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DEVELOPMENT OF SUSTAINABLE PRODUCTION SYSTEM USING VALUE STREAM MAPPING: A CASE STUDY

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Abstract: Many logistics companies have faced intense competition in the domestic and international markets due to the effects of globalization and the rapid development of technologies. In order to achieve a competitive advantage over other companies, managers transform their organizations by applying some management philosophies, such as the Just-In-Time philosophy, the Six Sigma concept, Lean Manufacturing Systems, etc. The group of lean tools consists of numerous techniques and approaches for business improvement. One of the most commonly used is Value Stream Mapping, which is implemented in this paper. Paper analyzes the production system of a company in Serbia that deals with plastic processing. The company's current state was analyzed using VSM, and as a result, potential areas for improvement in the production process and internal transportation were identified. In order to improve the production process, the paper suggests solutions to the problems that were pointed out, led by the flexibility of combining VSM with other methods as one of its key strengths. The results indicate that a system configured according to the ideal VSM would produce more products per shift, reducing waste, delays, and total costs to achieve sustainable production. This paper identified some of the key potential gaps as guidelines for further research in this area.

Keywords: value stream mapping, production system, internal transport, improvement.

1. Introduction

According to Toyota's founder, Chiharu Ohno considered lean manufacturing is a sustainable alternative that can produce profits for the companies in the supply chain. It involves looking at the timeline of the order that the customer gives us, as well as the reduction of waste by removing non-value-added materials, as stated by Ramesh and Kodali (2012). One of the most effective lean manufacturing methods for fast evaluation of products and information flow from door to door is Value Stream Mapping (VSM). This flexible and effective technique is used to represent product flows as snapshots. It merely describes the production behavior within a specified time frame relative to the entire production time. The potential application of VSM in production industries will be discussed in this paper. By reviewing the literature, it was observed that more and more authors are dealing with VSM, not only in theory but in its practical use. According to Andrejić *et al.* (2021), this tool is not too/extremely expensive to implement,

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which is why managers of many companies identify it as a simple method for improving current processes. For these reasons, this paper will take a look at a real production system and attempt to improve it using VSM. This would show the company's managers that it is possible to improve the functioning of the entire factory by eliminating waste in the production process while increasing the capacity of individual resources if necessary.

The paper is structured as follows: after the introduction in the second chapter, there will be a review of the literature on this topic. In the literature review, papers were analyzed in which VSM was used to solve similar problems. After that, the third chapter follows a description of the company whose production process was chosen as a case study on which the VSM tool will be applied. The analyzed company deals with plastic processing, and within its production system, the production part of article X will be selected. The complete process of plastic production will also be described in this chapter. The practical use of VSM tools will be presented in the fourth central chapter. Within that chapter, the current state of the production process in the company will first be reviewed using the VSM map of the current state. When looking at the current state, it is necessary to identify potential areas of improvement in the production process and propose improvement measures, which will also be done using VSM in this case. The potential ideal state of the system will be presented as a VSM of the ideal state. Ideal VSM represents the direction of continuous improvement towards sustainable production from all aspects (economic, ecological, social, etc.). At the very end, the improvement results obtained with the VSM tool will be discussed, and some directions for future research will be given.

2. Literature Review

This paper aims to describe the application of VSM in the production process to its improvement. Therefore, the literature related to the application of VSM with special attention to manufacturing is critically reviewed. Castillo, (2022), Dinesh *et al.* (2022), and others have published research on Lean and the application of VSM in manufacturing industries and supply chains. In recent years, the application of VSM has spread to many industrial sectors due to its ease of adaptation to a variety of environments. VSM can be applied to solve different types of problems related to waste reduction in different industries, from medicine and agriculture to mechanical engineering and logistics. This group consists of the papers by the following authors: Marin-Garcia *et al.* (2021), Melin and Barth (2020), and Stich and Groten (2015). The following is an overview of papers in which different authors dealt with the application of VSM in the field of logistics, primarily in the domain of production systems, intending to reduce all types of waste within them.

Verma and Sharma (2016) used VSM as a tool to develop sustainable manufacturing. In their research, they used the concept of VSM to look at unproductive processes that waste energy. They developed a method that enables a quick, easy, and comprehensive analysis of energy and material flows within production processes. The paper reviewed the improvements achieved in the observed processes in terms of eliminating waste of resources and waste. Tyagi *et al.* (2015) applied VSM as a tool to eliminate activities that do not add value to product development processes. Gas turbine production is considered to illustrate and justify the use of the proposed VSM-based framework. To achieve this, first of all, they developed a map of the current situation, which they used to investigate the places of occurrence of waste and their causes found during production. At the same time, a map of the future state was developed with the elimination of all losses and inefficiencies. In addition to numerous intangible benefits, they estimated that the VSM framework would lead to a 50% reduction in production time.

