing positive aspects from the systems of rationalization and invention, scientific organization of labor, etc.

According to J. Womack, "Lean production is a breakthrough approach to management and quality management, ensuring long-term competitiveness without a substantial investment based on the principle of universal reduction of possible losses, involving each employee in the process of business optimization " [13, p. 32].

According to D. Hobbs, "Lean production is a technique aimed at constantly reducing operating costs. Its task is to develop and implement a production line capable of producing different types of products in exactly the time that is really necessary for this [16, p. 33].

Each view reflects an important aspect of the concept under analysis and has every right to exist. In this case, in our opinion, this definition requires further reflection and addition. Taking into account the existing views of scientists, the author proposes

to clarify as a supplement what is meant by the concept of LEAN. The concept of LEAN refers to a strategy based on the principles of a systematic approach to determining simple solutions for identifying and eliminating hidden losses (production of goods/services), which allows by optimizing processes to improve the decisive performance of the enterprise: cost, quality, service and time, giving the consumer new competitive advantages, creating added value for customers and meeting their needs. The idea is to constantly strive to eliminate any type of loss, with the involvement of each employee in the procedure [17].

In general, the concept of LEAN can be considered as a special mechanism for modernizing technological processes at the enterprise, which makes it possible to reduce costs at the enterprise due to the introduction of these principles without attracting additional resources related to the purchase of advanced technologies, modern equipment, etc. [18], [19], [20].

The strengths of this LEAN concept are due to three factors:

1. This is a proven structure that provides forms and techniques that allow you to quickly get results (the method assumes the presence of losses and "attacks" losses without studying them, which is almost always extremely effective).
2. The approach works well at the level of ordinary employees, where there are a small number of small and minor losses (invisible to most managers).
3. Quickly gives actual results.

We propose to consider the features of the development Toyota Production System. Toyota, like many others, have recognized the limitations of too much emphasis on tools. They now use a Lean Enterprise house that differs from the 'tools' house.

The enterprise house is a wider view and emphasizes philosophy and approach. The 'whats', not the 'hows'. The Toyota Production System may be a house of tools, but the Toyota Enterprise system is far more broad [10], [21].

For example, of the article consider a lean enterprise [22]. The foundation is the ongoing challenge of continually adapting to the needs of customers, employees, and environment. There is kaizen or continuous change for the better. There is teamwork and emphasis on working together. And there is Gemba - the approach of hands-on, going to see oneself rather than management by remote control. The pillars are now continuous improvement and respect for people. These two go back to the origins of Toyota in the 1930s to 1950s with Sakichi and Kachiro Toyoda. Perhaps they go back to a main source of their inspiration, Samuel Smiles' Self Help [11]. These two support the Toyota Way – that hard to capture set of principles that Jeffrey Liker as attempted to summarise. And finally, the roof – thinking people – the real root of sustained performance. The concept of enterprise is important. 'Enterprise' means that Lean is not limited to 'manufacturing' or 'operations'. A Lean mindset is necessary for all functions – accounting, IT, HR, marketing, sales, purchasing, distribution, and of course design and development. And not just waste, but value.

Appropriately some have begun to say that TPS stands for Thinking People System, rather than Toyota Production System [10, 21].

The implementation of the Lean concept can be used in two ways: the first case, a set of one-time organizational and technical measures assumes that it is used in the reengineering of business processes in accordance with the methodology of M. Hammer [23]. In the second case, the creation of lean production actually means the development of known elements of the constant improvement of the kaizen system, which belongs to M. Imai, an ideologist of one of the most effective models for implementing the concept of lean production [24].

Kaizen in business is a constant improvement, from the workplace to senior management [15]. The main goal of kaizen is lossless production. It is known that companies using the LEAN concept apply the principle of creating cross-functional commands (command formation). For successful. A lot of attention, interest, planning and communication is required on the part of the top managers of the team in the enterprise. Every organizational project, according to D. Tepping, T. Shuker, should begin with the "cathball" procedure - throwing the ball [25, p. 26-27].

We propose to consider the basic principles of LEAN [26]:

1. Principle - Bottom-Up Control
2. Principle - Inventory Reduction
3. Principle - Continuity of transformations

The LEAN implementation project is not complete, the period of stability of any process is We summarize the main provisions of the LEAN concept, its role in ensuring the efficiency of engineering enterprises, noted in our study:

LEAN concept uses a project approach to solving specific tasks by means of initiative working groups and specialized departments.

The LEAN concept is focused on a process approach to managing enterprise improvement.

