

Research of Theoretical and Methodological Approaches to the System of Lean Manufacturing

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Abstract. This paper deals with the historical development of the lean manufacturing system in Russia, the United States and Japan. The modern significance of this direction is shown. It is given the authors' opinions on the necessity to improve the entire manufacturing system, search for new knowledge, thoughts, experience that will help enterprises in any industry remove waste products, improve production and management processes, introduce innovations. It is dealt with the main methods of lean manufacturing (Lean -methods), the most fundamental, basic ones of which are already actively introduced into the practice of domestic and western enterprises. It is shown the importance and significance of the Lean -methods based on: cost savings; time minimization; transparency of internal and external production processes; optimization and simplification of business processes; increase in productivity and production efficiency; continuous improvement aimed at loss prevention practices; staff development, quality management - production with "zero defects" in products and tools.

1. Introduction

The current state of the global economy, severe competition, limited resources, changes in tastes and preferences of customers require from economic entities continuous improvement, improvement of product quality, production efficiency, stability, profits increase. Manufacturing companies are trying to find the ways to reduce costs and provide customers with better services. Most companies operate under the principle of "costs plus profit", but high prices scare customers, which subsequently reduces market share. It is the market dictates its own conditions - what to sell, how and at what price. Therefore, western companies use the "reasonable price minus costs" formula. This principle allows you to save customers and earn profits. To implement it you need to reduce costs. Lean manufacturing companies are generally able to do this. In addition, significant savings on resources with the help of "lean" not only increase the profit of the manufacturer, but also improve the quality of products.

2. Main part

The development of the lean manufacturing started in the twenties of the last century in the United States of America. At that time Henry Ford first applied the term "lean manufacturing" using the concept of the lean management [7].

In the same period, the similar ideas were developed in the Soviet Union by A.K. Gastev. His book "Working Policy" dealt with the methods of teaching labor practices. The author called for the need to improve the entire production system. It concerned the cost price, productivity and quality of products.

According to A. Gastev, the production system needed radical organic transformations. The innovative approach was to bring the labor process "from a heavy yoke for the worker" into a "positive creative process." The team of authors led by A. Gastev. formed the concept of the working policy, which included the interrelated components: "The theory of labor movements in production processes and the workplace arrangement; rational industrial training methods; theory of managerial processes "[1].

It is important to note that this concept was able to cover various fields of engineering, technologies biomechanics, mathematics, machines, history, economics, pedagogy, geography, and geophysics. The authors themselves called their concept "techno-biosocial".

In his time famous American engineer Taylor F.W developed a system of scientific labor management, including four interrelated elements, "the development of rational methods and methods of work among workers; recruitment; workers' training and progress; close cooperation of the administration and the workers" [6]. At the Midvale Steel Works y, F.W Taylor ran the gamut from the operator to the chief engineer. It was the work in the workshop that allowed him to identify a number of problems that reduced productivity and brought losses. F.W. Taylor analyzed each part of the production process with the timer. He thoroughly studied the labor hours, breaking the total amount of work into components, measured each of them accurate to the second. F.W. Taylor called his concept scientific management, which has become known throughout the world.

We can assume that it is the works of F.W. Taylor, G. Ford, A.K. Gastev based the subsequent concepts of the lean manufacturing.

In the later Soviet period, Prof. O. A. Yermansky, who was involved in the problems of labor management, believed that "Nothing should be done as a routine, Everything, even the smallest detail, should be investigated scientifically beforehand. Everything must be foreseen in advance, expediently constructed and precisely established" [1]. The most important law of human labor, in his opinion, is gaining experience and skills when repeating the same movements. He developed the optimum criterion - the ratio of the amount of useful result to the amount of energy applied to achieve it. This indicator is used to assess the achieved effects of the implemented measures.

In the 1950s, F.W. Taylor's experience was successfully developed in Taiichi Ohno's works, a prominent eminent Japanese entrepreneur, engineer. He visited many Japanese and American plants and factories, identified a number of problems and inconsistencies. And at a time when many western and American companies were introducing a "sales promotion" system, T. Ohno focused the Japanese companies on a "just-in-time" or "dead-on-time" process. This principle, according to T. Ohno, "makes production works for the entire company in the way as the human body works for its owner" [4]. In his view, as the human body needs nutrition, sleep, rest, vitamins, physical activity, care and treatment during weakness and illnesses, so the company's production needs a system that will support the production process at the right moment and automatically regulate if necessary. and solve problems.

