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SMED Methodology Implementation in an Automotive Industry Using a Case Study Method

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Abstract

Nowadays is ever more important to reduce superfluous costs at industrial units. Only through such an approach the margin of profit could be increased. The aim of this paper is to demonstrate the contribution of the Single-Minute Exchange of Die (SMED) methodology to reduce setup times in the stamping process of metal components in the automotive industry. A qualitative approach based on a case study is used to demonstrate this contribution. In this case study the application of the SMED methodology provides considerable gains in terms of setup time reduction (45%) through a better reorganization of the work and arrangements. According to the case study the application of the SMED methodology should be accompanied by a reorganization of work, training and the implementation of a systematic and effective method of performing of the various operations that are executed at the enterprise.

Key words: *Human Resources, Lean Manufacturing, Setup Time, SMED, Tool Exchange*

1. INTRODUCTION

For many decades mass production contributed for the competitiveness of many organizations, particularly in the automotive industry due to its large scale production. Manufacturers traditionally used long production runs and large lot sizes in order to reduce the number of needed setups. However, this has contributed to a high work-in-progress, lengthy finished goods inventories and longer lead times. Meanwhile, in the last four decades this paradigm has changed dramatically towards a more diversified production, smaller quantities, with special emphasis on quality rather than quantity [1], [2]. This was mainly motivated by the globalization which has created the need for companies to increase their production flexibility by producing in smaller batches. Thus, this type of production leads to a significant increase on the setup frequency and consequently the ability to perform quick setup processes [3].

The macroeconomic context has also contributed to this change of paradigm. In the 1970s a set of changes such as the oil crisis, the significant fall in demand and the increased competition caused by more open markets forced companies to reconsider their productive models. Moreover, the price of the products started to be imposed by car manufacturers and defined by the market which forced companies to reduce production costs as a way of ensure profit margins [4], [5].

The change in the behavior of market patterns contributes to a reduced and more fragmented demand which requires also more frequent and faster deliveries. In this context, it is critical to increase the efficiency of production systems and reduce the waste in all contexts [6]. That is, the scenario was perfect to the development of the Lean philosophy.

The Lean Production concept has its origin in the TPS - Toyota Production System [7] and presents as main objectives the continuous improvement of processes and cost reduction through the elimination of waste [8]. The Lean philosophy is based on five fundamental principles [9]: (i) create value for the customer, (ii) identify the value stream, (iii) create flow, (iv) produce only what is pulled by the customer, and (v) pursue the perfection by continuous identification and elimination of waste.

Shingo considers seven types of waste [10]: overproduction, inventory, waiting, defects, over-processing, motion and transportation. Lean Production provides a set of tools and techniques that can be applied to reduce those wastes, namely SMED, 5S, Visual Management, Standard Work and Value Stream Mapping [11].

The success of this philosophy has justified its application from industrial environments to other sectors of activities [12], [13].

Today in industrial environment, waste elimination, such as the idle time, is an important issue since it is a non-value added activity representing costs and lack of productivity. At the same time, the diversification of products and the orders increasingly smaller leads companies to optimize the setup times associated to processes and machineries.

Reducing the setup times contributes to a set of advantages, such as: decrease the machines stoppages, decrease the non-added operations, make feasible the production of smaller lots, reduce setup scrap, decrease setup labour cost, make production system flexible; reduce product lead time, productivity and utilization of assets, and reduce manufacturing cost [14].

The Single-Minute Exchange of Die methodology (SMED) emerges in the production system at Toyota Company and is one of the methodologies integrated in the Lean Production philosophy that uses a set of techniques as a way of minimizing setup times, contributing to reduce idle times and increasing productivity. The SMED is considered a theory constituted by a set of techniques that make it possible to perform the equipment's setup and changeover operations in a shorter time [10], [15].

The SMED, which was developed by Shingo [10], is the main focus of this paper.

This technique is implemented in different contexts such as the re-engineering of the setup processes as a way of reducing it. Setups are inevitable whenever a manufacturing process makes more than a single product, but they are undesired because they contribute for increase idle time in production [16]. In some situations setups can consume high percentages of the total operating time [17]. Once the setup processes are analyzed it is possible to reschedule many tasks as external activities that are performed while the machine is operating. Also technical modifications allow some of the remaining internal tasks to be done externally [18]. The implementation of the SMED could involve small, inexpensive and highly target changes to the design of machines, processes and products [19]. Moreover, in the SMED technique tasks related to the machine setup are streamlined to make them faster and more efficient. Goubergen and Landeghem enhance the importance of companies reduce setup times as a way of improving flexibility and bottlenecks capacity and also minimizing costs [18].

There are several studies that have focused the SMED methodology in different sectors and with different purposes. In [20] was studied the application of the SMED methodology in the mould making industry to provide an insightful case study implementation in a SME processing polyurethane polyether foam with the purpose of highlighting the gains of productivity. In [21] was discussed the practical application of the SMED within a textile processing operation. The prerequisite requirements for successful SMED application are presented and discussed in their paper. In [22] the SMED methodology to reduce or eliminate the small stop time loss was used. An unified approach to aid the process engineers during the third step of the implementation of SMED is proposed in [23].

In [24] the focus is on the significance of quick changeovers in die-casting foundry environments. In this paper the authors demonstrate the practical application of the SMED showing how it can bring real breakthroughs in productivity to small and medium scale foundries. Moreover, it is suggested the application of other methodologies such as 5S, Poke-Yoke and specific tool-kits to further reduce setup times.

While most of the studies on SMED methodology focus on costs and productivity of equipment's and machines as the main benefits of its implementation, in our paper the human resources through a reorganization of work, training and implementation of a systematic and effective method of performing the various operations are highlighted as the main driver of productivity improvement and cost savings in using the SMED methodology. Being so, the main objective of this paper is to demonstrate the contribution of the SMED methodology to reduce setup times and consequently increase the human resources productivity in the stamping process of a producing plant in metal components and belonging to an industrial group in the automotive industry.

The paper is organized as follows. In the introduction, a background was performed to introduce the reader into the topic of the paper. Then, the methodology is shown to demonstrate the influence of the SMED on the setup times through a pilot project. After this, a case study on the automotive industry is described, and some considerations about the results are drawn.

2. METHODOLOGY

In this paper the case study methodology was chosen since provides the ability to investigate contemporary phenomenon within a real-life context [25]. One of the main advantages of case study is that it makes possible to determine the link between cause and effect [26]. This is important in this research, as the aim is to demonstrate the contribution of the SMED methodology (cause) to reduce setup times (effect) in the stamping process of a production unit in metal components and belonging to an industrial group in the automotive industry.

The “planned opportunism” [27] was used as a rationale for the case study selection: the selected case study is located near the researchers’ place of employment.

This methodology makes possible to answer the following research questions:

- Does the reorganization of the workplace with the SMED methodology contributes for the improvement of the setup times?
- What benefits does the firm obtain with the application of the SMED methodology?

Regarding data collection Forza [28] argues that data can be collected in a variety of ways, in different settings and from different sources. In a case study research in [25] is suggested that evidences may come from six main sources: documents, archival records, interviews (semi-structured, structured or unstructured), direct observation, participant-observation, and physical artifacts. Other sources of data can include informal conversations, attendance at meetings and events, surveys administered within the organization [26], films, photographs, and videotapes [25]. In this study, data collection was carried out through semi-structured interviews and secondary data.

- The researched industrial unit is implementing new projects and facing an increase in orders for the coming years. This context is pressing the firm to increase internal productivity through an optimization of setup performance in the existing equipment. In this attempt the Lean technique known as SMED is suggested to optimize the setup times and to improve the competitiveness of companies in the current and future production context [29].

3. CASE STUDY IN AN AUTOMOTIVE INDUSTRY

This section illustrates the implementation of SMED methodology in an industrial unit belonging to a Portuguese industrial group in the automotive sector. The influence of SMED on the setup times it is thoroughly analyzed.

3.1 **Case study profile**

The case study company belongs to an international Portuguese automotive industrial group founded in the 1980s with a growing expansion in Europe, Asia, and North and South America. Its presence worldwide accounts for a group of approximately 30 business units. The company has 80 employees and its core business is the production of metallic components for the automotive industry.

Regarding the production it shoes that it has quite an extensive portfolio of clients. The unit supplies stamped metal parts, sub-sets, soldered sets, chassis and more recently precision parts to the main Original Equipment Manufacturers (OEM) in the sector.

The firm has a diversified production of around 80 different products in the metal components. The area of production is about 7000 m^2 with an average of 80% of the firm’s production references being metal parts pressed on cold metal sheet, which is equipped with a pressing area ranging from 30 Tons to 630 Tons.

