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THE APPLICATION OF SMED METHOD IN THE INDUSTRIAL ENTERPRISE

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Abstract: The production process fluency is often interrupted by idle time. A significant proportion of individual idle times is caused by changeover. Trends, such as the individualization of requirements, the constant effort to meet the customers' requirements on time and the maintaining of the production process fluency at low costs, are aimed at eliminating idle time. In terms of contradictory goals such as individualization of customer requirements, which is reflected in the high variability of production / products and minimalization of the production time and its fluency, it is necessary to pay increased attention to the changeover process. The problem related to the changeover process can be solved in two ways: by reducing the number of changeovers (reducing production variability and achieving dissatisfaction with individual customer requirements) or by shortening the changeover time (while maintaining production variability and ability to satisfy a wide range of individual customer requirements). The Single-Minute Exchange of Die - SMED method is used to shorten the time duration of the changeover process and eliminate waste in the given process. The aim of the paper is to apply the SMED method in vibration welder changeover process in a selected industrial enterprise and thus achieve a shortening of the changeover process. The SMED method was applied in the enterprise which belongs to the group of small and medium-sized enterprises. The research method was indirect observation via video recording and time snap. Various types of waste were identified based on the analysis, and subsequently eliminated by proposed rationalization measures. Finally, the time duration of the changeover process before the analysis and after the implementation of rationalization measures was compared.

1 Introduction

The current business environment is characterized by turbulent changes and competitive pressure. There are several competing enterprises in each branch of industrial production. It means that potential customers have the opportunity to choose from several suppliers who are able to meet their individual requirements (price, quality, quantity, deadline, etc.). Individualization of products is a characteristic feature of 21st century manufacturing enterprises. Individualisation of products has led to comprehensive planning and control systems that make difficult a mass production of products [1]. Due to the fact, that the primary goal of every enterprise is to make a profit, and competitive pressures and individual customer requirements force enterprises to reduce costs, the only option for enterprises is to pay attention to those activities and processes that can be made more efficient by eliminating waste.

Aforementioned facts have stimulated the emergence and implementation of the lean manufacturing concept, whose sophisticated tools help reduce waste and meet customer needs at the lowest possible cost.

1.1 Lean production

The term "lean production" was first introduced by Womack in 1990 in the book The Machine that Changed the World [2]. However, the origins of lean management as a holistic concept date back to Japan (1950s) and is generally attributed to Toyota Company, whose production system is known as the Toyota Production System (TPS).

The mentioned management system can be described as production without everything unnecessary, i.e., a resolute reduction of the failures/defects and costs in production, saving space and time. It is a leaning of production management and a considerable decentralization to lower levels of production management. It specifies what creates and does not create value for customers [3].

Košturiak et al. [3] state that "lean" is a dynamic process of change that is driven by a systematic set of principles and best practices aimed at continuous improvement. Liker [4] explains that lean manufacturing is a philosophy that shortens time between the customer order placement and product delivery by eliminating sources of waste in the production flow. Alukal [5] shares this opinion and adds that lean helps enterprises to reduce costs, cycle times and unnecessary, non-value-added activities what is leading to a more competitive and agile business.

According to classical theory, lean manufacturing means producing simply in self-controlled production. It focuses on reducing costs via uncompromising efforts to achieve perfectionism. Every day in production includes the principles of Kaizen activities, flow analysis and Kanban systems. The effort involves all employees of the enterprise into changes - from top management to production workers. Lean manufacturing is not purposeless reducing of costs. It is primarily a maximization of added value for the customer. Lean is a way for enterprises to produce more, have lower overhead costs, and use their areas and production resources more efficiently [6].

The critical point on which lean manufacturing or lean enterprise focuses is value. The value can be formed in two ways:

1. The enterprise can reduce production costs by minimizing or eliminating waste or
2. by introducing other services that add value to the product and will be appreciated by the customer.

Waste refers to all activities, material or elements that do not add value to the final product or service [7]. At the same time, these activities or elements can also increase the product or service price, which the customer is not willing to accept [8]. In Japan, such a waste is marked by the word Muda. Muda means everything that uses / consumes the enterprise's resources but does not create value. Taiichi Ohno categorized the seven types of waste (Table 1).

Table 1 Seven types of waste by Taiichi Ohno (authors own elaboration according to [9,10])

	Type of waste	**Description**
1.	Overproduction	Production of more products than necessary for immediate use.
2.	Waiting	Idle time, waiting for material, machine, information and protracted decisions.
3.	Transportation	Excess transport and handling of products, semi-finished products and materials.
4.	Motion	Unnecessary movement of people (walking, reach) excessive physical activity.
5.	Inventory	Excess inventories of materials finished products and work in progress.
6.	Excess processing	Excess work, consumption of materials and production resources.
7.	Defects	Any production that results in reprocessing or scrap production.

Aforementioned seven basic types of waste are supplemented by the 8th type of waste: People - the untapped potential of employees and their creativity [11].

1.2 Changeover of machine

The time when large amounts (series) of narrow product assortments were produced is irretrievably gone. It is necessary for today's market to meet changing customer requirements. In order to ensure that customer requirements are met, the flexibility of business processes (the production of small production batches), is crucial. Therefore, the demand for "single and large quantity" products has gradually turned into a "high-mix and low volume" product demand. The set system requires frequent changes of production batches, therefore short changeover times of machines and production lines are required [12,13].

