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Upgrading the production process and improving the quality of linear double-row cages through value stream maping

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ABSTRACT

In an era of intense competition in the market, manufacturing companies confront the challenges of optimizing production processes and improving the quality of the products they offer. In this context, instruments such as value stream mapping (VSM), a logical map and a technological approach to the process become invaluable. The purpose of this article is to present a methodology for their application in the process of optimizing production time and improving product quality, as well as the results of a study conducted at a manufacturing company engaged in the production of linear technology solutions.

Keywords: upgrading, improving, production process, quality, bearing cage, value stream mapping.

INTRODUCTION

In the pursuit of scientific and industrial advancements, the role of unforeseen opportunities – often perceived as "luck" – can significantly influence progress, particularly in optimizing complex systems like manufacturing. However, relying solely on chance is neither sustainable nor sufficient to address the demands of modern production processes. This paper focuses on systematically improving manufacturing efficiency through the application of VSM, a structured approach that transforms the way production challenges are identified and resolved [1, 2].

The competitive nature of today's global markets, driven by rapid globalization and the dominance of e-commerce, necessitates continuous innovation in production processes. Companies must strive to deliver high-quality products at competitive prices to remain viable. These pressures underscore the importance of efficient manufacturing practices that go beyond isolated instances of success or accidental improvements. Instead, deliberate, methodical approaches such as VSM ensure consistent and measurable results [3, 4]. The research addresses critical gaps in traditional manufacturing by focusing on the systematic reduction of waste, optimization of workflows, and enhancement of communication within production teams. By analyzing and visualizing the flow of materials and information, VSM enables teams to pinpoint bottlenecks and develop actionable solutions. The paper emphasizes the integration of logic maps and modern technologies to bridge the often-overlooked connections between production steps, fostering a comprehensive understanding of how to enhance efficiency and quality systematically [5–7].

This study also highlights the broader implications of improvement methods. By refining the process for identifying areas of enhancement, implementing targeted changes, and monitoring their effects, organizations can create a cycle of continuous improvement. The research contributes to the growing body of knowledge in lean manufacturing, showcasing how structured methodologies like VSM can replace reliance on chance with strategic action, ensuring that production systems evolve to meet contemporary demands effectively and sustainably [8].

MATERIALS AND METHODS

The research was conducted at a company that manufactures linear technology solutions. The research process consisted of several key steps [9]:
1. Data collection: analyzing production documentation, measuring the durations of a given production stage, directly on the production hall, and interviewing employees.
2. Application of a logic map: visualizing the flow of information from the moment a customer inquiry is received, until the order is accepted for production.
3. Technology approach: depicting the current production process of a bearing cage using a technology approach.
4. VSM creation: development of a current state value stream map for the process under study.
5. Data analysis: identification of bottlenecks and areas of waste. Create a value stream map with suggestions for improvement.
6. Implementing changes: creation of a future state map, with process improvement tasks plotted. Implementation of proposed solutions and monitoring of effects.

The research concerns the production process of bearing cages, as a result of the problems reported by the production which are the poor quality of the punched holes for the gear unit - burrs and wavy surface of the resulting hole, is shown in Figure 1, and the long time and problematic nature of the assembly of the gear unit.

Value stream mapping

Value stream mapping – VSM, is a graphical representation of entire production processes, based on which it is possible to identify places, areas that can be upgraded, or improved or eliminated. Its primary function is to eliminate occurring mud, or waste in the company. Among these, the most common are inter-operational expectations, downtime, excessive storage and material handling. The creation of a VSM consists of three steps [10]:
1. Value stream analysis – VSA – this is a map representing the current course of the company's value stream [11].
2. Value stream design – VSD – this is a representation of possible changes, this map marks the areas that can be modified [12].
3. Value stream work plan – VSP – this is a map of the future state, i.e. after the implementation of the proposed changes [13].

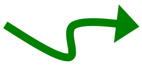
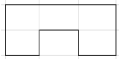
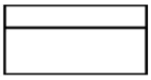
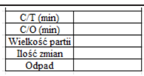
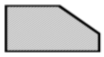
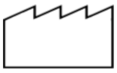
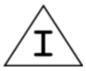
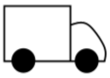
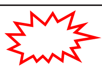
By conducting a VSM analysis, a company can obtain the following information, which can be helpful for improving the production process of the product under study. The first is to find sources of waste. Another advantage is to detect operations that do not add value and reduce the lead time of the entire order, reduce the costs incurred, improve and optimize the entire process. By creating a map, it is also possible to see the overall process that needs to be done to produce an order, from the moment it is placed by the customer to the moment the packed order is shipped [14]. The symbols that were used during the mapping, within the framework of the following work, are described in Table 1 [15].