In terms of organization’s philosophy the firm gives first priority to the safety of its employees, targeting a goal of zero accidents per year. Being a supplier of the main OEMs in the automotive market it is certified by ISO/TS 16949:2002 and ISO 14001:2004. ISO/TS 16949 is a technical specification which aims to indicate the specific requirements of ISO-9001:2000 for the automotive industry. Together with ISO-9001:2000 it specifies the requirements for a quality management system where a firm needs to demonstrate its ability to consistently provide product that meets customer and applicable regulatory requirements. This certification allows the company to fit its Quality system with the OEM's system [30].

The ISO 14001 is an internationally agreed standard that sets out the requirements for an environmental management system. It helps firms improve their environmental performance through more e efficient use of resources and reduction of waste [31]. It allows establishing an effective Environmental Management System, seeking through the commitment of the organizations to create a balance between profitability maintenance and environmental impact.

The headquarters of the industrial unit has already an enlightened view of the Lean Manufacturing (LM) philosophy and the corresponding practices. To be more competitive in a highly demanding market, the various units are encouraged to implement LM concepts and tries to share with them a high degree of commitment and incentive. An example of this is the integration of various objectives such as carrying out annually a set of Kaizen events in each unit and practicing the 5S.

The research factory is one among many that share this organizational culture focused on consistent integration of Lean Manufacturing with a medium-long term perspective.

3.2 **SMED methodology implementation**

In the studied period the production plant was facing a decrease in the production as a result of the end of some projects which were making the client portfolio becoming smaller and sales volume declining. However, the integration of new projects is also being developed contributing by this way to increase the quantity and volume of orders. In this context, the production plant need to implement new practices to increase the efficiency and productivity associated to the production processes in order to improve customers’ satisfaction.

The firm realized the necessity of implementing the SMED methodology as a way of increasing the productivity of several production processes.
The adoption of the SMED methodology intends to make setup processes more agile in the stamping sector and increase the availability of the equipment [32].
In order to meet the targets of the unit, the management created a project divided into several stages and supported by a pilot phase, which depending on its results would determine the following steps in implementing this methodology.
This case study shows the evolution of the different steps performed in the pilot project. The Figure 1 illustrates the steps involved in the SMED project which is quite similar to the ones adopted in [33].
The machine chosen for the pilot project was the Press 4. This machine was chosen not only because this is the stamping equipment with the greatest number of monthly setups in the studied unit, but it is also responsible for the production of the reference accounting for the greatest income.

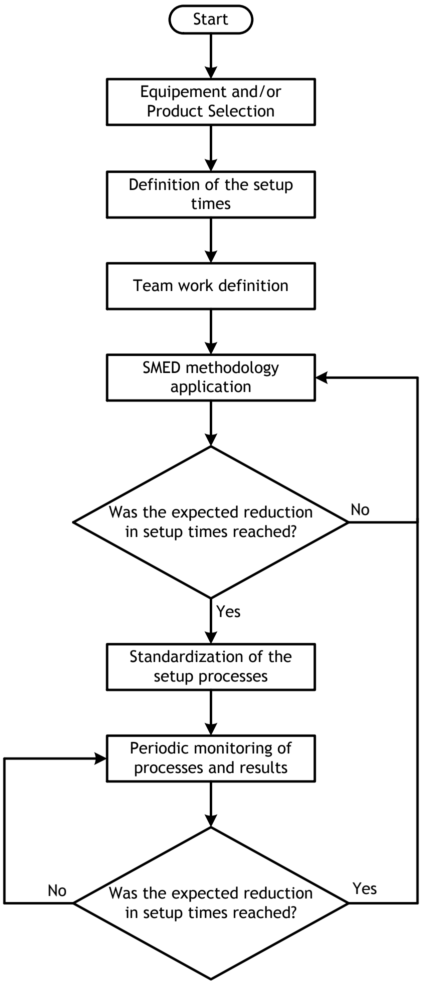


Figure 1. Steps for the implementation of a SMED project and adapted from [33].

The management of the unit had defined the objective of reducing the setup times between 35% and 40% at the beginning of the project. The team work was made up of the following elements: 1 Process engineer; 1 Process engineers on work placement; 2 Press and 4 operators (1st and 2nd shift); 2 Stamping team leaders (1st and 2nd shift).
The time limit for implementing and presenting the results of the pilot project was two months and the whole improvement process was to be implemented without any financial investment.

3.2.1 *The Project of the team*

Initially, the project team held some training on Lean Manufacturing, with particular emphasis on the SMED methodology. The team had prepared the implementation plan attending to the work that should be performed during the next months. The plan is illustrated in Figure 2.
The plant where the project was implemented has a stamping press area formed by a set of four main machines. Another set of six stamping machines is placed outside this main area, producing references in very small batches and not considered in the scope of this project which is the medium-term. The press units in the main area stamp alloy steel on cold metal sheet. The main stamping area operates in two daily shifts and is supported by the tooling and maintenance department, responsible for preventive and corrective maintenance of all equipment and tools.
Each shift employs four press operators and a team leader – responsible for the process supervision by providing the operators with support, supplying the documents in order to monitor the production, preparing for the setups and carrying out duties in the area of the quality.
Figure 3 represents part of the layout of the plant where the project was implemented. It shows the stamping area, the tool store area and the maintenance and tool department. The stamping area has a set of four main presses. Another six stamping machines are located outside this main area and are spread around the plant. The tooling store is in the same part of the maintenance and tools area, and the distance between press 4 and this department is around 40 meters.

3.2.2 *Data collection about previous setups*

The average setup times in the months leading up to the implementation of the project were registered in order to create a past record of the stamping process.

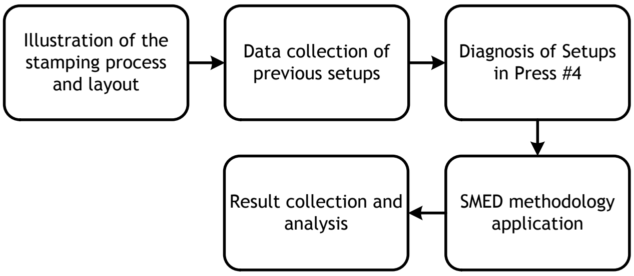


Figure 2. Phases of the SMED project implementation.

The data were collected from the Operations Department and the records of the Enterprise Resource Planning (ERP) system of the firm.
Table 1 shows that the setup times for the several presses are quite similar, which could be evidence

of the previous attempts to apply the SMED methodology to the process.

The average setup times for the stamping process are around 39 minutes, however considering the press 4, which integrates the pilot project of the SMED implementation, the average time was 40 minutes, as illustrated in the Figure 4.

According to the manager of the research firm it would be necessary to reduce the setup times for press 4 to an average of 25 minutes, in order to improve the productivity of the stamping process and improve the results for the pilot project.

3.2.3 *Diagnosis of the initial setup process for press 4*

During the first month of the project implementation all the processes of the changing references in press 4 were monitored by the team leader and the press operators during their respective shifts.

The process engineer collected all the data carefully in order to perform a correct diagnosis. The survey was made in a context of a normal production and also in occasional occurrences arranged with the SMED team in order to make the reference changes outside the production timetable. Such a data collection is summarized in Figure 5.

