Reduction of changeover time in a small manufacturing make-to-order enterprise: a case study

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Abstract: Increasing competition has led more and more companies towards a careful waste identification and removal process, often by introducing lean oriented concepts and tools. However, especially for the application outside of the Japanese automotive sector, the implementation of lean manufacturing could face barriers that are difficult to overcome. This is particularly true in Small- and Medium-Sized Enterprises (SMEs), where, as a matter of fact, several of the management principles proposed in one of the most accepted characterizations of lean manufacturing are not respected (e.g. lack of a long term philosophy; scarce training of management and staff; insufficient organizational processes and standardized procedures). Scientific literature agrees that not all lean tools are sustainable and effective for companies of different sizes and sectors. In this study, we focus on the SMED (Single-Minute Exchange of Dies), a set of techniques that allows to reduce the changeover times, and thus it is particularly suitable for make-to-order companies. In these contexts, short changeover times bring several advantages, such as less inventory, greater production capacity or wider production mixes, and shorter lead times. Goal of this work is to report a case study of SMED implementation in a metalworking SME, which produces small mechanical parts for oleodynamic systems. We focused on the changeover times of multi-spindle cam lathes. To implement SMED, we followed these steps: after data collection and processing, we split activities between internal and external ones, maximizing the latter and dividing them between two different types of operators. This work led us to design a to-be changeover process and its standard procedures. The results we achieved present a significant reduction in changeover times, and cost-savings generated by the shift of activities on less-expensive operators. Also, the to-be process reduces inventory levels and it increases production mix or capacity.

Keywords: Lean Manufacturing, SMEs, Single-Minute Exchange of Dies (SMED), make-to-order, Italy.

1. Introduction

The manufacturing evolution over the last twenty years is characterized by customized products. Manufacturing companies have paid attention to business solutions that improve both organisation and operation management to respond to this requirement (Bertolini, Romagnoli and Zammori, 2017). Many companies struggled in the new customer-driven and globally competitive market, resulting in a big challenge for organizations, that must look for new tools and methods to comply with this new market scenario; to respond to this, many manufacturers turned to 'lean manufacturing' (LM), aiming for a high flexibility in response to varying customer requests (Bhamu and Sangwan, 2014). LM is generally described from two points of view, either from a philosophical perspective, related to guiding principles and overarching goals (Womack and Jones, 1996), or from the practical perspective of a set of management practices, tools, or techniques that can be observed directly (Shah and Ward, 2003). With respect to the former perspective, LM aims to reduce wastes at all organization levels, whereas concerning the latter, the focus is on changing the traditional high-volume production paradigm to the 'low buffer' production system (Hopp and Spearman, 2004; Marangoni, Romagnoli and Zammori, 2013). Regarding the latter perspective, several elements have been considered for the implementation of the LM system. First of all, Pull Systems that rely on customer requirement has been proposed as alternative to Push Systems that rely on predetermined schedule (Dengiz and Akbay, 2000). Furthermore, Cellular Manufacturing defines facility operation clusters to minimize the process flow. Its evolutions, namely U-line concept and line balancing concept, stress the organization of fluctuating line flows (Das, Lashkari and Sengupta, 2007). Moreover, Kanban is a Material Flow Control mechanism which delivers the right quantity of parts at right time (Graves, Konopka and Milne, 1995). This strategy is developed by focusing on two aspects: (i) straightforward schedule without interruption, by means of one-piece flow that ensures just-in-time (JIT) production system, and (ii) backflow that relaxes the *takt time* and decreases the risk of machine failures and operator mistakes. Heijunka, also known as Production Levelling, enhances production volume as well as production mix and production efficiency by means of reducing waste and overcoming unfair use of people and equipment (Liker, 2004). Other strategies are well-known, out of these the Single Minute Exchange of Dies methodology (simply SMED) is the systematic reduction of changeover time by converting possible internal setting time (i.e. possible to carry out during machine stoppage) to external time (i.e. performed while the equipment is running), simplifying and streamlining the remaining activity (Dillon and Shingo, 1985). Sundar, Balaji and Kumar (2014) prove that organizations often focus on few lean aspects, such as Cellular Manufacturing, Pull System, or Production Levelling. On the contrary, companies often overlook to consider how to deploy tools suitable to face the increasing needs for optimising operations. Especially, focusing on SMED, we notice a gap in academic literature. If we query Scopus on SMED, as it is the largest abstract and citation database of peer-reviewed literature, it is possible to state that research community has been growing the interest in SMED applications just since 2017. For this analysis, we have used the Scopus 'Analyze Search Results' tool, and we have limited the output to timespan of the first publication (i.e. 1997) to 2019 (i.e. we have excluded 2020 to do not affect the result because of partial results).

