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DEVELOPMENT AND IMPROVEMENT OF A PRODUCTION COMPANY (AND THEIR PRODUCT) BASED ON THE VALUE STREAM MAPPING OF BUSINESS PROCESSES

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Abstract:
Value stream mapping is one of the basic tools used in the processes improvement or design – in accordance with the Lean concept. This paper presents a model of designing production processes and introducing new products to the market based on the analysis of the value streams flow in the production process. Particular attention was paid to the importance of input data necessary to plan a properly functioning production process, which results in a high-value product (from the customer's point of view). In the paper also the list of all the most important tools supporting all stages of designing new production processes or improving existing processes has been presented. Also the advantages of big pictures analysis using was highlighted. In this case value stream mapping and big picture analysis were oriented on quality in the product development process and contribute to: creating value (based on customer requirements) while maintaining timely deliveries and constant costs (Value Stream Mapping), sustainable use of tangible and intangible resources (removing waste at the design stage). However, from the company point of view, and particular in the cost level, the product can gain value because a lower input is required for its production. After improvement, the process lead time has been shortened in an area where value was not added, but the consequence of implementing the change is an increase in the production volume while maintaining the process transition time – therefore, unit costs of production will change.

Key words: *lean management, value stream mapping, production, lean manufacturing*

INTRODUCTION

In every industry, including the manufacturing sector, there is intense competition that is obliged to face ever-increasing quality, environmental, and economic requirements. A characteristic feature of rapidly advancing technologies is the associated production systems capable of manufacturing a group of products at a relatively low production cost [1]. Therefore, an excellent design of the production system is required, taking into account a vision for the future. This made the design of production systems for new enterprises a significant challenge. The main assumption in designing production systems is to ensure maximum productivity and process durability, thereby achieving cost-effectiveness. But in dynamic market in 21st century (characterized by rapid technological advancements, globalization, significant social and cultural changes), the primary goal is to enhance the responsiveness of production systems to unforeseen changes in product demand. In that case, Reconfigurable Manufacturing Systems (RMS) have advantages of both serial production and flexible manufacturing systems. The concept of RMS was introduced in the 1990s to meet the challenges posed by competition and globalization [1, 2]. Due to the significant dependence of processes on the flow of streams, each design of such a system poses a considerable challenge [3]. The reconfigurability of such a system should refer to the ability to restructure the system or completely re-engineer it. In this context, the reconfigurability of the system involves the ability to restructure the

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production system by adding, removing components, or changing the structure of the production system [4].

The application of such production systems largely supports and accelerates the implementation of various innovations, particularly product and process innovations. The complexity of product realization has significantly increased due to the requirements related to ecological, social, and economic sustainable development [5]. This has led to a growing demand for innovations in new materials, production technologies, processing processes, and new business models to better utilize products, materials, and resources. Most innovations arise through the continuous improvement of the competencies of participants in the process, usually specialists in chemical and materials engineering, as well as production engineering. While breakthrough changes may not necessarily occur in research and development departments and are equally likely to happen in the production or utilization stage, they unquestionably require thorough confirmation [6]. Depending on the business goals of a manufacturing company, when choosing a system configuration, it is essential to consider four main performance indicators:

1. Investment costs: the financial investment required for the implementation of a production system. It includes expenses related to the purchase of machinery, technology, software, employee training, and other resources associated with introducing the new system.
2. Flow velocity of value streams: this indicator encompasses various aspects related to production efficiency: machine park efficiency, machine work efficiency, organization of information flow: the effectiveness of information transfer, including data management, communication between machines and people, and mapping of the production progress.
3. Responsiveness to demand: the production system's ability to adapt to changes in market demand.
4. Consistency level between product quality and customer requirements: Assesses how well products meet customer expectations in terms of quality. A high level of consistency indicates that products align with customer expectations, contributing to customer satisfaction and loyalty.

