Management and Production Engineering Review
Volume 10 • Number 2 • June 2019 • pp. 60–68
DOI: 10.24425/mper.2019.129569

A CASE STUDY OF VSM AND SMED IN THE FOOD PROCESSING INDUSTRY

Miguel Malek Maalouf[1], Magdalena Zaduminska[2]

[1] *Department of Materials and Production, Aalborg University, Denmark*
[2] *Supply Chain Planner, Welltec A/S – DK-3450, Allerod, Denmark*

Corresponding author:
Miguel Malek Maalouf
Department of Materials and Production
Aalborg University
Copenhagen, Denmark
phone: (+45) 2764 2504
e-mail: mml@business.aau.dk

Received: 1 October 2018
Accepted: 29 April 2019

Abstract
The relatively limited application of lean in the food process industries has been attributed to the unique characteristics of the food sector i.e. short shelf-life, heterogeneous raw materials, and seasonality. Moreover, barriers such as large and inflexible machinery, long setup time, and resource complexity, has limited the implementation and impact of lean practices in process industries in general. Contrary to the expectations in the literature, we bring in this paper a successful experience of lean implementation in a company of the food-processing sector. By focusing on two lean tools (VSM and SMED), the company reduced changeover time by 34%, and increased the production capacity of the main production line by 11%. This improvement enabled the company to avoid the use of temporary workers by extending the worktime of its workforce during peak months. Moreover, the reduction of setup time avoided the use of large lot size in production, which, in turn, reduced the total cycle time of production and the incidence of quality problems.

Keywords
food industry, process industry, lean, changeover, value stream mapping.

Introduction

In order to survive in the new competitive manufacturing environment, companies need to improve their productive systems to meet the demand posed by the markets [1]. The Lean production paradigm emerged as one of the manufacturing systems that could help companies achieve this goal. The principles of lean manufacturing is the identification and elimination of wastes or non-value added activities by using appropriate tools and techniques [2, 3]. Inspired by the positive result of lean manufacturing at Toyota, many companies across different industry sectors, sizes and geographic regions tried to apply lean manufacturing principles in order to improve efficiency and productivity. However, studies show mixed results of lean manufacturing implementation across sectors and organizations [4, 5]. Indeed, the evidence shows that the implementation of lean manufacturing should take into consideration the characteristics of the production environment and other organizational factors, such as the size of the organization, types of suppliers and customers, degree of automation, and type of products and quality assurance requirements [6, 7]. For instance, manufacturing environments characterized by highly variable demand, large product variety, low volumes and variable order processing times, are likely to put some restrictions on the applicability of a range of lean tools and practices [8].

Moreover, there is relatively limited application of lean in continuous process industries because of the barriers created by the sector's large and inflexible machinery, long setup time, and resource complexity [9]. In particular, the low impact of lean manufacturing in a process industry like the food industry has been attributed to the unique characteristics of the food sector i.e. short shelf-life, heterogeneous raw materials, seasonality, and varied harvesting conditions [10]. Furthermore, complex production chain, inflexible machinery and complicated network of many suppliers and buyers hugely affect storage, conditioning, processing, packaging and quality control [11]. All these factors might be increasing the difficulties associated with the implementation of lean in the food processing [12].

Contrary to the expectations in the literature, we bring in this paper a successful experience of lean implementation in a company of the food-processing sector. Due to confidentiality agreement, the company is referred to as Company A, which has adopted lean as a framework in order to eliminate waste and increase production efficiency. The company's operations are dominated by high seasonality of production, short expiry date of manufactured products and heavy rotation of employees. Moreover, it produces a wide range of products, which is associated with frequent and lengthy changeovers taking up a large part of the operating time. The company's main objective is to reduce the main category of waste associated with its production, which is the lengthy changeover time. It has implemented a range of lean tools and techniques such as Value Stream Mapping, 5S, SMED, standardized work, and Flow. In this paper, we focus on two lean tools (VSM: Value stream mapping and SMED: Single Minute Exchange of Dies), which had the most direct effect on the removal of wastes and the increase of efficiency in the company. While the value stream analysis gave a general view of the state of the waste embedded in the production process, the company used the SMED tool to target directly the main waste in its main production line and reduce significantly the changeover time of its main production line. The key contribution of this study is the identification of the mechanisms by which the use of VSM and SMED have successfully contributed to improve production efficiency in company A. In the next sections, we present the theoretical background followed by the methodology, empirical analysis, and conclusions.