Focusing on studies related to Small and Medium Enterprise (SMEs), just 68 results are provided, and 30 out of the total (about the 50%) have been produced in 2019. Appendix A provides the reader with the string we have used to query the Scopus database (last access on 9th March 2020). This result really puzzled us, since SMEs aim to reply to all kinds of customers and their order quantity for keeping a competitive advantage, and decreasing setup times allows to produce parts in small batches helping company to reply to several smaller customers' order in a short time (Azizi, 2015). This eventually means to increase flexibility, as the ability to respond to markets demands by policies and actions switching between one product and the others (Nemetz and Fry, 1988).

In the present paper we propose a case study, led by the University of Parma, providing an application of SMED technique within a SME that manufacture metal parts by turning operation. The study aims to reduce the changeover times of multi-spindle cam lathes. The remainder of the paper is structured as follows. In section 2 we provide an overview of LM in SMEs' environment and the basics of the SMED. Section 3 is devoted to the description of the company with which the SMED project has been developed. In Section 4 we describe the case study by means of the phases of the project to implement the SMED in the focal company. In section 5 we provide the reader with preliminary results since the project partners (i.e. University and the focal company) are still running the project. Finally, section 6 is devoted to conclusion and future developments.

2. An overview on Lean Manufacturing in SMEs

The root of LM, as a revolution of the trade-off between productivity and quality in mass production practices, grew from production systems rethinking in the motor industry and it is well-known that moved from the story of the Toyota Production System (TPS), which fuelled one of the greatest corporate success stories (Ohno, 1988). However, the book 'The machine that changed the World' (Womack, Jones and Roos, 2007) introduced the term 'lean production' (a synonym of LM) in 1990 and played a key role in disseminating the concept of just-in-time (JIT) outside of Japan. By combining both philosophical and technical points of view, LM provides a complex of principles and techniques that allow to create and add value, to both products and practices, though wastes reduction at least, which develops into more efficient resource utilisations (Emiliani, 1998). Although LM principles are, nowadays, well-established both in academia and practitioners' world, some barriers to LM deployment exists. Lots of Lean definition are provided, however just someone is consistent (Dahlgaard-Park and Pettersen, 2009), and among them Liker' portraying (Liker and Meier, 2006) is one of the most valid (Dahlgaard-Park and Pettersen, 2009). Especially four principles, out of all fourteen of this characterisation, are useful to highlight, and they can be summarised as (i) long-term and (ii) leadership and management strategies, (iii) standardisation, and (iv) continuous improvement. These principles are suitable to consider since are the same that other studies (Hu *et al.*, 2015) have proven to be fundamental when implementing lean principles within the SMEs' environment, regardless the business they do. On the contrary, Moeuf *et al.* (2016) have proven that SMEs actually are conflicting these principles, their strategies are middle-low term tailored, and they suffer from both (i) a lack of company knowledge and management strategies, and (iii) the lack of standardised procedures and estimated methodologies, either to perform the company activities and to improve them.