A significant number of authors dealt with the application of VSM to reduce losses in the food supply chain, with a special emphasis on production. Within the applied VSM, they looked at the year and country of production and the activities that led to the appearance of waste in the food production process. One of the more significant paper that considered this problem is the paper of De Steur *et al.* (2016). Abdoli *et al.* (2017) applied dynamic VSM within a warehouse system. They performed an analysis of all activities from receiving to shipping of goods, to see which activities do not add value to the goods, eliminate them, and thereby improve the storage system. Andrejić *et al.* (2021) in their research, conducted a comparative analysis of the processes of manual ordering and automatic ordering using VSM. The case study they observed refers to a real system: a retail chain in Serbia. The research results show significant savings in various activities and a total time saving of 92.31%.

By developing a dynamic VSM, it is possible to examine systems that are more complicated than those analyzed by a classical VSM. Simulation can be used with VSM to increase flexibility and dynamically change the state of the system. An example is the work of Ramadan *et al.* (2012). In their work developed a dynamic VSM using RFID technology. Furthermore, some works, such as Fallas Valverde (2019), deal with the application of VSM in a specific industry. In his work, Fallas Valverde applied VSM to the wood industry to increase its efficiency. Many authors have applied VSM in combination with various MCDM methods with the aim of increasing system efficiency. Fukuzawa (2020) applied VSM to identify and resolve bottlenecks in individual functions and departments, primarily in production processes. The goal was to increase the value of the entire supply chain. Lu *et al.* (2011) used a combination of MCDM methods and VSM to optimize the ordering process in one supermarket chain. Gurumurthy and Kodali (2008) used the VSM tool to measure the quality and success of production system alternatives generated by MCDM methods. There are numerous papers where the authors use the DEA method in combination with VSM to evaluate the efficiency of the system. One of the more significant investigations is by Pattanaik and Koteswarapavan (2020). Regarding the manufacturing environment, previous studies justify the use of VSM in several industries by identifying its successful applicability to real-world examples. According to the aim of the paper, the possibility of increasing the efficiency of the production system in the real system will be considered.

3. Case Study

In this chapter, a company whose production process will be improved with the help of VSM tools will be presented. Basic information about the company, its operations, and production technology is provided. A detailed analysis of the specific production process was carried out, which was described from receiving the order for production to the finished product. The production process will be shown in the form of a diagram, where the sequence of each activity can be seen in detail. The analysis is followed by the definition of potential areas of improvement from the aspect of the production process and internal transport.

3.1. Company Description

The company that will be analyzed in the paper operates in Serbia and its primary activity is the processing of plastics. The name of the company is protected by the company's business policy, as well as all internal documents of the company that were used during the creation of the paper. In its production plan and program, the analyzed company has a wide range of products for the needs of almost all economic activities: construction areas; chemical, food, automotive, and arms and military equipment industries; agriculture; wastewater processing; production of electrical appliances; packaging; sanitation; and furniture parts. The final products of this company are present not only in all countries of the region (Southeastern Europe) but also in the markets of Western Europe, primarily Austria, Belgium, and Norway. Also, the analyzed company's products, as components built into various devices, are distributed in about 50 countries around the world, including the USA and Russia. The company has certificates for the quality management systems ISO 9001:2015 and SORS 9000/14, as well as the certificate ISO 14001:2015.

For this paper, a group of plastic products was selected for further analysis. Within that group, the selected ***article X*** was selected for detailed analysis. The reason why ***article X*** was chosen for analysis is its participation in the volume of business, with about 75%, according to the company's report for the first half of 2022. The observed company applies several different product manufacturing technologies in its production. The choice of technology for production depends on the material from which a certain product is made. The technology applied to article X is:

- **Injection of thermoplastic materials—thermoplastics**

Injection molding of thermoplastics is a physical process where plastic granules are softened under the influence of temperature and then injected into a mold under pressure. The mixture takes the form of a mold during cooling and drying. In the analyzed company, ABS material is used for ***article X***. The injection molding process processes many materials, mostly thermoplastics:

- PVC – Polyvinyl-chloride;
- ***ABS - Acrylonitrile Butadiene Styrene;***
- PS – Polystyrene;
- PC – Polycarbonate;
- PE – Polyethylene;
- PP – Polypropylene; and
- PA - Polyamide.

3.2. Process Analysis

Figure 1 shows the production process of ***article X*** made using thermoplastic injection technology. The production process is presented in the form of a diagram and shows only the production of the housing (*main component*) of ***article X***. The diagram presents all the instructions and necessary information for the personnel who implement the technological process. In addition to the technological process, the diagram shows a list of all activities that are implemented.