Theoretical background

Lean Production System (LPS) is the systematic approach of identifying and eliminating all wastages through continuous improvement to pursuit customer satisfaction. The primary goal of LPS is to reduce cost and improve productivity by eliminating major manufacturing waste in all work activities. Application of the LPS is guided by five principles consisting of 1 – specifying value, 2 – identifying the value stream, 3 – making the value flow, 4 – configuring of pull system by customer, and 5 – pursuing perfection [2]. LPS consists of a set of tools and practices that assist in the identification and steady elimination of waste (Muda) such as VSM, 5S, SMED and standardized work. These tools focus on certain aspects of a manufacturing process to eliminate waste, improve quality and reduce time and costs [13]. Among the lean tools, Value Stream Mapping have received increased attention as it provides a framework to start the process improvement through a systematic approach [14]. In the next sections, we present VSM and SMED, which are the two main tools used by the company to improve its production efficiency.

Value Stream Mapping (VSM)

The Value Stream Mapping (VSM) technique was introduced as a functional method to help practitioners rearrange manufacturing systems according to a Lean perspective in a systemic or holistic way [14]. VSM is a visualization tool that allows to capture, in a schematic manner, a flow of value in a given process [15]. As a result, it allows for quick and clear identification of critical information for the improvement of the production process [15, 16]. Within the same context, [14] indicate that the main properties of VSM fulfill the needs of a framework for the improvement of the manufacturing system, which facilitates lean implementation.

As for the implementation process, [14] mention five phases, which are (1) selection of product family; (2) current state mapping; (3) future state mapping; (4) definition of improvement plan; and (5) implementation of improvement actions. The future state mapping (third phase) defines the Lean tools and techniques to be used in order to achieve the improved future state map. As such, while mapping the current production process, the material flow of the product is traced back from the final operation in its routing to the storage location for raw material. For each step, parameters such as cycle time, TAKT time, work in progress (WIP), and set up (changeover) time are measured or calculated, facilitating the identification of value-added and non-value-added activities in the manufacturing process. The information flows are also incorporated to provide demand information, which is an essential parameter for determining the scheduling process in the manufacturing system for which the Current State Map is being developed. As for the future state mapping, it usually involves the introduction of a range of lean practices, such as the implementation of takt-time, continuous flow, smoothing of product mix, pull systems, and the improvement of the overall process efficiency by using work method, cycle time improvements, changeover time reductions and preventive maintenance. In the next section, we present the SMED technique used by the company and explain its main features.

Single Minute Exchange of Die (SMED)

Single Minute Exchange of Die (SMED) is one of the core lean production methods for reducing waste in a manufacturing process. It provides a rapid and efficient way of converting a manufacturing process from running the current product to running the next product. Rapid changeover is key to reducing production lot sizes and thereby improving flow [17]. SMED is often used interchangeably with *"quick changeover"*. According to [18], *"the need for SMED and quick changeover programs is more popular now than ever due to increased demand for product variability, reduced product life cycles and the need to significantly reduce inventories"* (p. 27). SMED involves a sequence of four basic phases [17, 19]. The first phase involves the preparation of detailed observation, and the analysis of the existing organization of work at the workplace with particular emphasis on retooling processes. The second phase focuses on the separation of internal retooling (the current setup operations that must be performed while the machine is shut down) from external retooling (the setup activities that can be performed when the machine is running). The third phase entails the transformation of the internal setups to external ones. The fourth step refers to the standardization of all aspects of the operation retooling and the determination of the retooling standards. Among the recommended techniques for reducing setup time, [20] and [13] mention the adoption of parallel operations, the mechanization of the setup process and the elimination of adjustments. In particular, the adoption of parallel operations is employed on operations with large processes (like the food process in Company A), which involve setup work on both sides or at both the front and back of the machine. If only one worker performs all setup activities, much time is wasted as the worker moves from side to side or back and forth around the machine [20].