Questions arise so far. Is it possible to implement, albeit partially, LM principles within SMEs? Whether it is, what kind of instruments to adopt? Does it exist a 'toolkit' of techniques in order to develop LM-based processes in SME' environments? The general answer does not exist, off course. However, Matt and Rauch (2013) have proposed seven clusters of LM techniques generally suitable to SMEs. These are: (i) 5S methodology, (ii) Benchmarking practices, (iii) Kaizen approach, (iv) JIT production system, (v) Pull production strategies, (vi) SMED, (vii) Value Stream Mapping. Among these, the only SMED falls outside management and control practices (Matt and Rauch, 2013) that traditionally require long-term planning to be implemented. Furthermore, it is a bit fuzzy to propose some techniques, since they entail lots of strategies and methods, whose theories are independent to the same LM theory, e.g. JIT techniques (Hopp and Spearman, 2004). As a result, SMED seems to be a good compromise solution to trigger the company adopting LM techniques and principles. Furthermore, starting from the manufacturing area and gradually involving all the business operation seems to be the best approach for SMEs (Rose *et al.*, 2011). In next subsection we provide the reader with just essential principles of SMED, since the technique is really well-known in both literature and experts' environment. We refer to the Shingo's study for SMED full description.

2.1 A brief overview on SMED

SMED, the popular name of 'quick change-over time' was introduced and developed by Shigeo Shingo (Dillon and Shingo, 1985). Based on indirect measurement point, such as time and video monitoring, the authors separated the changeover time into internal and external set-up times. The former refers to 'Inside Exchange of Die' (IED), namely those activities performed by stopping the machine. The latter refers to the ‘Outside Exchange of Die’ (OED), namely those activities performed without stopping the machines. The authors provided a framework to convert suitable internal set-up to external set-up. Furthermore, the SMED framework proposes (i) the introduction of an assistant operator working in parallel with the senior operator during the IED, and (ii) designing one touch set-up practices to limit the change over time within 10 minutes. Finally, a last step requires the standardization of tasks, by means of visualization tool and the introduction of systems such as jigs and other attachments. Finally, SMED allows to improve production capacity, efficiency, and quality, as well as to reduce lead time, production costs, and inventory levels. This is possible by considering as main criteria, when mapping the set-up activities towards the SMED, the following elements: (i) time, (ii) costs, (iii) use of resources, (iv) facility layout, (iv) equipment maintenance, and (v) quality off course (Almomani *et al.*, 2013).

SMED technique in Italian industry is successfully applied: for instance, Chiarini (2014) improved the OEE from 40% up to 60% by reducing to 37% the set-up time through the SMED implementation in a plastic injection process for producing moulds. Faccio *et al.* (2015) reduced the medium changeover time by 64% in a pharma company. Generally, results achieved mostly depend on the specific case study. Before focusing on changeover optimisation, in fact, analysts should understand the whole process and match the changeover redesign to the specific environment, as proved by Braglia, Frosolini and Gallo in their studies (2016, 2017). Next section fulfils this goal.

3. The SMED project in Mi.Ol.

The University of Parma and Mi.Ol. S.r.l. (fictitious name of the focal company, used because of a non-disclosure agreement) have been involving in a fruitful partnership over the last five years. The long-term aim of the project is the company processes reengineering, by means of low-middle term sub-projects towards the optimisation of operations and the design of business intelligence tools. One of these sub-projects is about developing the SMED technique the manufacturing operations during a still running one-year project. In these section we first describe the focal company, then we provide the preliminary analysis of the problem.

3.1 The focal company Mi.Ol.

Mi.Ol. S.r.l. is a SME based in Parma, employing about thirty people, whose majority work in the shop floor. The company manufactures precision small metallic parts for hydraulic and oleodynamic distributors by turning operation (Figures 1-2).

Figure 1: Mi.Ol. products. Picture has been sketched because of trade secret

Its strategy is make-to-order and Mi.Ol. mainly produces customers’ drawings in batches that typically range from 100 up to 300,000 units. Machineries are twelve multi-spindle cam lathes and four CNC mono-spindle lathes. CNC machines are easy to set, but everyone has low production capacity: set-up lasts six hours, more or less, and hourly throughput ranges from 50 to 100 parts per hour. On the contrary, multi-spindle cam lathes have high production capacity and they can produce up to 500 parts per hour (each single machine). Unfortunately, set-up time for changeover can last up to twenty-four hours, which sounds like three workshop shifts.