1. Order to expand the work on continuous improvement of production processes, control bodies are created that implement and monitor the decisions made.
2. To ensure the unity of approaches to the implementation of LEAN tools in practice, the company develops a set of provisions and regulatory documents regulating the activities of various departments.

Thus, the effectiveness of the LEAN concept in plants and factories is partly due to the fact that many of the tools of this method greatly contribute to ensuring concentration, structure and discipline. When properly applied, it also develops a strong sense of ownership among ordinary workers.

Based on this, LEAN is a single set of extremely efficiently selected tools that can be applied to the production process. In addition, despite the fact that the basic

philosophy of LEAN (elimination of losses, cells, pulling instead of ejecting) refers to any work, its standard tools, applied without significant modification not to production, but to office procedures, are much less effective. With this in mind, in order to obtain a synergistic effect and maximum results, the concept of LEAN should be introduced using the concept of fast-reacting and active production.

Next, consider the following concept that meets the modern requirements for ensuring the competitiveness of enterprises - this is the concept of Industry 4.0.

Implementation concepts should be well aligned with an integrated approach to production system management when implementing Industry 4.0 lean production management.

2.2. Development concepts ‘‘Industry 4.0’’

Industry 4.0 is currently one of the leading terms in the world of business and organizations. The concept was presented at the Hanover Fair in 2011 and quickly attracted great attention not only in Germany, but also on the world stage. The Industry 4.0 concept is associated with the fourth industrial revolution in manufacturing, where technological trends such as digitalization, robots and artificial intelligence transform production processes [27]. A more accurate definition of Industry 4.0 is that it is "a new approach to manufacturing process management, providing real-time flow synchronization and allowing for unitary and individual production of products." The growth of Industry 4.0 is facilitated by government subsidies and attention, and Industry 4.0 has quickly become a large and profitable industry in its own right. Technology providers (such as SAP), consulting firms (such as McKinsey, Boston Consulting Group), and conference organizers, compete for market share associated with Industry 4.0 by offering and providing support and assistance services. The latest methods, such as artificial intelligence and robotization, the Internet of Things (IoT) and 3D printing, virtual and augmented reality, are quickly becoming an integral part of our daily existence [16]. One of the main technologies of Industry 4.0, which is used to predict production processes, is the Internet of Things (IoT). With IoT, different personal devices and sensors can be connected to the network and transmit data on the state of production equipment, production lines and other production parameters.

In 2023, the global IoT market in industry totaled more than \$118.37 billion and will reach \$1.11 trillion by 2028. In Russia, by 2030, it is expected that the volume of this market will grow to 147.25 billion rubles. The Internet of Things is a complex of connected and connected to the Internet a variety of devices that exchange information. Similarly, the Industrial Internet of Things is designed to combine equipment, employees and cloud data [28]. With thousands of sensors installed in the enterprise and software, it is possible to automatically monitor production and control it: monitor the quality of products by choosing optimal modes, or monitor the condition of equipment to predict its wear and tear and replace parts in a timely

manner, extending its life and preventing downtime due to accidents. Based on data analysis, you can increase the load pointwise, thus increasing performance. Previously, statistical data collected manually or not collected at all were used for analysis. This made it more difficult to access accurate information to assess the current and forecast future state of production. All of this can now be seen in real time using the Internet of Things. Today, such promising development vectors as smart city and home systems, predictive diagnostics systems in industrial segments, robotics, medicine, scientific developments in the artificial intelligence industry stand out on the IoT market in Russia [29].

IoT is also actively used in the IT segment responsible for the software part of the hardware objects that are connected to the Internet. Some IoT technologies allow you to simulate reality and test various scenarios in digital and using a digital twin. The digital twin of an industrial enterprise is a copy of it in a virtual environment. The function of the digital twin is to reproduce processes and operations in the enterprise with high accuracy, which allows you to solve a wide range of business problems. In the philistine worldview, sometimes there is an erroneous idea of a digital twin as a 3D model, which is used to visualize the production infrastructure without any additional meaning and functionality. But that's not right. The digital twin is, first of all, immersion in the logic of the processes taking place in the company, their digitization and, most importantly, the analytics of the data obtained using artificial intelligence. This is a promising technology of the future, and not a single large industrial enterprise in Russia in 10 years can be imagined without it [30]. The digital twin in an industrial enterprise provides accurate forecasting of production volumes, helps to determine the optimal amount of equipment for organizing the production process and the necessary reserves of production resources. The technology evaluates the peak and optimal performance of each unit in the production chain to predict the volume of contracting and helps to control the wear of equipment under various loads. Digital twins are also effective in the operation of industrial construction facilities. In addition, such solutions are used to assess the effect of the introduction of digital technologies and the commissioning of technological, engineering and bench equipment. Depending on the specifics of the work of a particular enterprise and its development strategy, the functionality and interface of the twin can be changed to solve specific problems. A distinctive feature of the digital twin is that this asset can work for the company forever [28]. Against the background of the spread of smart devices and the development of data transmission networks, the interest of major players in the software market in SCADA systems (Supervisory Control and Data Acquisition, dispatch control and data collection) is growing. Already, with the help of such solutions, it is possible to aggregate information from sensors and sensors for monitoring and controlling equipment into a single data lake and generate reports with visualized data for decision makers.