In addition to the direct reduction of changeover time, the implementation of SMED had two other benefits, which are reduction of lot size and improvement of product quality. In this context, [20] explains that production is a network of processes and operations. That is, the process of transforming material into product is accomplished through a series of operations. Four distinct process elements can be identified in the flow of transforming raw materials into products: processing, inspection, transportation, and delay. There are two types of delay: process delay and lot delay. While, in process delay, an entire lot waits while the previous lot is processed, inspected or moved, in a lot delay, while one piece is processed, the others wait. They wait either to be processed or for the rest of the lot to be done. This phenomenon occurs in inspection and transport as well. Moreover, delays can be caused by lengthy setup, unbalanced flow between processes, or by buffers or safety stocks, which are allowed between processes to avoid machine breakdowns or rejects delaying succeeding processes. When tool and die changes cause extended delays, it makes sense to reduce the apparent per-unit processing time by increasing lot size. This does however increase storage and handling costs. Increasing lot size can mean also more quality problems and more material waste as it will make it more difficult to identify quality problems in large lots and can result in rejecting big lots of products [20]. In most cases, however, setup times can be reduced significantly using SMED, which consequently reduces the need of increasing lot size.

Lean implementation in process industries

In order to understand the issues associated with lean implementation in the process industries, it is important to distinguish between the characteristics of discrete and process industries. While in discrete industries, the manufactured products are discrete, individual units and involve operations on individual items or groups of similar items (e.g. automobiles), process industries are those where the finished products are bulk items that cannot be individually separated (e.g., chemicals and food products). Process industries can also have discrete finished goods, but their production calls for operations where the units being worked on cannot be separated (e.g., steel and glass) [9]. Moreover, process industries are generally characterized by high fixed capital with large and fixed production machinery and inflexible processes. That is, process industries are known as quantity production industries, which are devoted to produce large quantities of one type of product with high demand rate. As consequence, managers in this type of environment have been slow to adapt the ideas of lean, in part because of the relative inflexibility of this production system. As an example, it is much more difficult to produce in small lots in the process industry, where setup times tend to be long and it is costly to shut down the process for a changeover. Furthermore, the tools needed for the elimination of waste are usually different in continuous process manufacturing than the ones recommended for discrete manufacturing. For instance, an important lean concept like Takt-time, which is prevalent in most discrete manufacturing industries, is difficult to implement in process industries as the Takt-time of the production is already defined by design of the machinery. Moreover, since all machines in process industries are connected by design, then the WIP (work in process) is usually under control in processing industries [4, 21]. In the next section, we present the methodology used in this study.

Methodology

This is a single case study aiming to investigate how company A used VSM and SMED in order to eliminate waste and increase production efficiency. Case study enables researchers to approach the phenomenon in real life context [22]. We used primary data (structured and semi-structure interviews, and observations) and secondary data in order to achieve triangulation and reduce the researcher bias in all phases of the implementation process [22]. The improvement process in company A draws heavily on the approach recommended by [14], and includes the following three phases: (1) The current state mapping; (2) the analysis and identification of waste; (3) the implementation of improvement actions (towards a desired future state).

Current state mapping

Before starting the current value stream map, we chose Line 1 as the focus of improvement, which accounts for 84% of the total production at company A [14]. The Current State Map contains the material flow of all activities in Line 1 from raw material until packaging. For each activity, we calculated the production per minutes, which helped us identify the bottlenecks in the production flow.