Before the SMED project development, two approaches were adopted over last years, aiming to (i) scale economies and (ii) scope economies. The former relates to multi-spindle machines overproduction to minimize the number of set-up and thus reduce the single-product-unit cost. It is well-known that this approach results in even increasing stock quantities, which increase the warehouse costs and fixed assets. Furthermore, this approach needs for puzzling over the meaning of Make-To-Order as production strategy adopted by the company. The latter approach, pursuing scope economies, relates to a recent more structured reengineering of production routings, developed in collaboration with the University of Parma. Firstly, the partners have analysed customers’ order history to assign routings to each product with respect to the order quantities, i.e. small order batches to CNC machines and large order batches to multi-spindle cam machines. Secondly, products are clustered in product families on the basis of a similarity index properly calculated. Since this is not the focus of the paper, we do not linger over this study and we just say that products whose similarity index is suitable are grouped in the production order and thus are machined on the same lathe, increasing efficiency of the system. This activity has been preliminary to the SMED.

3.2 Multi-spin cam lathe changeovers

Cam machineries have six spindles working simultaneously. Each lathe allows to work parts axially or radially, or to machine the front surface of the parts, that makes these machineries into real machining centres. Mi.Ol. parts generally require thirteen settings, out of all twenty-two possible settings of each lathe.

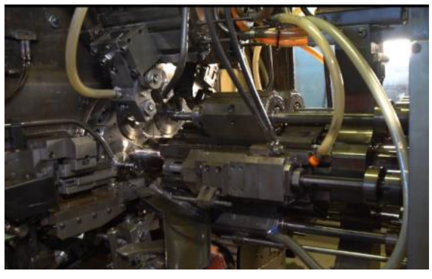

Figure 2: internal view of the multi-spin cam lathe

The main problem faced setting up these machineries relates to the impossibility to fully reset the machining area, which results in a ‘zero’ setting differential between (i) last position of the previous machining and (ii) backward movements to work the next. Furthermore, these lathes also need for set up of turret and toolholder, and operators tune such complex of equipment when machinery stops because they need to work inside the machining area. Beyond being strictly timed for machinery stop, these operations need to be combined with connected operations during machinery uptime, performed by the operator to compensate settings for wear of tools. It is further suitable to track all the settings carried out towards compensation of wear to have a reference in the next equipment setting. The same applies when changing inserts of tools. Hence, the changeover process is very time-consuming, and inefficiencies get the process into a real mess more.

In the following bullet points we provide some simple statistics on changeover times, further shown in the chart in Figure 3. All data refer to 2019.

- 221 changeovers on multi-spindle cam lathe
- Mean time of each changeover is twelve hours
- Median of time distribution is about ten hours
- First and third quartiles of time distribution are six hours and seventeen hours, respectively

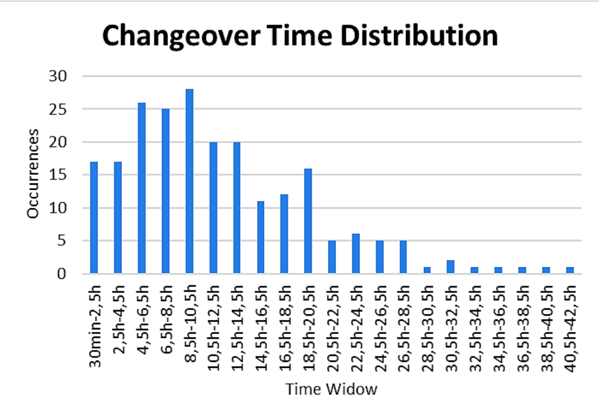

Figure 3: changeover cumulated-time distribution.

4. Implementing the SMED: case study description

The SMED project in Mi.Ol. is two-stage designed. In the first stage we have focused on the whole process redesign and it entails the activities listed in the numbered list below.

1. Data gathering and present state mapping, i.e. the changeover process AS-IS.
2. Analysis of the present state.
3. Splitting tasks into IED and OED.
4. IED task analyses and transformation in OED tasks, whether suitable.
5. Introduction of toolmaker assistant, and splitting IED and OED tasks into different job descriptions of toolmaker and his assistant.
6. Analysis of toolmaker' job description, and attribution of his suitable tasks to other operators, i.e. (i) toolmaker assistant and (ii) tool warehouseman.
7. Standardisation of duties and tasks of the future state, i.e. releasing the SMED changeover process (TO-BE).
8. Implementing and maintaining the SMED.

