Fernandes, Anita
Teixeira, Senhorinha
Ferreira, Ana Cristina Magalhães

Application of SMED to reduce parameterization times in the production of corrugated carton packaging

http://hdl.handle.net/11067/7398
https://doi.org/10.34628/GETR-QP34

Metadados

Data de Publicação 2023

Resumo Companies are constantly enhancing their processes and operations to improve productivity while reducing costs. This has led many companies to implement a Lean Production philosophy. Lean Production involves a multi-level process to identify and prioritize the waste as non-value-adding activities, providing recommendations to reduce and/or eliminate them. This work was carried out in an industrial company dedicated to the production of corrugated carton boxes for several sectors, whereas, the ma...

Tipo bookPart

Editora Universidade Lusíada Editora

Application of SMED to reduce parameterization times in the production of corrugated carton packaging

DOI: https://doi.org/10.34628/GETR-QP34

Anita Fernandes[1], Senhorinha Teixeira[2], Ana Cristina Ferreira[*3,4,5]

[1] Department of Production and Systems, University of Minho
4800-058 Guimarães Portugal
pg42952@alunos.uminho.pt

[2] Department of Production and Systems, University of Minho
4800-058 Guimarães Portugal
st@dps.uminho.pt

[3]MEtRICs, University of Minho, 4800-058 Guimarães, Portugal
[4]ALGORITMI, University of Minho, 4800-058 Guimarães, Portugal
[5]COMEGI, Universidade Lusíada, 4760-108 Vila Nova de Famalicão, Portugal
acferreira@dps.uminho.pt

Abstract. Companies are constantly enhancing their processes and operations to improve productivity while reducing costs. This has led many companies to implement a Lean Production philosophy. Lean Production involves a multi-level process to identify and prioritize the waste as non-value-adding activities, providing recommendations to reduce and/or eliminate them. This work was carried out in an industrial company dedicated to the production of corrugated carton boxes for several sectors, whereas, the main objective was the application of Lean Production principles and tools and to control setup times while minimizing the production cycle time. The production line under study corresponds to an automatic case-maker machine that converts

* Corresponding author.

cardboard plates into different box formats through automatic printing, cutting, slotting, creasing and collage processes. Each production order requires a specific parametrization process, which consumes a considerable amount of time and human resources. Thus, a time study was carried out to identify all the operations, controls, stops and movements through sequence diagrams. With the collected data, the SMED tool was applied to reduce the setup times of the case makers. With the application of SMED, it was possible to reduce the setup time by 28% for production orders with cutting tools and 39.6% for production orders without cutting tools. With this analysis, the company can release one of the three operators at the automatic production line to perform other value-added operations.

Keywords: Lean production; Operations management; SMED; Corrugated carton industry.

1. Introduction

The competitive evolution of the industry markets imposes on organizations the adoption of innovative methods and technologies in order to respond to the customer´s demand objectives in a reduced time horizon. This scenario occurs because organizations are faced with a high level of customer demand, establishing quality levels, customized products and reduced delivery times [1]. It became inevitable to find ways to respond to market demands, managing numerous variables that depend on the production process complexity and variability of product requirements [2]. Due to market instability, companies need to implement new and/or optimized methods based on continuous improvement [3, 4]. Companies are focused on continuous improvement (*Kaizen*) approaches to achieve their targets in terms of quality and costs. Companies base their strategy on mapping the value chain, identifying the cycle and setup times, the amount of Work in Process (WIP) and the respective efficiency. Their purpose is to reduce delivery times through the creation of a productive flow capable of responding quickly to customer orders [5].

Lean Production is based on the pillars of the Toyota Production System (TPS) by applying the concept of "doing more with less" through restructuring corporate methods and by eliminating waste. The two core fundamentals of TPS are Just-in-Time (JIT) and *Jidoka*. JIT corresponds to the production strategy based on what and when is needed, and in the amount needed, so goods are produced only when there is an actual demand. In turn, *Jidoka* (autonomation) means "automation with human intelligence" because it is based on the principle that equipment support systems with the ability to distinguish good parts. In addition to these concepts, TPS preconizes that companies must focus on production levelling (*Heijunka*) and standard work [6–8] while also highlighting the application of various, vital lean production tools. Shifting the trade-off between productivity and quality, the book discusses the preparation stages needed before implementing a JIT system. After an introduction to lean manufacturing and JIT, it introduces readers to the fundamentals and practice of Kaizen, paying special attention to lean manufacturing tools. The book demonstrates how to use the 5S approach (with the stages of Seiri, Seiton, Seiso, Seiketsu and Shitsuke. Nonetheless, all these approaches comprise a set of techniques that, when combined, maximize value for the consumer while reducing costs through the successive elimination of waste throughout the production process.

