

Productivity Improvement of a Production Line Through Quick Changeover Concept – A Case Study

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Abstract

This paper describes a project that aims at the reduction of setup or changeover times in a final assembly line that produces automotive instrument panels, using the Quick Changeover concept and, methodologies and tools associated with Lean Production. Setup or changeover times are non-productive times, and therefore are considered waste, having a direct impact on line availability, reducing its Overall Equipment Effectiveness (OEE). In this way, high changeover times reduce the productive flexibility, as they lead to a deliberate reduction in the number of changeovers, and consequently to the increase of produced stocks.

The factors that most contributed to the high changeover times were the high waiting times, the necessary adjustment after changeovers due to breakdowns, the lack of means to a Quick Changeover which resulted in excessive displacements of the line operators, and the lack of a changeover standard that defines clearly who performs each task.

Through the application of the SMED methodology, and the implemented improvements and standards, the total changeover time of the studied line was reduced from 57.5 to 23.7 minutes, representing an improvement of approximately 59% compared to the initial time. The result represents an additional production opportunity of 23 units per production change and shows the impact of the implementation of Quick Changeover concept and associated tools, achieved with the collaboration of people with different skills.

Keywords

Lean Production, Continuous Improvement, Changeover, SMED, Standard Work.

Introduction

Quick changes in technology, globalization of production industries and reduction of products life cycle are the main factors for the increase of industrial competitiveness at a global scale.

Lean Production concept aims to identify and eliminate waste through continuous improvement processes, allowing companies to become more flexible and competitive [1]. This methodology involves tools and techniques that promote improvements in companies operations and processes. Among them, Quick Changeover (QCO) is a

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concept to improve and reduce the changeover times between products of different families. High setup or changeover times result in the manufacturing of high production lots, which lead to the reduction of productive flexibility and creation of stocks. Related to QCO, an important tool is SMED – Single Minute Exchange of Die, that has been in the first line of activities regarding the reduction of setup times.

This paper presents a project whose primary goal was the improvement of the changeover process between two product families that are manufactured in a final assembly line, using the SMED methodology. To do so, several improvement actions were implemented and changeover activities were standardized. The paper points out the competencies involved in the implementation of the actions, showing the need for transdisciplinary in SMED application.

The company, a car instrumentation clusters manufacturer, seeks to continuously improve their processes through the reduction of costs and delivery times, reacting differently to the level of orders. For that purpose, the Lean Production [2] concepts have been adopted since 2002. Based on Toyota Production System (TPS) [3], the company has developed their own Lean Management System.

The present paper is structured in 5 different sections. Firstly, a brief literature review is performed. Then, the case study is presented and analyzed, and a description of the initial state of the changeover process is presented. In section 3 are described the implemented improvement actions, whose results are discussed in section 4. Finally, conclusive notes are presented in section 5.

1. Literature Review

In 1990, the Lean concept was widely disclosed through the best-seller “The Machine that Changed the World” [2], which made TPS known in the Western World. Under the designation of Lean Production, it was presented as “doing more with less”, a new productive system capable to produce the same with less resources [2]. TPS emerged in the automotive sector and it was created by the Japanese engineers Taiichi Ohno and Shigeo Shingo in the 1950s. This philosophy is based in two major pillars, Just-In-Time (JIT) and “Autonomation” (or Jidoka in Japanese). The first means that every processes produce only what is necessary, when is necessary in the necessary amounts. The second one is defined as “making the equipment or operation stop whenever an abnormal or defective condition occurs” [4]. This model of productive system aims to reach maximum productivity by reducing waste and through continuous process improvement.

The Lean philosophy is based on 5 fundamental principals: (i) specify Value, (ii) identify the Value Stream, (iii) guarantee a Continuous Flow, (iv) implement a Pulled System, and (v) seek Perfection. Waste (Muda in Japanese) represents any activity that consumes resources but does not add value to the final product. Taiichi Ohno [3] and Shigeo Shingo [5] identified the 7 original categories of waste that can be found on the shop floor: overproduction, waiting times, transportation, movements, over or inadequate processing, inventory and defects. To remove these waste factors, several tools and techniques should be implemented by companies, such as: Value Stream Mapping (VSM), Kaizen/ PDCA Cycle, Visual Management, Standard Work (SW), Total Productive Maintenance (TPM), 5S and SMED. These tools have proved to be effective in reducing waste and, therefore in improving productivity [6].