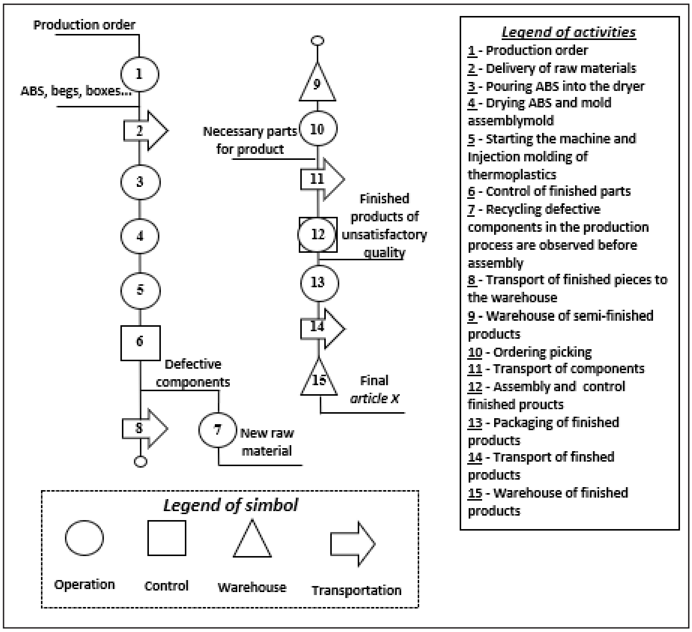

Fig. 1.
The Production Process of Article X

The production process begins with the making of a production order. After receiving the production order from the sales department, operational preparation issues a production work order (1). Based on the received order, the employee from the production sector delivers all the required materials that are necessary for the work (2). For the analyzed product, it is necessary to deliver ABS raw materials, boxes, and other auxiliary materials. At the beginning of the production process, it is also necessary to deliver the mold into which the thermoplastic is injected. A forklift is used for the implementation of these operations. After the delivery of ABS, it flows into the machine that realizes the drying of the material (3). At the same time, the assembly of the mold and the preparation of the workspace are carried out by an employee with a cantilever crane (4). After the material has dried, it has flowed into the tank of the machine, and the thermoplastic injection into the mold begins gradually. The machine is semi-automatic, so the software of the machine itself has memorized the parameters of this product from the previous production cycle. The employee adjusts the machine according to the technological procedure and the technical card located next to the machine. When setting the production parameters, it compares the technical specifications of the product with the data remembered on the machine (5). Some of the parameters that are entered before injection molding are:

- The injection temperature ranges from 190° to 230°;

- The injection pressure;
- The dose - the amount of material ingested; the injection speed; and
- The duration of chamber cooling is expressed in hours.

After setting all the parameters, the employee adjusts the machine into operation. At the end of the machine operation, the employee opens the mold and takes the finished part (6). The resulting part of the product is removed from the mold, finished if necessary, and placed in the prescribed packaging, which is moved to the next workplace by a conveyor belt. The employee is obliged to check whether the obtained piece meets the required affinities by visual inspection. The employee checks whether the piece is cast in its entirety, whether there is any irregularity on the surface of the piece, a gap, or the like. The product is packed in a bag and all together in a cardboard box. Parts that are of unsatisfactory or defined quality are deposited by the worker in the designated container, and such parts are cut up and sent for recycling. Recycling is done in a mill where the parts are ground and shredded to obtain new regenerated material (7). The regenerated material obtained is used for another product that is less demanding in terms of quality.

Finished parts that have passed control, after filling the entire pallet, are transported (8) to the semi-finished product warehouse (9). The resulting piece, the housing of article X, is assembled with other parts (components) (10) and transported to the assembly department (11). In the assembly department, in addition to assembly, control of the assembly is also carried out at the same time (12). At the end of the analysis process, article X is completed with all the accompanying parts. Belt conveyors are used for the movement of components during assembly. After assembly, each finished article X is placed on the line for testing where its operation is simulated. If the product after control meets the quality standards, it is packed on a pallet in the amount of 50 parts (13). After that, the pallet is transported (14) to the warehouse of finished products (15).

3.3. Problems in the Production Process

Within each system, there are numerous potential areas for performance improvement. Such places can usually be called “problems” in the production process. The causes of problems can be numerous, but in the literature, they are most often grouped into the following categories, according to Stich and Groten (2015) and Gurumurthy and Kodali (2008):

- Human factors: incompetence, delay, ignorance of the process, mistakes, etc.
- Technology: machine failure, outdated production technology, etc.
- Information: inadequate hardware and software, information delay;
- Resources: disappearance, lack of energy.