The manufacture of more complex devices requires the modernization of the - production facilities of companies. The more complex the production, the more

complex the sensors and the more valuable information they provide. Against the background of the active growth of data flows, the negative role of the human factor increases and the risks of making wrong decisions increase due to the fact that a person cannot process all the information collected. The specified requirements are applicable both to commercial firms and non-profit organizations. Any organization should quickly and adequately respond to changes in the situation in society and the market, make appropriate changes in their activities [31].

3. Research design

3.1. *Optimizing the implementation of digital technologies in the context of Industry 4.0*

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?

Optimizing the adoption of Industry 4.0 technologies is the process of developing and applying methods and strategies to maximize the opportunities provided by new technologies related to digitalization and automation of Lean management. The goal of optimization is to improve the efficiency, quality and competitiveness of companies by using advanced technologies and improving production processes. Optimizing the implementation of Industry 4.0 technologies can include analyzing and optimizing production processes, using artificial intelligence algorithms, implementation of production management systems, management of customer relations.

Therefore, Smart Enterprise or Smart Factory integrates some elements (**Figure 1**) that, sometimes, are developing for itself and, sometimes, they are competitive. Actually, they can be all connected and there is no Industry 4.0 without setting up basics of Lean management (process identification and process measuring [32]).

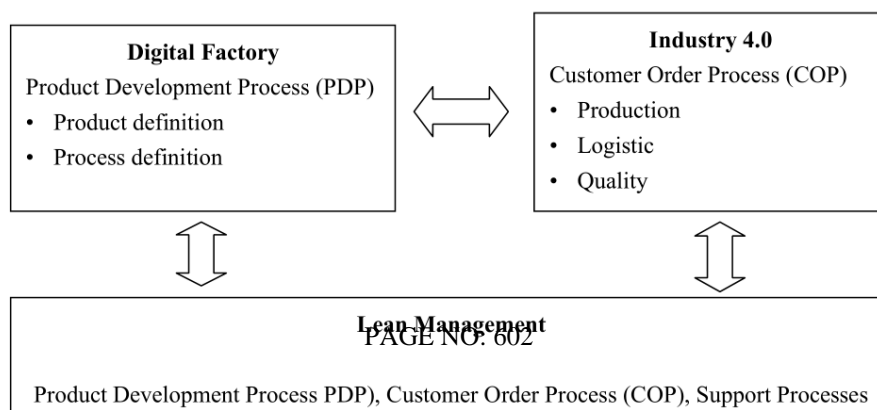


Fig. 1. Optimization approaches and their underlying technical processes (Huber, 2016)

Sanders, Subramanian, Redlich, and Wulfsberg (2017) believed interaction between I4.0 and lean causes synergies and helps them to adopt precisely) [33].

The current investigation found 5 papers that confirm this issue. Mayr et al. (2018) explored whether lean management and I4.0 can support each other or not [34].

The relationship between I4.0 and lean manufacturing is vital for the quality and reliability of products. Additionally, there is a high level of synergies between them. Dombrowski, Richter, concluded high dependencies between cloud computing, avoidance of waste, zero defect, and big data [35].

Comparing the characteristics of Lean management (LM) and Industry 4.0 (I4.0), it is possible to realize the resemblance of them [36] The five principles of LM cited by Womack et al. (1990) added with the “People” principle suggested by Hines et al. (2004) seem to be close related with the core competences of I4.0 cited by Bitkom [37].

3.2. Integration of digital technologies using lean manufacturing

One of the most important tasks of today's domestic science in the field of Lean management organization is to find scientifically based solutions for the effective functioning and improvement of production processes of enterprises. This includes the extensive use of digital technologies and the development of practical planning methods at all levels of the organization of production processes.

The combination of Lean Production and Industry 4.0 is still being researched and is called Lean 4.0 [34, 38, 39]. Rittberger & Schneider used the Human-Technology-Organization-Model (HTO) to compare and combine Lean Production with Industry 4.0 and to identify possible potentials. They show that the Lean Production approach focuses on the organization and the humans, such as employees or customers, and their interaction [34],[40], [41].