When analysing the different types of machine idle times that have a significant impact on its availability / production capability, the time required for changeover is one of the most critical times. The time related to the machine changeover to another order is the time when the machine or line is not producing. It can also be a source of problems in managing production in small batches. When the process of changeover takes a long time, production management can use two ways to solve the issue. The first one is to combine related production batches into large quantities to minimize the number of machine changeovers. The second way, which is generally better comparing to batches combination, is to find the causes of long changeover times [14].

The term changeover can be understood from three perspectives. The first one, narrow point of view, defines the time when the machine is between two production batches. The second one, more broadly understood point of view is explained as the time between the production of the first production batch last piece and the production of the first good piece of the next production batch. Figure 1 shows the second point of view of the changeover process.

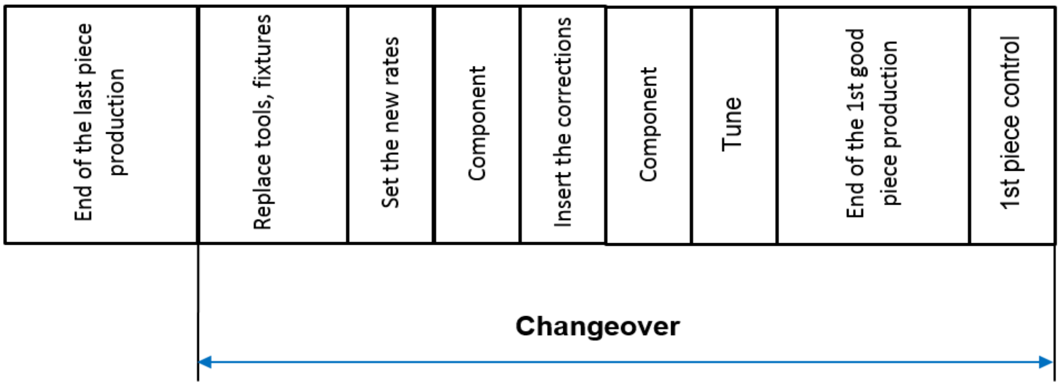

Figure 1 Changeover process [12]

The third explanation of the term focuses on speed and explains changeover as the time between the standard speed of the first production batch and reaching the standard speed of the next production batch [15].

To shorten the changeover times, it is necessary to identify and analyse waste that prolongs the change in production batches. The basic types of waste include [16]:

- searching,
- walking,
- waiting,
- missing standards,
- insufficient planning,
- calibration,
- missing tools.

1.3 SMED method

The Single-Minute Exchange of Die - SMED method is used to reduce waste in the production system, shorten the production lead time and standardize times of machine change activities [17]. The goal is the change from one product type to another in the shortest possible time and in the most efficient way. Many enterprise states that methods for reducing changeover time require investment. In fact, the failure to implement a rapid changeover system causes the enterprise increased costs due to ide time between production batches. Achieved time savings will enable the enterprise to produce products faster, which will also reduce delivery time [18]. Implementation of the mentioned SMED method also improves the level of safety and ergonomics in the enterprise [19]. The whole procedure of the method implementation is based on a detailed analysis performed directly at the workplace [12]. The method is based on the following basic steps [20]:

1) separation of internal and external changeover activities,
2) reduction of internal activities time,
3) reduction of ‘external activities time,
4) reduction of the changeover process time.

The differentiation of internal and external activities is based on the current situation analysis, which is usually carried out via video analysis [19]. In the first step, the question, whether the activity is performed internally or externally is answered [12]. Internal activities can be implemented only after the device has stopped running [21,22].

The time of internal activities is considered idle time. Internal activities include activities such as checking device replacement or disassembly of the toll from the machine [12]. On the other hand, external activities can be implemented during the machine production, before and after the production machine changeover [23]. Activities are performed outside the machine and include operations such as preparing tools or bringing forms from storage.

If the activity is internal, the question of what measures are needed for the transformation between external activities is answered. If it is not possible to transfer the activity to external one, it is necessary to propose the measures to shorten its duration [12]. Enterprises can reduce changeover time by improving work organization. Typical failures in the incorrect work organization include the preparation of tools, work aids, maintenance of tools, but also transport operations carried out only after the machine has stopped running [19].

The third step focuses on measures that can reduce the time of external activities [12]. The reduction of external changeover time is mainly due to the improvement of the workplace organization [20]. Improving of storage or tools and forms transport contributes to improve the whole process of changeover and can minimize the search or unnecessary movement of employees [24].

At the same time, it includes also a constant reduction of internal and external changeover time. In the last step, enterprises try to eliminate the changeover process especially by standardizing parts.

There are general recommendations to eliminate waste and achieve rapid changeover, which include [19,20]:

- standardization of changeover activities,
- standardization of machines,
- visualization of the changeover process,
- parallel execution of operations,
- use of quick couplers,

- use of automatic tools,
- automatization of the changeover process,
- creation of changeover teams.

1.4 SMED method in the context of Industry 4.0

The last stage of production management development is the Industry 4.0 paradigm which aims to connect the physical and cyber worlds with the latest technologies [26]. It represents the integration of the Internet of Things and the Internet of Service into the production environment. The interconnection of machinery, warehouses and production lines creates a cyber-physical system (CPS) which uses cloud access to record and process large amounts of data and thus create the basic concept of Industry 4.0 [27].