As indicated by the literature [7, 8, 9, 10, 11], there are six fundamental steps in designing a production system that ensures adequate responsiveness to changes. Based on the essential features of a modern (adaptable to rapid changes) production system, principles have been formulated:

1. Determine the production system's capability in terms of production cost-effectiveness, assuming market variability.
2. Design a production system capable of adapting to new products - ready for continuous improvement, innovation, and re-engineering.
3. Optimize the built-in quality control of the product within production systems.
4. Design the production system around a product family.
5. Maximize the system's productivity through the reconfiguration of operations.
6. Perform effective maintenance that collectively maximizes machine reliability and system throughput.

The term “development and improvement of a production company” refers to the entirety of activities necessary for the development and practical application of new technical solutions. Typically, these innovative processes result from collaborative work, often involving interdisciplinary teams or even institutions. Such interconnected processes require linking the efforts of all collaborators and providing suitable conditions for achieving overall innovative objectives [6, 12, 13, 14]. During the implementation of innovations, it is also beneficial to utilize appropriate tools and methodologies, such as Lean, Six Sigma, or Value Stream Mapping. These tools aid in a detailed analysis of processes and the implementation of effective improvement actions (Table 1) [15, 16, 17, 18, 19]. Specifically, Lean Management tools like Value Stream Mapping (VSM) contribute to understanding the nature of all business processes within the company. VSM is indispensable in identifying processes and analysing their current state. The choice of tools depends on the specifics of the organization, the type of process to improve, and the goals to achieve. It is important for the goals to be measurable, specific, and appropriately tailored to the context to help the organization focus on achieving success in the improvement process.

The main assumption of the company's functioning is to constantly satisfy the clients' needs, improve processes, but above all to maximize the value of the offered products. In this regard, the development of the enterprise should be analyzed on many levels. It is obvious that the basis for the sustainable business functioning is financial stability (financial liquidity) and proper strategic management – management of capital both technical and intangible [14]. Value creation is influenced by both direct and indirect forces. Strategic and financial decisions treated as an indirect factor, while improvement through research and development (R&D), open and continuous innovation practices as a direct factor. However, research and development (R&D) improvement, open and continuous innovation practices are recognized as processes of creating and maintaining competitive advantage [13].

Table 1

Stages of development and improvement of a production company with possible applicable technologies and tools

Setting Objectives:	To begin with, define the objectives, aim to achieve through process improvement. Whether it's enhancing efficiency, reducing costs, improving quality, or something else, these goals should be measurable and specific.	– SMART Goals – Balanced Scorecard – Key Performance Indicators (KPIs) – Benchmarking – Voice of the Customer (VOC) – Hoshin Kanri – OKR (Objectives and Key Results)
Process Identification:	Choose a specific process to enhance. It could be a business process, a manufacturing process, a service process, or any other that is crucial for the organization.	– SIPOC (Supplier-Input-Process-Output-Customer) – flowcharts – Gemba Walks – Workflow Diagrams
Process Mapping:	Create a map of the selected process, illustrating its steps, stages, interactions, and dependencies. Utilize tools like workflow diagrams or Value Stream Mapping (VSM), where appropriate.	– Workflow Diagrams – Diagramy Gantta – BPMN (Business Process Model and Notation) or UML (Unified Modeling Language), – Data Flow Diagrams – Collaboration Tools - kanban – Prototyping Tools
Problem and Waste Identification:	Analyse the current state of the process and pinpoint areas that require improvement. These may include sources of delays, overwork, errors, inefficiencies, resource wastage, and more.	– Root Cause Analysis: 5 Whys, Ishikawa diagram – Data Analysis and Performance Metrics – Lean Six Sigma tools – Process Analysis Techniques: time and motion analysis, material flow analysis, or energy efficiency analysis – Customer Surveys and Feedback – Benchmarking
Data Collection and Analysis:	Gather data related to process performance, such as durations, costs, product quality, etc. Analyse this data to understand where issues occur and their underlying causes.	– Spreadsheet Software – Data Visualization Tools: Tableau, Power BI, or open-source tools like R or Python with data visualization libraries – Monitoring and Measurement Tools) – Quality Analysis – Cost Analysis Tools – Process Analysis Tools
Designing the Future State:	Based on the identified problems, develop a plan for the future state of the process. Determine how the process should look to achieve your objectives. This may involve changes in technology, procedures, work organization, etc.	– A3 sheet – FST (future state map) – VSD (Value Stream Diagram) – Gantt chart (with milestones) – Digital twins
Action Plan:	Create a plan for implementing the proposed changes. Define who is responsible for each task, set deadlines, and identify the required resources.	– Flowchart – Logical maps – Flow maps – Building organizational structure
Implementation and Monitoring:	Put the planned changes into action within the process and closely monitor their impact on performance and objectives. Ensure that new procedures are understood and adopted by employees.	– SPC – Statistical Process Control – FMEA (Failure Modes and Effects Analysis) – PFMEAP (Process Failure Modes and Effects Analysis)
Continuous Improvement:	The process of improvement is not a one-time effort; it must be ongoing. Regularly assess the process's efficiency and effectiveness, then introduce further enhancements.	– PDCA (Plan-Do-Check-Act) – FMEA (Failure Modes and Effects Analysis) – PFMEAP (Process Failure Modes and Effects Analysis) – SPC – Statistical Process Control
Team Engagement:	Involve the employees who are engaged in the process in its improvement. They often have valuable ideas for enhancements and a deep understanding of how the process operates on a daily basis.	– Mind map – Brainstorming