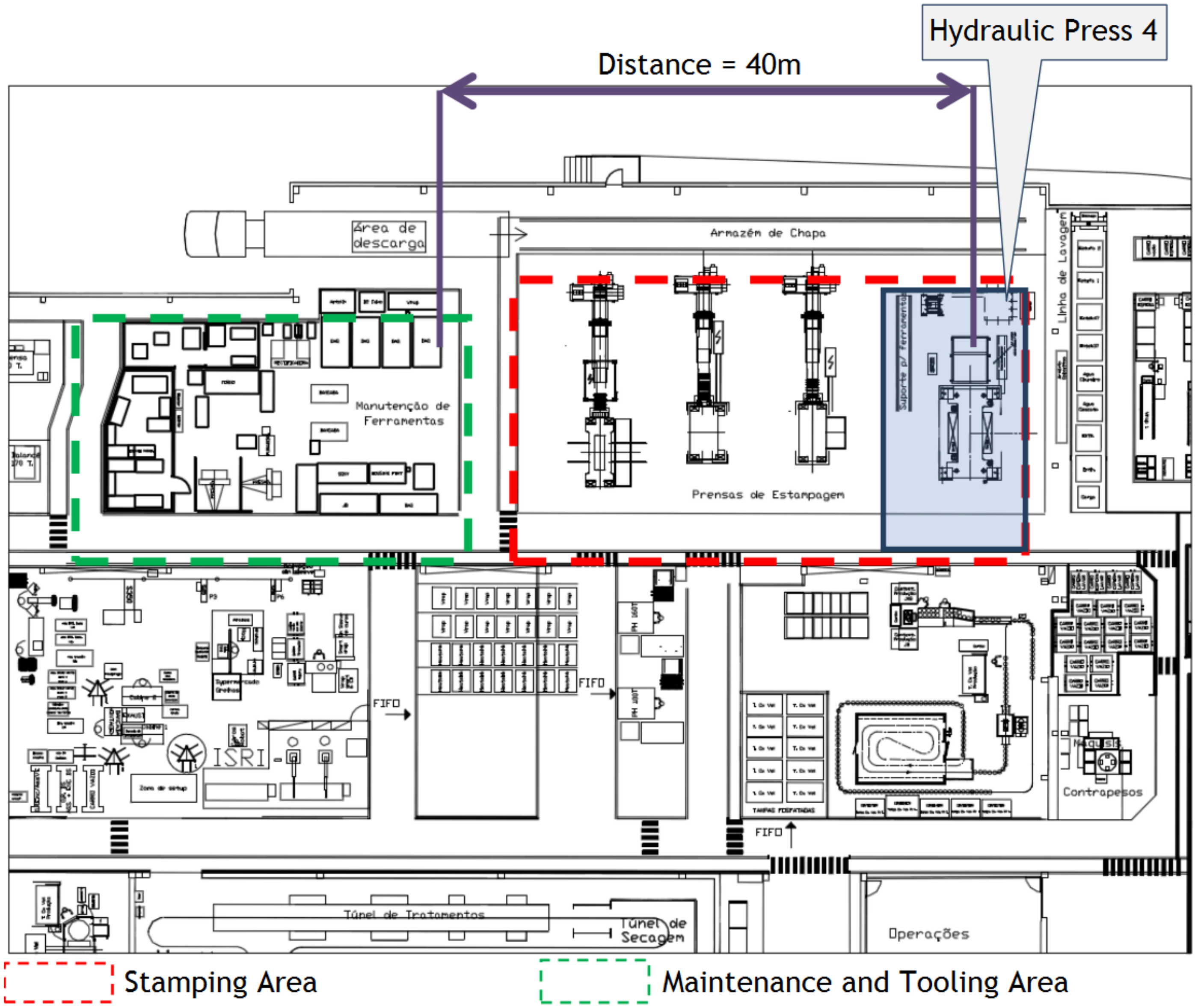


Figure 3. The layout of the stamping zone.

Table 1. Average setup time and frequency during the last eight months before the project.

		Month A	Month B	Month C	Month D	Month E	Month F	Month G	Month H	Average setup
Press 1	Average setup time (min)	43	42	37	41	39	38	41	39	
	Nº of setup's	12	9	3	3	16	9	16	21	
Press 2	Average setup time (min)	38	41	38	38	39	41	31	39	
	Nº of setups	13	10	6	4	7	9	9	5	
Press 3	Average setup time (min)	42	40	38	39	40	43	41	27	
	Nº of setup's	12	8	6	3	9	9	10	10	
Press 4	Average setup time (min)	42	40	39	41	42	38	36	44	
	Nº of setups	15	17	13	6	18	16	14	16	
Global	Average setup time (min)	41	41	38	40	40	40	37	37	39
	Nº of setups	13	11	7	4	13	11	12	13	10

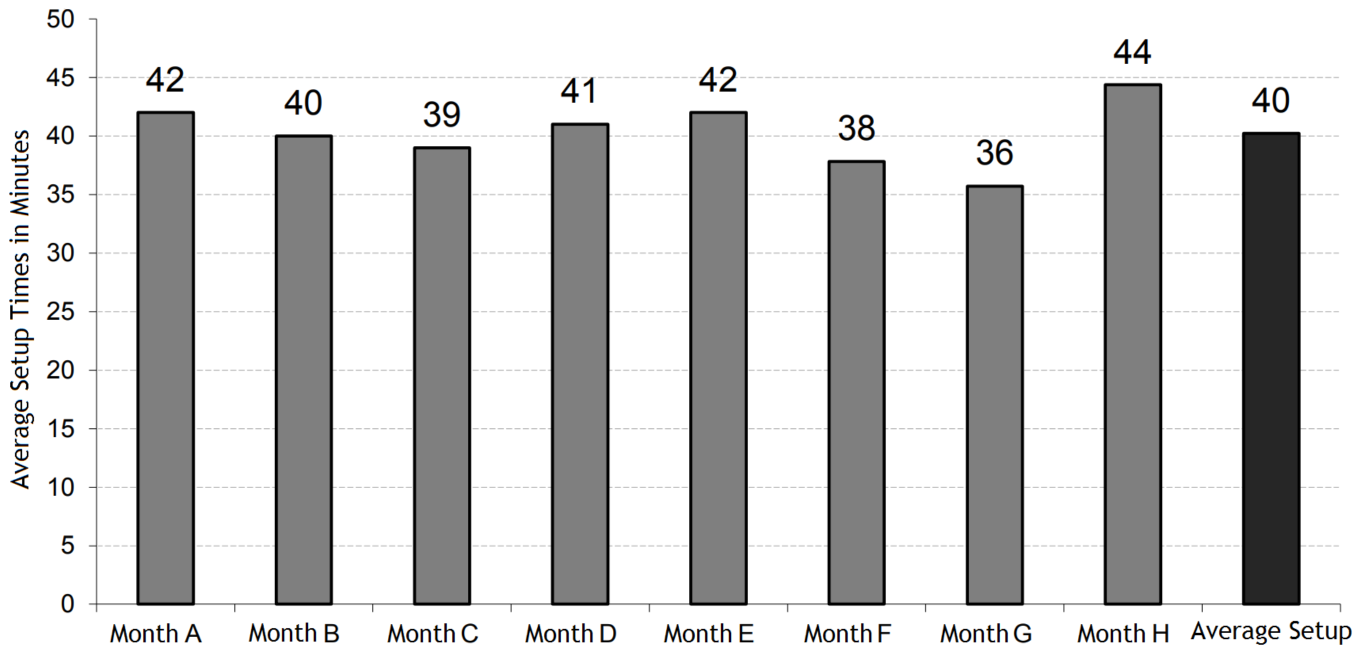


Figure 4. Average setup times for the studied Press 4.

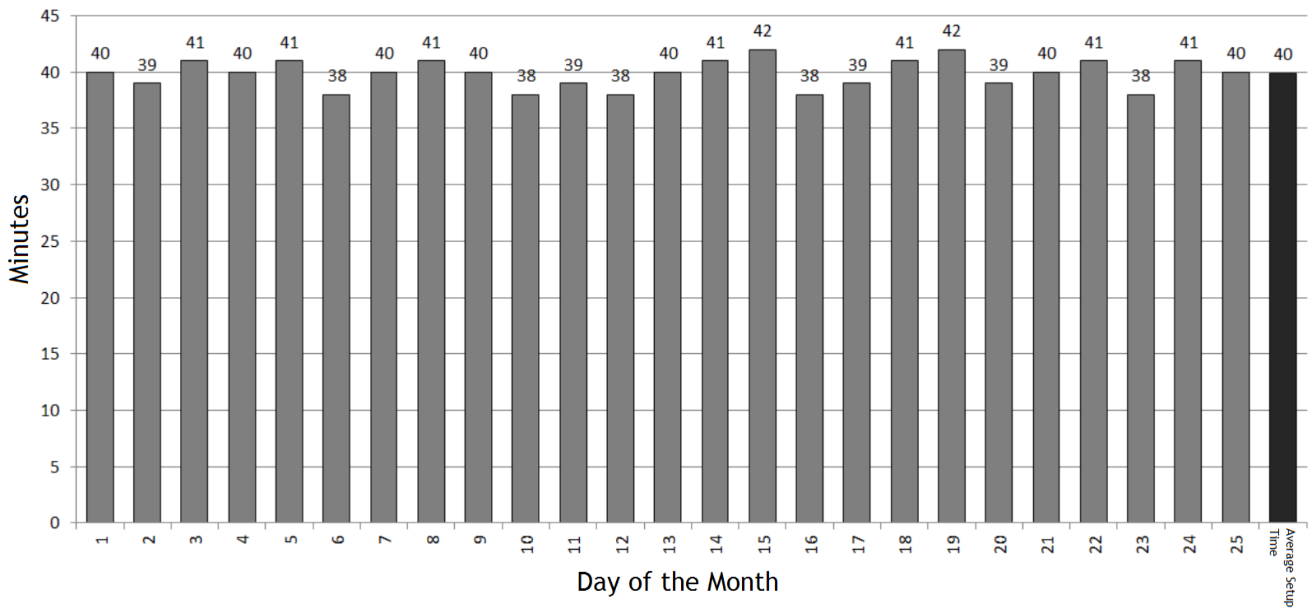


Figure 5. Setup times of the Press 4 during the first month of the implementation of the SMED Project.