The whole redesign process has been performed towards the 5s methodology, aiming to reduce wastes. This means that specific operators' tasks and the whole changeover process has been analysed keeping in mind the paradigm Sort, Set in Order, Shine, Standardize, Sustain.

The second stage of the project entails reengineering of the whole changeover process, and definition of processes specific to each product family, and it is currently underway. Hence, the present paper describes implementation and result of the first stage of the project. Confidentiality agreement does not allow us to provide the reader with real quantities and thus we provide fake number, but their validity and the proportions are suitable.

4.1 Changeover process AS-IS

Data to analyse the process have been directly gathered in the workshop during changeovers, monitoring and interviewing toolmaker and other operators in the course of their duties over one months. Sequences of tasks in the current state and mean times to perform them, regardless specific random problems, have been defined according to the data gathered. The same applies to notices of task issues.

Elaboration of data have thus provided preliminary information on the changeover. Firstly, we have mapped all the toolmaker' motions. Because of space constraints, we are not able to provide the Spaghetti Chart we have analysed; however we can state that mostly, the operator left the work bench to collect tools, spindles, and more in general equipment useful to his work. Moreover, we have analysed times of tasks by means of Pareto chart (see Figure 4).

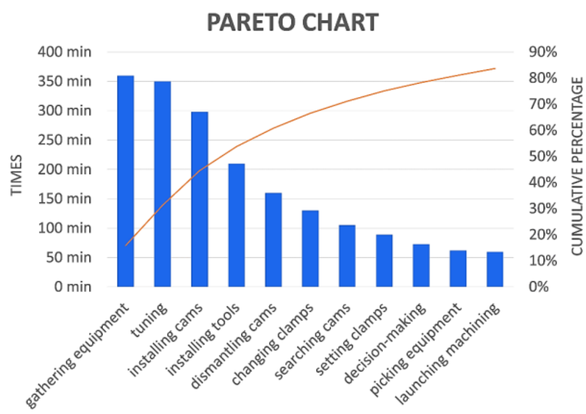

Figure 4: Pareto' chart of changeover task times

This analysis has confirmed that collecting equipment was the most time-consuming activity, and the operator spent 20% of his time to move equipment from drawers and shelves to his work bench. In the chart we provide the activity covering the 80% of whole 2,300 minutes spent for changeover in the period of analysis for providing the picture as clear as possible.

4.2 IED and OED characterisation

Each task has been analysed more in detail and we have split them, as previously monitored, into IED and OED.

Making OED tasks which previously were IED has been the first real contribution towards the SMED redesign of changeover. Generally, new OED tasks refers to those that entail material handling and providing information on the next set-up.

Furthermore, changeover tasks have then been split into different job description, which is the second real contribution to the SMED implementation in Mi.Ol., and to our knowledge on SMED it represents the novelty of this study. Before doing it, it has been introduced a new role, namely the toolmaker' assistant, and tool warehouseman' job description has been widened to involve some tasks previously assigned to the toolmaker. Here some consideration. Toolmaker is an operator very specialised on his craft. Mi.Ol. toolmaker' hourly wage is very expensive, the 150% of other operators' workshop. The tool warehouseman has a wage about 80% of the toolmaker' one. Even if we have not calculated the savings (since it is not the focus of the study), a first real advantage of splitting task into less skilled functions is the economical way to distribute monthly wages because of tasks redistribution.

Criteria to redistribute tasks, have been the following: (i) assigning tasks to operator according to his skills, namely craft works requiring high skills to toolmaker, (ii) assigning unskilled tasks to the assistant, (iii) assigning tasks relating to tool and equipment motions to the warehouseman. Table 1, in the form of checkbox, provides (i) the former IED tasks that have been transformed into OED, and (ii) task redistribution among operators. Convention adopted is the following: T is the toolmaker, A is the Assistant, W is the Warehouseman, and I/O is the new task typology according to SMED, i.e. IED/OED. Tasks are listed according to the standard process progression.