Studies the authors show the main advantages of an Industry 4.0. First of all, the digital platform contributes to creating new jobs and attracting investment. This improves productivity and product quality and reduces risk and improves resource management [28],[29], [30].

The Industry 4.0 trend is often used to denote the fourth industrial revolution, which involves the introduction of cyberphysical systems into production that can negotiate and cooperate. In general, digitalization in the industrial sector in Russia and Europe has fallen on the rails, and is even gaining momentum. Today, our share of

digitalization is slightly more than 22% of the total world economy. This is quite good, and Russia is ahead here: from the point of view of digitalization, 7% of companies are leaders, 19% are innovators, and only 1% of us are lagging behind, although in Europe and in the world there are 9%. About 40% of industrial enterprises plan to digitalize in the next five years. This suggests that there is a good trend in Russia, and it will develop [42].

The implementation concepts need to be well aligned with methodological approach to managing the production system when implementing the concept of lean.

The combination of Lean Production and Industry 4.0 is still being researched and is called Lean 4.0 [34],[38], [39].

Moreover, it is a holistic and long-term-oriented methodical approach that requires a change of employees' attitudes and awareness to reach a continuous value stream by avoiding waste [43],[44].

Supplementary, Industry 4.0 is technology-focused and requires a high degree of process orientation with clearly defined processes [45],[46].

It covers the interface of technology with both humans and the organization [47].

Any manufacturer wants to receive maximum results from production. For this, enterprises from different industries invest in the means of management and optimization of technological processes. In the context of digital transformation of enterprises, the need for equipment reliability unites. Perhaps this is the obvious key object of digitalization. No matter what product the enterprise produces, equipment malfunction always leads to losses, downtime [39].

At the same time, if an enterprise uses digital technologies to predict and prevent equipment malfunction, such an opportunity would be a big plus for the enterprise.

Concerning the first perspective, many scientific papers state that Lean Production is the basis for Industry 4.0[48], [49], as Industry 4.0 technologies are assumed to build on the holistic approach of the Lean Production System [50].

The survey of Tortorella & Fettermann confirms that Industry 4.0 is introduced more likely if Lean Production is already implemented [41]

An essential requirement of Industry 4.0 is a certain degree of process orientation with defined processes, customers, suppliers, tasks, and times [35]. Supporting this, Lean Production Systems generate standardized, transparent, and waste-free processes [51], [52].

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).

4. Results

4.1 Implementation of lean and digital manufacturing project

Let's consider a well-known process at the enterprise. At the beginning of the process, data is collected from sensors. Then their complex processing by algorithms by software is carried out, taking into account processes and production. Further, to ensure the correct operation of the entire circuit, actuators are immediately activated. It is known that the enterprise has other technological processes that do not fit into the framework of such a closed cycle. The amount of process data can be limited and information collection can be carried out manually, and the analysis is practically not carried out. An example of such processes is monitoring the reliability of the equipment. Monitoring the security of processes, employees, and energy management. Using digital tools in this case, we understand that it is necessary to close the circle, or automate all these areas (Figure 2).

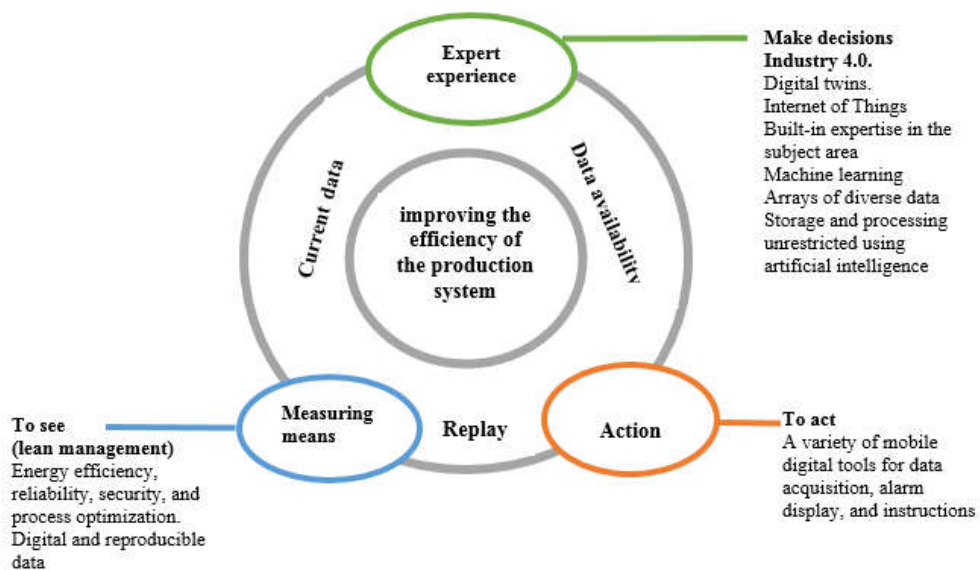


Fig. 2. The scheme of the cycle of improving the efficiency of the production system with the integration of Industry 4.0 lean enterprise management