It is necessary to analyze the current state of the company to identify problems in production and potential areas of improvement throughout. The analysis of the current state of the production process was carried out by recording the real state of the system and surveying the employees. A comprehensive survey of employees about challenges and potential problems in the company was carried out by conducting interviews. Five different problems in the production process were identified. Observed problems or gaps can be grouped into two categories:

1. Problems affecting the production process:

<u>Human factor (P1):</u> *damage during assembly, bad components* – During the assembly of ***article X***, some components are damaged but some of them could be of unsatisfactory quality. This can lead to a poor seal or an inability to finish the assembly process. During the simulation of functioning, it was observed that gaps and mistakes in the sealing caused water leakage during the operation of ***article X***. The consequence of that are products of unsatisfactory quality, thereby reducing system productivity and prolonging the production cycle. By analyzing the current situation, it was observed that during one shift, an average of 85 parts of ***article X*** are produced, of which an average of 4 parts can be characterized as finished products of unsatisfactory quality.

<u>Technology (P2):</u> *overheating of the machine* (*inadequate technological condition*): Due to the overheating of the machine that injects thermoplastics during injection molding, defects occur on the piece that can be characterized as of unacceptable quality. Similarly, production can be stopped until the machine temperature returns to a defined range to resume operation. The main consequence of this is the extension of the production cycle, including the reduction of production capacities. In the observed system, an average of 7 waste components per shift is observed in the production process before installation.

<u>Resources (P3):</u> *low voltage electricity*: In the company, the current electrical installation is quite old (*more than 25 years old*), so the electricity is often low voltage. Low voltage increases the drying time of raw materials. Due to the low voltage, it is observed that the drying of the material takes an average of 23 minutes longer (*based on previous observations*).

2. Problems affecting the realization of industrial/internal transport:

<u>Technology (P4):</u> *falling of raw materials from the pallets*: At the start of the production process, during the delivery of ABS material from the warehouse of raw materials to the material drying machine, there is a frequent occurrence of the fall of the canister with ABS from the pallet. The canisters with ABS that the observed company receives from the supplier are of an irregular shape and therefore need to be palletized upon receipt. The fall of the canister can significantly increase the time of the production process because on one pallet there is the raw material that is necessary for one shift (*1420 kg*). Due to the fall of the canister, the time required to eliminate the consequences is an average of 11.3 minutes. In addition, the drop in raw materials leads to packaging damage causing additional costs. The frequency of these downtimes shows that a package falls every 5 forklift cycles (*20%*) for 10 working days.

<u>Technology (P5):</u> *technological state of the belt conveyor*: The belt conveyor connects the workplaces within the assembly process of ***article X***. The conveyor is in very poor, worn condition, which slows down the transport of component parts between workplaces. A special problem is a small width of the belt (*about 0.5 m*), which allows the transport of only one component, reducing productivity.

<u>General and individual goals are defined according to the observed problems in the company.</u>

<u>General goals</u>: reduce the amount of waste and low-quality parts during production; remove all interferences that were observed when recording the operation of the system; reduce the duration of certain activities; and increase the capacity of the production system.

Individual goals: regular maintenance of production machines and equipment and, as needed, procurement of new machines and equipment; improved organization of the shipment of goods from the warehouse; handling preparation.

4. Value Stream Mapping Method – its Significance, Place, and Role in the Intralogistics System

VSM provides a valuable visual representation of the process of goods movement from the customer's order to the final fulfillment of his request. The process of process mapping deepens the understanding of the work systems that deliver value to customers and provides a new perspective from the customer's point of view. As a result, creating a value stream map can be effective for making better decisions and designing work processes.

It is necessary to map the movement of materials throughout the entire company. Analyze the flow of materials from the place of reception of the raw materials to the delivery of the finished product to the customer. It is an important step in VSM because it helps to identify waste and locate where it originated. VSM uses a simple visualization to represent the value stream and enables the collection, analysis, and presentation of information. This tool allows all stakeholders, from the newest associates to the most senior associates, a graphical way to visualize the process, making it easier to understand (Nash and Poling, 2008). It is used as an effective method to evaluate the effectiveness of the observed process; this is done by removing real waste and demonstrating what the process might look like if the waste was removed, as discussed by Hines et al. (1999). VSM is a tool usually used in the lean approach. Martin and Osterlingv (2014) describe the value stream as a series of activities that fulfill a user request, where material and information flows are analyzed. These activities include the design, manufacture, and delivery of the product or service. The value stream reflects the basic product flows; the production flow from raw materials to the customer and the design flow spanning from concept to launch. Rother and Shook (2003) say that all these activities are classified as non-value-adding or value-adding. The goal of a VSM is to identify where non-value-adding activities occur and their effect on the overall value-adding functions. This visual tool helps analyze and redesign manufacturing and supply chain processes.