The differences between setup times was found not to be representative and the sequence of entry and exit references did not have a significant impact on the results. This is due to the several tools having many similar characteristics and also to the change processes which does not require very different operations.
Based on the analysis made on the setup processes during the first month it was possible to identify the following two main time consuming activities: 1) to insert a new tool, 2) to remove a previous tool.
Besides being too slow, these activities implied the displacement of tools throughout the factory with the stoppage of the machine.
All the tasks associated to the change of reference in press 4 were recorded, as can be seen in Table 2. The survey covered all the steps involved in the setup, the preparatory tasks and the post-setup stage, for all the production references allocated to this machine. In addition, considering that the process always involved the team leader and the press operator, the tasks performed by each one at each moment and the respective average times were scheduled.
It should be noted that the allocation of tasks between the operator and the team leader did not follow a fixed pattern at the date of starting the project. Within the SMED team there was a commitment to establish a pattern in this task allocation by using the list created as a guide model in order to obtain a more stable process as improvements were implemented.
From the point of view of the SMED methodology this moment corresponds to the preliminary stage where there is no division between internal and external work. Indeed, in this phase the different tasks were classified as internal or external according to the need to carry them out with the idle equipment or not. Figure 6 illustrates the processing of external work tasks with the equipment stopped.
There is a clear desynchronization of activities between the two elements, resulting from the lack of a well-thought out implemented system and work method. Figure 6 illustrates the work time of each element. This scheme intends to demonstrate the time spent by each element and the associated stoppages. The different moments associated to the beginning and finishing work by the team leader and operator are shown in Figure 6.
The most obvious short-coming at this moment was the existence of long waiting time during the process. The total time to change references was, in average, 51 minutes of which 45 minutes corresponds to the setup time. The operator presented a long time waiting period of around 15 minutes while the team leader presented two periods of waiting.
The main reasons given by the operators and the team leader for the inefficiencies occurred in the preliminary stage are: a) execution of external tasks during the setup, including the preparation of raw material, movement of tools, utensils and containers, and quality control of the last exiting production pieces; b) time lags between the operator and the team leader to perform tasks jointly which originates a waiting time. The sequence of tasks is not balanced giving rise to bottlenecks.

3.2.4 *Application of SMED methodology on Press 4*

From the problems identified in the preliminary stage, the team set out to apply the SMED methodology in order to achieve the desired goals. The application of the method focused essentially on stages 1 and 2.

Stage 1: Separation of internal and external tasks:

Some of the tasks performed by the operator in the initial stage were transferred to the team leader. This represents external work having an impact on internal tasks performed by the operator. This separation of external and internal work allowed the operator to focus on effective setup tasks, leaving the others to the team leader. At the same time, other internal setup tasks carried out by the operator were transferred to the team leader as a way of shortening the idle time of the equipment and turning more productive the waiting time of the team leader.
The period of setup preparation for this element had to be redefined, as demonstrated in Table 3, contributing for increasing the number of tasks performed in this phase. This contributes to increase the availability of the leader to receive new tasks and help in others.

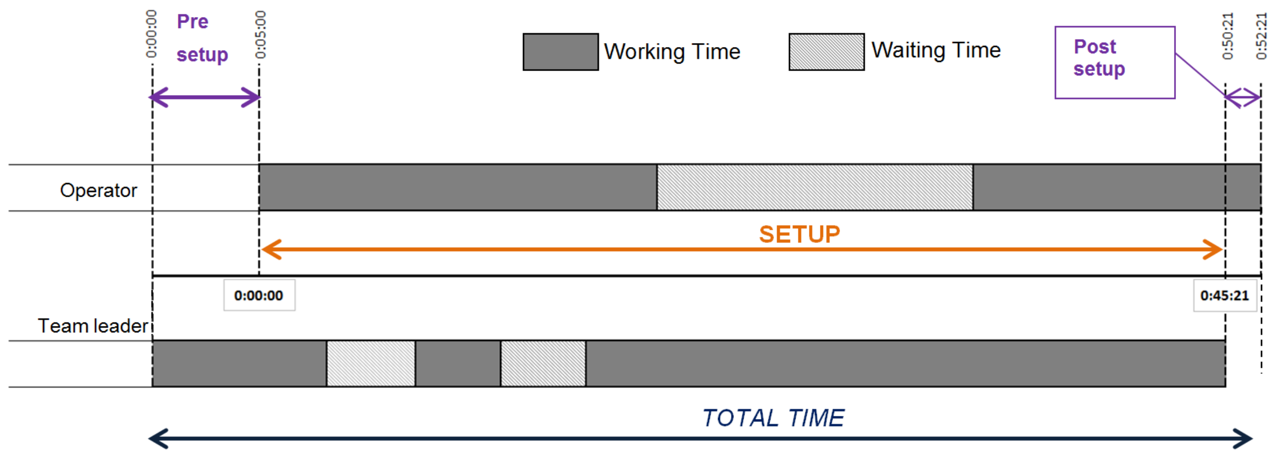


Figure 6. Working and setup time of operator and team leader during the process of changing references.

Table 2. Tasks and corresponding schedule at the beginning of the SMED implementation project. Where E means an External Task and I means an Internal Task.

Operator		t (sec)	t (sec)		Team Leader
			60	E	Determine the next production reference
			60	E	Print the monitoring reports
			120	E	Prepare control means for producing (DMM and control planes)
			60	E	Bring the kit to change along the press
Stop the press	I	10	30	E	Seek for Bridge with the new roll
Open security doors	I	3	25	E	Unwrap new roll
Wake lubrication support band	I	10	20	E	Fasten new roll
Remove grease support and load the change kit	I	60	80	E	Take new roll for the car
Remove the last piece and put on the control bench	I	20	20	E	Loosen new roll
Control the last piece of the previous series	E	60	10	E	Cut longitudinal strap
Records number of pieces of the previous series	E	60	246	N/A	Waiting
Remove part of the exit gutter	I	30			
Put output trough in the warehouse and bring new	E	60			
Clean scrap	I	60			
Remove band cut and put in the parts output table	I	35			
Close the security doors	I	3			
To Download the press	I	10			
Open security doors	I	10			
Unscrew front of the tool and remove gutter	I	180	180	I	Unscrew the back of the tool and remove the gutter
To up press	I	10	60	E	Pack gutter in warehouse and bring new
Extract table	I	50	250	N/A	Waiting
Search the bridge to the table	E	60			
Arrest tool	I	190			
Table of cleaning and positioners	I	200	436	E	Tool movement to the warehouse
Waiting	N/A	896	190	I	Loosen previous tool and arrest the next tool
			380	E	Transporting the new tool for the press
			90	I	Put tool on the table
Push forward the new tool and fit gutter	I	180	180	I	Tighten back the new tool and fit gutter
Put on the press table	I	60	70	I	Positioning the new car roll
Programming parameters (blow, step and reset counter)	I	50	20	I	Loosen and remove strap hooks to the floor
To Download the press	I	10	90	I	Unwind plate to the feeder
Lift the press	I	10	30	I	Put new output gutter
Remove previous piece counter and take the whip	E	180	180	E	Seek and position of the new piece container
Put the sheet on the tool	I	90	30	I	Connecting the oil
Cutting waste of sheet	I	30	35	I	Lubricate the band
Setting step	I	90	30	E	Remove Bridge workspace
Control the first piece	E	60	20	E	Tidy up pallet trucks
Register control of the first piece	E	60	20	E	Change Tidy kit

Table 3. Overloaded of the team leader before the stoppage of the machine for the setup.

	Preliminary stage		Stage 1	
Setup Preparation– Team leader	Determine the next production reference	60’’	Determine next production reference	60’’
	Printing monitory reports	60’’	Printing monitory reports	60’’
	Prepare control means	120’’	Prepare control means	120’’
	Bring the change kit near the press	60’’	Bring the change kit near the press	60’’
	Total	**300’’**	Bring the container of the new piece near the press	90’’
			Bring the bridge near to the new roll	30’’
			Unwrap the new roll	25’’
			Hold the new roll	20’’
			Bring a new roll to the car	80’’
			Loosen new roll	20’’
			Cut the longitudinal strap	10’’
			Total	**575’’**

Table 4. Changes in the activities performed by the operator and the team leader between preliminary stage and stage 1.