To improve processes, SMEs need to select and prioritize improvement actions. According to Shafeek [9], improving the carton production system requires a special culture of adopting the concept of continuous improvement. The author has studied the production cycle times and has applied tools such as the Single Minute Exchange of Die (SMED) to speed up the exchanges of manufacturing tools, making processes more flexible and optimized. Another study developed in a Carton company applied SMED and other quality tools to reduce the production lead time. Initially, a Pareto analysis was conducted to identify the most important causes of inefficiencies in the production system. High setup times and lack of organization in the job shop were identified as the most probable problems. Improvement proposals were based on SMED methodology, 5S technique and visual management. With the integration of these tools, it was possible to achieve an average reduction of 47% in the setup time, representing an economic saving to the company [10]. Despite the high relevance of the SMED tool, some authors focus on the difficulties of its application. Moxham and Greatbanks [11] argue that the application of SMED is not easy to implement for all types of industries. Each productive system should be first analysed, starting from the specification of the operations and task identification and parametrization. The prerequisites or requirements for successful SMED applications also depend on the cooperation of the operators. SMED has also been considered one of the many lean tools that reduce waste and increase quality [12].

This work was carried out in an industrial company dedicated to the production of corrugated carton boxes and the main objective was the application of the SMED tool to control setup times while minimizing the production cycle time. Section two presents the automatic line production line, with special attention given to identifying the parameterization tasks of the case makers. The third section briefly explains the SMED methodology and the fourth section presents the results from SMED implementation.

2. Description of the case study

The present work was conducted in a company dedicated to the production of corrugated carton boxes. In this section, the production system of the case study is described.

2.1. Description of the automatic line processes

The production process is divided into four main processes: (1) case maker parameterization; (2) sample production; (3) automatic production and (4) packaging of boxes. In the machine parameterization, three operators are responsible for the preparation of the machine which includes placing the cardboard plates at the automatic line entrance, removing and replacing printing cliché, ink reservoirs and cutting tools. In this process, it is also required to parametrize the outside case maker console to define all the parameters required to execute a specific production order.

While preparing the case maker, if printing is required, the operator collects the ink and the cliché and places the reservoir in the machine. If the boxes to be produced have cutouts, it is necessary to assemble the cutting tools. The same procedure is performed regarding the collage system and the need to refill the glue container.

After the parametrization process, the automatic line is triggered to produce a sample of the desired box for validation. In this process, size, format creases and cuts are approved by the operator in charge of the automatic line. With the sample validation, the case maker is ready to produce the batch quantities necessary to satisfy the Production Order (PO). During automatic processes (printing, cutting, creasing, pasting glue and strapping) there is no interference by any operator. At the case maker exit, the packaging is carried out. The boxes are divided into small batches, being transferred to the palletizing area, where the film and the strap are placed around the pallet and shipped to the warehouse. Figure 1 illustrates the production system flowchart, considering the different operations resulting in different packaging models.