From this diagram, we see that, firstly, we need data - digital, reproducible, actual data in real time to make the right decision. The source of this data can be new means of measurement, or completely new technologies for collecting data. For example, using sensors, sensors. Then, data is transferred to any computer, any application, or

any employee anywhere in the world through a common available Internet. This data is then analyzed using digital technology. For example, digital twins, analysts with machine learning elements, or with the involvement of employees, experts. Thanks to cloud storage, we have almost unlimited opportunities for analyzing, storing and processing data using analytical tools. All this work is aimed at one act aimed at the implementation of digital transformation projects. Thanks to the use of digital tools, the performer can be located many kilometers from the point where the data was obtained, or analyzed.

Secondly, we change the meaning of the work of production processes and behavior taking into account the data and recommendations from analytical tools. These technologies enable you to design, create, and capture results from new business models. Traditionally, it is employees of production enterprises who are engaged in optimizing technological processes. They independently collect data and process it using software, or involve their own engineers to solve the problem. But recently, within ten years, many geographically remote objects have appeared, such as: test centers, landfills, mines, oil and gas production platforms, etc. As a result, the idea of a control center for integrated, so-called digital production appeared. It became clear that you can collect experts in one center, where all the data would be transmitted. Instead of sending an expert to the enterprise. However, this still happens within the information system of one company, and is supported by resources only by its employees. Thanks to the digital transformation and the idea of the industrial Internet of Things, the company receives a new approach to the provision of services.

From an economic perspective, Huber expects a more efficient implementation of Industry 4.0 technologies when Lean Production is already present [32]. The other central perspective is that technological advancements of Industry 4.0 might complete or even enhance Lean Production activities and positively affect its efficiency [35], [53], [54].

Bauernhansl and Kieviet highlight the potentials of Industry 4.0 for Lean Production Systems facing complexity and flexibility simultaneously by applying appropriate technologies [55], [56], [57], [58].

In this case, the company can attract remotely, use digital outsourcing, i.e. digital services of experts of a third-party organization, which means that it is not necessary to involve its own employees for analysis and data processing. This is a very effective business model that solves the problem of organizing and performing work.

In order to use the domestic potential of digitalization in full force, it is necessary to follow the recommendations [28],[29],[30].

1. Avoid excessive haste - it carries significant risks. You can't instantly translate all production into digital.
2. Forcing digitalization with a low level of information security is dangerous.
3. Gradual reforms are needed, and you need to start with less.
4. The digitalization of production and the economy is nothing more than very big costs. Therefore, it is necessary to stimulate investment, create a regulatory - framework and, most importantly, take care of digital literacy, the development of

digital competencies of workers.

Let's draw the line of the above, the introduction of digital technologies has certain advantages, but excessive haste and forcing digitalization carries serious risks. It is preferable to gradually carry out activities.

Therefore, this scientific contribution provides a systematic approach to identify the implications of Lean production and Industry 4.0 methods on target dimensions that are significantly important for the development of production system enterprises.

4.2. 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. 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 due to the fact that, 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.

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 that 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.

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 1. Description of the operation

No. operation	Description of the operation
10	Retrieving components and assembling the base of the structure X
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 in accordance with 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 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 Table 2.

Table 2. Improvements introduced as part of 5S and Standardization

No. operation	Description of the operation
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.

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, act strictly according to the instructions. For example, workshop in recent years has 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, 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

The introduction of new methods for organizing the production system requires a restructuring of the way of thinking and approach to business, firstall, 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, 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 is able to 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].

5. 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.

6. 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. The study examines a practical example of an enterprise's transition to digitalization. From an economic perspective, Huber expects a more efficient implementation of Industry 4.0 technologies when Lean Production is already present [32]. The other central perspective is that technological advancements of Industry 4.0 might complete or even enhance Lean Production activities and positively affect its efficiency [35], [53], [54], [59],[60].