Preliminary Stage

Task	Operator		t (sec)	t (sec)		Team Leader
	Stop the press	I	10	30	E	Seek for the crane for the new roll
	Open the security doors	I	3	25	E	Unwrap the new roll
	Open the lubrication support band	I	10	20	E	Fasten the new roll
A	Remove the grease support and load the change kit	I	60	80	E	Take the new roll for the car
	Remove the last piece and put it on the control bench	I	20	20	E	Loosen the new roll
B	Control the last piece of the previous series	E	60	10	E	Cut the longitudinal strap
B	Register the number of pieces of the previous series	E	60	246	N/A	1st waiting period for the Team Leader
	Remove the part of the exit trough	I	30			
C	Put the output trough in the warehouse and bring a new one	E	60			
	Clean scrap	I	60			
	Remove the band cut and put in the parts output table	I	35			
	Close the security doors	I	3			
	Close the Press	I	10			
	Open the security doors	I	10			
	Unscrew the front of the tool and remove the trough	I	180	180	I	Unscrew the back of the tool and remove the trough
	Open the press	I	10	60	E	Pack the trough in the warehouse and bring a new one
	Extract the table	I	50	250	N/A	2nd waiting period for the Team Leader
D	Search for the crane for the table	E	60			
E	Lock the tool	I	190			
	Cleaning of the Table and Positioners	I	200	436	E	Tool displacement to the warehouse

Stage 1:

Task	Operator		t (sec)	t (sec)		Team Leader	Task
	Stop the press	I	10	30	E	Seek for the crane for the new roll	
	Open the security doors	I	3	25	E	Unwrap the new roll	
	Loosen the lubrication support band	I	10	20	E	Fasten the new roll	
	Remove the last piece and put it on the control bench	I	20	50	I	Remove lubrication support and load the change kit	A
	Remove the part of the exit pieces and place the change kit	I	30				
	Clean the scrap	I	60	60	E	Put output trough in the warehouse and bring a new one	C
	Remove the band cut and put it on output table for the parts	I	35	58	E	Search for the crane for the table	D
	Close the security doors	I	3				
	Close the Press	I	10				
	Open security doors	I	10				
	Unscrew the front of the tool and remove the remains	I	180	180	I	Loosen the rear of the tool and remove the remains	
E	Lock Tool	I	75	75	I	Lock Told	
	Cleaning of the Table and Positioners	I	200	436	E	Tool displacement to the warehouse	

B: Both tasks continued to be made by the operator but the post setup phase.

I - Internal Task   E – External Task

It can also be observed that the second waiting time of the leader occurs while the operator fetches the crane and secures the tool alone. The reorganization of work and task transfer are performed in the following way:

- Tasks A and C became part of the team leader's duties, occupying part of his waiting time.
- Tasks highlighted with the letter B were still allocated to the operator but were now performed in the post-setup period.
- Task D was placed in the leader's 2nd waiting period;
- Task E was divided between the two elements, reducing the time necessary for its execution, and fitting the half corresponding to the team leader in his 2nd waiting period.

The task of removing the container of the previous reference of the process and subsequent transport to the work in process (WIP) was redefined. The operator is no longer responsible for handling containers and the team leader now brings the new container in the setup preparation stage, ensuring it is ready for immediate installation.

In this way, during the setup stage it only becomes necessary to switch the exiting container and position the entry container, resulting in the consumption of 90 seconds within the setup, compared to the 180 seconds necessary before the improvement.

With the improvements reached from the preliminary stage to stage 1 it was possible to reduce the setup time from 45 minutes to 35 minutes. The total work time of the team leader did not increase with the

additional tasks and it was even reduced, confirming that his time was indeed optimized. The separation between internal and external tasks always involves the operator as the central element because he is the one who performs the greatest number of internal tasks while the team leader being only an auxiliary element. Therefore, separating internal and external work does not mean that all internal tasks will be performed outside the idle time. It means that almost all of the tasks should be removed from the internal work time of the operator and assigned to the work time of his auxiliary. Indeed, the stoppage time decreased as the operator has fewer internal tasks to perform. But this did not happen because the other tasks were allocated exclusively to the preparation or post-setup stage.
Table 5 shows the time difference associated to the change of reference between the preliminary stage and stage 1 with a notable reduction in setup time.

Stage 2: Converting internal into external tasks:

According to the analysis of the initial stage the greatest setup time consumption occurs in removing and inserting tools period. This process managed by the team leader implied movement of tools while the machine was idle, thus causing long waiting times for the operator. This stage focused on the set of activities associated to the greater time consumption.
The logistics of tools, which formed part of internal work was redefined, thus creating intermediate support near press 4. Therefore, the entry tool was then brought to the location in the pre-setup stage, ready for an immediate change. The intermediate support served to receive the exiting tool, which was then transported to the store once the setup was finished.
Compared to the initial state when the tools covered a distance of 40 meters in internal time, after the performed change, the distance during the setup became only 2 meters. The tool-changing process took 26 minutes, as opposed to 14 minutes after implementing this improvement. Table 6 illustrates the changes performed in the tasks from stage 1 to stage 2.
Indeed, task B of moving the tool to the store ceased to be performed as an internal task. Instead, the exiting tool came to be installed in the intermediate support saving 316 seconds compared to the previous stage. In turn, task C of loosening the exiting tool came to be performed by the two elements in parallel. This was possible because the task was performed in the press area, which did not happen before when only the team leader went to the store to deposit the tool.
Task B no longer made sense, since the crane now remained next to the press from the moment the entry tool was brought in the pre-setup stage. In fact, the elimination of this task left a gap in the work sequence of the team leader.

Table 5. Time evolution in the preliminary stage and the stage 1.

	Preliminary stage	Stage 1
Pre - setup	5 min	9 min
Setup	45 min	35 min
Post - setup	2 min	4 min
Total Time	52 min	48 min

Table 6. Changes in the activities performed by the operator and the team leader between the stage 1 and 2.

Stage 1:

Operator		t (sec)	t (sec)		Team Leader
Remove the cut band and put it in the table of the output parts	I	35	58	E	Bring the crane to the table (A)
Close the security doors	I	3			
Close the press	I	10			
Open the security doors	I	10			
Unscrew the front of the tool and remove the trough	I	180	180	I	Unscrew the back of the tool and remove the trough
Open the press	I	10	60	E	Pack the trough in the warehouse and bring the new one
Extract the table	I	50			
Lock the tool	I	75	75	I	Lock the tool
Cleaning of the table and positioners	I	200	436	E	Tool displacement to the warehouse (B)
The operator is waiting (C)	N/A	896	190	I	Unscrew the previous tool and tighten the next
			380	I	Move the new tool to the press (D)
			90	I	Put the tool on the table
Tighten the front of the new tool and place the trough	I	180	180	I	Tighten the back of the new tool and place the trough

Stage 2:

Operator		t (sec)	t (sec)		Team Leader
Remove the cut band and put it in the table of the output parts	I	35	58	N/A	3rd waiting
Close the security doors	I	3			
Close the press	I	10			
Open the security doors	I	10			
Unscrew the front of the tool and remove the trough	I	180	180	I	Unscrew the back of the tool and remove the trough
Open the press	I	10	60	E	Pack the trough in the warehouse and bring the new one
Extract the table	I	50			
Lock the tool	I	75	75	I	Lock the tool
Cleaning of the table and positioners	I	200	120	I	Remove the tool to the stand
Unscrew the previous tool and tighten the next	I	80	80	I	Unscrew the previous tool and tighten the next
The operator is waiting	N/A	75	75	I	Put the tool on table
Tighten the front of the new tool and place the trough	I	180	180	I	Tighten the back of the new tool and place the trough

I = Internal Task
E = External Task

Work performed in the pre setup phase

Move the tool to the warehouse after the setup

Table 7. Changes in the tasks of setup preparation between the stage 1 and stage 2.