Lean manufacturing and digitization or Industry 4.0 appear to be two different approaches. One is more a philosophical and organizational approach (lean manufacturing) and the second one focuses on technology (digitization) [28]. Lean management methods use simplification and standardization to manage the complexity prevalently at the expense of flexibility. Digitization has the ability to counter the deficit [29]. However, approaches represent two paths with the same goals, increasing efficiency and productivity [28]. Hoellthaler, Braunreuther and Reinhart refer to digitization as another development step of lean management in production processes [29]. Industry 4.0 creates space for building a lean enterprise. It enables easier and more comprehensive understanding of customer requirements and needs (Big Data), as well as immediate sharing of necessary data through complex supply chains and networks. Smart enterprises can produce more with less waste. Industry 4.0 also enables faster "one-piece flow" of customized products and has the potential to rapidly reduce inventory through efficient deliveries [30].

The authors Hoellthaler, Braunreuther and Reinhart stated that lean philosophy has reached its limits at the time with the constantly increasing complexity of production processes, for example due to the accumulation of information and its interconnection, increasing volatility and accelerating the growth of time pressure. Digitization offers an opportunity to overcome the limits of lean manufacturing by increasing the ability to manage the complexity and by increasing flexibility. The digitization requires a lean foundation as a prerequisite for creating a maturity-based model regarding "lean" and "digital" in the mentioned theory.

Furthermore, the authors Hoellthaler, Braunreuther and Reinhart points out, that the level of readiness for digitization is proportional to the number of employees in the enterprises, which means that the less employees the enterprise has, the less it is digitized. Therefore, particulary SME particular have a deficit in terms of digitization, as they create the largest share of non-digitized enterprises [29].

Strategic management literature explains that SMEs often lack a comprehensive strategy, Information Technology (IT) maturity and technical expertise to cope with major technological revolutions in the industry [31]. In reality, majority of manufacturers, SMEs in particular, can only digitize certain areas of thein operations, such as digitizing thein customer relationship management or production planning and control [32].

Theoretically, lean manufacturing principles and procedures can be successfully implemented in the traditional way and without using IT resources. But on the other hand, based on practical experience, it is recommended that IT tools should be key to achieve LM efficiency in the 4.0 industry era. The integrative nature of IT allows lean manufacturing processes to integrate and support each other [26].

In addition, the production or process controllers use (e.g. distributed control system, control and data acquisition supervision, programmable logic controller and remote terminals) jointly with industrial robotics and software allow machines to automatically control production orders, identify product types and further load the appropriate program and installation of the right tools without manual intervention, features that facilitate SMED and remove non-value added activities from the changeover process [26].

The aim of SMED is to reduce downtime and cost caused by setup processes. Increased flexibility through short setup times support the production of small lots while achieving short lead times and maintaining a low level of stock [33]. It is expected that the highest impact on setup time will have in addition to augmented reality and plug and play also additive manufacturing. As additive manufacturing processes are not product-specific, therefore the varying work-pieces can be produced with minimum setup times. Times for selection, search and tools and work pieces adjustment are omitted. On the other hand, small adaption, temperature adjustments and etc. will still incur.

The authors Feldmann and Gorji has stated that SMED can also be applied to additive manufacturing. Considering that setup times are already technologically reduced to a minimum, the impact is expected to be rather small. However, SMED will remain of fundamental importance for reducing the physical setup time [34].

SMED and Industry 4.0 SMED is used to reduce changeover time. As was mentioned before, the Industry 4.0 uses tools like plug and play, modular manufacturing, and additive manufacturing to reduce the setup time. Some of the tools were identified by [33]. as Industry 4.0 tool, which can be linked SMED method application. The tools are as follows: additive manufacturing, plug and play, virtual reality, auto-ID, digital object memory, digital twin/simulation, real-time computing, machine learning [33].

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2 Methodology

The data obtained by observation in a selected industrial enterprise were used as a basis for the paper elaboration. Selected industrial enterprise is focused on exterior and interior mirrors production and direction indicator for cars. The authors of the paper will pay attention to the changeover process on the line producing direction indicators.

The subject of the current state changeover analysis will be the vibration welder. The vibration welder changeover is performed in the enterprise due to the change of production batches from one type of product to another one after the weekly required (planed) production is fulfilled. The reason for changeover process was the long changeover time, as well as the fact that changeover occurs 5 times per week. At present, the changeover is performed by two employees (Maintenance worker 1 and Maintenance worker 2, as well as by quality employee who approve the release of products based on quality criteria and also by production operators, who are needed in the first piece's production.

The basic research method was indirect video observation. The video was recorded by two moving cameras, which monitored the sequence of employees work individually. AVIX SMED software was used to process the acquired video data. The videos were also processed separately in the software. Although the videos were recorded and uploaded into the software separately, it was necessary to determine the links between the employees' activities in the software, as some activities are interdependent.

Based on the analysis, the wastes were identified and subsequently eliminated by rationalization measures. In the end, the current duration of the changeover process and its duration after the implementation of rationalization measures was compared.