4.3 Release and Standardisation

Once the changeover tasks have been redesigned towards the SMED, we have standardised some activities ancillary to the process, but however affecting it. A mini-delphi method, as in Neaga and Henshaw (2011), has been applied to discuss what activities needed a suitable management system (i) to reduce activity times and (ii) to better perform the changeover more in general.

- Main spindle collet kit management system: kits have been introduced to main spindle collets (simply clamp in charts and tables), feed finger, and guide ring, used during the bar changeover. The management of these kits is responsibility of the tool warehouseman.
- Cam management system: according to the machining, cams have been paired. When the machining stops, the assistant, who is in charge of dismantling cams, stocks them suitably.
- Equipment management system: the assistant, who is in charge of reset the machinery at the end of the process, is responsible of (i) collecting all equipment used in the machining and (ii) packing up them and fixing the places.

At the end of this standardisation phase, the system is released and consistently deployed in the workshop.

Table 1: tasks redistribution

T former task	A	W	I/O
Picking Production Order, picking drawings, picking instruction sheets of next set-up		X	O
Comparison between instruction sheets of current and next set-ups		X	O
Listing equipment suitable for next set-up, not used for the current one		X	O
Collecting all the suitable equipment for the changeover, once this is available. Using the suitable cart to move the equipment		X	O
Consulting the Operation Manager in case of some equipment unavailability. If necessary, suspending the changeover		X	O
Listing cams to dismantle		X	O
Listing toolholders to dismantle		X	O
Cleaning the machining area of machineries	X		I
Checking ramps	X		I
Preparing oil piping	X		I
Dismantling tools and equipment	X		I
Reset physical configuration of machinery	X		I
Dismantling cams	X		I
Sharpening tools and insert, according to their use			O
Regenerating tolls and insert (outsourcing)			O

5. Results

Since the project is still running, just partial results can be provided. In particular, we have monitored the changeover times of the most processed part over the last six months, an oleodynamic plug of the most important customer. The part is here named PF001. Production order are usually 100,000 parts/batch, and the yearly throughput of this part is +300,000 pieces/year. This product has suitable similarity index to all other part of the same family product, i.e. oleodynamic plug. Thus, changeover can be performed in two ways. The former is about linking the production of this part to other similar parts, using their changeover (Configuration #1). The other is about perform a new changeover starting all steps from a scratch as it is impossible to link production batches because of similarity index is not suitable (Configuration #2).

Next tables present the mean time and cost differences between previous changeover tasks (AS-IS) and tasks as redesigned towards SMED optimisation (TO-BE). Mean time are provided in form of hours and decimal unit (e.g. 0.5 hours means 30 minutes), and percentage difference. Costs are calculated according to Mi.Ol. hourly valuing. Table 2 is about Configuration #1, whereas Table 3 is about Configuration #2. Data are elaborated by means of the dataset provided by the company MES. Lots of improvement to the process have been achieved.

First of all, total changeover time reduction, about 8% in both configurations, as well as time spent by toolmaker working on changeover decreases about the 34%. Secondly, downtime reduction ranges from 25% to 30%, the maximum achieved when is possible to link more batches. Thirdly, labour cost goes down the 13%.

Table 2: changeover improvements for PF001 - Configuration #1

RESOURCES	TO-BE	AS-IS	Δ TO-BE/AS-IS	
SET-UP	10.88 h	11.83 h	- 0.95 h	-8.03%
DOWNTIME	8.27 h	11.83 h	- 3.57 h	-30.14%
TOOLMAKER	7.67 h	11.75 h	- 4.08 h	-34.75%
ASSISTANT	0.60 h	0.08 h	+ 0.52 h	+620%
WAREHOUSEMAN	2.62 h	0 h	+ 2.62 h	/
SET-UP COSTS	307.42 €	354.17 €	- 46.75 €	-13.20%

Table 3: changeover measurements for PF001 - Configuration #2

RESOURCES	TO-BE	AS-IS	Δ TO-BE/AS-IS	
SET-UP	17.62 h	19.25 h	- 1.63 h	-8.48%
DOWNTIME	14.33 h	19.25 h	- 4.92 h	-25.54%
TOOLMAKER	11.02 h	16.62 h	- 5.60 h	-33.70%
ASSISTANT	3.98 h	2.63 h	+ 1.35 h	+51.27%
WAREHOUSEMAN	2.62 h	0 h	+ 2.62 h	/
SET-UP COSTS	475.58 €	551.17 €	- 75.58 €	-13.71%

We have further measured the improvement in changeover process of the whole product family oleodynamic plug. clustered as PFXXX. Results refers to the same monitoring period and they makes use of the same dataset provided by the MES.