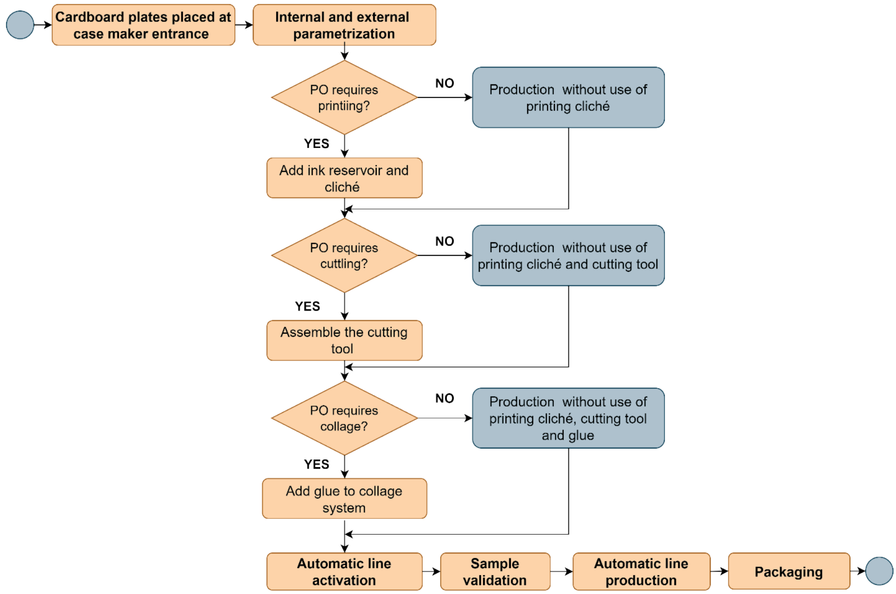

Figure 1: Description of the production process.

The production process in detail can be observed in Figure 2. The corrugated cardboards (point 1) are placed on the feeder mat of the case maker (point 2). The cardboards go through up to four printing groups (point 3,4,5,6) depending on the number of inks needed to produce the carton boxes. Each of the printing groups requires the placement of clichés and inks, and they are made up of a set of rollers that guarantee the fixation of the cliché and allow the transfer of ink to the cardboards. Its passage between the cliché and the pressure roller completes the print process. The ink is transferred by suction from the different ink containers placed in each machine. Then, the cardboard passes through the slotter and rotary die cutter (points 7, 8) where the cardboard plates are cut through the rotating action of the blades. In this step, the creases of the box are also made, which allow the boxes folding. All cutting tools and clichés are specific to a given order. After cutting, the cardboards flow through the closing system (point 10) for pasting glue and pass to the beater (point 11).

The already-processed carton plates are then grouped and counted in flat lots (point 12). At the end of this process, they are wrapped in the strapping machine (point 13) and sent by a conveyor belt (point 14) to the pallets. The batches are then palletized (point 15) and sent to the finished product warehouse (point 16).

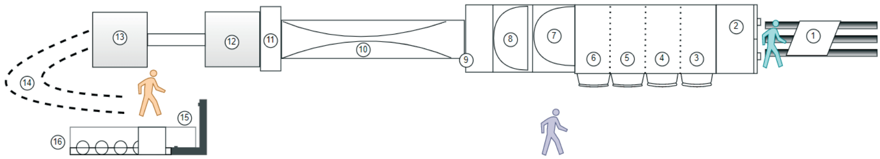

Figure 2: Detailed description of the production process at the case maker automatic line, identifying the loading operator (green), the case maker manager (purple) and the unloading operator at the automatic line exit (orange).

2.2. Description of the case maker parametrization

In order to be able to implement the SMED tool, all setup tasks carried out during the complete parameterization process were identified and the precedence relationship has been established, as presented in Table 1. For this analysis, a total of ten POs considering production batches of 1000 units were monitored. The goal was to observe several variants of the process, namely, the type of cardboard, different box sizes, the need for printing, the need for assembling the cutting tool, and the closing system (i.e., collage in this specific study). The setup process involves 3 operators: the loading operator at the case maker entrance (OPA); the case maker manager in charge of the machine parametrization (OPB); and the unloading operator at the automatic line exit (OPC).

Table 1.Tasks of case maker setup identification, precedence relationships and operators' responsibility

Task ID	Task Description	Precedence	Operator
T1	Analysis of PO needs	-	OPA; OPB; OPC
T2	Case maker opening	T1	OPB
T3	Collecting printing clichés near the case maker	T1	OPA
T4	Collecting cutting mould tools near the case maker	T1	OPA
T5	Inside case maker parametrization	T2, T3, T4	OPB
T6	Washing colour printing units	T3, T4	OPA
T7	Washing clichés	T6	OPA
T8	Conveyor belt activation to move cardboards	T7	OPA
T9	Adjust the carton size on the case maker feeder	T8	OPA
T10	Case maker closing	T5, T6	OPB
T11	Case maker exterior console parameterization	T10	OPB
T12	Adjust the transport bridges	T11	OPB
T13	Printing indicative labels to place on pallets	T1	OPC
T14	Picking up damaged cardboards	T13	OPC
T15	Adjusting the strapping system	T14, T12	OPC

All three operators start by analysing the needs of the PO (T1). While the case maker manager opens the case maker (T2), the loading operator collects the printing clichés (T3), as well as the cutting mould tools (T4). Meanwhile, the case maker manager initiates the inside parametrization (T5).