Changeover time can be defined as the elapsed time between the last “good” product of the previous cycle and the first “good” product of the next cycle [7]. Changeover and setup are the required changes of tools and necessary adjustments to equipments in a change of production. The QCO has the objective of improving changes in order to reduce their times [8].

SMED is a methodology which is usually associated to QCO, and it was developed in Japan by Shigeo Shingo during the 1960s. The main goal is to simplify the process and reduce setup times, reaching single digit changeover times of less than 10 minutes [9].

According to Shingo [9], there are 2 types of setup operations: internal setup – operations that can only be executed with the machine stopped/turned off, and external setup – operations that can be executed with the machine in normal operation mode.

This methodology is based in 4 distinct stages:

- Preliminary Stage – Internal and External setup operation are indistinguishable;
- Stage 1 – Separation of Internal from External operations;
- Stage 2 – Conversion of Internal into External operations;
- Stage 3 – Optimization of all setup operation aspects.

Between the several advantages of low setup times are the increase of productive flexibility, reduction of stock, work in progress (WIP) and associated costs, and the decrease of lead time, since the operations system can answer quickly to the market’s needs.

In this context, Raul Lopes et al. [10] presents a case study showing that SMED has a positive contribution to reduce all kinds of waste, by reducing the setup time in approximately 97%.

However, the achievement of significant results through SMED implementation requires the collaboration of people with different skills.

2. Diagnosis of Initial Situation

The project took place in a final assembly line which produces instrumentation clusters for 2 automotive brands, designated in this paper by X and Y. Figure 1 shows the fluxogram that resumes the productive process. It involves 26 workstations, from which 21 require setup operations: tool exchanges, program selections and replacement of materials.

The productive process occurs with 6 operators, 1 supporting operator and 1 material provider (PoUP), all led by a line leader. With this team, the line has a Cycle Time (CT) of 88.5s and a Takt-Time (TT) of 98.3s, whereas the operator 3 presents a cycle time of 88.4s, being the line bottleneck.

As aforementioned, the Shingo SMED methodology begins by a Preliminary Stage. During this project it was necessary to study the initial state of the line changeover according to the following steps:

1. **Initial Observation:** to identify the workstations that require setup operations, the used tools and their location;
2. **Video Recording:** to document all operations and movements during setup;
3. **Dialog with the operators:** to better understand the changeover process and identify potential problems;

4. **Video Analysis:** detail every setup operation, registering elapsed time, number of operators required and traveled distances;
5. **Creation of an Initial State Spaghetti Diagram:** to represent the operators movements during changeover process and identify areas with more entropy.

After the initial observation, it was concluded that the process was desorganized. The operations were executed randomly according to their need. The conditions were poor and there were constant breakdowns with high duration. Although setup operations are defined by their simplicity, the lack of standards and an inefficient distribution of these operations by all operators make this process apparently complex, where several types of waste can be identified.

After the preliminary stage, that allows identifying a duration of 57 minutes for the conclusion of all setup operations, stage 1 of SMED methodology was carried out to reduce this value. This requires the classification of changeover activities in internal and external operations. A total of 198 setup operations were identified, with only 3 of them being considered as external. The external operations were executed by the supporting operator, since it is the only operator available to do them.

The main wastes identified in the initial stage were the movements, representing about 24.5% of the total changeover time. These concern the operators movements to pick up/put down the workstation keyboard, to return the material of the previous product back to the line edges, and to get and storage tools.

3. Improvement Actions

A team was formed to identify and implement actions for the reduction of wastes identified and evidenced in stage 1. The team included the project owner; the TPM coordinator; the responsible for line planning and final assembly processes; the responsible for test systems workstations; the responsible for ergonomics assessment; a person who has supported the solving problem system of the company; and the production team leader.

The team meetings were followed with an Open Point List (OPL) that included the implemented improvements assigned for each team member.

Shingo [8] refers that implementation of stages 2 and 3 of SMED methodology, that consists of identification and implementation of improvements to reduce changeover, does not need to be executed in sequence, and therefore, it was applied simultaneously.

3.1. Action 1 – Automatic change of programs in Testing Workstations

The team concluded that the major need of time reduction was related the waits, representing 22.7% of the total setup operations. These waiting times were directly associated to the need of restarting the workstation applications to change the testing program for the new product. With the know-how in information technology and electrotechnology of the responsible for test systems, it was possible to reconfigure the testing workstations which makes these operations no longer necessary as they are now run automatically. This action allowed the reduction of setup operations total time in approximately 23.6%.