Logic map

A process logic map is a tool by which a set of sequential activities and the flow of information in a company can be illustrated in a clear way. These maps are particularly helpful when creating the so-called VSM, which means value stream mapping. Such a map can illustrate, for example, the sequence of successive activities and decision-making stages,

Figure 1. Described quality problems of the beaering cage

Table 1. Symbols used in value stream mapping

	Verbal/direct communication		Department
	Electronic transmission of information		Work cell
	Push		Back loop
	Transportation of production materials / finished goods		Maximum processing time
	Operator		Go and see
	Proces		Pull production
	Data describing the process		KANBAN transport card
	Outside company		KANBAN production card
	Warehouse		Instructions
	Manual transfer of the product		Stationary storage
	Conveying the product using a truck		Changing the existing tool / method of performing operations
	Land transport		Supermarket
Q x	Quality check		Application of the FIFO method
	KAIZEN		

in a given company, that take place from the moment a customer inquiry is received, until it is approved and proceeds to execution. As in the case of creating a manufacturing process in technological terms, specific symbols are used in the creation of logic maps [16, 17]. The logic map shown in Figure 2 presents the flow of information that takes place inside the surveyed company, from the moment a customer places an order until it is accepted and proceeds to fulfillment.

The technological view of the process

The technological approach to the manufacturing process is to delineate all the successive steps that need to be performed to obtain the finished product. For this purpose, a systematized set of symbols has been adopted to represent a given operation, assembly, pre-processing, proper processing, transportation, quality control, or storage, and many others [18]. The diagram shown in Figure 3 illustrates the manufacturing process for the production of bearing cages with a gear unit, in technological terms. The process begins with the intake of the necessary input materials for production, and so, in the process under consideration, the intake occurs three times:

- at the beginning the intake of the flat bar from which the cage will be made,
- then the rolling elements for filling the basket, needed at the stage of filling the basket,
- the final, third intake of materials from the warehouse occurs when the gear units are made.