Bauernhansl and Kieviet highlight the potentials of Industry 4.0 for Lean Production Systems facing complexity and flexibility simultaneously by applying appropriate

technologies [55], [56], [57], [58].

In this case, the company can attract remotely, use digital outsourcing, i.e. digital services of experts of a third-party organization, which means that it is not necessary to involve its own employees for analysis and data processing. This is a very effective business model that solves the problem of organizing and performing work.

In order to use the domestic potential of digitalization in full force, it is necessary to follow the recommendations [28], [29], [30].

The result of the study is an assessment of the possibility and expediency of applying the considered cycle of improving the production system using the concept of lean manufacturing, digital technologies for the enterprise.

The conclusion of this study is that the implementation of the cycle of continuous improvement of the system should be carried out in stages using digital technologies with the involvement of personnel, which is necessary and possible in the digital space and a lean enterprise. The advantages of this approach lie in the evolution, when the development of process control methods does not replace the existing control system and is not some kind of parallel initiative, but complements the control system with practical methods of process control. In addition, the integration of Industry 4.0 using Internet of Things, digital twin and other technologies is much better perceived by business leaders and greatly simplifies their involvement in the development of process management methods. This approach allows us to support developments in the field of describing procedures that well reflect the multidimensional requirements imposed on industrial enterprises, are the fruit of the work of more than one generation of people and represent significant intellectual value. Thus, an integrated approach to management in the context of lean, digital production in an enterprise and modern tools is a reliable way to transfer an enterprise to digital management methods and can be used in enterprises.

References

- [1] V. W. Y. Tam and K. N. Le, "Quality improvement in construction by using a Vandermonde interpolation technique," *International Journal of Project Management*, vol. 25, no. 8, pp. 815–823, November, 2007.
- [2] [15] L. Machuca-Villegas, G. P. Gasca-Hurtado, and M. Muñoz, "Measures related to social and human factors that influence productivity in software development teams," *International Journal of Information Systems and Project Management*, vol. 9, no. 3, October, 2021.
- [3] W. E. Hefley and M. Bottion, "Skills of junior project management professionals and project success achieved by them," *International Journal of Information Systems and Project Management*, vol. 9, no. 1, September, 2021.
- [4] P. Parviainen, M. Tihinen, J. Kääriäinen, and S. Teppola, "Tackling the digitalization challenge: How to benefit from digitalization in practice," *International*

Journal of Information Systems and Project Management (IJISPM), vol. 5, no. 1, pp. 63–77, January, 2017.

[5] Kääriäinen, Jukka; Pussinen, Pasi; Saari, Leila; and Kuusisto, Olli "Applying the positioning phase of the digital transformation model in practice for SMEs: toward systematic development of digitalization," *International Journal of Information Systems and Project Management: Vol. 8: No. 4, Article 3*. Available at: <https://aisel.aisnet.org/ijispm/vol8/iss4/3>, 2020

[6] A. Gemino, B. Horner Reich, and P. M. Serrador, "Agile, Traditional, and Hybrid Approaches to Project Success: Is Hybrid a Poor Second Choice?," *Project Management Journal*, vol. 52, no. 2, pp. 161–175, 2021, doi: 10.1177/8756972820973082.

[7] M. Špundak, "Mixed Agile/Traditional Project Management Methodology – Reality or Illusion?," *Procedia Social and Behavioral Sciences 27th IPMA World Congress*, vol. 119, pp. 939–948, 2014, doi: 10.1016/j.sbspro.2014.03.105.

[8] Reiff, Janine and Schlegel, Dennis "Hybrid project management – a systematic literature review," *International Journal of Information Systems and Project Management: Vol. 10: No. 2, Article 4*. Available at: <https://aisel.aisnet.org/ijispm/vol10/iss2/4>, 2022

[9] S. Morcov, L. Pintelon, and R. J. Kusters, "Definitions, characteristics and measures of IT project complexity-a systematic literature review," *International Journal of Information Systems and Project Management*, vol. 8, no. 2, pp. 5–21, 2021, doi: 10.12821/ijispm080201.

[10] T. Ohno "Toyota production system: beyond large-scale production." Productivity Press, Cambridge, Massachusetts, 1988.

[11] Womack J.P., Jones D.T. and Roos D. "The machine that changed the world". Rawson Associates, New York. 1990

[12] T. Tanaka "Target Costing at Toyota," *Journal of Cost Management*, Spring, pp. 4–11, 1993

[13] Womack J., Jones D. *Lean thinking: banish waste and create wealth in your corporation*. Moscow, Al'pina Publisher, 2011. 473 p.

[14] M. Rother, *Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results*, New York, McGraw-Hill Education, 2009.