3.2. Action 2 – Reduction of travels and tool storage: allocation of lighter jigs close to the respective workstation

Almost all tools involved in changeover process have small dimensions, however, some of them are heavy and are stored in a cabinet located at the end of the production line with the exception of two jigs who are right above the respective workstation. An ergonomic evaluation was conducted to define where tools should be located and how they should be manipulated during changeover. After evaluating the tools weight and making the respective validation through NIOSH (National Institute for Occupational Safety and Health) method, it was defined that the 8 tools of workstations MF-7A, MF-9A and MF-9B should be stored in the end-of-line cabinet, which must be externally transported to the line entrance before changeover. The remaining tools should be stored as close as possible to the respective workstation.

Firstly, a movable cabinet was created to store the 18 jigs of BUR50, 3 jigs of FCT50 and 1 jig of AOI40, which will be externally transported to the changeover process by the supporting operator to the respective workstations.

Afterwards, drawers and holders were created to store the jigs of workstations MF-3, MF-7, MF-9, MF-10, AOI50 and SUB50 in the respective stations or as close as possible to them. Some of the mentioned improvements are depicted in Figure 2.

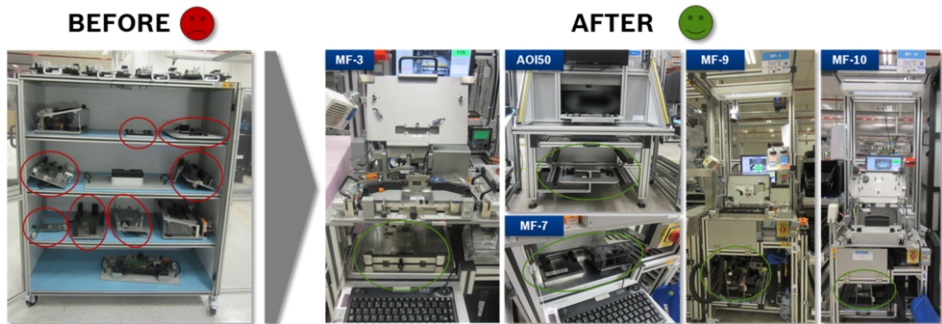


Figure 2. Before and after of some tools storage.

The implementation of this action was essential for a significant reduction of the internal travels during changeover from 355.4 to 86.3 m, representing an improvement of 76%.

3.3. Action 3 – Conversion of internal in external operations

The Stage 2 of SMED requires a new operations analysis to identify activities that can be converted in external operations. In this way, one of the highest setup time was related to MF-7. This is essentially due to one of the more complex activities consisting of returning and preparing the materials related to the dials needed to produce the product, which is a thin and fragile material. Therefore, it became clear that this operation should be executed externally while in normal production by the supporting operator, so that during changeover time, only the replacement of the dial dispenser be needed. With this improvement, the internal operation time went from 190 to 7.3s, resulting in a reduction of 96%.

Similarly, the preparation of the new product's labels for workstation MF-8 was improved. A labels dispenser was implemented and this activity was assigned to the

supporting operator in order to be performed externally, reducing about 81.3% the setup time.

3.4. Action 4 – Identification of the storage location of each tool

The next step was the implementation of the fourth S of the 5S methodology, the standardization. Labels with the necessary tool information were created in order to make possible the definition of a storage procedure. With this action, the time spent searching for tools stopped being necessary, therefore reducing the setup time. However, all operators should respect these identifications in order to simplify this task.

3.5. Action 5 – Implementation of parallel operations supported by a changeover standard

According to the SMED Stage 3, the implementation of parallel operations consists of dividing internal operations and assigning them to 2 operators in order to be executed in parallel, reducing the total setup time. This technique was applied to almost all workstations since most had changeover operations that could be executed in parallel. To make it possible, the supporting operator should follow the production flow of the last unit respecting the standard work of each operator.

In order to better depict the performed activities during the changeover process, a Standard Work Combination Table was created, containing:

- A Gantt Diagram that highlights the parallel tasks;
- A matching between the macro-task with the respective SPL – Single Point Lesson;
- The activities associated with the respective workstation;
- The indication of tool location;
- The occupation of each operator, their tasks and estimated time;
- A levelling graph regarding the operator's occupation and the workstations during changeover.

The major reduction of the total setup time was noticed, as an improvement of 59% was verified. In this way, it is estimated that the total changeover operations takes about 23.7 minutes.