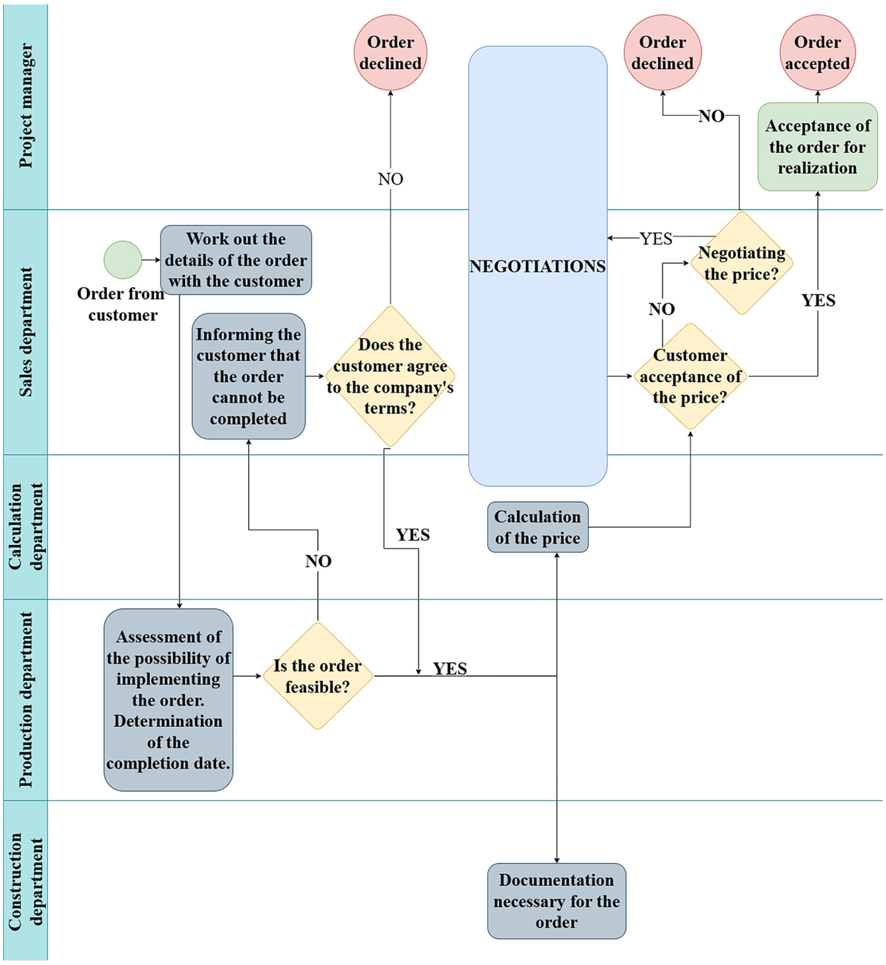


Figure 2. Logic map

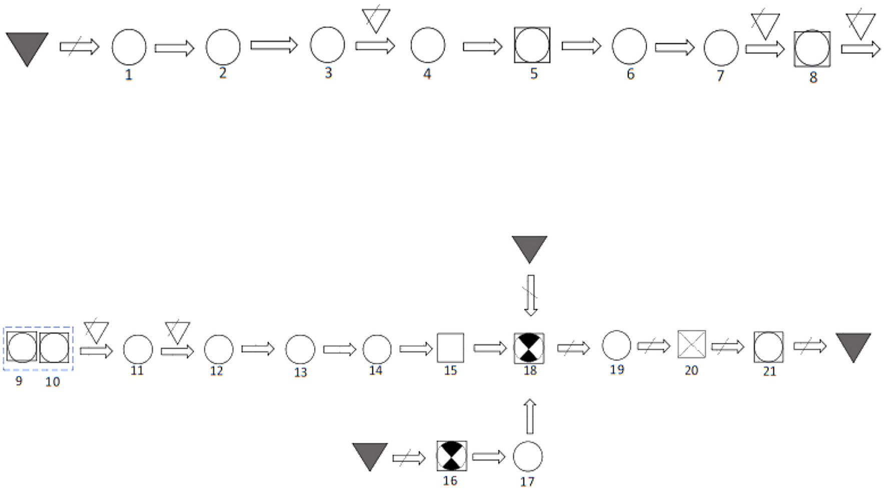


Figure 3. Technological approach to the production process of the bearing cage

Subsequently, the process goes through all the operations that are necessary to obtain the finished product and send the product to the customer. This is the stage where the manufacturing process ends. A schematically drawn manufacturing process in technological terms is shown in Figure 3. Each number, has a specific operation assigned to it. Table 2 is an explanation of what is done step by step to get the finished product.

Table 2. Stages of bearing cage production in technological terms

Number	Action
1	Punching the holes for needles
2	Machine straightening
3	Grinding
4	Cutting to size
5	Custom milling
6	Chamfering the edges of the basket faces
7	Straightening I
8	Bending (90°)
9	Hole punching for gear unit
10	Hand finishing of the holes for the gear unit
11	Straightening II
12	Packaging + shipping to cooperator [Phosphating].
13	Receipt of goods + Inspection after phosphatization
14	Filling with needles
15	Inspection for the possibility of rolling elements falling out
16	Assembling the gear unit
17	Finishing of the gear unit
18	Assembly of the gear unit with the cage body
19	Washing and conservation
20	Final inspection
21	Packaging

Mapping the production process of the bearing cage

In order to make a value stream map of the current state, it is important to prepare all the necessary information, which will then be included in the map. Based on the collected data, a value stream map was created for the production of bearing cages with a gear unit. It is illustrated in Figure 4.

Currently, the production cycle time for 10 pieces of bearing cages, 100 mm in length, having 50 needles is 389.3 min. In addition, 4 months are needed to fulfill the order of input materials for production. Also included in the cycle time are 52 days and a period of up to 1 year during which the components used for production are stored. The value-added time is 292.3 min plus the 30 days needed for the phosphatization process.

Figure 5 presents a value stream map in its current state, where areas, places of the process that can be upgraded in some way, and thus improve the quality / efficiency of the overall process, are marked.