Later using the concept of T. Ohno, Shigeo Shingo and Masaaki Imai developed a system of the quick equipment changeover (SMED- Single Minute Exchange of Dies) and introduced the Kaizen methodology.

Along with the Japanese researchers, American specialists continued to study this subject area.

Thus, the work of W. Ouchi and R. Johnson "Made in America under Japanese management" is proof of this. The authors made a comparative analysis of the American and Japanese approaches to production management and came to the conclusion that some approaches of the Japanese management are connected with the Japanese culture and therefore are not available in American production [5].

However, association of these features only with the Japanese mentality seems controversial. Nevertheless, the proceedings of the authors are significant and reasonable.

Later W. Ouchi, coauthored with A. Yeager, published the work "Theory Z: How American Business Can Meet the Japanese Challenge" , "in which the authors came to the conclusion that success of Japanese companies can be explained by the complete participation of the worker in the

production process, while the management takes care of the private and family life of each of their subordinates.”[11]

The works of American specialists can be considered as an attempt to understand and study the Japanese phenomenon of the industrial success.

For example, in the United States, James Womack and Daniel Johns established the Institute and Academy for Lean Manufacturing. In their opinion, lean manufacturing is a breakthrough in management and quality control, “ensuring long-term competitiveness without significant investment” [2,12].

In general, researchers of the lean manufacturing believe that it is possible to get rid of losses and achieve prosperity in companies if we introduce the “zero defects” system, a system for finding and solving problems, flexibility, and establish long-term relationships with consumers [8,9].

Eventually the concept of the lean manufacturing began to transform into the concept of "lean enterprise", "lean management". Besides the term “lean” began to be applied to the country, city, region, industry, administrative district. Instead of the term "lean" you can meet the term "thinking".

This is due to the translation. The English word “lean” literally means “thin, skinny, economical, poor or empty” or “to slope, to rely, to incline, to press, to tend.”

The term "lean production, lean manufacturing" generally refers to the activities that is aimed to eliminate activities that do not add value to the final product or service from the consumer's point of view. The author of the term is John Krafcik, who is currently the President of Hyundai Motor America" [10].

It is believed that John Krafcik put across the fact in the “lean manufacturing” that in the new type of production in question, there is nothing superfluous.

Many domestic and foreign authors still discuss this subject, in their works they offer the translation as "sparing production" or "prudent production". In domestic publications one can find the terms – "harmonic, synchronous, delicate, flexible or low-cost production", as well as "perfect production". Most likely, there are other versions, but we hold the same opinion as the majority and use the term "lean manufacturing".

3. Methodology

As the study showed, in reality, lean is a business methodology that contributes to the formation of the value stream for the customer through the guiding principles: continuous improvement, discipline and responsibility. Lean is a search for new knowledge, ideas, experience that will help enterprises in all industries do away with the wastes, improve production and managerial processes, introduce innovations.

However, it should be mentioned that in different countries Lean methodology has different forms of existence. For example, in the United States, Lean is a system of tools and methods to reduce wastes and add value to each process, and in Japan Lean is considered a way of thinking rather than a set of tools.

To understand the methodology of lean production it is necessary to consider the main methods, tools, approaches that are used in the global Lean management system. For this, we will use the works [2,3,4,5,11,12].

The first method. Value Stream Mapping – is literally translated as "making a map of a value stream". Russian-language sources often use the wording "systematization of the value stream" or "map of the value stream creation", "mapping of the value stream creation – VSM". It is a tool that visualizes the process of turning raw materials into finished products sold to consumers. Its objects are material and information resource flows, as well as time-consumption.

The pioneer in VSM is Toyota Corporation. VSM is a way that can clearly show the steps which are necessary to ensure that the needs of consumers have become a product or service. Value Stream Mapping (VSM) is often referred to as "Stream Kaizen", i.e. continuous improvement of value streams. It is the best tool to identify and plan the opportunities for production improvement. VSM is designed to visualize the current state, plan and implement the future state with measurable goals.