Analysis and identification of waste

Based on the information obtained in the Current State Map, the company analyzed the different types of waste in the process. The company prioritized the changeover process because it constituted the biggest contributor to efficiency increase with immediate results and minimum investments.

Implementation of improvement actions (desired future state)

A Future State Map is generated for improving the value-adding steps and eliminating the non-value adding steps (waste) in the current map. Rother and Shook provide guidelines to follow when generating the Future State Map for an improved manufacturing system [14]. Among the guidelines, the implementation of a continuous flow is achieved by increasing the production availability at the bottleneck and reducing changeover time of the machinery. In this case, the bottleneck constituted the interface between non-discrete (raw material) and discrete (jars) steps in the process, which enabled better leveling of the production load on the pacemaker process. Afterwards, a list of actions was defined and implemented in order to reduce changeover time.

Lean implementation at company A

Company A deals with the processing of fish and, as a subsidiary, it produces for its sole client – the parent company. That is, production at Company A is based on confirmed orders from the parent company and is geared to a seasonal market that demands a delivery of a variety of products. The main product is “herring salad” and the main production lines at company A are:

- Line L1 – Main production line of herring salad in jars and plastic buckets, which is the focus of improvement, representing 84% of total production at company A.
- Line L2 – Production line of marinated herring.
- Line L3 – production line of herring salads in small plastic cups with a weight from 65 g to 100 g.

The main difficulty in this order-based production is fluctuation of demand. While daily fluctuations can be addressed through load and capacity leveling, monthly or annual fluctuations must be handled without carrying inventory to level total annual load. At Company A, seasonal distribution of production often leads to a peak of demand of fish products in the winter, and the production capacity is usually insufficient to satisfy demand in the peak time (Fig. 1 shows the variation in capacity utilization per month). Moreover, the company is unable to build large inventories due to short expiry date of the products. As consequence, delays in delivering orders on time have occurred repeatedly, which often leads to loss of sales and customers. In order to deal with fluctuations, Company A usually adds a second shift during the peak period by hiring temporary workers, which tend to increase the costs associated with the learning of newly recruited operators. Moreover, seasonal work is usually accompanied by increased number of production errors and lower product quality. As we can observe in Fig. 1, there is excess of machine capacity at Company A (49% during peak period and 75% during normal demand). Moreover, temporary workers are hired because overtime of regular workers is not sufficient to deal with demand fluctuations. In the next sections, we present the three phases used in the improvement efficiency in Line 1: Mapping of the Current Value Stream, Waste identification (Analysis), and Implementation (Future State).

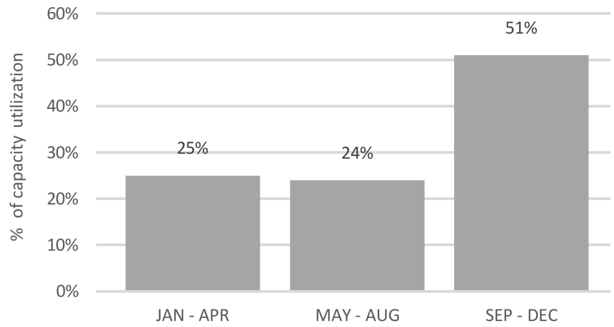

Fig. 1. Percentage of capacity utilization of L1 in 2014.

The Current value stream map

The mapping focused on the production flow of the main line of production (L1). Line 1 produces a family of products called "herring salad" in jars and plastic buckets, of two flavors and different sizes. This product family represents 84% of production volume, which makes it the first candidate for lean implementation by containing the biggest opportunities for efficiency improvement. Line 1 has the characteristics of a process industry with discrete finished goods (Herring jars), where product discretization occurs during the production (see Fig. 2). In Fig. 2, the discretization occurs in the second machine (Multi-Weight), where herring is received in a continuous process from the previous stage (Bites sorter) mixed with other ingredients, and put into jars or plastic buckets of different sizes. Moreover, the Multi-Weight machine is the bottleneck, and tend to determine the production flow and takt-time for the whole line. Moreover, the Multi-Weight machine represents the push-pull interface in the production process, as