Based on the value stream map created for the production process of HW 10 bearing cages with a gear unit, several improvement possibilities were identified. First, it is recommended to change the

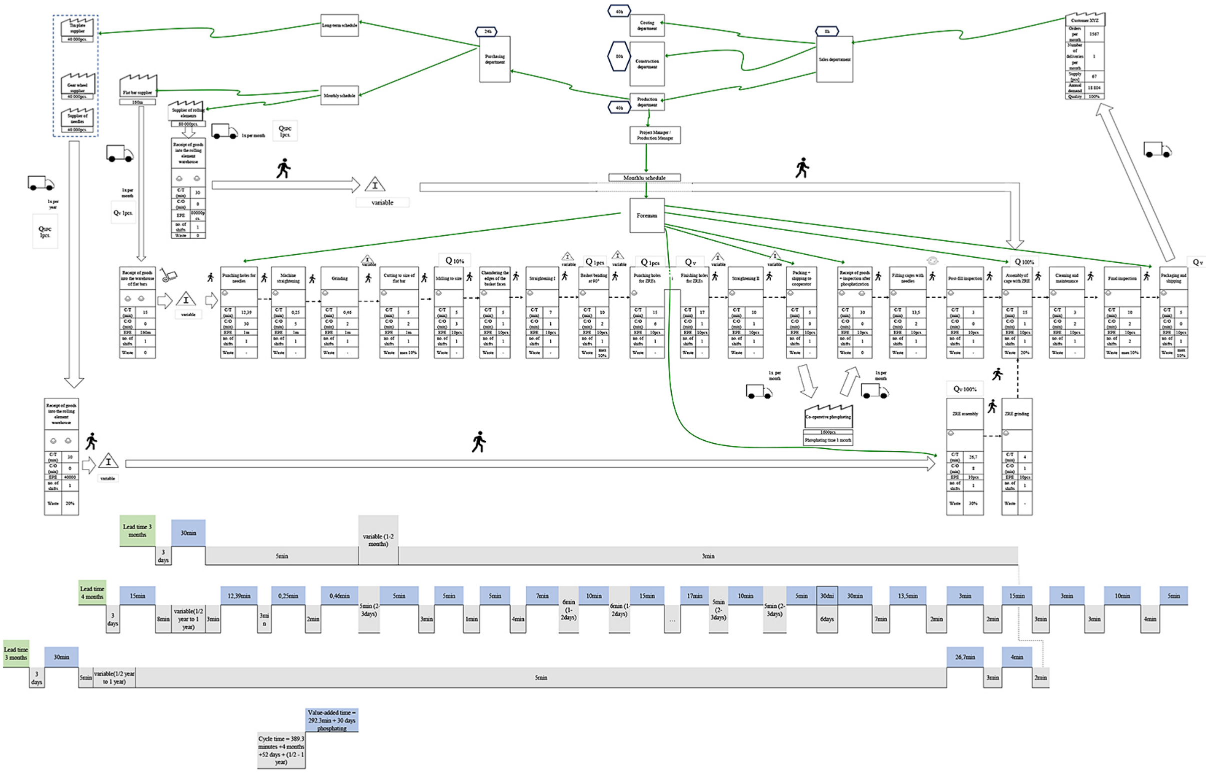


Figure 4. Value stream mapping – current state

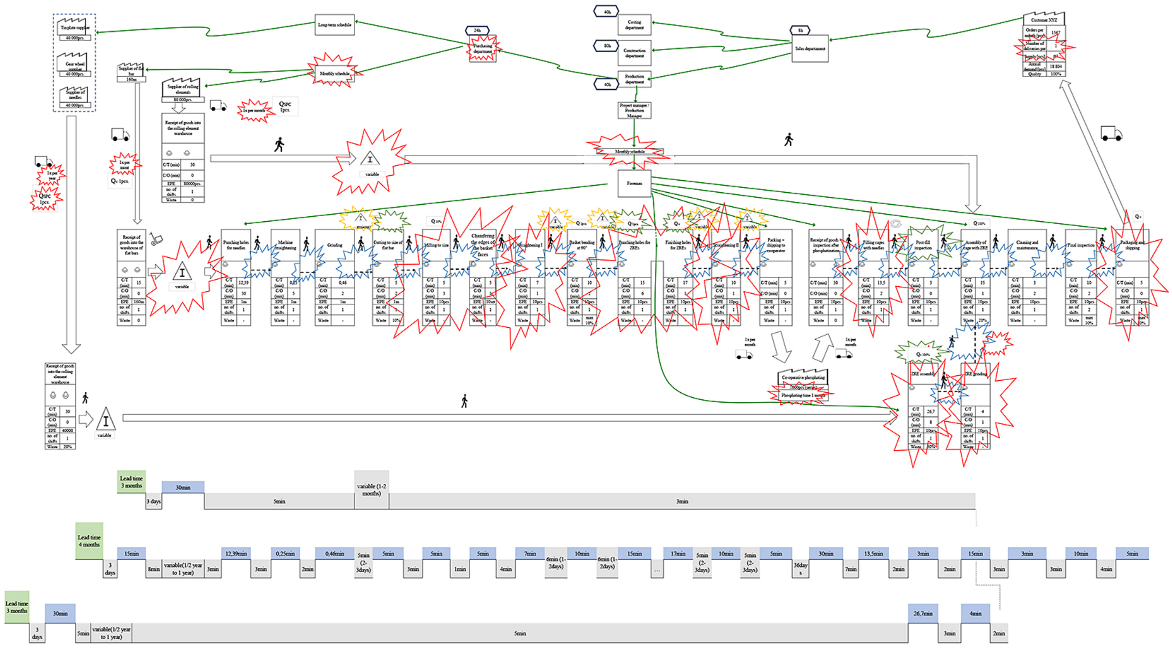


Figure 5. Value stream mapping – current status with marked possibilities for improvement

production method from a pushing system to a pulling system and to introduce KANBAN cards to enhance workflow management. The purchasing department should adopt a "go and see" approach to stock evaluation before placing orders. Production planning could be improved by determining daily production requirements instead of monthly targets and switching to weekly or daily production schedules. Similarly, delivery schedules for finished goods should align with a Just-in-Time (JiT) approach, occurring weekly or daily. JiT principles could also be applied to the supply of flat bars and rolling elements to eliminate unnecessary storage.

Stricter control of input materials should be implemented, alongside the introduction of the FIFO (First-In, First-Out) principle to optimize inventory flow. Efforts should be made to reduce the need for intermediate storage and introduce additional quality controls after the cutting stage. Streamlining processes at the milling and chamfering stages could eliminate excessive transport. Transitioning from manual to machine-based straightening for both shifts would improve efficiency. The inspection process for punched holes in gear units should be conducted at 100% accuracy, with clear criteria established for evaluating hole correctness. Moreover, the punching tool for gear units could be redesigned to eliminate the need for finishing and reduce changeover time.

Considering alternative cooperators for the phosphorization process might address bottlenecks in this area. Automation of the cage-filling process for rolling elements and the introduction of visual inspection directly at the needle-filling station would help eliminate unnecessary transport and feedback loops. Pulling gear units instead of pushing them would further align the workflow with lean principles. Establishing a feedback loop between unit assembly and manufacturing could help minimize excessive waste, while a change in gear unit manufacturing technology might improve overall efficiency. A stationary magazine should be introduced at the unit assembly station, coupled