The loading operator washes the printing units (T6) in case that the carton boxes in production requires printing with different colours. The same operator is also responsible for washing the clichés (T7). Afterwards, he activates the conveyor belt to move the cardboards to the case maker feeder (T8) and in turn adjusts the carton size on the case maker feeder (T9).

Once the case maker parametrization tasks are completed, the case maker manager closes the machine (T10) and starts the exterior console parameterization (T11), adjusting the transport bridges (T12) which facilitates the box closing. At the automatic line exit, the unloading tasks include printing indicative labels to place on pallets (T13), picking up damaged cardboards from the previous POs (T14) and adjusting the strapping system (T15).

3. SMED methodology

SMED is a tool used to reduce the setup time in industrial equipment, allowing to increase the operational availability of machines and workers. Since the production has moving from push to pull production systems, the best way to reduce the size of each batch was to reduce stop downtime for changing the formats or products references [13, 14]the aim of this study was to reduce changeover time to improve productivity by applying Lean Manufacturing (LM. The implementation of the SMED tool starts with the detailed analysis of all the operations carried out during the process under analysis. Two types of operations associated with setups are identified, differentiating the internal from the external operations. Internal operations are those that can only be carried out with the machine stopped, whereas, external operations are those that can be carried out with the machine in operation. The SMED methodology is implemented in four main steps:

Step 0 - The internal and external setup conditions are not differentiated and, therefore, the equipment is stopped for long periods. During this phase, the operations and the respective sequence are identified. Also, it can be conducted a time study to determine their duration.

Step 1 - Separate internal from external setup operations – the setup process must be properly divided into internal and external setup operations. At this stage it is possible to critically identify the waste of time in carrying out internal operations that can be completed externally.

Step 2 - Convert internal setup into external setup – after the operations separation, it is necessary to convert internal operations into external ones, in order to reduce the downtime.

Step 3 - Rationalization of all setup operations – in this phase all operations (internal or external) must be studied in order to verify if it is possible to reduce execution times or even eliminate the operation.

The SMED implementation is usually supported by visual management tools and 5S technique, which contributes to the operations identification [15].

4. Results from SMED application

After a critical analysis of the production process, some problems affecting its productivity were detected. The main problems were the low availability of the case makers for the production, resulting from the high setup times. The need for 3 operators for the setup process also represents a high resource allocation rate for the company. In this section, the different steps to implement SMED in the automatic line are presented and explained.

4.1. Setup operations network

For the implementation of SMED it was necessary to map the setup operations that currently influence the production cycle times and clearly identify the responsibilities of the operators, balancing all the operations. In addition, a time study was carried out in order to quantify the tasks duration, based on timing measurement technique. All the case makers parametrization activities identified by Table1 are considered as internal setup. The inside parametrization is the task with the longest duration, being a great part of the time spent in the assembly of the cutting tool.

After stablishing the precedence relationships between the setup tasks, a graph network was elaborated prior to SMED application (Figure 3). It is important to explain that the tasks T3 and T4, collecting printing clichés and the cutting tools were grouped. In the production orders requiring printing and cutting, the loading operator performs both tasks simultaneously.

Based on the analysis of the setup tasks times, it can be verified that there is a considerable difference in allocation time between the three operators, with the case maker manager being the busiest (56% of the setup time). The setup process has a total duration of 28.18 minutes.

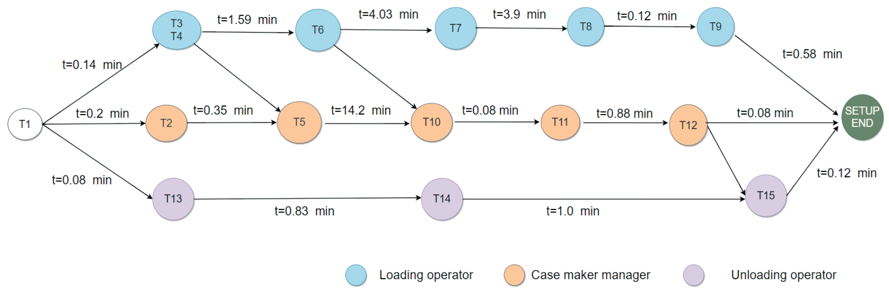

Figure 3: Precedence network for case maker setup before SMED application.