In the literature, it is widely recognized that value maximization is the main goal of all companies, based on the three main reasons [12]:

1. The value of the products has an impact on the value of the enterprise (e.g. share prices of listed companies);
2. The inventory value reflects the management level and effectiveness of future strategic changes;
3. The increased market value of the business (due to the increased value of the product) is the basis for further investment development.

Based on the hypothesis that the innovation process is a key factor in the development of competitive advantage that allows companies to achieve higher profits than competitors. Enterprises should constantly strive to improve processes, consolidating the importance of continuous innovation at the stage of making strategic financial and organizational decisions. Under this assumption, the entire management process should be conducted on a Lean Production basis without any delay. A review of growing enterprises in Europe indicates that the implementation of the Lean concept is very beneficial. However, it requires a lot of commitment from all participants of the process. Many enterprises are struggling with the implementation of the Lean concept due to poor understanding of the concept and incorrectly implemented management tasks (still in the manner of classical management) [7, 20]. Lean concept is strongly associated with all process improvements in the product value creation. Interestingly, in the Lean concept, the product value and actually its creation refers not only to increasing the functionality of the product (changes, reconstruction, etc.), the value of the product increasment in the Lean concept is to produce the same product, but using minimized resources (eliminating waste, minimized inventory, reduction of processing time etc.). Moreover, this assumption is in line with the company's financial management perspective.

METHODOLOGY

One of the first Lean tools that is used to monitor processes as well as to visually manage processes and process changes is the aforementioned value stream mapping (VSM). In contrast to the logistic process flow, the Lean concept assumes that the value stream flow is associated with both the flow of material factors (technical – materials, products, semi-finished products, auxiliary materials) as well as with the flow of information (technical information, procedures, organizational information ect.). The main task of a process map creation is to objectively identify areas that can be responsible for process slowdown (e.g. bottleneck), their disruption (e.g. possible production errors, failures, deficiencies) or their incorrect course (e.g. loss of time or incorrect order of operations). To effectively begin designing or improving a process, its necessery to identify five areas that are mandatory elements of every process map [21, 22].

Area 1: Defining customer specifications involves:

- Identifying the subject for analysis,
- Customer needs and service criteria (quantity, delivery frequency, packaging techniques, delivery schedules, delivery quality),
- Inventory levels within the analyzed subsystems.

Area 2: Recognition of information streams involves:

- Generating forecasts regarding order volumes,
- Continuous analysis of order fulfillment,
- Identifying recipients of information concerning order fulfillment and production processes,
- Examining the timing of information flow (measured by wait times for information processing),
- Identifying individuals responsible for order processing, as well as the extent of information exchange between suppliers and recipients.