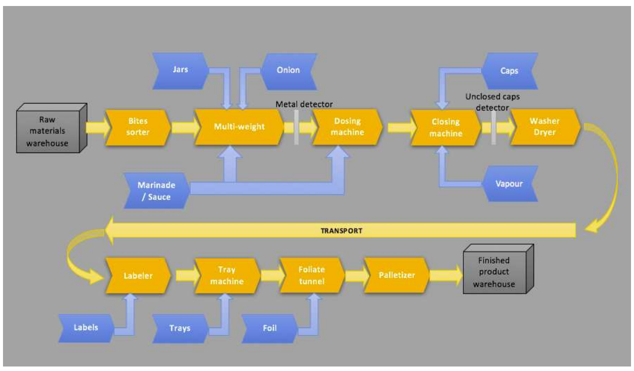

Fig. 2. Production flow of Line 1.

it is the point where production can be pulled downstream according to customer demand. In the current state map, the productivity of each machine in Line 1 was calculated and the bottlenecks were identified (see Fig. 3).

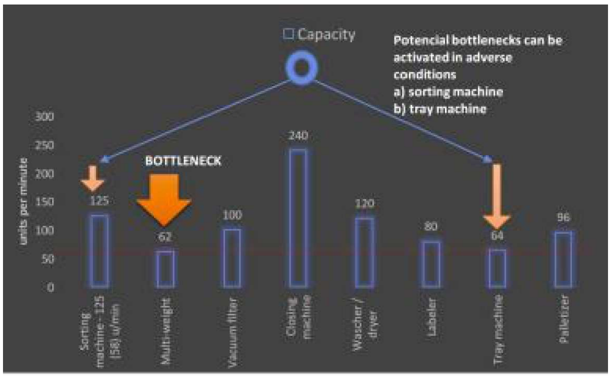

Fig. 3. Capacity (units per minutes) for all workstations in Line 1.

Waste identification (analysis)

A look at Fig. 3 reveals 2 bottlenecks in the production flow of Line 1: the multi-weight and the tray machines. The company decided to focus on the the multi-weight machine as it involved the longer set-up time with major impact on the productivity of the whole line. In order to get a better understanding of the types of waste present in the multi-weight machine, the team observed and mapped the value added and non-value added activities of this section of Line1 during a typical 8-hour shift. As such, the main data collected was related to time of value added and non-value added activities for all products processed in the 8-hour shift (from 7:00 am to 15:00 pm). This illustration exercise gave both workers and managers a clear idea of value-added activities and wastes associated with this machine (Fig. 4). A look at Fig. 4 reveals two types of wastes:

- Stoppage caused by technical problems, which can occur sporadically in different points in the production line. The analysis showed that these technical problems cannot be solved in the short run as they involved major investments for upgrading the machinery.
- Waste caused by changeovers and retooling. In addition to time waste, the analysis showed errors and problems during the retooling process, such as setting incorrect parts or entering wrong operating parameters of machine into control systems. As consequence, it was decided to focus on the retooling, which represented the largest actionable opportunities for efficiency improvement.

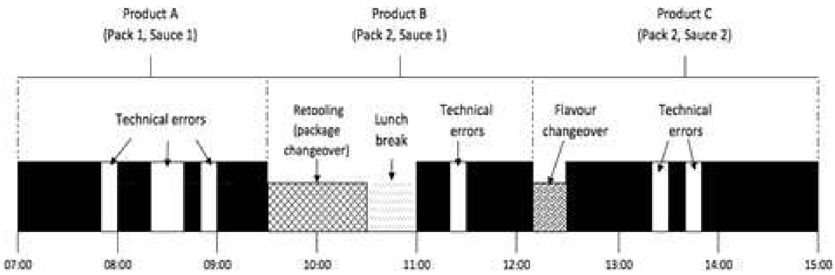

Fig. 4. A typical 8-hour shift including changeovers, technical errors and lunch break.