There are several key features of VSM that deserve mention. First of all, the VSM must be created by a multidisciplinary team that includes frontline employees. One of the core principles of lean is that empowering front-line employees to lead improvement efforts creates a cultural transformation in the organization toward one of continuous improvement. Furthermore, frontline workers understand the process in more detail than managers. Second, the VSM must be detailed enough to allow the identification of all non-value-added steps. The cumulative improvement from many small changes makes lean an important tool for sustainable business. Third, for each step in VSM, the team must consider whether the step brings value to the company and whether there is a more efficient option. VSM is divided into two parts, which will be briefly explained in this paper. The first is the current state map, which represents the current flow of the process. The second is the future state, which is a future vision of what the value stream should look like after the company makes improvements. By implementing improvement measures, the state of the system changes and tends to reach the VSM ideal. As such, VSM represents a continuous improvement, Lee *et al.* (2014) concluded in their research, Simon and Canacari (2012), and others.

4.1. VSM Current Situation

Within the framework of the mapping, the emphasis was on the time component, that is, the duration time of each activity. In this paper, VSM will be performed within one shift. Mapping of all key activities within the observed production process will be carried out. The output from the system is the number of completed parts, the number of component wastes in the production process observed before the assembly of ***article X***, the number of finished products of unsatisfactory quality, and the number of employees within the shift.

Figure 2 indicates an overview of all activities with time duration within the analyzed production process. The times are expressed in minutes (per shift, per part, per pallet), and the observed period is one shift lasting 8 hours. The analyzed company operates in 3 shifts daily. Based on this, any time saved in one shift will have a significant impact on time savings on a weekly basis. Figure 2 also indicates the engagement of resources during the realization of each activity. The analysis does not include activities that last a very short time, are implemented simultaneously with the already analyzed activities, and are assumed to not have significant importance for the whole production process. Some of those activities are taking tools, moving products by workers, packing products in boxes, etc. These activities don't have significant impacts on time and cost savings.

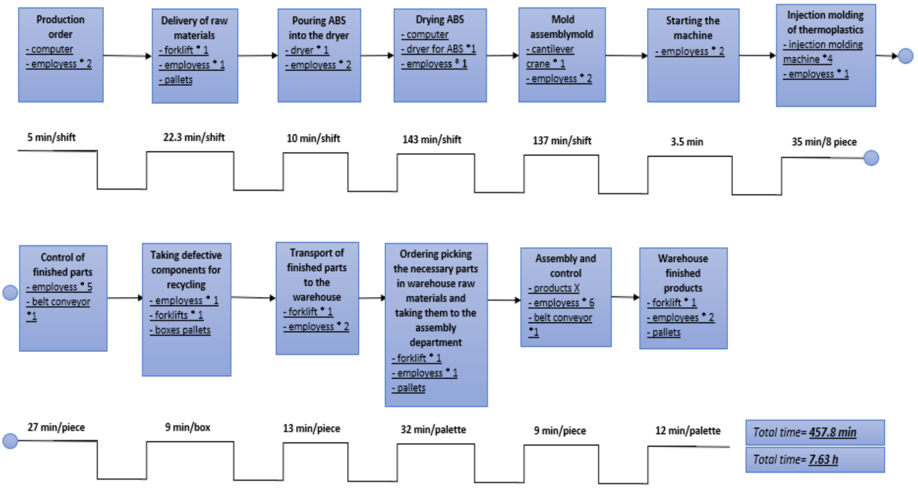

Fig. 2.
VSM Current Situation

The duration of the activity was obtained by recording the system in the company's production processes, whereby the mean value of the duration of the activity was taken for 10 working days. The analysis includes the delivery of raw materials as one activity during the shift. As all other transport activities are realized simultaneously with other activities in the VSM, the duration of each of those activities is taken in the case when they are realized for the first or last time during the shift. The activities considered in the analysis are:

- Production order – average time **5 min/shift**;
- Delivery of raw materials – average time 8 min + 14.3 min (time od interrupts) = **22.3 min/shift**;
- Pouring ABS into the dryer – average time **10 min/shift**;
- Drying ABS – processing 240 min – 137 min (model assembly mold time) + 23 min (time od interrupts) = **143 min/shift** (The mounting of the mold is done during the drying of ABS. For this reason, in the analysis, the drying time of ABS is reduced by the duration of the mounting process);
- Mold assembly mold – average time **137 min/shift**;
- Starting the machine – average time **3.5 min**;
- Injection molding of thermoplastics – average time **35 min/8 piece**;
- Control of finished parts – average time **27 min/piece**;
- Taking defective parts for recycling – average time **9 min/box**;
- Transport of finished parts to the warehouse – average time **13 min/piece**;
- Ordering picking the required parts in warehouse raw materials and taking them to the assembly department – average time **9 min/pallets**;
- Assembly and control ***production X*** – average time **32 min**;
- Warehousing finished products – average time **12 min/pallets**.