4.2. Separation and conversion of internal into external setup

Based on the evaluation of the graph network, the outsourcing of possible tasks was proposed in order to reduce the setup process and, consequently, the productive lead time. In this sense, each task was analysed and classified as internal and external setup, as presented by Table 2.

Table 2.Proposed separation and conversion of internal tasks into external setup

Task ID	Task Description	Internal	External	Time during setup (min)
T1	Analysis of PO needs		☑	-
T2	Case maker opening	☑		0.35
T3	Collecting printing clichés near the case maker		☑	-
T4	Collecting cutting mould tools near the case maker		☑	-
T5	Inside case maker parametrization	☑		14.20
T6	Washing colour printing units	☑		4.03
T7	Washing clichés		☑	-
T8	Conveyor belt activation to move cardboards		☑	-
T9	Adjust the carton size on the case maker feeder	☑		0.58
T10	Case maker closing	☑		0.08
T11	Case maker exterior console parameterization	☑		0.88
T12	Adjust the transport bridges	☑		0.08
T13	Printing indicative labels to place on pallets		☑	-
T14	Picking up damaged cardboards		☑	-
T15	Adjusting the strapping system		☑	-

In total, eight tasks were converted to external setup (T1, T3, T4, T7, T8, T13, T14 and T15). The analysis of the PO must be carried out by all operator involved in the case maker parameterization process; however, operators can carry it out before the automatic line stops. Task T3 and T4 can also be externalized. Since the PO are available at the beginning of each work shift, an operator can previously collect and transport the printing clichés and the cutting mould tools near the automatic line. Regarding T7, the clichés removed from the case maker can be washed after the automatic line start. During the wating times, the loading operator can activate the conveyor belt to move cardboards. All tasks performed by the unloading operator (T13 to T15) can be performed while waiting for the completion of the previous PO. Despite the outsourcing of all these operations, it was not possible to shorten any of the tasks. Operators already perform their tasks without considerable waste.

4.3. Proposed setup for case maker parameterization

Based on the conversion of internal into external setup, a revised precedence network is proposed as depicted by Figure 4. With the externalization of 8 tasks, case maker parametrization requires the machine to stop for a period of 20.20 minutes, the remaining tasks being able to be carried out with the automatic line in operation. This outcome results in a setup time reduction of 28%. In addition to reducing setup time by around 28%, with this improvement proposal, one of the operators (the unloading operator) could carry out other value-added activities for the company. If the PO do not require cuts, the setup time reduction is higher, corresponding to 39.6%.

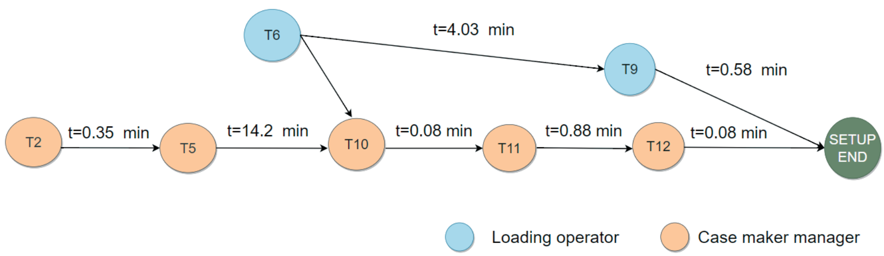

Figure 4: Precedence network for case maker setup after SMED application.

Considering that, on average, the total cycle time for the production of 1000 boxes corresponds to 100.53 minutes, a setup time reduction of 28% can represent an important contribution to the reduction of productive lead time in the corrugated carton sector. With the reduction of lead time, the automatic line has a higher availability to accommodate additional orders.