with a comprehensive gear unit inspection plan. Finally, improving lighting at the grinding station would enhance working conditions and potentially improve productivity. Based on its analysis of the feasibility and cost-effectiveness of the proposed changes, the company decided to implement several key improvements. For the purchasing department, a "go and see" approach was adopted to enhance stock evaluation. An additional weekly schedule was introduced, which is ultimately intended to serve as the master production schedule. Stricter control of input materials was established, along with the application of the FIFO principle. Quality assurance measures were enhanced by implementing a 50% inspection rate after the cutting stage. In the production process, excessive transport was eliminated at the milling and chamfering stages by optimizing working nests.

The inspection of punched holes for gear units was increased to 100%, with each piece temporarily set for inspection as a short-term solution. Additionally, the tool used for punching gear units is being redesigned to eliminate the need for hole finishing and reduce changeover time, with development currently underway. Instructions are being created to standardize the evaluation process for the accuracy of gear unit holes and the gear units themselves. Visual inspection was introduced directly at the needle-punching station to avoid unnecessary transport and loopbacks. Gear units are now being pulled through the process, supported by the introduction of KANBAN cards and a supermarket system.

To further streamline operations, a feedback loop was implemented between unit assembly and manufacturing to reduce excessive waste. Lighting at the grinding station was improved to enhance working conditions. Inter-operational storage was minimized, leaving only one necessary storage point between the straightening and 90° basket-bending stages. A stationary magazine was introduced at the unit assembly station, and a new tool for gear unit assembly was implemented. JiT supply systems are under consideration, with efforts underway to establish cooperation with a nearby company to facilitate their implementation. Pull production and the use of KANBAN cards are in the process of being fully implemented. Lastly, the company is exploring the possibility of engaging another subcontractor for the phosphatization process and is actively searching for suitable alternatives. The implemented changes are illustrated in Figure 6.