After mapping the value stream of the production process, it is possible to determine the characteristics of the system in one shift. The following Table 1 provides an overview of the main characteristics of the production system. The obtained data shows that the total time needed to make 85 finished products is 7.63 h. During this, 27 employees were hired. After the injection molding process, there are on average 7 parts of waste components in the production process observed before assembly, after which they are recycled. It has been noted that during the assembly and testing of article X, an average of 4 finished products of unsatisfactory quality appear, which is due to bad components or damage by workers during assembly.

Table 1
Characteristics of the System by Shift

Total time duration	7.63 h
Number of employees	27 employees
The number of component wastes in the manufacturing process was observed before assembly	7 parts
Number of finished products of unsatisfactory quality	4 parts
Number of finished products	85 parts

To see the success of the business of the observed company, it is necessary to calculate the utilization of the system and resources that indicates in Table. The obtained data shows the production time is 95% of the total working time. As the number of waste components in the production process observed before installation is 7 out of 85 totals produced during the shift. The number of finished products of unsatisfactory quality is 5, and the percentage of these errors is 8.2% and 5.9%, respectively. As it takes 457.8 minutes to produce 85 parts of finished products, the average time per product is 5.39 minutes. The data given in the table serves as a basis for comparing systems before and after improvement.

Table 2

System Utilization

System characteristics	**Utilization (%)**
Using of working time	7.63/8=95%
Percentage of waste components in the manufacturing process observed before assembly	7/85=8.2%
Percentage of finished products of unsatisfactory quality	5/85=5.9%
Takt time	(457.8)/85=5.39 min/piece

4.2. VSM Ideal Situation

After analyzing the current situation within VSM, the goal is to analyze each activity and see which and how it can be acted upon to shorten the time of its realization. The activities that will be taken into the further analysis are those activities within which the existing problems were defined in the previous part of the paper.

- ***P1***: The causes of waste are low-quality components and damage by employees. Production of defective components can be eliminated by introducing a Kanban system, which would leave such parts in the semi-finished warehouse, where they would not be put in the order picking or later in assembly. The Kanban system improves communication between workers by using cards on which each worker enters data on what has been done and in what state the part was done. It is estimated that the introduction of the Kanban system would reduce waste components **from 5 to 2 parts per shift**. Human error can be eliminated by introducing automatic assembly and testing systems, and thus the productivity of the assembly system can be increased. Since such systems themselves are very expensive, it is not realistic to consider them.
- ***P2***: About 40% of poor castings are caused by lousy mold shape, while the other 60% are the staff responsible (*due to mistakes in data entry*). Changing the mold alone would reduce the casting of defective parts **from 7 to 4 per shift.**
- ***P3***: The factory operates in a building that is over 25 years old and therefore the electrical installation is in poor condition. One of the solutions to this problem is related to modifying the entire installation of the facility. Due to high costs, a more favorable option is the installation of current transformers in the company. The transformers will ensure a stable voltage, which is necessary for

production. The implementation of this solution enables the realization of ABS drying in the prescribed time. It would reduce the current drying time by about **23 minutes**.

- ***P4***: At least two realistic solutions to this problem are available. The first is to replace the existing EURO pallets with box pallets and to eliminate the chance of the load falling off the pallet. Another solution is to replace the forklift gripper. Instead of the existing ones, it is necessary to install grippers that enable direct gripping of the canister without the use of pallets. This way of handling the canisters eliminates the possibility of the load falling. When choosing a solution in this situation, it is necessary to examine the technical and operational characteristics of the forklift and whether it supports the appropriate gripping device.
- The company supplies raw materials (ABS) every week. In one delivery, the observed company received 27 canisters of ABS. In that case, it is necessary to provide 30 box pallets. As the cost of 30 box pallets is higher than the investment in forklift grippers, it is obvious that investing in improving the equipment is a more favorable solution here. The use of box pallets would be more profitable for a longer time, but the acquisition of the gripping device can be realized in a shorter time. The implementation of this solution would completely eliminate interruptions caused by falling raw materials from pallets. The potential time saving that would be achieved in this case is the **shortening** of the duration of this activity by on average **14.3 minutes**. This time is needed to eliminate the damage due to the realization of this problem and re-delivery of raw materials to the workplace. The expected reduction in the duration of the realization of this activity was calculated at 64%.
- ***P5***: A solution that can be implemented in the short term is to replace the existing belt conveyor with a new one that has twice the width of the belt or to add another belt conveyor next to the existing one. Given that the technical condition of the existing belt conveyor is not at an enviable level, looking in the long term, it is more profitable to buy a new conveyor. In the current state, there is a possibility to keep both belt conveyors, and over time, completely switch to a new one. The goal of this solution is to increase the capacity of the system in the segment of product assembly and testing. It is possible to realize this in practice, but it is too expensive. In the conversation with the employee, it was concluded that when implementing this solution, the installation time would be about 40% shorter (***from 9 minutes to 6.7 minutes***), and the capacity of that segment would increase by about 55%. The implementation of this solution would require an increase **in the number of employees from 6 to 8** in this part of the production system.