Area 3: Recognizing material flows centers on:

- Specifying the company's needs for raw materials and products from planned deliveries (e.g., delivery sizes, supplier numbers), packaging,
- Identifying process components, determining operation types, and their durations,
- Identifying error and resource waste locations,
- Establishing production batch sizes,
- Analyzing workplace utilization.

Area 4: Establishing the correlation between material and information flows:

- Integrates previously acquired data and facilitates determining the required information at various stages of the production process, as well as appropriate actions in case of disruptions.

Area 5: Analysis and assessment of value addition:

- A comprehensive analysis determines the total duration of the production cycle (value-added + non-value-added) and the time spent adding value during the cycle (value-added).

The process map presented in this work pertains to the manufacturing process at a glassworks. The rules of glass production are very similar, regardless of the glass type. It melts into a homogeneous mass of all ingredients at high temperature then is formed and cooled. The production of glass products is continuous – which means that once started, the furnace continuously works for several years. The continuity of the process significantly impedes the implementation of Lean and individual innovations – therefore, due to the long-term production cycle of the furnace, it is worth considering continuous innovations.

RESULTS AND DİSCUSSİON

The first step is to prepare a glass set, i.e. it is precisely measured proportion of: silicon oxide (SiO_2), sodium oxide (Na_2O), calcium oxide (CaO), magnesium oxide (MgO), aluminum oxide (Al_2O_3), potassium oxide (K_2O), sulfur oxide VI (SO_3) and dyes, if necessery. The prepared glass set with cullet (max. 80%) is fed through a chute pocket straight into the furnace. The next stage of glass production, i.e. melting, takes place in a glass furnace (melting tank), where the temperature is around 1600-1650°C, where the batch temperature is about 1500°C. The glass charge into the tank is also homogenized by a special process regulated with the content of chemical

compounds that disintegrate under the temperature (disintegration with gas evolution). The melted mass is subjected to a temperature stabilization process. Special processes that take place in a glass furnace are slow and long-lasting and it is not possible to shorten the processing time without affecting the final properties of the product. This kind of process is typical special process. The chemically and thermally homogenous glazing charge, under the influence of gravity flows out through an extruder with a regulator. The drops fall into the guide, which transfers the portioned material to the pre-mold, and there the drop is formed into a glass bubble. Then the miniature bubbles are transferred to the right form, the so-called negative of the finished product, and it is where the final shape and size of the product comes into play. The time it takes to shape the drop, blowing out and precooling is greater than the time it takes to produce the next drop series. Using conveyor belt, the formed product is moved for refinement and stress relief. The final stage, as in any production process, is the quality control of the finished product. Glass products are inspected in terms of error-free shape, glass distribution, presence of impurities and cracks.

Figure 1 presents a sample process map (current state map) for the production of glass products – the process map visualizes the glass production process in one of the small European glassworks, which in the era of revitalization has attempted to implement Lean principles in its enterprise.

As it results from the data presented on the current state map, the total time of the process flow (lead time L/T) for the selected production volume is about 21 hours and 14 minutes while the time of value adding (VA) is about 17 hours and 19 minutes. The calculation shows that almost four hours in the production cycle are an obvious loss. Therefore, it is the areas where no value is added to the product that should be selected to implement the first steps of improvement or should be tested for the possibility of implementing some kind of process or organizational innovation (or continuous innovation). During process observation, special attention has been paid to the moment when drops of glass mass are formed. This is the operation that has the strongest effect on slowing down the process. Unfortunately, it is not possible to accelerate this procedure, because the drop falls under the influence of gravitational forces. The capacity of the machines in the next steps in the process gives the ability to perform the forming multiple times during the single drop formation. Therefore, the first step is to improve in this area. After the initial research in the company, it was possible to introduce a change in the form of multiple feeders, working independently (in a rotary system) – the drop is cut off directly from the extruder and forwarded for further processing. In this way, the bottleneck has been eliminated.

As it is well shown on the process map, the production operations themselves are only one of the areas of value stream flow. Completeness of the process, while improving it, is also ensured by posted information flows, such as: order volumes, frequency, orders, product specifications, production scheduling, raw materials and packaging delivery schedule, time and method of delivery and storage etc.