5. Main conclusions

In this paper, SMED tool was applied to reduce the setup times of an automatic production line. The study was carried out in an industrial company dedicated to the production of corrugated carton boxes. The production process is divided into case maker parameterization, sample production, automatic production and packaging. Using the SMED tool and for the production of batches of 1000 boxes, the proposed conversion of internal setup tasks into external setup led to a reduction of 28% in setup time. SMED is an effective tool for any industry if the production operations are correctly sequenced. In conclusion, despite the existence of many improvement opportunities for companies with low level of quality maturity they can significantly benefit from the adoption of Lean tools to reduce the productive lead time.

Acknowledgements

This research was supported by the Portuguese Foundation for Science and Technology (FCT), within the Project Scope: UIDB/00319/2020 (ALGORITMI) and UIDP/04077/2020 (METRICS).

References

1. Boran S, Ekincioğlu C (2017) A novel integrated SMED approach for reducing setup time. Int J Adv Manuf Technol 92:3941–3951. https://doi.org/10.1007/s00170-017-0424-9
2. Tiacci L, Saetta S (2009) An approach to evaluate the impact of interaction between demand forecasting method and stock control policy on the inventory system performances. Int J Prod Econ 118:63–71. https://doi.org/10.1016/j.ijpe.2008.08.010
3. Roriz C, Nunes E, Sousa S (2017) Application of Lean Production Principles and Tools for Quality Improvement of Production Processes in a Carton Company. Procedia Manuf 11:1069–1076. https://doi.org/10.1016/j.promfg.2017.07.218
4. Eguía I, Villa G, Lozano S (2017) Efficiency Assessment of Reconfigurable Manufacturing Systems. Procedia Manuf 11:1027–1034. https://doi.org/10.1016/j.promfg.2017.07.213
5. Dinesh SN, Shalini M, Vijay M, et al (2022) Improving the productivity in carton manufacturing industry using value stream mapping (VSM). Mater Today Proc 66:1221–1227. https://doi.org/10.1016/j.matpr.2022.05.015
6. Pinto JLQ, Matias JCO, Pimentel C, et al (2018) Lean Manufacturing and Kai-

zen. In: Just in Time Factory:Implementation through Lean Manufacturing Tools. Springer, pp 5–24

7. Kehr TW, Proctor MD (2017) People Pillars: Re-structuring the Toyota Production System (TPS) House Based on Inadequacies Revealed During the Automotive Recall Crisis. Qual Reliab Eng Int 33:921–930. https://doi.org/10.1002/qre.2059
8. Chiarini A, Baccarani C, Mascherpa V (2018) Lean production, Toyota Production System and Kaizen philosophy. TQM J 30:425–438. https://doi.org/10.1108/TQM-12-2017-0178
9. Shafeek H (2019) Lean Manufacturing Implementation in Carton Industry — A case study. In: 2019 Industrial & Systems Engineering Conference (ISEC). IEEE, pp 1–9
10. Roriz C, Nunes E, Sousa S (2017) Application of Lean Production Principles and Tools for Quality Improvement of Production Processes in a Carton Company. Procedia Manuf 11:1069–1076. https://doi.org/10.1016/j.promfg.2017.07.218
11. Moxham C, Greatbanks R (2001) Prerequisites for the implementation of the SMED methodology: A study in a textile processing environment. Int J Qual Reliab Manag 18:404–414. https://doi.org/10.1108/02656710110386798
12. Charrua-Santos F, Santos BP, Calderón-Arce C, et al (2019) Scheduling Operations and SMED: Complementary Ways to Improve Productivity. In: Reis J, Pinelas S, Melão N (eds) Springer Proceedings in Mathematics & Statistics, Industrial. Springer, Cham, pp 221–227
13. Bukhsh M, Khan M, Zaidi I, et al (2021) Productivity improvement in textile industry using lean manufacturing practices of 5S and SMED. In: Proceedings of the International Conference on Industrial Engineering and Operations Management. IEOM Society International, Singapore, pp 7374–7385
14. da Silva IB, Godinho Filho M (2019) Single-minute exchange of die (SMED): a state-of-the-art literature review. Int J Adv Manuf Technol 102:4289–4307. https://doi.org/10.1007/s00170-019-03484-w
15. Guzel D, Shahbazpour Asiabi A (2022) Increasing Productivity of Furniture Factory with Lean Manufacturing Techniques (Case Study). Tech J 16:82–92. https://doi.org/10.31803/tg-20211010121240