[15] Thomas Grunberg *Performance Improvement: Department of Production Engineering Royal Institute of Technology*. Stockholm, Sweden, 2007. 223 p.

[16] P. Dennis Hobbs. *Lean Manufacturing Implementation: A Complete Execution Manual for Any Size Manufacturer*. Ross Publishing, Incorporated, J. 2003.

[17] V.L., A.G Popov Tashkinov. Resource-process management at development of production systems *Journal of Economy and Entrepreneurship*, no. 11, part 2, 2015.pp. 674–677.

- [18] A.E. Luzin, Yu.V. Babanova (Post-Fordism - three key production paradigms of the new century. *Management in Russia and abroad*, No. 6, 2013.pp. 18 – 26.
- [19] D.M. Malikova The mechanism of effective relationship between complex automation and the organization of lean production in mechanical engineering // *Vestn. IzhGTU named after M. T. Kalashnikov*. 2016, No. 2. - P. 33–36.
- [20] V.I. Mamonov Some aspects of the concept of fast-reacting production.I. Mamonov, V.A. Poluektov, E.M. Yakutin *Economics, management and social policy*. Sept. Oct. pp.49–52. 2014
- [21] Liker J.K. and Morgan J. "The Toyota product development system: integrating people, process, and technology." Productivity Press, 2006
- [22] Jordi Olivella, Ruben Gregorio Organizational Practices Lean Enterprises Adopt to Focus on Value Streams, *Journal of Enterprise Transformation*, 4:4, 309-328, DOI: 10.1080/19488289.2014.919973. 2014
- [23] M., Hammer Champy *Reengineering the Corporation: A Manifesto for Business Revolution.*, Harper Business Essential., USA. P. 2003 p.259.
- [24] M.Imai *Kaizen: The Key to Japan's Competitive Success*, MacGraw–Hill, New York.1986
- [25] D Tapping., T.Shuker (2009) *Lean office. Value stream management / Per. from English*. Raskin A.L.; Under scientific ed. Bashkardin E.A.. - M.: RIA "Standards and Quality", 208 p.
- [26] A.G., Tashkinov) Elaboration of the development management concept of the industrial and economics system of the air engine building enterprise. *PNRPU Sociology and Economics Bulletin*, no. 4, pp. 209-221, DOI: 10.15593/2224-9354/2023.4.15. 2023
- [27] E. Hofmann, & M. Rüsç. Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, 89, 23–34. <https://doi.org/10.1016/j.compind.2017.04.002>
- [28] A.G. Tashkinov, Methodological approach to the development of digital transformation of an enterprise. *Journal of Innovations in Business and Industry*. Vol. 03, No. 03 doi: 10.61552/JIBI.2025.03.006 pp.177-186, 2024
- [29] V.V Glukhov, A.E. Loginov. Tools for assessing telecommunication network performance indicators. *π -Economy*, 16 (6), 142–154. DOI: <https://doi.org/10.18721/JE.16610>, 2023
- [30] A.G. Tashkinov The implementation of lean and digital management techniques using Artificial intelligence in industrial settings. *Discover Artificial Intelligence*. – 2024. Vol. 4, Iss. 1. P. 1-23. DOI: doi.org/10.1007/s44163-024-00186-5. Scopus.
- [31] A.V. Babkin, A.G. Tashkinov Stages of developing a methodological approach to assessing the effectiveness of digital transformation projects for an industrial enterprise. *Bulletin of the South-Western State University. Series: Economics. Sociology. Management*. 2024; 14(4): 70–93. <https://doi.org/10.21869/2223-1552-2024-14-4-70-93>
- [32] W.Huber, *Industrie 4.0 in der Automobilproduktion*, Springer Fachmedien, Wiesbaden. 2016.