The implementation of previously defined solutions that are characterized as cost-effective would lead to the savings presented within each solution, as well as to an increase in productivity. Figure 3 shows the duration of all defined processes after the implementation of improvement measures (*those whose implementation was said to be cost-effective and possible*).

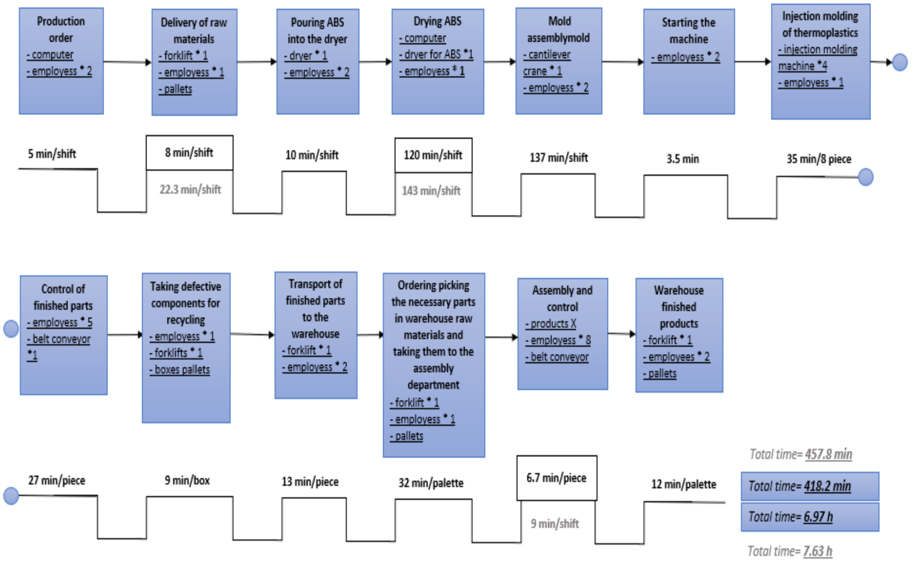

Fig. 3.
VSM Ideal Situation

After completing the VSM and improving the production process, it is necessary to determine the characteristics of the system so that the obtained results can be compared with the results before improvement. Table 3 provides an overview of the main characteristics of the observed production. The obtained data shows that the total time needed to realize the production process would be 418.2 minutes. In this case, 29 workers would be hired, who would produce 94 parts in the observed time. Due to the replacement of the mold for the casting process after the injection molding process, an average of 4 component wastes would appear in the production process before installation, which is further recycled. Due to human errors damaged during assembly, an average of 2 finished products of poor quality would be produced during the article X assembly and testing.

Table 3
Characteristics of the System by Shift after Discussed Improvement

Total time duration	6.97 h
Number of employees	29 employees
Percentage of waste components in the manufacturing process observed before assembly	4 parts
Number of finished products of unsatisfactory quality	2 parts
Number of finished products	94 parts

To see if the improvement in the production process of the observed company has been successful, it is necessary to calculate the utilization of the system and resources. The following Table 4 shows the percentage utilization of resources and the success of the system. The obtained data shows that the time spent at work amounts to 87.13% of the total time of the shift so that the existing number of employees can be engaged in other activities or the capacity of the existing one can be increased. As the number of waste components in the production process observed before the final product was assembled was 4 out of 94 totals produced during the shift, and the number of finished products of unsatisfactory quality was 2, the share of these errors is 4.3%, and 2.1%, respectively. Since it takes 418.2 minutes to produce 94 finished products, it can be concluded that each finished product needs 4.44 minutes.

Table 4

System Utilization after Improvement

System characteristics	**Utilization (%)**
Using of working time	6.97/8=87.13%
Percentage of waste components in the manufacturing process observed before installation	4/94=4.3%
Percentage of finished products of unsatisfactory quality	2/94=2.1%
Takt time	418.2/94=4.44 min/piece

Table 5 compares the characteristics of the system before and after the implementation of the proposed solutions. The following indicators were compared: total time duration of the production process; the number of workers; the number of waste components in the production process observed before assembly; the number of finished products of unsatisfactory quality; the number of finished products in one shift; and average time per product.