After the changes, the production cycle time for 10 pieces of bearing cages, 100 mm long, having 50 needles is 320.1 min. In addition, 4 months are needed to fulfill the order of input materials for production. Also included in the cycle time are 41 days and up to 1 year during which the components used for production are stored. The value-added time is 241.1 min plus the 30 days needed for the phosphatization process.

RESULTS

The use of tools such as VSM, logical map and technological view of the process brought significant benefits in terms of optimizing production processes and improving product quality. Identified bottlenecks and waste have been effectively reduced, which allowed the company to achieve

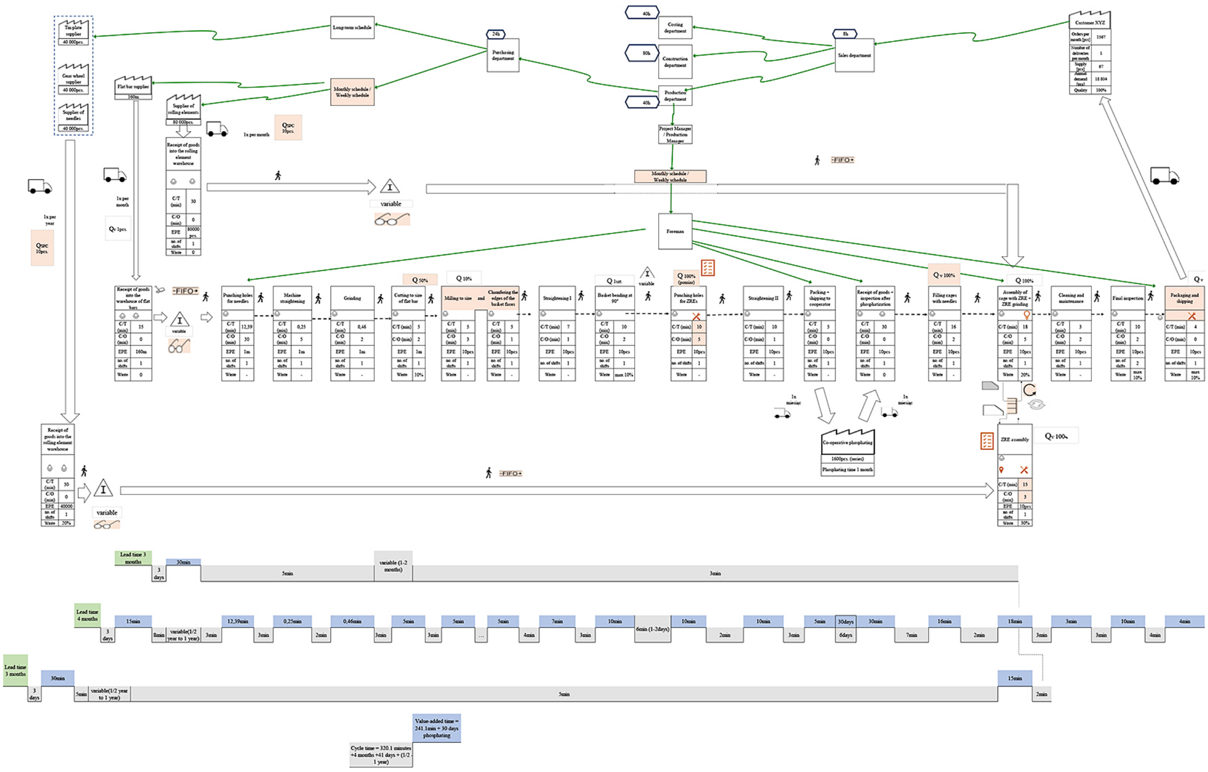


Figure 6. Value stream mapping – future state

its goals. The results of the study confirm that a systematic approach to analyzing and optimizing production processes is key to increasing a company's competitiveness. In the future, it is worth continuing to monitor and improve implemented solutions and invest in new technologies to maintain high quality and production efficiency.

Based on the analysis of the production process of the bearing cage with the gear unit, it was noted that there are many places that can be changed, in order to achieve better results. The results achieved based on the changes made so far, as to the reduction of times are shown in Table 3.