	BEFORE – Stage 1		AFTER - Stage 2	
***Setup Preparation* – Team leader**	Determine the next production reference	60''	Determine next production reference	60''
	Printing monitory reports	60''	Printing monitory reports	60''
	Prepare control means	120''	Prepare control means	120''
	Bring the change kit near the press	60''	Bring the change kit near the press	60''
	Bring the container of the new piece near the press	90''	Bring the container of the new piece near the press	90''
	Bring the bridge near the new roll	30''	Bring the bridge near the new roll	30''
	Unwrap the new roll	25''	Unwrap the new roll	25''
	Hold new roll	20''	Hold new roll	20''
	Bring new roll to the car	80''	Bring new roll to the car	80''
	Loosen new roll	20''	Loosen new roll	20''
	Cut longitudinal strap	10''	Cut longitudinal strap	10''
			Transport the new tool to the bracket	**380''**
	Total	**575''**	**Total**	**1005''**

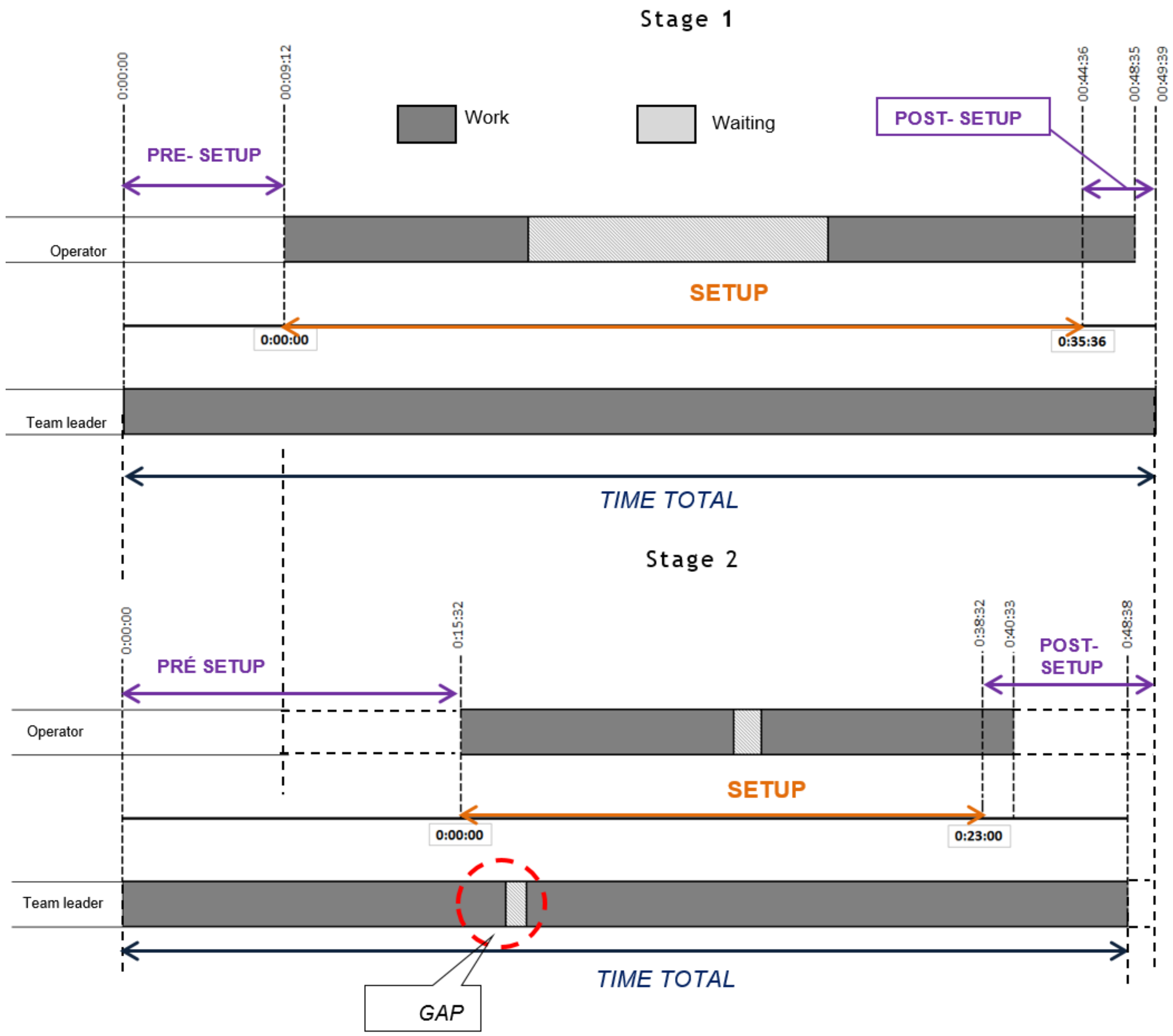


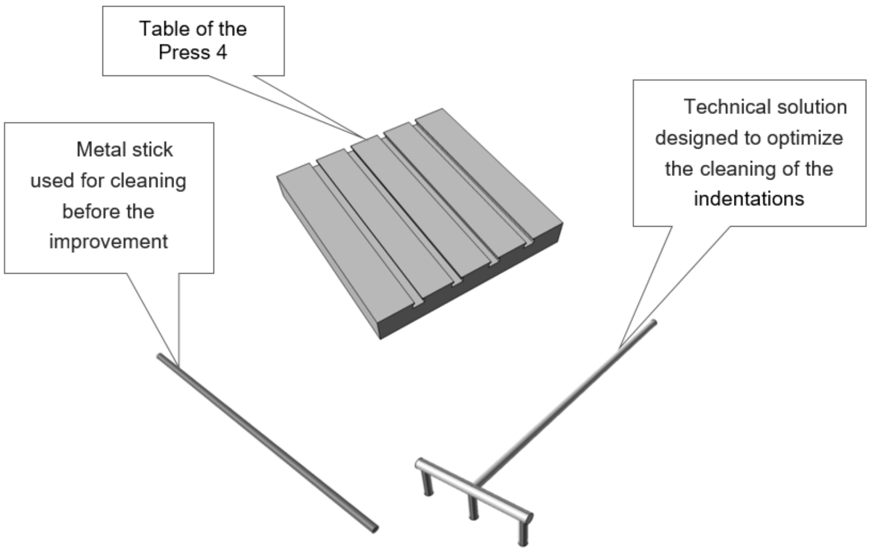
Figure 7. Improvements between stage 1 and 2.

Stage 3: Optimizing all setup activities

The work regarding this stage was divided in three fundamental activities: (1) optimizing tasks through technical solutions; (2) optimizing the method by reorganizing the task sequence; (3) standardizing operations of reference change.

Cleaning the press table is a task performed by the operator and consists of removing scrap metal remains and other strange materials trapped in the grooves. The process was performed with a metal stick passing along the grooves and removing the scrap. A simple new cleaning tool was developed, thus achieving an effective gain in the time required for this internal operation. This improvement is illustrated in Figure 8.

The cleaning and removal of scrap metal was developed for the operator but this activity is suggested to be divided with the team leader. By making that division the waiting time still remains in the sequence of the team leader, closing the gap that had been transferred from stage 2. Table 8 demonstrates the aforementioned process.



Before (Stage 2)		After (Stage 3)	
Cleaning of the table and metal sticks	200''	Cleaning of the table and metal sticks	70''
		Reduction in setup times	130''

Figure 8. Technical solution allowing to optimize the table clean-up operation.

Table 8. Elimination of the stoppage of the team leader by the split of tasks and the schedule reorganization.

Stage 2:

Operator		t (sec)	t (sec)		Team Leader
Cleaning of the scraps	I	60	60	I	Put the trough in the warehouse and bring a new one
Remove the cut band and put on output table of the parts	I	35	58	N/A	Waiting Period
Close security doors	I	3			
Close the press	I	10			
Open security doors	I	10			

Stage 3:

Operator		t (sec)	t (sec)		Team Leader
Cleaning of the scraps	I	30	30	I	Cleaning of the scraps
Remove the cut band and put on output table of the parts	I	35	58	E	Put the trough in the warehouse and bring a new one
Close the security doors	I	3			
Close the press	I	10			
Open the security doors	I	10			

I - Internal Task E – External Task

3.2.5 *Changing the sequence of the programming parameter activity*

This improvement could already have been contemplated in previous phases, but as it is a continuous process all the improvements already reached should be critically overlooked. Indeed, it became clear that in order to eliminate the waiting time of the operator, it was enough to fit into this inactive period the planned parameters of the machine. This activity should be performed in internal work, but there is no technical limitation to be done after inserting the tool of the new reference. Table 9 demonstrates the change in the moment that this activity is performed in the sequence of the operator's tasks, between the stages 2 and 3.

Finally, and observing the summary in the diagram in Figure 9, a reduction in setup time from 23 minutes to 20 minutes is obtained and the waiting time motivated by the inactivity of the operator is successfully eliminated. The possible improvements were made in the available useful time, regarding the three stages of the SMED methodology, and in doing so, the targets defined by management were reached and exceeded.

The total working time was not noticeably reduced, the reduction being from 52 minutes at the beginning of the project to 48minutes at the end. Yet, most of the time when the machinery was stopped it was reduced greatly from 45 minutes to 20 minutes.

This outcome was very important to demonstrate that SMED provides notable gains in the method and arranging stages. In this sense, it was possible to demonstrate the gains in the productivity and reducing the lead times.

3.2.6 *Standardizing operations of reference change.*

This pilot project demonstrated that over the three stages of SMED methodology there were tasks that from their theoretical definition would be applicable in different stages. This is the case of different individual tasks performed in parallel.

Once the desired level of improvement was reached it is necessary to maintain the obtained results. One of the most important factors for the methodology and its results is the continuous and systematic monitoring of the process.