VSM consists of three blocks:

1. A production or process flow is a traditional flowchart that records the value creation path from left to right, starting with the purchase of raw materials and ending with the shipment of products. If in addition to the main process there are additional or auxiliary processes, they are applied under the main. Thus, the main tasks are separated from the side ones.

2. Information or communication flow – at the top of the VSM the flows of information are represented by arrows that occurs in parallel with the production. Both formal and informal data exchange are taken into account. Information flows are plotted on the map in free form, just as they actually occur.

3. Timeline and distances are the lines that are drawn at the bottom of the map. The time line is divided into upper and lower parts. The lead time, which is the waiting period, is displayed at the top. The duration of the cycle is plotted below. There may be another line below the time line, on the very bottom, showing the path along which the product or staff are moving within the process.

Value stream mapping is performed on a variety of scales – from simple administrative procedures to large-scale production in the global market. The method helps to identify steps that do not add value and should be removed, as well as the weak points where the process can be improved, accelerated, where it is possible to reduce costs and provide a safer working environment.

The second method. Pull production- is "pulling". In lean manufacturing there are two competing concepts that allow to adjust to changes in demand – these are push and pull systems, i.e. push and pull. Let's consider their differences.

Push is a production system that operates based on demand forecasting. In it, raw materials are "pushed" into production according to the schedule. Pull is a system where each operational unit performs its functions depending on the state of the warehouse and the current demand. The push system uses information about the external environment to work, the pull system uses information about the internal environment. However, the external factors also affect the inventory. Pulling, which depends on demand at the moment, can be compared to an elevator. It starts when the button is pressed, even if there is only one passenger inside. Push is like an escalator. It works regardless of whether someone is walking on the moving escalator. Pulling is an attempt to listen to the consumer and sell what he needs, not what the company produces. The system works like a supermarket, where the shelves are filled with the goods selected by consumers. However, not only the wishes of the user form the production system in the pulling system. Within an enterprise it is established special relationship: the Department becomes the internal customer for the previous Department in the flow and the internal supplier for the next one. The number of processes is regulated by the need for the next section. In the push system, each section is controlled by a "center", which controls the volume of tasks and deadlines. The workshops exist as if separately from each other. Nobody on the site cares what will happen to the products that will be sent to the next site.

It should be noted that the assistant in the implementation of the pull production method is the KANBAN system. Let's consider it later.

The third method is the KANBAN system- KANBAN. Like the concept of the lean manufacturing (Lean), the Kanban system was developed by Toyota's managers. There the workers exchanged with signal cards, "Kanban", (translation from Japanese), personally handling the production process. The cards were attached to the container with the components. These cards had information about the number and number of components, which department sends them and where they should arrive.

The main value of the Kanban system, which is widely used in pulling, is not in the cards themselves, but in the regulation of work in progress. The card is only the simplest way to transmit the production signal. If the Kanban cards run out in the workshop, then the next warehouse is full.

This approach adds flexibility to the production process, which can be customized. The low level of work in progress allows to see troubles in the processes better and eliminate them, rather than redirect them along the downstream. Kanban is one of the most famous pulling systems. But it is not

the easiest one. After all, stocks in warehouses can be controlled not only for a single workshop, but for the entire production. This system is called ConWIP – short for Constant Work-in-Progress.

The fourth method - ConWIP (Constant Work-in-Progress) – is a constant level of work in progress. The cards that have a limited quantity are attached to a specific product. When it ends, the card is withdrawn and returned to the first workshop. Each workshop can operate without restrictions, rather than wait for a card from the next level, as it occurs in the Kanban system. ConWIP-card accompanies the components to the workshops, which can start production if raw material is available. The purpose of the system is to reduce the number of cards, thereby reducing the volume of work in progress. There is a linear connection: reducing WIP performance increases in the same proportion. If the "work in progress" reduced twice as much, then the speed of manufacturing components will increase twice as much. ConWIP is aimed to launch jobs at the very last moment to speed up production.

The fifth method - Kaizen (KAIZEN) – translated from Japanese "Kai" and "Zen" – are "changes" and "well" – is a philosophy of changes for the better or a philosophy of continuous improvement of business processes. Kaizen as a method is the involvement of the labor force in the process of improvement. Each employee should come up with (with the possibility of subsequent implementation) from 3 to 5 improvements in business processes every month. The significance of this method is not in a separate improvement, but in a combination of hundreds of small improvements that constantly move business processes forward.