Value-added time decreased by 51.2 min, and cycle time by 69.2 min and 11 days, due to the elimination of inter-process storage. As can be seen, continuous flow achieves high results on the duration of the entire product manufacturing cycle.

On the basis of frequent problems as to the input materials for the designs, increased control at the input also helped to increase the quality of the products and eliminated the problems encountered in later stages of production with the fit of the units in question. The quality of manufactured products was also influenced by the introduction of uniform instructions on how to control the results obtained after the various stages of production.

It turned out to be crucial from the point of view of cycle time and quality to change the tooling on the gear unit assembly station, as well as the punching of the hole for the component. The tools used previously proved to be outdated and unable to meet the accuracy and productivity requirements. Also, changing the production system from push to suction-pull and creating a supermarket made it possible to achieve a smoother flow of components between assembly stations. One significant issue identified internally is the inability to accurately determine the time required for machine changeovers. This is a critical oversight, as changeover time does not contribute any value to the finished product and is, therefore, a form of waste that should be minimized or eliminated. Addressing this inefficiency is essential for further process improvements. Additionally, consideration should be given to implementing a JiT system to reduce unnecessary movement and storage of input materials, which further streamlines the production process.

Another notable observation is the absence of a dedicated person responsible for replenishing materials at specific workstations. Currently, each operator must leave their workstation to retrieve the necessary materials from the warehouse. This practice is highly inefficient, as it requires operators to halt machine operations and spend valuable time locating input materials. This interruption not only affects the productivity of the individual but also impacts the overall workflow. Assigning a dedicated materials handler would help resolve this issue, ensuring that operators can focus on their tasks without unnecessary delays.

The process has been able to improve to some level, but even more optimization is possible after more detailed observations and accurate time measurement of the entire production process. In addition, the company should consider developing the quality management system it currently has. The main features of the contemporary approach to quality management are:

- the application of quality management procedures to all management issues, including the establishment of policies, strategies, organizational structure and the formation of a work culture all employees are involved in quality assurance,
- prevention of problems rather than their removal,
- the main responsibility for quality assurance rests with management, which initiates and organizes quality improvement activities,
- a sense of shared responsibility providing job satisfaction and increasing motivation,
- knowledge of customer expectations and requirements is collected,
- quality pays for itself,
- the goal is to produce "no shortages" through continuous improvement,
- planning the process in such a way that it is "right the first time".

On the basis of this article, it is possible to see the great effectiveness and validity of carrying out systematic quality management activities. These activities make it possible to capture the problem areas that reduce the efficiency of a given production process. A good tool that does not require a lot of money is Value Stream Mapping,

Table 3. Times after improvements

Value-added time	51.2	min		
Cycle time	69.2	min	11	days

which illustrates the current course of production and allows a clear presentation of what is currently the problem and what improvements to make, in order to achieve better results.

CONCLUSIONS

The implementation of VSM in the production process of bearing cages has demonstrated significant advantages in optimizing both efficiency and product quality, even within the constraints of limited production time. By thoroughly analyzing and redesigning the workflow, we achieved a substantial reduction in value-added time. Value-added time was reduced by 51.2 min and cycle time was reduced by as much as 11 days and 69.2 min.

These improvements not only highlight the versatility and effectiveness of VSM as a lean manufacturing tool but also underscore its impact on addressing production bottlenecks, reducing waste, and enhancing overall process transparency. The integration of VSM into the production process ensures that resources are allocated more effectively, promoting a culture of continuous improvement and operational excellence.

By applying VSM, the production process is now more agile, responsive, and aligned with the growing demand for high-quality bearing cages in competitive markets. This case study reinforces the importance of adopting lean methodologies like VSM to drive sustainable growth and maintain a competitive edge in the mechanical manufacturing industry.

The application of VSM in improving production processes is widely recognized as one of the key tools in Lean Management. This tool enables the analysis and optimization of material and information flows, identifying areas of waste (muda) and pointing out potential improvements. The analysis conducted in this study confirms that VSM is effective in streamlining production processes; however, its efficiency depends on several key factors that require detailed discussion.

In this study, the implementation of improvement actions based on the value stream map yields the best results, when it incorporates the experience of machine operators and production workers. Additionally, it is important to consider the role of technology in facilitating the mapping process.

In conclusion, while VSM is a versatile tool for improving production processes, its effectiveness largely depends on the context of its implementation. It requires proper team engagement, the use of available technologies, adaptation to process specifics, and the establishment of an organizational culture that supports continuous improvement.

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