3.6. Other actions

Besides the aforementioned improvements, other actions with less impact were implemented. Among them, the implementation of the software QCO Modular in MF-4, whose purpose is to: provide the number of produced units and units to be produced, plan the production sequence, give information about product change, generate alerts during changeover (if necessary) and call maintenance if assistance for change is required.

The integration of the training about QCO standard in the operators competence matrix was another important action. The purpose is to create the habit of application of the changeover procedures and standards by the operators, as well as to explain what are the advantages of following them. This cooperation is essential to achieve positive results with the SMED methodology.

Other improvements were proposed, being currently under evaluation. Among them, the assignment of external operations to the PoUP operator. Being the operator responsible to supply the materials to the line edges, he would also be responsible to supply and store the tools that are in the end-of-line cabinet for the changeover.

From a mechanical point of view, a jig concept improvement was also proposed that involves replacing the current screw fixation system for a quick coupling system.

4. Results Analysis

Through Lean Production tools and SMED methodology, an effective, simple and organized setup process was implemented, allowing a significant reduction of waste.

With the implementation of action 2, it was possible to reduce the changeover traveled distances from 355.4 to 86.3m regarding internal operations. This impact is visible by comparing the initial (Figure 3) and final state (Figure 4). A large percentage of movements was eliminated through the creation of tool storage drawers and holders close to the respective workstation. The operations of approaching the movable cabinet with the remaining tools and jigs are made externally and previously to changeover by the supporting operator.

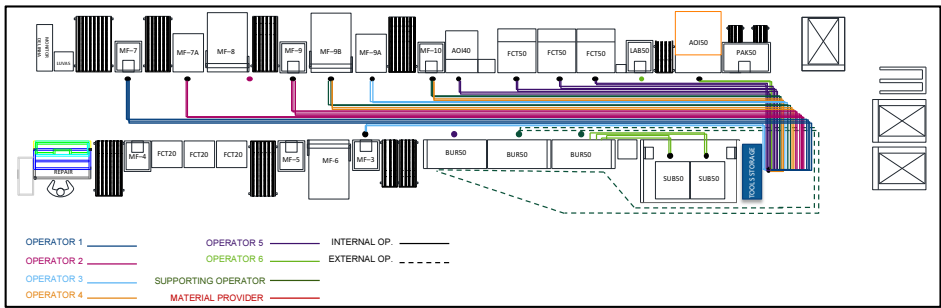


Figure 3. Spaghetti Diagram of initial situation.

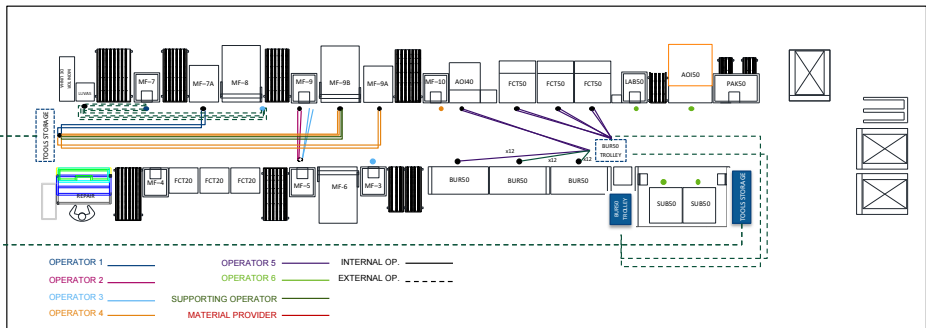


Figure 4. Spaghetti Diagram of final situation.

Figure 5 shows the obtained results through the improvement actions and also an estimation considering the remaining proposals. However, these results do not consider the impact of the parallel operations in the standard work.

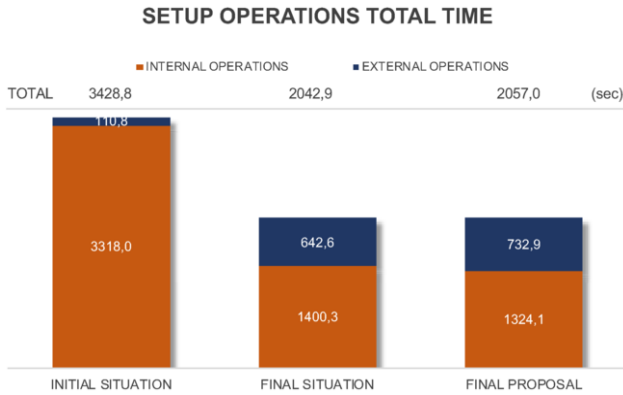


Figure 5. Results obtained from the implemented actions.