Table 4: changeover improvement for PFXXX

RESOURCES	TO-BE	AS-IS	Δ TO-BE/AS-IS	
SET-UP	401.27 h	437.25 h	-35,97 h	-8.23%
DOWNTIME	342. 42 h	437.25 h	-94,83 h	-21.69%
TOOLMAKER	268.88 h	410.88 h	-141,99 h	-34.56%
ASSISTANT	51.98 h	26,37 h	+25,56 h	96.94%
WAREHOUSEMAN	80.46 h	0	+80,46 h	/
SET-UP COSTS	185.28 €	214,23 €	-28,95 €	-13.51%

Data provided are mean times calculated from mean time of parts belonging to the PFXXX family regardless if they have been linked to other product or not. We are aware that results are less valid that those of the single part monitoring, but they however provide the reader with an idea of improvements achieved and how the SMED make it worth Company's while.

6. Discussion and future research

The present paper provides an implementation of SMED technique within an Italian manufacturing SME producing small precision metallic parts for hydraulic and oleodynamic distributors. The study belongs to a wider project still running, and the results presented refer to the improvements that were already achieved. Although there are few studies on SMED implementation in SMEs environment, it is well proven that SMED is a robust technique that can help SMEs, both in Italy and abroad, to improve their processes. Studies have proved that the best way to apply the SMED is to map the specific process. Moving from these considerations, we deemed appropriate to fully map the process for better detecting how to effectively intervene beyond the traditional SMED approach. As a result, considering the key figure of the toolmaker, for the company analysed, we propose a novel approach, relating to the attribution of tasks to the operators according to their skills. The usefulness of implementing SMED technique lies on the fact that spending less time in performing set-ups allows to reduce economic batch quantities (EBQ) resulting in even increasing flexibility and stock reduction. We have proved that SMED allows to optimise set-up. Although the benefits achieved (i.e. about 9%) seems to be far from results from other studies (i.e. on average 60%), the reason lies on a previous set-up optimisation different from SMED, and the very specific nature of the changeover process in Mi.Ol. However, according to the results we have achieved, we have calculated that 13% labour cost reduction – as for part PF001 – allows us to reduce the economic batch quantity by 7%. Furthermore, reducing batch quantities means less times spent to work them, then increasing our product mix by 7%. On the contrary, for the same EBQ we have calculated a product mix however increasing by 8.6%. In addition to the labour cost saving experienced, we have una-tantum saved about 60,000 € by the new tool and equipment management system. These were money tied up in material spread over the whole workshop. More in general, this system allows a more efficient use of equipment, eliminating wastes.

As previous said, partners are still running the project. The current phase of the project is twofold. Firstly, we are reengineering each task of the general changeover process. Secondly, we are reengineering the changeover of specific product family processes, focusing on those whose production orders of EBQ are more than a predetermined threshold. This would improve the process, further decreasing times and costs spent on changeovers.

Another aspect possible to investigate is how to structure the task according to minimisation of operator motions, since we have proved that this really affects process time-consuming. Furthermore, it would be interesting to quantify cost saving, whether it exists, when the machinery works less time, since among two consequent batch order it is possible to have routine maintenance more frequent and then decrease extraordinary repairs.

Authors are working on some of these topics for future research.

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Appendix A. Query string adopted in Scopus

Number of studies on SMED implementation in SMEs' environment is obtained by means of the following query string: ((TITLE-ABS-KEY ("lean manufacturing")) AND (("Single Minute Exchange of Die") OR ("SMED"))) AND (sme OR smes OR "Small and Medium Enterprise").