Changeover data analysis

In 2014, out of a total of 1928 hours available in the year, the real production time of line L1 was 907 hours (47%). Changeovers consumed 536 hours (28%), while machine breakdowns totalled 485 hours (25%). The distribution of operating hours of the L1 (2014) is presented in Fig. 5. Based on this data, the company set an aim to use SMED in order to reduce the changeovers time up to 45%. This means that 241 hours will be moved from the non-value to the value-added zone (production time). Moreover, the team mapped the hours spent on changeovers of the total workforce of L1 taking into consideration a standard eight-hours working day in 2014 and lunch break of 30 minutes a day (6.25% of working day) (see Fig. 6). A look at Fig. 6 revelas that retooling consumed up to 23% of the overall working hours adding up to 5602 hours in 2014. The improvement should also amount to 45% of retooling hours of the workforce (2520 hours).

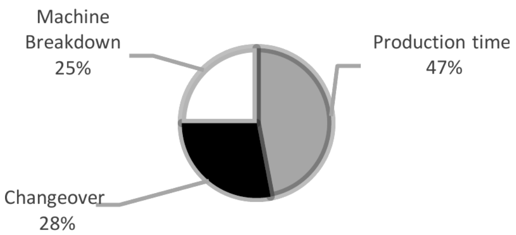

Fig. 5. The division of operating hours of L1 in 2014.

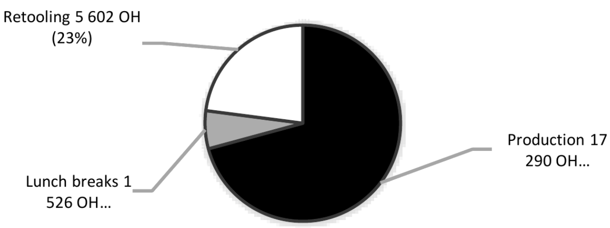

Fig. 6. Operating hours of total workforce in L1 (in 2014).

Types of changeovers

Products processed in line L1 (herring salads) are packed in jars and plastic buckets. Each of the individual packaging variant includes an additional assortment associated with the recipes (two subgroups: salads in flavored marinade or in sauce). Schematically, the complexity of the range of products is shown in the diagram in Fig. 7 showing the multiple variants of products. The number of actual changeovers among the variants of products is further specified in the matrix in Fig. 8. The matrix in Fig. 8 shows that out of a total of 27 possible retooling, 9 options are excluded while 14 changeovers rarely occur. The remaining 13 options are the most frequent changeovers (eight are related to product size and five aimed to flavor change).

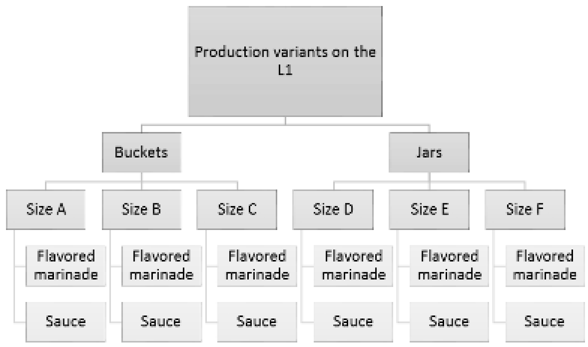

Fig. 7. Products variants in Line 1.

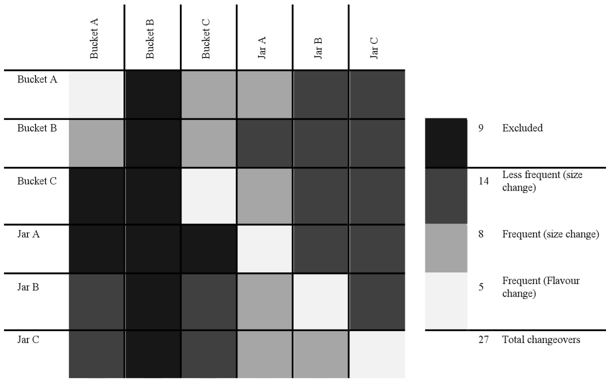

Fig. 8. Matrix of changeovers' variants.