It is estimated that the total changeover time of the final situation is 23.7min, a decrease of about 59% relative to the initial situation. This reduction of changeover time, increases the productive time, which can be reflected in a cost of opportunity. Therefore, this project estimates the production of 23 additional units per changeover, and a decrease of lost units generated by changeover, increase the possibility of a higher number of changeover events which enhances the line flexibility.

A future work proposal is the implementation of MTM (Methods-Time Measurements) which is a pre-determined times method, obtained through a standard table. It is a tool for describing, structuring, conforming and planning the work systems making them more efficient. Once the changeover operations are influenced by the Human element, it is relevant to apply this method in order to better define the working method in a planning phase. With this method it is also possible to document in detail the whole changeover process, increasing its transparency and quickly identifying potential reductions of time and costs. It also eliminates discrepancies in the times estimated for different operators doing the same task.

5. Conclusions

The implementation of SMED methodology allowed the standardization of the line changeover process through the application of Standard Work. This is the starting point that supports the continuous improvement since it is through it that processes can be improved.

A simple and organized changeover process was obtained, resulting in a significant time reduction of about 59%. In order to do that, all good practices were registered in a Changeover Standard Work Instruction, which comprises the Standard Work Combination Table, the Standard Work Chart, the Standard Work Balance Chart and the changeover SPLs. A process confirmation should be made periodically to check if all procedures are being followed and to check for deviations in the implemented actions. This task should be made by the project team along with the production team leader, which also ensures a permanent interaction with the operators, enhancing their training monitorization.

This work constitutes a basis for future work, facilitating this approach in other production lines. A future work improvement should involve the application of MTM

(Methods-Time Measurement), which is a powerful tool to better detail the process and to predict possible improvements in an early stage.

The obtained results matched the initial expectations and goals, allowing the company to reach: a reduction of non-productive times, an increase of the productive capacity, a higher flexibility that leads to smaller lots and subsequently to stock reduction, a reduction of operational costs, smaller and simple setups, and an uniformization of the changeover procedures which results in less errors and an improvement of quality. The success of Quick Changeover concept implementation was achieved only through teamwork and the contribution of all.

To achieve significant results in the implementation of SMED methodology, it is necessary to define clearly the role of each member and to involve different skills, such as: knowledge in mechanical engineering - to find and implement technical adjustment and quick setup solutions for tools; knowledge in information technology and electrotechnology - in automated systems to implement solutions for identification of the new product and parameterization of the process; knowledge in ergonomics and work psychology - to identify and eliminate situations that can lead to injuries, cause fatigue in the operators, or hinder the accomplishment of the task; Knowledge in time study and production planning - in production lines to avoid production bottlenecks and ensure the availability of tools and materials when requested and define the time required for each setup activity.

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References

- [1] J.P.Womack and D.T. Jones, *Lean thinking: Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, New York, 1996.
- [2] J.P. Womack, D.T. Jones and D. Roos, *The Machine that Changed the World – The Story of Lean Production*, Rawson Associates, New York, 1990.
- [3] T. Ohno, *Toyota Production System: Beyond Large-Scale Production*, 3rd ed, CRC Press, Ed., New York, 1988.
- [4] Y. Sugimori, K. Kusunoki, F. Cho and S. Uchikawa, Toyota Production System and Kanban System – Materialization of just-in-time and respect-for-human system, *International Journal of Production Research*, Vol. 15, 1977, pp. 553–564.
- [5] S. Shingo, *A Study of the Toyota Production System From Industrial Engineering Viewpoint*, Productivity Press, Portland, 1989.
- [6] R. Carvalho, A. Alves and I. Lopes, Principles and practices of lean production applied in a metal structures production system, *Lecture Notes in Engineering and Computer Science: Proceedings of The World Congress on Engineering 2011*, 2011, pp. 744–749.
- [7] D. Severson, *The SMED system for reducing changeover times: an exciting catalyst for companywide improvement and profits*, P&IM Review with APICS News, 1988.
- [8] The Productivity Press Development Team, *Quick Changeover for Operators*, Productivity Press, Portland, 1996.
- [9] S. Shingo, *A Revolution in Manufacturing: The SMED System*, Productivity Press, Cambridge, 1985.
- [10] R. Lopes, C. Neto, and J. P. Pinto, Quick Changeover – Aplicação prática do método SMED, *Kerâmica*, 2010, pp. 31-36.