3 Analysis of the vibration welder changeover process

The enterprise where the analysis and subsequent application of the SMED method was performed to improve the changeover process can be included among the medium-sized enterprises. Recently, the enterprise has begun to focus on the implementation of smart solutions and elements of Industry 4.0 in the form of collaborative robots. However, in the area of machine changeover, the enterprise does not apply any elements of Industry 4.0. AviX software was used to analyse the current state of art of changeover process. Due to the sensitivity of some data and the enterprise's request, the paper do not include print screens from the software.

As was mentioned before, the changeover is performed by Maintenance 1, Maintenance 2, quality employee and production operators. In order to perform the required exchange, it is necessary to bring the vibration form from warehouse remoted 50 meters from the line. Maintenance personnel must walk to the warehouse, locate the appropriate form according to the project number and load it on the positioning trolley. One maintenance worker must pick up and transport the trolley with form to the line where the exchange will take place. The second maintenance worker will ensure the transport of the empty trolley needed to store the old form to the line. The next step is to replace the vibration form. The exchange of vibration forms consists of the specific activities listed in Table 2 and Table 3.

After the changeover process, it is necessary to transport the trolley with the old form to the original place in the warehouse and return for the empty trolley. These activities are provided by only one maintenance worker while the other maintenance worker performs the changeover process.

4 SMED method implementation

The implementation of the SMED method for reducing the changeover time was performed based on the procedure shown in Figure 2. The authors of the paper were focused on the first 5 steps.

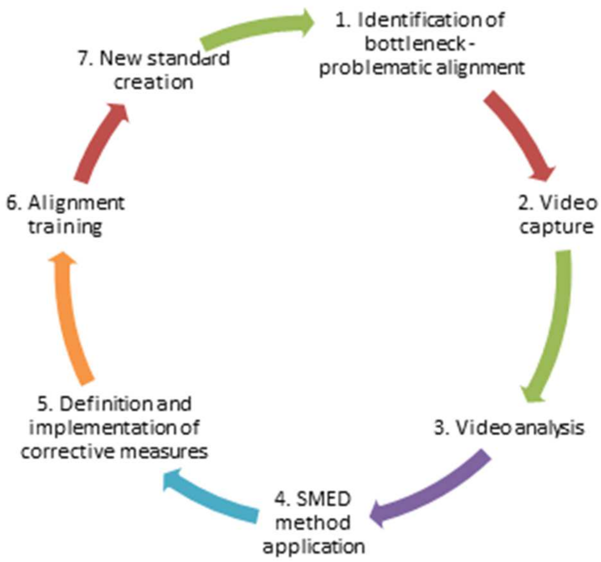

Figure 2 Procedure of SMED method implementation (authors of the paper own elaboration according to [12])

1) The identification of a bottleneck consists of production facility determination to which the SMED method will be applied. To determine the bottleneck, value stream mapping or the overall efficiency calculation of the production facility is used. The workplace that determines the total capacity of the production system is chosen. In this case, it is a line producing direction indicators which has an impact on the entire exterior mirror production. The production equipment is a vibration welder, which changeover process is problematic from an organizational and time point of view.

2) The video capture is necessary to collect the information needed to perform a current state analysis of the production equipment changeover process [35].
3) Video analysis of the changeover process was performed using AviX SMED software. The work of individual maintenance workers was divided into separate activities with their duration (Table 2, Table 3). Activities are categorized into 4 groups according to their meaning: Necessary activities, Value added activities, Loss or Waiting.

Table 2 Maintenance worker 1 activities (authors of the paper own elaboration, 2019)

Activities	Duration [s]	Meaning
Walking to a new form	18.8	loss
Searching for the form	8.5	loss
Waiting for trolley positioning	26.1	waiting
Loading the form on the trolley	4.6	necessary activities
Moving with the empty trolley to the welder	27.1	loss
Walking around the welder	15.8	loss
Inserting the centring pins	19.5	value added activities
Carrying the table up to the stop of the centring pins	23	value added activities
Loosening the upper screws	37.2	value added activities
Waiting for the Maintenance worker 2	8.3	waiting
Dropping the table to the tool change position	8.7	value added activities
Problem loosening of centring pins	31	loss
Loosening the 2 lower screws	37	value added activities
Pulling the pins out of the form	3	value added activities
Shifting the unlocked form	2.2	value added activities
Walking for the new form (behind the welder)	12.1	loss
Bringing a new form to the welder	9.9	value added activities
Moving the new form to the welder	7.3	value added activities
Walking to the front of the welder	16.4	loss
Centring the shape with the centring pins	20.3	value added activities
Tightening the lower screws by hand	4.1	value added activities
Tightening the lower 2 screws with the key	27.7	value added activities
Taking the table up to the stop	14.5	value added activities
Tightening the upper screws	41.6	value added activities
Securing the table at the bottom	9.4	value added activities
Removing the centring pins	10.6	value added activities
Implementing a parameter set	26.7	value added activities
Bringing the preheating device to the line	35.6	necessary activities
Installing a preheating device	33.5	value added activities
Automatic tuning of the head and welding of the 1st pieces to perform a destructive test	79.4	value added activities
Destructive test	40	value added activities
Waiting for production release	155.4	loss
Releasing the production by quality worker	33.4	necessary activities

Table 3 Maintenance worker 2 activities (authors of the paper own elaboration, 2019)

Activities	Duration [s]	Meaning
Walking for the form	19.8	loss
Moving the trolley to the form	5.4	necessary activities
Trolley positioning	32.4	necessary activities
Transporting the form to the welder	33.6	necessary activities
Waiting for the welder release by the Maintenance worker 1	50.3	waiting
Walking to the welder door	4.7	loss