Implementation (future state)

The implementation focused on the implementation of SMED in order to reduce changeover time at the bottleneck. The first phase of SMED involved the mapping of the sequence of all activities related to the retooling of this machine (Multi-weight in Fig. 2).

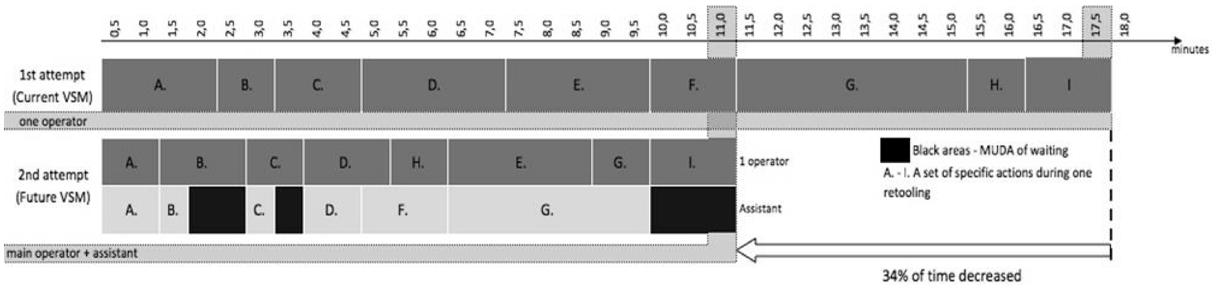

Fig. 9. Comparison of retooling time before and after the addition of helper (retooling assistant).

Figure 9 depicts the sequence of activities performed during changeover with timeline in minutes for each activity. The total time of retooling using one worker (Current state in Fig. 9) is 17.5 minutes involving 9 activities (A,B,C,D,E,F,G,H,I).

Implementing parallel operations

Operations in L1 involve setup work on both sides or at both the front and back of the machine. If only one worker performs these operations, much time and motion are wasted as the worker goes from side to side or back and forth around the machine. But when two workers perform the parallel operations simultaneously, set up time can be reduced due to the economies of movement. According to [20] by adopting parallel operations in retooling, an operation that takes one worker 30 minutes to complete may take two workers only ten minutes. Moreover, when such parallel operations are employed, setup man-hours are the same as or less than they were with one worker and the operating rate of the machine is increased [20]. It is important to note that a business case was needed in order to clearly show that adding one worker is not waste (and should not be considered as waste) as the benefits of this action exceed its costs. According to [20], the option of adding worker is often rejected by managers, who think they can spare another worker to assist with setup. Therefore, a convincing cost benefit analysis was made in order show the importance of this method where even an unskilled worker can provide the necessary assistance effectively. The benefits of the SMED implementation are shown in the following comparative chart and contains the situation before and after the addition of helper for retooling (The future state in Fig. 9). The time of retooling was reduced from 17.5 minutes to 11.5 minutes. As a result, the addition of a second operator has reduced changeover time by 34%. Figure (10) presents the timeline of retooling activities of the two operators. Moreover, our analysis shows that the first operator was busy 65.6% of the time where the second operator (helper) was busy 27.6% of the time during the whole retooling process. The remaining time can be used in other productive or support activities.

Outcomes of SMED implementation

With gathered data and prepared plan, the company decided to start the implementation in the end of 2014 – beginning of 2015. The reduction of changeover time of Line 1 (producing 84% of total production) generated increase of ca. 11% of the production capacity (kg/h) of the L1 in 2016 (Fig. 10). Additionally, SMED brought another important improvement in the employment fluctuation related to the seasonality of production. Before the improvement, the factory had to activate a two-shift system for employees on the line during the high season of the year (last four mounts, from September to December), which was associated with an increase in the employment and related costs. After the implementation of SMED, the company only extended its typical working day from 8 hours to 10 hours for regular employees in the pre-holiday period, without the need to activate a second shift.