- [33] Sanders, A., Elangeswaran, C., & Wulfsberg, J. Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management*, 9(3). doi:10.3926/jiem.1940. 2016.
- [34] A. Mayr, M. Weigelt, A. Köhl, Grimm S, Erll A, Potzel M, Franke J Lean 4.0 - A conceptual conjunction of lean management and Industry 4.0. *Procedia CIRP* 72:622–628. 2018
- [35] U.Dombrowski, & T.Richter, The Lean Production System 4.0 Framework–Enhancing Lean Methods by Industrie 4.0. Paper presented at the IFIP International Conference on Advances in Production Management Systems. 2018.
- [36] P. Hines, M.Holwe, & N. Rich,. Learning to evolve: A review of contemporary lean thinking. *International Journal of Operations and Production Management*, 24(10), 994-1011. doi:10.1108/01443570410558049.2004
- [37] V., V Bitkom, V., ZVEI e.V.. *Implementation Strategy Industrie 4.0*. 2016
- [38] K. Dennis Detlef Zühlke. Lean Automation enabled by Industry 4.0 Technologies. *IFAC-PapersOnLine*:1870–5. 2015.
- [39] G. Ante, F.Facchini, G. Mossa, S. Digiesi Developing a key performance indicators tree for lean and smart production systems. 51(11) pp. 13–8. 2018
- [40] S.Rittberger, M.Schneider Continuous Improvement of Lean Processes with Industry 4.0 technologies. 11th International Doctoral Students Workshop on Logistics. 2018
- [41] GL Tortorella, D. Fettermann Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies. *International Journal of Production Research* 56(8):2975–87. 2018
- [42] Fundamentals of the digital economy and business transformation: textbook/team of authors; ed. E.Yu. Sidorova. M. KNORUS, 2023. 260 p.
- [43] J. Metternich, M. Müller, Meudt T, C Schaede, Lean 4.0 – zwischen Widerspruch und Vision. *ZWF* 112(5):346–8. 2017
- [44] U. Dombrowski T. Richter, P. Krenkel Interdependencies of Industrie 4.0 & Lean Production Systems: A Use Cases Analysis. *Procedia Manufacturing* 11:1061–8. 2017
- [45] F. Dillinger, C. Messmer, G. Reinhart Industrie-4.0-Technologiekreis für produzierende Unternehmen. *ZWF* 116(9):639–43. 2021
- [46] S. Rittberger, M. Schneider Continuous Improvement of Lean Processes with Industry 4.0 technologies. 11th International Doctoral Students Workshop on Logistics. 2018
- [47] F. Rosin, P. Forget, S, Lamouri, R. Pellerin Impacts of Industry 4.0 technologies on Lean principles. *International Journal of Production Research*, 1-18. *International Journal of Production Research* 58(6):1644–61. 2020
- [48] B. Mrugalska, MK. Wyrwicka Towards Lean Production in Industry 4.0. *Procedia Engineering* 182:466–73. 2017
- [49] F. Bertagnolli Lean Management: Einführung und Vertiefung in die japanische Management-Philosophie. Springer Gabler, Wiesbaden, Heidelberg. 2018

- [50] T. Bauernhansl, M ten Hompel, B. Vogel-Heuser *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration*. Springer Fachmedien Wiesbaden, Wiesbaden. 2014
- [51] T. Ōno *Das Toyota-Produktionssystem: Das Standardwerk zur Lean Production*. 3rd ed. Campus-Verl., Frankfurt am Main. 2013
- [52] P. James Womack, Daniel T. Jones. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation, Revised and Updated*. New York, NY: Free Press.2010
- [53] C.Prinz, N. Kreggenfeld, B. Kuhlenkötter *Lean meets Industrie 4.0 – a practical approach to interlink the method world and cyber-physical world*. *Procedia Manufacturing* 23:21–6. 2018
- [54] BG. Rüttimann MT. Stöckli *Lean and Industry 4.0—Twins, Partners, or ontenders? A Due Clarification Regarding the Supposed Clash of Two Production Systems*. *JSSM* 09(06):485–500. 2016
- [55] T Bauernhansl *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung · Technologien · Migration*. Springer, Dordrecht. 2014
- [56] A Kieviet *Digitalisierung der Wertschöpfung: Auswirkung auf das Lean Management*. in Künzel H, (Ed.). *Erfolgsfaktor Lean Management 2.0*. Springer Berlin Heidelberg. Berlin, Heidelberg, pp. 41–59. 2016
- [57] T.Wagner, C Herrmann., and S.Thiede, *Industry 4.0 Impacts on Lean Production Systems*, *Procedia CIRP*, vol. 63, pp. 125–131, doi: 10.1016/j.procir.2017.02.041.2017
- [58] J.Hambach, K. Kümmel, J. Metternich *Development of a Digital Continuous Improvement System for Production*. *Procedia CIRP* 63:330–5. 2017
- [59] A. G. Tashkinov *Enterprise management in the context of digital transformation International Journal of Management Trends: Key Concepts and Research 2024*. Vol. 3, Iss. 1.P. 67-76. DOI 10.58898/ijmt.v3i1.67-76.
- [60] Tashkinov AG *The application of industry 4.0 into the company's production activities through effective decision-making*. *Scientific Reports*. 2025; 15:34202.<https://doi.org/10.1038/s41598-025-15688-0>. Scopus, Web of Science