Opening the welder rear door	4	necessary activities
Loosening the screws on the upper form	28.2	value added activities
Closing the welder door	10.8	necessary activities
Waiting for the Maintenance worker 1	39.1	waiting
Walking to the welder door	2.7	loss
Opening the welder door	3.1	necessary activities
Loosening the 2 bottom screws	21.7	value added activities
Pulling the connectors out of the form	11.1	value added activities
Moving with the empty trolley to the welder	5.3	necessary activities
Loading the form on the trolley	6.7	necessary activities
Moving the trolley sideways	7.3	necessary activities
Adjusting the trolley towards the welder	7.3	necessary activities
Moving the form into the welder	6.3	value added activities
Connecting the connectors	26.8	value added activities
Tightening the bottom screws	41.5	value added activities
Closing the welder door	7.9	necessary activities
Waiting for the Maintenance worker 1	12.7	waiting
Walking to the welder door	3	loss
Opening the welder door	4.6	necessary activities
Tightening the screws of the upper form	24.4	value added activities
Closing the welder door	6.2	necessary activities
Moving the empty trolley from the new form	31.6	necessary activities
Walking for the form	19.2	loss
Moving the trolley with the old form	28.5	necessary activities
Trolley positioning	13.9	necessary activities
Inserting the form into the rack	15.8	necessary activities

Figure 3 shows the percentage of Value-added and Non-value-added activities in the changeover process performed by Maintenance worker 1. Most of the activities carried out were Value-added activities in the process. The total duration of the activities carried out by the Maintenance worker 1 was 848.6 s, as he ensured the entire changeover process, from the preparatory activities to the release of production by the quality employee. All activities within the changeover were carried out only after the production equipment has stopped running, i.e. all activities can be marked as internal activities. The operator was waiting for the maintenance worker to perform a destructive test, instead of preparing the components, and then started preparing the components.

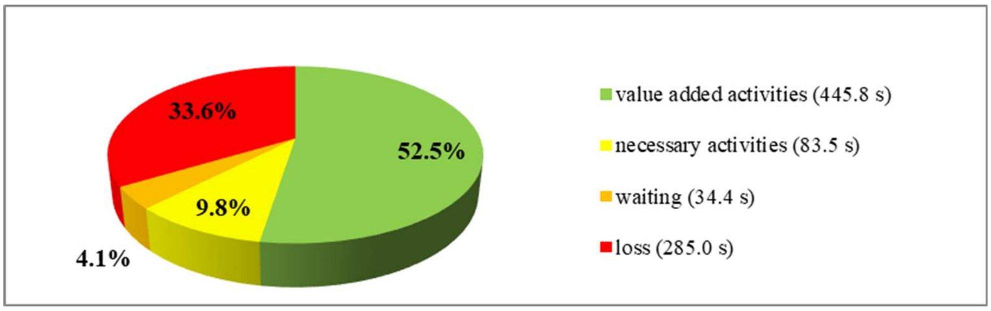

Figure 3 Activities categories of the Maintenance worker 1 (authors of the paper own elaboration, 2019)

Figure 3 shows that Value-added activities create 53% (445.8 s) of the changeover activities total duration. Non-value-added activities have a duration of 402.9 s, which represents 47%. From the Non-value-added activities time are 285 s Losses (34%), 34.4 s (4%) Waits and 83.5 s (10%) represent Necessary activities.

Figure 4 shows the percentage of Maintenance worker 2 individual activities. The total duration of the Maintenance worker 2 performance is 536 s, due to the fact that Maintenance worker 2 participates in the process of changeover only in part of the certain activities' implementation.

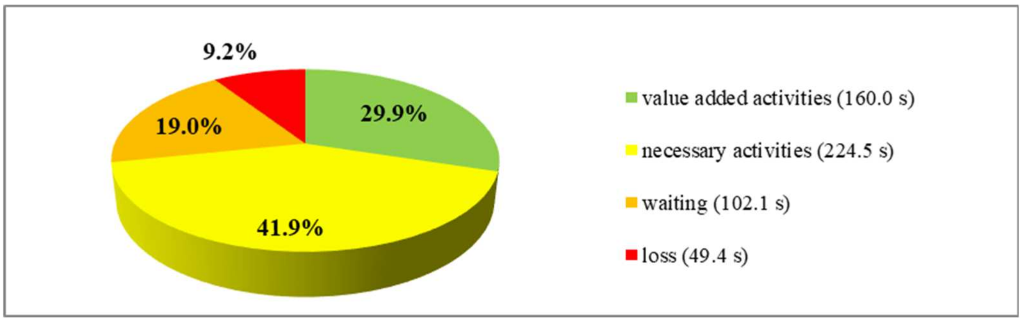

Figure 4 Activities categories of the Maintenance worker 2 (authors of the paper own elaboration, 2019)

Figure 4 shows that Non-value-added activities predominate - 70% (376 s) of the Maintenance worker 2 activities total duration. Activities in the Value-Added category create 30% (160 s) of the process. Within the category of Non-value-added activities, the largest percentage is represented by Necessary activities - 42% (224.5 s). Waste in the form of Waiting has a duration of 102.1 s (19%) and Losses represent a 9% (49.4 s) share of Non-value-added activities.