At the end of the pilot project, the SMED team structured an operational method resulting from the successive development of the reference change procedure throughout the application of the methodology.

The definition of a standardized operational method is fundamental to monitor and help operators in developing this procedure. It serves as a training for new operators.

The operational method should contain the sequence of tasks to be performed, the operator assigned, the time defined for carrying them out and the auxiliary tools necessary.

It should also separate tasks to be performed inside the setup time from those that are part of the preparation stage and the subsequent stage, becoming a useful tool in both preparation and execution of the setup.

Table 9 – Reorganization of the tasks schedule.

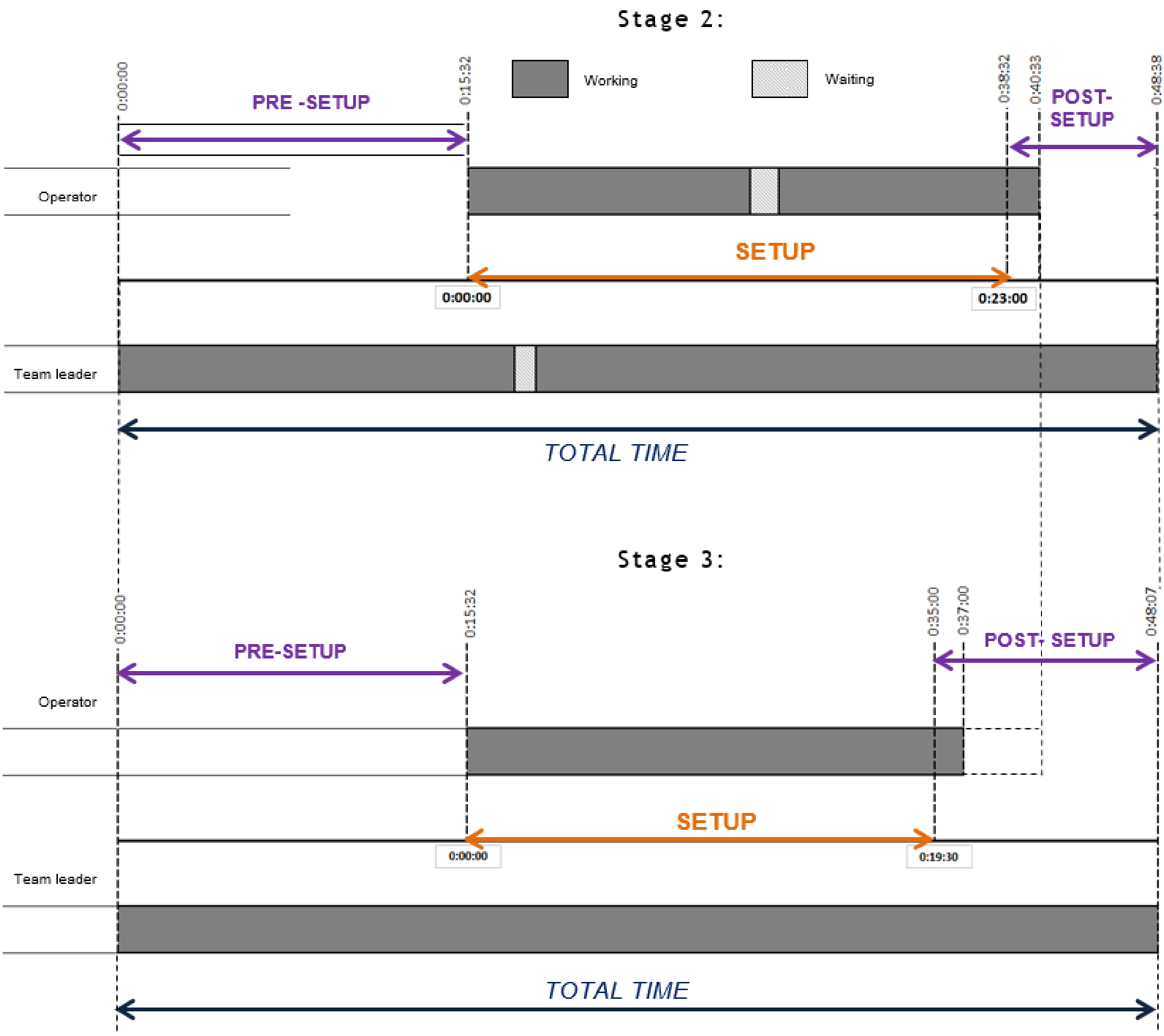
Stage 2:

Operator		t (sec)	t (sec)		Team Leader
Waiting Period	**N/A**	75	75	I	Place the tool on the table
Tighten the front of the new tool and put the gutter	I	100	100	I	Tighten the front of the new tool and place the trough
Place the table on the press	I	60	70	I	Positioning the new car roll
Programming parameters (hit, step and reset counter)	I	60	20	I	Loosen and remove strap hooks to the floor
Close the press	I	10	90	I	Unwind the roll's plate to the feeder

Stage 3:

Programming parameters (hit, step and reset counter)	I	75	75	I	Put the tool on the table
Tighten the front of the new tool and place the trough	I	100	100	I	Tighten the front of the new tool and place the trough
Place the table on the press	I	60	70	I	Positioning the new car roll
Close the press	I	10	20	I	Unwind the roll's plate to the feeder

I - Internal Task E – External Task



	Preliminary Stage	Stage 1	Stage 2	Stage 3
Pre-setup	5min	9min	15min	15min
Setup	45min	35min	23min	20min
Post-setup	2min	4min	10min	13min
Total Time	52min	48min	48min	48min

Figure 9. Improvements reached across all stages.

4. CONCLUSION

This study provided a deeper knowledge about the Lean Manufacturing production model and particularly on SMED methodology. The implementation of the SMED method through the pilot project produced relevant results, considering the objectives drawn up by management for the work team. Indeed, it was possible to achieve a greater reduction in setup times.
However, considering the state-of-the-art of SMED methodology, it is necessary to take into account some important factors in order to have a broader view of the obtained results.

Firstly, it should be highlighted that as the firm was already familiar with the Lean philosophy it demonstrated again an understanding of the potential of the methodologies and associated tools, as well as the improvement that can be reached by employing them without requiring an additional investment.
The SMED methodology is divided into various stages. Its application on the shop floor should respect the separation of internal and external work,

thus converting internal work in external and improving all activities.

This pilot project demonstrated that over the three stages of SMED methodology there were tasks that from their theoretical definition would be applicable in different stages. This is the case of different individual tasks performed in parallel.

The whole SMED project was developed without considering re-engineering and/or acquisition of new equipment. Therefore, the set of factors associated to the optimization of the equipment design for reference change was not applicable on the shop floor. Indeed, this application of the methodology was based on reorganization of work, training and implementation of a systematic and effective method of performing the various operations. It was thereby confirmed that SMED provides notable gains in the method and organization components, and the improvements obtained were in the order of 45% reduction in setup time.

The company needed to increase the productivity of its whole system and integrate the SMED methodology without benefiting from the whole set of advantages that can arise from its implementation, namely, reducing batches, raising quality, increasing the frequency of setups and reducing lead times.

The SMED project focused only on reducing setup times and did not contemplate the application of the improvements to reduce preparation times and the post-setup period. This was because in the shop floor the focus is on the time the machine is stopped and its optimization.

By definition, the setup corresponds to the time the machine is idle between the last part of the previous reference and the first quality part of the entering reference. In this study, validating the quality of the first quality part was placed in external work. Certainly, this may give rise to various criticisms regarding the rigorous definition of the setup concept. From the definition of setup, production would only start after the validated part. Such a strategy would only make sense if there was a high probability of the first part not being of quality. It was decided to keep the production batch while validation of the first “suspect” part was performed.

For the upcoming improvements, the continuous monitoring of setup activities in press 4 is necessary, so that the implementation of best practices stills over time. The operational method was defined but it is necessary to respect its importance in the future.

It will be important for the company to define a monitoring strategy, determining a group of people in charge of this task to consolidate all the work done in the pilot project and make the SMED results sustainable. The implementation of SMED within this company opened up several opportunities for new improvements, perhaps even for new jobs in the future. Planning may lead to re-dimensioning of batches, which will be distributed over a greater number of machines, contributing to increase production flexibility and making possible the implementation of a Just-In-Time production system.

ACKNOWLEDGEMENT

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5. REFERENCES

[1] E. Juehling, M. Torney, C. Herrmann, and K. Droeder, “Integration of automotive service and technology strategies,” CIRP J. Manuf. Sci. Technol., vol. 3, no. 2, pp. 98–106, Jan. 2010.