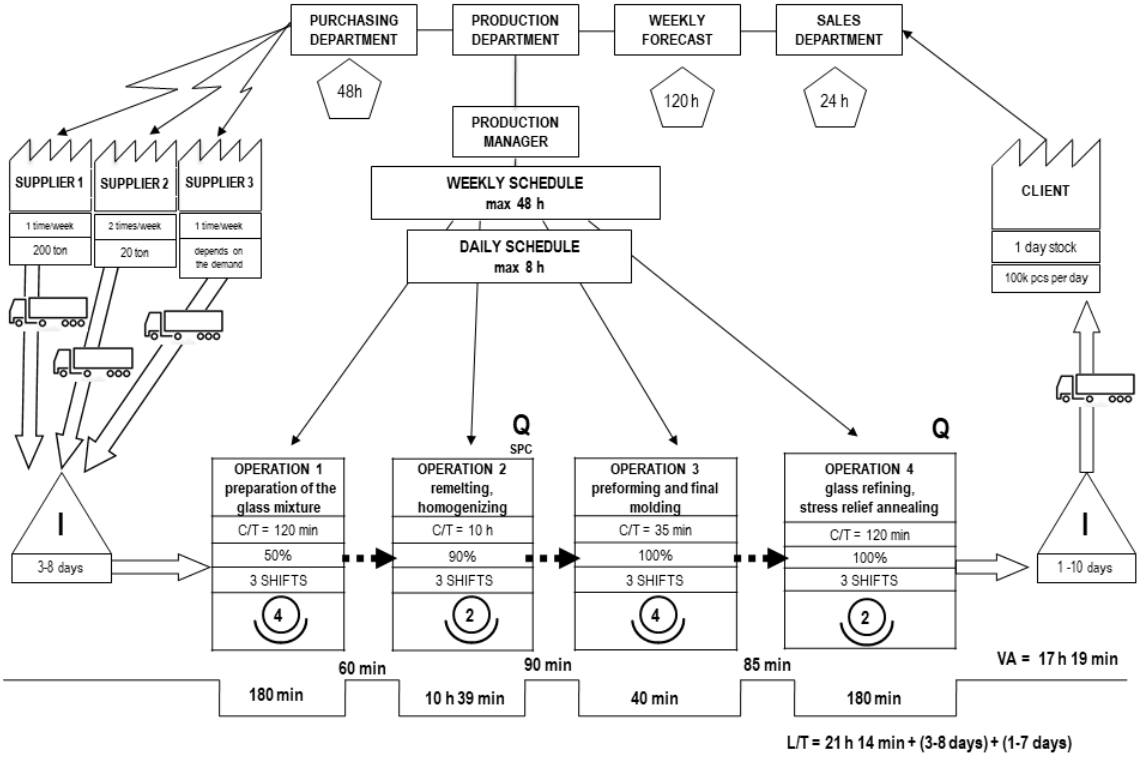

Fig. 1 Process map for the glass products production process

CONCLUSİONS

Increasing the value of a product is possible in many ways. One of them is the implementation of product innovations. Changing the design of the product brings the need to introduce many changes in the production and organization processes. Therefore, many companies that care for sustainable development and ensure a high market position are looking for other methods to increase the value of the product. One of such methods is the implementation of Lean Production management principles that result in the further improvement in line with the Kaizen philosophy and continuous process innovation. Enterprises that do not anticipate increasing the value of the product through a change in usability, increase its value by reducing losses arising in production processes. In the discussed example one of the Lean tools has been presented, i.e. value stream mapping (VSM). Map of material and information flow is extremely helpful in identifying losses arising in the process. In the customer point of view, the product produced in a process without or with Lean principles has the same value. However, from the company point of view, and particular in the cost level, the product has gained in value because a lower input is required for its production. After improvement, the process lead time has been shortened in an area where value was not added, but the consequence of implementing the change is an increase in the production volume while maintaining the process transition time - therefore, unit costs of production will change.

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