Figure 5 is a summary percentage of the changeover process current state. It contains the duration of the activities of both maintenance workers, which represents a total of 1384.7 s. Value-added activities represent 44% (605.8 s) and Non-value-added activities 778.9 (56%) of the total changeover time. Within Non-Value-Added Activities, Losses have a duration of 334.4 (24%), Waits 136.4 s (10%) and the Time of Necessary Activities is 308 s (22%).

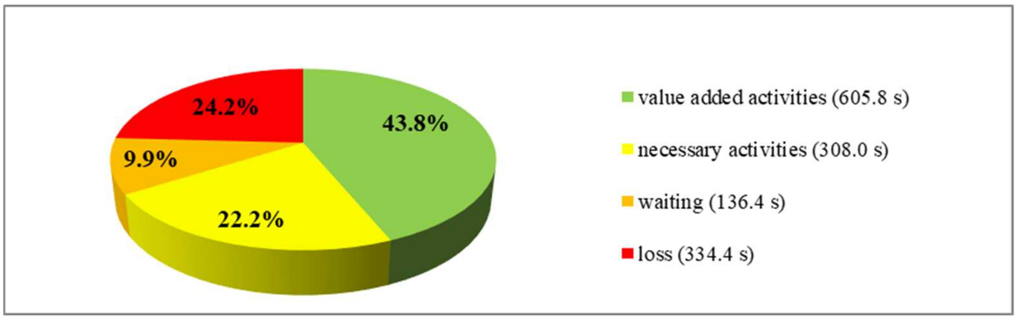

Figure 5 Activities categories of the changeover process (authors of the paper own elaboration, 2019)

Based on the current state changeover analysis, the following wastes were identified:

- Walking: long distances that maintenance workers have to walk to secure a new form. It is 50 m between the workplace and the form warehouse, where also a preheating device is stored and its delivery and installation are provided by a Maintenance worker 1:
- Locating the form in a rack.
- Walking: walking of maintenance workers when changing a new form (replacement must be done by the maintenance workers together, as the form is heavy). Maintenance worker 1 must move from the front of the welder behind the welder, to the workstation of Maintenance worker 2, move the new form to the welder and then move back to his original place.
- Waiting: monitoring the work and waiting for the Maintenance worker 1 to complete his work. It results from the mentioned links between activities (unnecessary movement of Maintenance worker 2 due to monitoring the colleague and after completion of activities performed by Maintenance worker 1 return to his workplace)
- Waiting for the release of production by quality employee.
- Repeated performing of operations when tightening the screws with a ring spanner.
- Tightening and loosening the screws on the upper and lower part of the form is performed separately
- The biggest idle time was waiting for part release, which includes the actual production of parts by the operator to enable the quality check of the parts by the team leader.

4) Application of the SMED method. To optimize the process, the previously described procedure of the SMED method consisting of 4 steps is used, with the aim to perform activities more efficiently [35]. The method is based on 4 basic steps [20]:

a) In the first step, the authors divided the activities into internal and external according to whether they can be implemented during the operation of the production equipment or whether the machine needs to be shut down. The following Maintenance worker 1 activities were classified as external activities:

• walking to a new form,

- searching for form,
- waiting for the trolley positioning,
- loading the form on the trolley,
- moving an empty trolley to the welder,
- walking around the welder.

In the case of Maintenance worker 2, the following activities were included among the external activities:

- walking for form,
- moving the trolley to the form,
- trolley positioning
- transferring with the trolley to the welder,
- returning an empty trolley from a new form,
- walking to the welder,
- returning the trolley with the old form,
- trolley positioning,
- placing the old form on the rack.

The internal changeover time (Maintenance worker 1) decreased from the original 848.6 s to 754 s by including and regrouping activities from internal to external ones. For Maintenance worker 2, the time of internal activities was reduced to 335.8 s.

b) The second step is aimed at eliminating the time of internal activities (performed during the shutdown of the production facility), which will be achieved by the proposed measures (Table 4).

Table 4 Proposed measures to eliminate the internal activities time (authors of the paper own elaboration, 2019)

Waste	**Proposed measures**	**Benefits**
Watching the Maintenance worker work by Maintenance worker 2	Loud informing a colleague about the operation completing	Elimination of unnecessary walking (movement)
Multiple tightening of screws with ring spanner	Procurement of a pneumatic screwdriver	Elimination of multiple screw tightening
Tightening and loosening the screws on the upper and lower part of the form carried out separately	Tightening and loosening the upper and lower screws at the same time	Elimination of unnecessary walking (movement)
Moving to the warehouse and transporting the form.	Procurement of a trolley with a push-pull drive	Form change performed by one maintenance worker, improvement of ergonomics, elimination of unnecessary movement
Waiting for the operator to prepare the components for the destructive test by the Maintenance worker 2	Preparation of components during the destruction test	Reduction of idle time

c) The third step of the SMED method is to reduce the time of external activities performed during the changeover process by implementing the measures listed in Table 5.

Table 5 Proposed measures to eliminate the external activities time (authors of the paper own elaboration, 2019)

Waste	**Proposed measures**	**Benefits**
2 employees need to transport the form to the machine	Procurement of a trolley with a push-pull drive	Elimination of external activities of the Maintenance worker 2 related to transfer of the form to the machine,
The long distances that maintenance workers have to walk to secure a new form	Changing the position of the rack with forms and preheating equipment	Shortening the length of the walk
Looking for the form in the rack	Colour resolution of form labels	Elimination of the form search

The colour resolution of the form labels according to its affiliation to the individual projects is shown in Figure 6.