[2] R. Godina, J. C. O. Matias, and S. G. Azevedo, “Quality Improvement with Statistical Process Control in the Automotive Industry,” Int. J. Ind. Eng. Manag., vol. 7, no. 1, pp. 1–8, 2016.

[3] S. A. M. Elmoselhy, “Hybrid lean–agile manufacturing system technical facet, in automotive sector,” J. Manuf. Syst., vol. 32, no. 4, pp. 598–619, Oct. 2013.

[4] K. Stylidis, C. Wickman, and R. Söderberg, “Defining Perceived Quality in the Automotive Industry: An Engineering Approach,” Procedia CIRP, vol. 36, pp. 165–170, Jan. 2015.

[5] R. Godina, E. M. G. Rodrigues, and J. C. O. Matias, “An Alternative Test of Normality for Improving SPC in a Portuguese Automotive SME,” in Closing the Gap Between Practice and Research in Industrial Engineering, Cham, Switzerland: Springer, 2018.

[6] Nurul Fadly Habidin, Sha’ri Mohd Yusof, and Nursyazwani Mohd Fuzi, “Lean Six Sigma, strategic control systems, and organizational performance for automotive suppliers,” Int. J. Lean Six Sigma, vol. 7, no. 2, pp. 110–135, May 2016.

[7] Kyle B. Stone, “Four decades of lean: a systematic literature review,” Int. J. Lean Six Sigma, vol. 3, no. 2, pp. 112–132, Jun. 2012.

[8] D. R. Kiran, “Chapter 22 - Kaizen and Continuous Improvement,” in Total Quality Management, Butterworth-Heinemann, 2017, pp. 313–332.

[9] D. R. Kiran, “Chapter 25 - Lean Management,” in Total Quality Management, Butterworth-Heinemann, 2017, pp. 363–372.

[10] S. Shingo and A. P. Dillon, A Study of the Toyota Production System: From an Industrial Engineering Viewpoint. CRC Press, 1989.

[11] Ibrahim A. Rawabdeh, “A model for the assessment of waste in job shop environments,” Int. J. Oper. Prod. Manag., vol. 25, no. 8, pp. 800–822, Aug. 2005.

[12] A. Moeuf, S. Tamayo, S. Lamouri, R. Pellerin, and A. Lelievre, “Strengths and weaknesses of small and medium sized enterprises regarding the implementation of lean manufacturing,” IFAC-Pap., vol. 49, no. 12, pp. 71–76, Jan. 2016.

[13] M. Bevilacqua, F.E. Ciarapica, I. De Sanctis, G. Mazzuto, and C. Paciarotti, “A Changeover Time Reduction through an integration of lean practices: a case study from pharmaceutical sector,” Assem. Autom., vol. 35, no. 1, pp. 22–34, Jan. 2015.

[14] M. A. Almomani, M. Aladeemy, A. Abdelhadi, and A. Mumani, “A proposed approach for setup time reduction through integrating conventional SMED method with multiple criteria decision-making techniques,” Comput. Ind. Eng., vol. 66, no. 2, pp. 461–469, Oct. 2013.

[15] M. Kemal Karasu, M. Cakmakci, M. B. Cakiroglu, E. Ayva, and N. Demirel-Ortabas, “Improvement of changeover times via Taguchi empowered SMED/case study on injection molding production,” Measurement, vol. 47, pp. 741–748, Jan. 2014.

[16] S. C. Trovinger and R. E. Bohn, “Setup Time Reduction for Electronics Assembly: Combining Simple (SMED) and IT-Based Methods,” Prod. Oper. Manag., vol. 14, no. 2, pp. 205–217, Jun. 2005.

[17] B. Stefansdottir, M. Grunow, and R. Akkerman, “Classifying and modeling setups and cleanings in lot sizing and scheduling,” Eur. J. Oper. Res., vol. 261, no. 3, pp. 849–865, Sep. 2017.

[18] D. Van Goubergen and H. Van Landeghem, “Rules for integrating fast changeover capabilities into new equipment design,” Robot. Comput.-Integr. Manuf., vol. 18, no. 3, pp. 205–214, Jun. 2002.
[19] R. Rodríguez-Méndez, D. Sánchez-Partida, J. L. Martínez-Flores, and E. Arvizu-BarrÓn, “A case study: SMED & JIT methodologies to develop continuous flow of stamped parts into AC disconnect assembly line in Schneider Electric Tlaxcala Plant.,” IFAC-Pap., vol. 48, no. 3, pp. 1399–1404, Jan. 2015.
[20] A. C. Moreira and G. C. S. Pais, “Single Minute Exchange of Die. A Case Study Implementation,” J. Technol. Manag. Innov., vol. 6, no. 1, pp. 129–146, Mar. 2011.
[21] Claire Moxham and Richard Greatbanks, “Prerequisites for the implementation of the SMED methodology: A study in a textile processing environment,” Int. J. Qual. Reliab. Manag., vol. 18, no. 4, pp. 404–414, Jun. 2001.
[22] Samuel Jebaraj Benjamin, Uthiyakumar Murugaiah, and M. Srikamaladevi Marathamuthu, “The use of SMED to eliminate small stops in a manufacturing firm,” J. Manuf. Technol. Manag., vol. 24, no. 5, pp. 792–807, May 2013.
[23] M. Braglia, M. Frosolini, and M. Gallo, “Enhancing SMED: Changeover Out of Machine Evaluation Technique to implement the duplication strategy,” Prod. Plan. Control, vol. 27, no. 4, pp. 328–342, Mar. 2016.
[24] Bikram Jit Singh and Dinesh Khanduja, “SMED: for quick changeovers in foundry SMEs,” Int. J. Product. Perform. Manag., vol. 59, no. 1, pp. 98–116, Dec. 2009.
[25] R. K. Yin, Case Study Research: Design and Methods. SAGE, 2009.
[26] Chris Voss, Nikos Tsikriktsis, and Mark Frohlich, “Case research in operations management,” Int. J. Oper. Prod. Manag., vol. 22, no. 2, pp. 195–219, Feb. 2002.
[27] A. M. Pettigrew, “Longitudinal Field Research on Change: Theory and Practice,” Organ. Sci., vol. 1, no. 3, pp. 267–292, 1990.
[28] Cipriano Forza, “Survey research in operations management: a process-based perspective,” Int. J. Oper. Prod. Manag., vol. 22, no. 2, pp. 152–194, Feb. 2002.
[29] P. G. Ferradás and K. Salonitis, “Improving Changeover Time: A Tailored SMED Approach for Welding Cells,” Procedia CIRP, vol. 7, pp. 598–603, Jan. 2013.
[30] T.-M. Yeh, F.-Y. Pai, and K.-I. Huang, “The critical factors for implementing the quality system of ISO/TS 16949 in automobile parts industry in Taiwan,” Total Qual. Manag. Bus. Excell., vol. 24, no. 3–4, pp. 355–373, Apr. 2013.
[31] J. A. Oliveira, O. J. Oliveira, A. R. Ometto, A. S. Ferraudo, and M. H. Salgado, “Environmental Management System ISO 14001 factors for promoting the adoption of Cleaner Production practices,” J. Clean. Prod., vol. 133, pp. 1384–1394, Oct. 2016.
[32] R. I. McIntosh, S. J. Culley, A. R. Mileham, and G. W. Owen, “A critical evaluation of Shingo’s ‘SMED’ (Single Minute Exchange of Die) methodology,” Int. J. Prod. Res., vol. 38, no. 11, pp. 2377–2395, Nov. 2010.
[33] J. Kušar, M. Starbek, T. Berlec, and F. Žefran, “Reduction of machine setup time,” Stroj. Vestn., vol. 12, no. 56, pp. 833–845, 2010.

Implementacija SMED metodologije u automobilskoj industriji koristeći metod studije slučaja

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Apstrakt

U današnje vreme, veoma je važno smanjenje suvišnih troškova u industrijskim jedinicama. Samo putem takvog pristupa profitna marža bi se mogla povećati. Cilj ovog rada je da pokaže doprinos metodologije brze izmene alata (SMED) kako bi se smanjilo vreme podešavanja u procesu štampe metalnih komponenti u automobilskoj industriji. Za demonstriranje ovog doprinosa koristi se kvalitativni pristup zasnovan na studiji slučaja. U ovoj studiji slučaja primena SMED metodologije daje značajan doprinos u smislu smanjenja vremena podešavanja (45%) kroz bolju reorganizaciju procesa rada. Prema studiji slučaja primena SMED metodologije treba da se sprovodi simultano uz reorganizaciju procesa rada, izvođenje obuka i implementaciju sistematskog i efikasnog načina obavljanja različitih operacija koje se obavljaju u posmatranom preduzeću.

Ključne reči: *Ljudski resursi, Lean proizvodnja, pripremno vreme, SMED, izmena alata*