Table 5

Compared the System's Characteristics

System characteristics	**VSM current situation**	**VSM ideal situation**	**The result**
Total time duration	457.8 min	418.2 min	decrease 7.87%
Number of employees	27 employees	29 employees	increase 7%
The number of component wastes in the manufacturing process was observed before installation	7 parts	4 parts	decrease 57%
Number of finished products of unsatisfactory quality	5 parts	2 parts	decrease 60%
Number of finished products	85 parts	94 parts	increase 10%
Takt time	5.39 min	4.44 min	decrease 18%

Due to the implementation of the proposed solutions, the production process would be shortened by 7.87%, which was the main goal of the process improvement, while the number of workers would increase by only 7% (Table 5). It is obvious that adding employees would increase the costs for the company, but it also promotes social sustainability, which is crucial in the current economic situation. Additionally, it may be inferred that this measure is justified when all the advantages that an increase in employee numbers would bring are taken into account (effects on reducing errors, increasing productivity, and shortening the time it takes for the manufacturing process to be realized). The number of finished products of unsatisfactory quality would decrease by about 57% compared to the current situation. After the implementation of the improvement measures, the number of finished products at the level of one shift would be higher by about 10%. The reduction would also be reflected in the average time per product, by about 18%. In addition to all the aforementioned effects, the improvement of the existing system would also lead to a reduction in injuries and an increase in safety at work (Đurđević *et al.,* 2022).

5. Conclusion

This paper presents the use of VSM tools for requiring of reducing waste in the production system. As the increase in the application of VSM for the needs of various optimizations in the manufacturing sector has been observed, this paper discusses numerous possibilities for increasing economies of scale. As the increase in the application of VSM for the needs of various optimizations in the manufacturing sector has been observed, this paper discusses numerous possibilities for increasing economies of scale. Using VSM, the current situation in the company was first analyzed. After that, by analyzing the existing situation, it was detected in which segments within the system there were problems.

In the analyzed company, problems related to production technology and internal transport processes were observed. Problems that affect the production process can be divided into three categories: damage to the product, overheating of the machine (poor technological condition), and low voltage of electricity. In the implementation of logistics activities in transport, some of the observed problems are: the fall of raw materials from the pallet and the unsatisfactory technical condition of the belt conveyor. The focus of this research was calculating the total duration of the production process, the number of employees, the number of waste components in the production process observed before assembly, the number of finished products of unsatisfactory quality, the number of finished products, and the average processing time per product.

After discussing the current business situation in the company, measures to improve the production process were proposed. Some of them are the change of the gripping device of the forklift, the change of the mold for pouring products, the increase in the capacity of the belt conveyor, etc. A VSM of the potential ideal state was performed that indicates the following reductions:

- 7.87% reduction in the total time required for the manufacturing process;
- reducing the number of employees who are engaged by 7%;
- before the assembly of ***article x***, the number of component wastes in the manufacturing process was reduced by 57%;

- 60% reduction in the number of finished products of poor quality;
- the average processing time per product by 18%;
- in between, there is an increase in the number of finished products by 10%.

It is evident from the findings that certain system benefits may be realized if the suggested improvement actions were put into practice. The goal of any suggested measure that would be taken is to expand production and achieve sustainable production. Even if adding more employees is one of the "unpopular strategies," because of the cost increase, it has a beneficial impact on social sustainability. Because VSM has numerous advantages, it can be used in a wide range of industries, and more and more research is using it. In addition to all the benefits, it is necessary to point out certain disadvantages of VSM. The disadvantages are reflected in the fact that it does not take environmental and social factors into consideration. It also lacks economic measures for "value" (ex. profit, throughput, operating costs, and inventory expenses). It is inadequate in its display of the facility's layout and spatial structure. In order to overcome the mentioned shortcomings, the application of other approaches to solving this type of problem should be investigated. Some of the possible approaches are simulations, as a stand-alone tool, or in combination with VSM. This approach creates the so-called dynamic VSM where changes made in the system can be viewed directly in the model. Also, VSM can be successfully combined with MCDM methods, as shown in the literature review. In this case, the DEA method would be good for evaluating the efficiency of the system. MCDM methods could be used to select the proposed alternative solutions.

This paper provides a kind of methodological approach that can be used in all production systems in companies from various industrial sectors. The approach can, if necessary, be altered to accommodate the company's size and industry. As a result, the approach offers a useful tool, especially for identifying operations that do not add value to the system.

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