Project type	**Colour resolution**
Project 1	
Project 2	
Project 3	
Project 4	
Project 5	

Figure 6 Proposed colour resolution of the form labels (authors of the paper own elaboration, 2019)

d) The fourth step is reduction of the total changeover time.

In the fourth step, the goal is to reduce the total time of internal and external activities in the changeover process. The proposed measures of an organizational nature are as follows:

- the preheating device is brought and installed by the Maintenance worker 2,
- external activities performed by the Maintenance worker 2 connected with the removal of the form from the previous production will be performed by the Maintenance worker 1.

The percentage of individual activities categories of both employees after the implementation of the above-mentioned solutions is shown in Figure 7 and Figure 8.

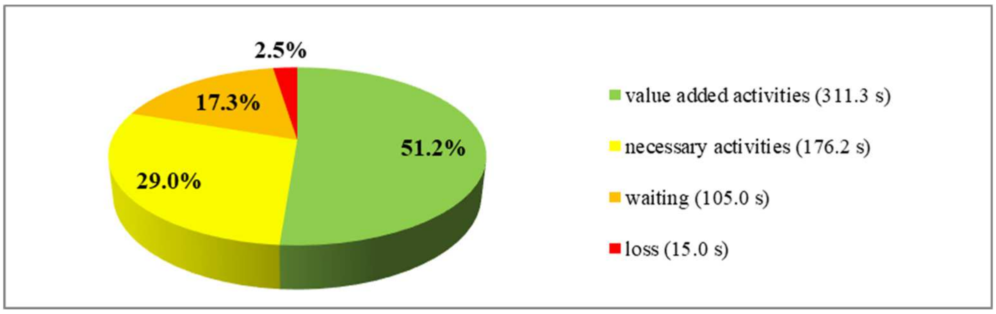

Figure 7 Activities categories of the Maintenance worker 1 after the measures' implementation (authors of the paper own elaboration, 2019)

Figure 7 shows that after the proposed solutions / measures implementation in the form of activities division into internal and external ones and regrouping of activities between employees, Value added activities represent 51% and Non-value-added represent 49% of the total duration of activities performed by Maintenance worker 1. Although the percentage Non-value-added activities increased, a significant decrease was reached in activities Losses.

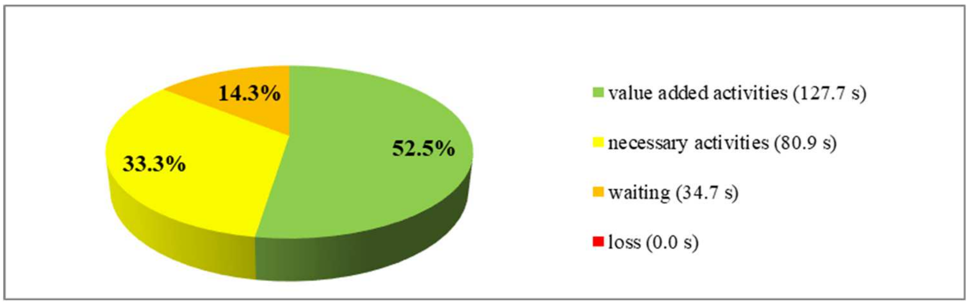

Figure 8 Activities categories of the Maintenance worker 2 after the measures' implementation (authors of the paper own elaboration, 2019)

Figure 8 shows the percentage of activities performed by Maintenance worker 2 after the implementation of the proposed solutions. The graph shows that Value-added activities represent 52% of the total changeover time and Non-value-added activities 48%. From the activities performed by Maintenance worker 2, all activities that represented a loss in the process were eliminated. For other activities included in the category Non-value-added activities, there was also a percentage decrease in the share in the changeover process. The percentage of Value-added activities has increased from the original 30% to 50%.

Figure 9 shows the change in the share of individual activities in the overall changeover process.

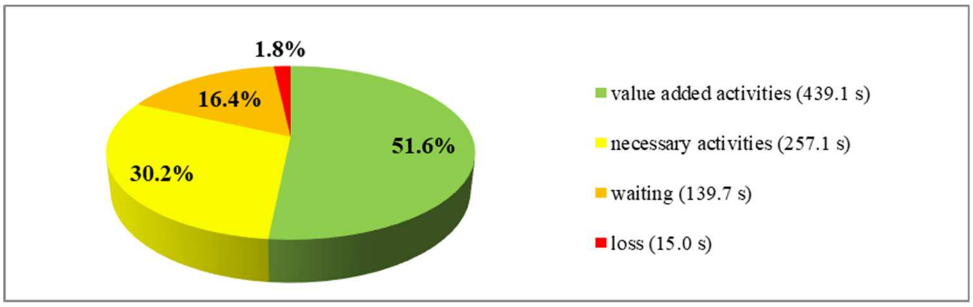

Figure 9 Activities categories of the changeover process after the measures' implementation (authors of the paper own elaboration, 2019)

From Figure 9 result that most activities in the process add the value (52%). Non-value-added activities represent 48% of the changeover process.