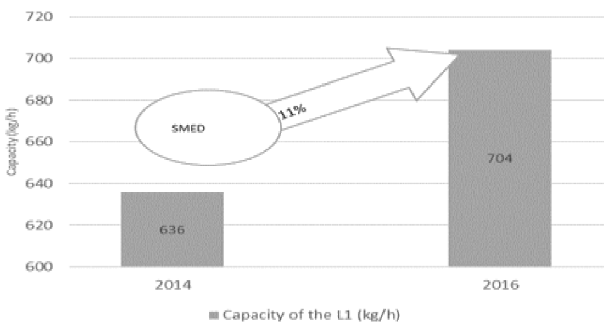

Fig. 10. Annual increase of efficiency related to SMED implementation.

Summary of the implementation: the CIMO framework

In order to explain the logic underlying the sequence of actions and decisions related to SMED implementation in company A, we use the CIMO fra-

Table 1
The CIMO framework applied to SMED implementation in Line 1.

Intervention (I)	Problems in context (C)	Mechanisms (M)	Outcomes (O)
– SMED implementation in Line 1	– In food processing line with inflexible machinery, retooling is time consuming as it involves many movements on each side of the line. – One worker will make a lot of unnecessary movements during retooling. – Smoothing and speeding the flow is not an option as the takt-time and WIP are defined by design. – Seasonality of demand based on orders from parent company – Short expiry date of products. – Stoppage due to machinery are expensive to solve and depends on long-term investment policy.	– Reduce retooling time through parallel operations by using two workers. – Changeover time reduction enables small lot size, which reduce delivery cycle time, which is crucial in case of seasonality and shorter life time of products. – Small lot size facilitates the identification of quality problems and, in case of rejection, the scrapped materials is reduced.	– Improvement in efficiency (faster retooling). – Small Lot sizes. – Shorter delivery time. – Less quality problems and scrap. – No need for second shift of temporary workers (investment in training and increased defects). The two hours overtime of regular shift are sufficient to meet the seasonal demand.

mework of [23], which describes problems in the context of interventions, triggering mechanisms (M) and producing outcomes. The framework is based on a generative model of causality, which holds that, to infer a causal outcome (O) between two events, the researcher needs understand the underlying mechanism (M) that connects them and the context (C) in which the relationship occurs. So, for example, in order to evaluate whether a training programmes (I) reduces unemployment (O), the researcher would examine its underlying mechanisms (M) (e.g. have skills and motivation changed?) and its context (C) (e.g. are there local skill shortages and employment opportunities?). According to this framework, the basic question – what works? – changes to “what is it about this programme that works for whom in what circumstances?” As such, this framework is especially appropriate for this study as the implementation of lean is dependent on context, which in turn affect the underlying mechanisms that influence the outcomes. This framework has been used both prospectively (in formative evaluations) and retrospectively in research synthesis. In this study, we use the framework retrospectively as a research synthesis in order to add clarity to the contextual factors and underlying mechanisms that influenced the implementation of SMED at company A.

Conclusions

In this paper, we brought a successful implementation of lean tools in a company in the food processing industry. The company operates in a manufacturing environment of high seasonality of demand and short lifetime of products. Moreover, the continuous process manufacturing seems to limit the range of lean tools that can help increase efficiency of the main production line in the company. The study shows that the focus on limited range of tools can achieve good results if the tools fit the manufacturing constraints of the company. As such, the use of value stream mapping (VSM) and SMED enabled the reduction of the waste related to changeover time by 34% and increased the production capacity of Line 1 by 11%. This improvement enabled the company to achieve production goals by extending the working time of one shift (from 8 to 10 hours during the peak period) and avoid the use of temporary workers during peak months. Moreover, the reduction of setup time avoided the need of increasing the processing lot size, which can increase the total cycle time of production and the incidence of quality problems [20].

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