The scope of the method is large – from the supplier to the customer. Unfortunately, not many companies can master the art of Kaizen with the participation of all staff. Western companies use the technique of Japanese consultants to solve problems in their business processes. For example, a step-by-step change (improvement) of business processes is created in a relatively short period of time, headed by an expert consultant. This approach allows to improve the company constantly in order to maintain or increase the market share, to regain their positions, to be able to respond quickly to changes in competitors.

The sixth method - Jidoka (Jidoka – Autonomation) – is the Lean method, which is widely used in the production and development of products. Besides, this method is known as autonomation, which is able to protect the company from the supply of low-quality products or defects. The search for the problem is automatic. It is possible to stop production if an error is detected. At the same time one employee can control the operation of several devices, which leads to a reduction in production costs, and also minimizes the cost of errors' correction (in comparison with if they were found not immediately, but only at the end of the production cycle). Jidoka is based on 4 simple principles: to detect the anomaly; stop the process; fix the problem; investigate the root cause.

These four steps can be applied in various sectors of production and non-production, and can also serve as the basis for sustainable achievement of the continuous improvement of the production process.

The seventh method - Andon (Andon) – from English it means "sign" or "signal", from Japanese – "paper lantern". It is a visual aid system that warns operators and managers about any failures or malfunctions in the production system and allows to stop the process until the detected defect has become massive. It is based on the methodology of Jidoka.

Andon as a visual or sound communication system can be triggered automatically or manually by a machine or person with the help of: a cord that can be manually pulled out (used on Assembly lines); light (a bulb) - red, yellow and green; a flag (also red, yellow and green) that is placed in a special holder to signal the problem. Thus, timely elimination of the problem allows not to spend resources on elimination of consequences on a global scale in the future.

The eighth method - Lean Six Sigma (LSS) - Six Sigma (includes the 5S method) is an integrated methodology based on two methodologies - American and Japanese. Six Sigma is a system of actions, the purpose of which causes an increase in the quality of products and, consequently, an increase in customer loyalty. The method is based on the effect of the standard deviation indicator. The more opportunities for varying the internal and external production factors, the higher the level of quality

deviations. The smaller the variation of values according to a certain characteristic, the higher the quality of the products produced. The essence of the method is in the proper arrangement of the workplace. To do this, according to the developers of the method, it is necessary to:

1. Sort and remove what is not used;
2. Arrange in a convenient manner what is used;
3. Maintain cleanliness and order;
4. Create standards of control;
5. Improve by applying the created standards.

There are certain skill levels in the Six Sigma methodology (LSS): "Black Belt" is a company's strategist who can solve global problems and control the LSS introduction process; "The Green Belt" - those that become the main driving force behind the introduction of the LSS concept; "Yellow Belt" - work directed by the "Green Belt", performing narrow specific tasks in the solution of which they can and should be real experts; "White Belt" - a person has mastered the basic set of knowledge and understands what the LSS method is.

The effect of the use of six sigma is that rather quickly there is an identification of problems in production caused by improper arrangement of the workplace and minimizing them (for example, getting rid of the pile of the tools that were used a month ago, and now only make the workers spend time searching for the right one among them). Thus, labor productivity increases; product quality is improved by reducing defects; the probability of accidents decreases; the workplace is adjusted; a comfortable working environment is created.

The ninth method - Just in time (JIT) is the method invented by T. Ohno at the Toyota plant, but the idea was taken from the experience of the American supermarkets, when they ordered and replenished only those products that disappeared from the shelves, that is, that were bought by customers. But for the perfect work of Just-In-Time method, there must be a number of conditions:

1. Stable production
2. Highly qualified staff;
3. Absence of breakdowns at the plants and factories;
4. Reliable suppliers;
5. Quick installation and changeover of the equipment.

This method has several advantages: maintaining the company's competitiveness due to better customer satisfaction and cost reduction (in particular, for storage of finished products); flexible response to changes in demand due to the rapid re-adjustment of production, lack of accumulation and obsolescence of products; reduction of the production cycle due to the acceleration of the production process and a quick return of investments; release of resources and their direction for the manufacture of other products or fulfilment of tasks for which there was not enough money and time.

It should be noted that this concept is useful not only within the framework of the production process, but also for each worker, since it guarantees employment by increasing competitiveness, eliminating excess work in progress, reducing time for the equipment changeover etc.