A comprehensive evaluation of the proposed solutions aimed at improving the changeover process is based on a comparison of the previous changeover time and the changeover time after the implementation of all corrective measures. The changeover process time has been reduced from the original 848.6 s to 607.5 s. In the previous changeover process, all activities were performed during shutdown of the equipment, indicating that the changeover time was considered idle time.

After applying the first step of the SMED method – division of specific activities into internal and external categories, the idle time (changeover time) was 754 seconds (time duration of internal changeover activities). It the changeover time (607.5 s) after the implementation of corrective measures, external activities that are performed during the operation of the welder are also included. The changeover time, which includes only internal activities that represent idle time, is 480.8 seconds.

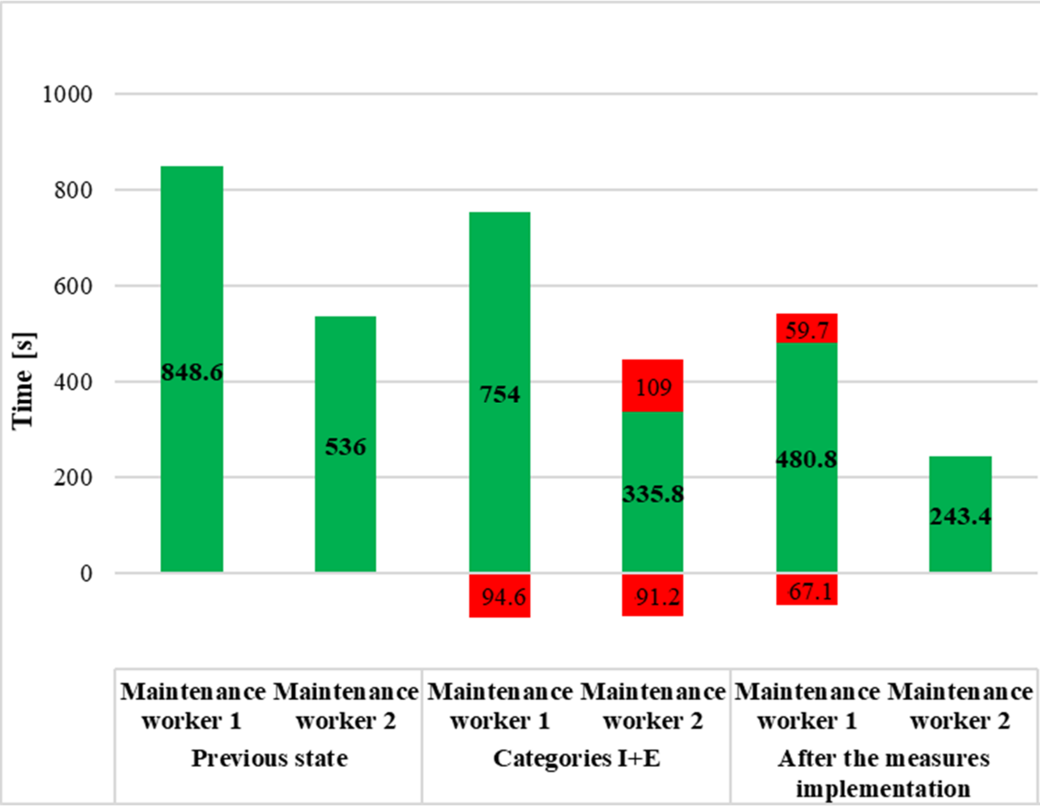

Figure 10 Time duration of the changeover process (authors of the paper own elaboration, 2019)

From the abovementioned results that the idle time was reduced by a total of 367.8 s. The authors of the paper also consider the percentage of activities marked as Losses to be only 2% of the total changeover process as the greatest benefit. A graphical comparison of the changeover process duration of the previous state, the state after division the activities into internal and external ones, and the status after corrective measures has been implemented is shown in Figure 10 (green colour represent the duration of internal changeover activities (equipment idle time) and red represents external activities which are performed while the machine is running). A comprehensive evaluation of the proposed solutions aimed at improving the changeover process is based on a comparison of the previous changeover time and the changeover time after the implementation of all corrective measures. The changeover process time has been reduced from the original 848.6 s to 607.5 s. In the previous changeover process, all activities were performed during shutdown of the equipment, indicating that the changeover time was considered idle time.

5 Conclusions

In the production process, there are often activities that do not add any value to the product. The customer is not willing to pay for these activities and therefore it is necessary to eliminate them. To solve the problem, enterprises are implementing elements of lean manufacturing into the practice. Leaning of the enterprise's production process will reduce costs, increase utilization of production capacity, resources and improve economic results.

The effort to satisfy specific customer requirements cause variability in production, which has the effect on interrupting the continuous production process by changing the settings / adjustments of the machine. Due to the interruption of production, changeover can be considered waste. The mentioned waste cannot be completely excluded from the production process, therefore the authors of the paper focused on shortening its time duration by applying the SMED method.

Due to the size of the enterprise and the number of employees, small enterprises, or some medium-sized enterprises, usually do not invest into the elements of Industry 4.0 (alternatively only partially into selected activities), but gradually implement lean principles and methods. Especially for small enterprises, the fact is that many of them are not ready and able to manage the Industry 4.0 tools as an extension of the lean concept, because the lean concept itself is currently a challenge for them.

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