At the same time there are disadvantages. For example, a large dependence on suppliers that geographically must be close to production and provide it with the necessary resources within strictly limited time periods. The increase in the cost of materials, since orders for small batches are always higher at cost. There are problems with the staff - their labor vulnerability increases due to the changes in contracts and working hours. The increase in transportation costs, since the goods must be delivered as often as required without their warehousing. Increased requirements for project management in the case of an unregulated workflow, when there are idles of the workers. High dependence on the international and national market conditions - price hikes for fuel, transport, raw materials, other materials etc.

The tenth method - (SMED - Single Minute Exchange of Dies) - is a quick changeover - from the English "Single Minute Exchange of Dies" - is "a quick replacement of stamps". The method allows you instantly to switch over to the stages of the production process, it reduces the financial and time costs for the production and storage of products. In order to use SMED effectively, one need to

understand the purpose of introduction of the tool. These may be: reduction of equipment downtime and production capacity; reduction of stocks of work in progress (parts, materials, half-finished products); product range expansion. SMED can be introduced for 7 stages:

1. To separate internal and external operations. Internal operations are performed only after shutdown (stop) of the equipment. External operations do not require shutdowns.

2. To standardize external operations. As part of this stage, it is necessary to consider thoroughly the workflow and identify the opportunities for standardization. Each company has its own idea of this stage. For example, here emphasis can be done on standardization and regulation of the equipment changeover actions. These actions are low-cost, however, according to specialists, they account for about 70% of the total shortened time, what makes the introduction of SMED effective.

3. To turn the internal operations into the external ones. For this, it is necessary to check which of the operations are mistakenly perceived as internal and find the ways to turn such operations into external ones.

4. To improve the internal operations. To do this, it is enough to understand where there are problems in production: to determine the best time for each operation; to select an employee who can deal with the problem best of all; to determine who can do the work instead; to determine the best place to do the job.

5. To improve the external operations. For this, it is necessary to make up the checklists, to do functional checks, to introduce parallel operations

6. To automate the production processes to the maximum.

7. To improve constantly the workflow, involving the management, project managers, workers in this process. SMED is one of the most powerful tools in the concept of “lean manufacturing”. Thanks to the introduction of SMED, the time delays between the stages of production are significantly reduced, and thus the level of resource costs is reduced.

The eleventh method - Total Productive Maintenance (TPM) - is a system of universal equipment maintenance. This concept is aimed at improving production efficiency, stabilizing and continuously improving equipment maintenance processes, introducing a system of preventive maintenance and work on the “zero defect” principle.

It must be said that the term “universal” refers not only to industrial and economical maintenance, but also to the entire system of the effective maintenance of the equipment during its entire service life.

The TPM solves multi-tasking problems. For example: continuous improvement of the production process and loss prevention; maintenance of the equipment (inspection, cleaning, equipment checkout, lubrication procedure); schedule of equipment maintenance, operation readiness of the equipment for the production process; in-service training of the staff; equipment start up control; quality management is the production with “zero defects” in products and equipment; administration: elimination of losses and wastes in non-production areas; production ecology: workplace and environmental safety - minimization of accidents, use of filtration and cleaning systems.

The TPM approach based on minimization of losses in different variants is introduced at enterprises around the world. It is a well-known statement of Taiichi Ohno: “Forces of Toyota do not come thanks to the healing processes, but due to the preventive maintenance of the equipment” [4].

4. Conclusion

Of course, this work has considered not all the tools of the lean manufacturing, but the most major and basic ones, which are already being actively introduced at the domestic and western enterprises.

All the Lean methods are based on cost savings, minimization of time, transparency of the internal and external production processes, optimization and simplification of business processes, increase of productivity and production efficiency.

As the Lean -methodology holds, in order to ensure long-term survival in today's economy, businesses must constantly improve themselves, move forward, improve skills of their staff, upgrade facilities, hold informational innovations, arrange the working space correctly, solve the problems of

ergonomics, involve the staff effectively in the process of production ,use the talent and potential of the staff properly, eliminate the imbalance in the production and management.

5. Acknowledgements

The work is realized in the framework of the Program of flagship university development on the base of the Belgorod State Technological University named after V.G. Shukhov.

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