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Application of Lean Production Principles and Tools for Quality Improvement of Production Processes in a Carton Company

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Abstract

This work presents an industrial case study focused on improving the quality of production processes, using lean production tools. The analysis of the initial situation was done using cause-effect diagrams, Pareto's analysis, study of setup times and performance indicators, allowing identifying the main problems, such as high setup times, low availability of machines, lack of organization in the working area. Improvement proposals were implemented in the bonding section, like the SMED methodology, the 5S technique and visual management. As result it was achieved an average reduction of 47% in the setup time, corresponding to 10114€ of monthly profit.

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Keywords: 5S Technique; Lean Production; Quality Tools; SMED; Visual Management.

1. Introduction

In general, companies are under pressure to improve productivity and quality while reducing costs. This has led many of these companies to implement a Lean Production philosophy [1]. Lean Production is a multidimensional approach that covers a variety of management practices that aim to reduce waste and improve operational

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effectiveness [2]. However, the application of the practices alone does not ensure the implementation of the Lean philosophy. In addition to technical factors, any Lean implementation should consider non-tangible change factors, such as creating a supportive learning environment and developing leadership in the organization.

Companies may follow a different strategy and bet on continuous improvement of the quality of their products / services, to retain customers and gain market share. Continuous improvement of processes is a key concept of Total Quality Management [3], but it is not the only way of improving a process. In this context, a management strategy that combines TQM principles with Lean Production principles has proved to be adequate for many companies [4].

Other methodologies such as reengineering or automation can also result in improved performance. Thus, these mechanisms to improve company competitiveness may compete for internal resources. Particularly in small to medium sized companies (SMEs) the use of quality tools is low [5, 6]. To improve processes SMEs need to select and prioritize improvement actions [7]. This study aims to assess the effectiveness Lean production and TQM principles to provide evidence on the results companies could obtain.

This work was carried out in a SME of the sector of the production of corrugated cardboard boxes and lithographic boxes for several uses having as main objective improving quality and performance of a production process applying TQM and Lean Production principles and tools.

2. Methodology

The case study methodology is used to respond research questions such as "how complex events happen". In this case describes a SME that decided to apply Lean Production and TQM principles to its operational processes. The case study will characterize: the company operational processes; the application of Lean and TQM principles and tools; and its quantitative results.

A researcher doing an internship over four months in this company carried out the main activities described. The production process for obtaining the main product (boxes) is divided into six sections, whereby the products go through and undergo changes before reaching the end customer. These sections are described below:

- Design: Creates and develops the image that will be printed on the box;
- Cardboard Cutting: The paperboard rolls are cut in the desired dimensions for the cartons;
- Printing: Makes the impression in the paperboard plane;
- Bonding: After the cardstock plans go through printing, it is necessary to make them stronger. The reinforcement of the plans is made, by gluing a plan of corrugated cardboard, denominated of micro;
- Cut and Fold: Shapes the box according to the type of box that the customer wants. The collapsible planes are pressed against cutting and creasing blades, using a desired mold for the carton;
- Peeling: Removes all surplus material from the box. Thus, the operators manually "peel" the plans, leaving only the box ready to assemble.

Because there were not enough resources to do a detailed analysis and improvement proposal in all of the above mentioned sections, it was decided to carry out a Pareto analysis of the non-conformities found in the various sections and thus select for improvement the section with the largest number of non-conformity records. As can be seen in Fig. 1, the section where most defects have occurred is the Bonding section, which accounted for about 60% of the non-conformities detected during previous year.

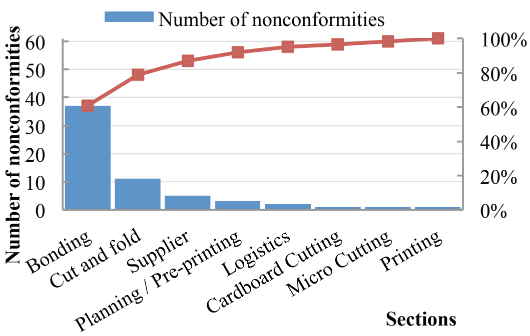

Fig. 1. *Pareto chart on the number of non-conformities per section*

For this reason, it has become appropriate to base this project on this section with the aim of improving the quality of the production process and consequently reducing the non-conformances produced here.

In an initial phase, an analysis and diagnosis of the Bonding section are presented, followed by improvement proposals for to the problems encountered. Finally, an analysis and discussion of the results obtained is carried out, comparing the before and after the implementation of the improvement proposals.

3. Analysis and Diagnosis of the Bonding Section

The key equipment of this section consists of three machines: CC1, CC2 and CC3. Its main function is the gluing of a micro plane to a cardboard plane, thus making the carton more robust. To manufacture the carton on these machines, the following raw materials are required: paperboard, micro-reels and glue containers.

3.1. Equipment Performance Analysis

In order to know the performance of the machines, the Overall Equipment Effectiveness (OEE) indicator was calculated. For this, over 10 consecutive days, production data were recorded, such as shift time, opening time, cycle time, quantities produced per machine, number of non-conforming parts, among others. The results obtained are shown in Table 1. The maximum value for the speed indicator was considered, since these data were difficult to obtain, taking into account the type of machines in the section. Analyzing the obtained results, it is verified that CC1 is the one that presents a lower availability value, because low quantity productions are allocated to this machine, which implies several setups. Regarding the quality of production, since it would be difficult for operators to inspect all the produced plans, non-conformities can be detected in the following sections. This causes the quality indicator to be high because only some non-conforming plans are identified and removed by the operators in this section.

The fact that the daily production changes influenced the total availability of the machines led to the study of the setup times of the machines.

Table 1. Comparison of the OEE value of the three machines with the world class value

Indicators	Machines			World class values
	CC1	CC2	CC3	
Availability (%)	37.3	62.1	69.5	90
Performance (%)	100	100	100	95
Quality (%)	99.4	99.9	99.7	99.9
OEE (%)	37	62	69	85

3.2. Changes of Manufacturing Orders - Setups

Since the company did not have data on setup times, it was recorded the setup time for ten setups for later analysis. Table 2 shows the average setup time per machine.

Table 2. Average setup time of the machines

	Machine		
	CC1	CC2	CC3
average setup time (min)	11.823	15.33	19.10

Observing the operators, it was possible to identify the operations necessary to carry out during the stopping and preparation time of the machines for the following manufacturing order (MO). The stops for the change of MO generally consist of in arranging the remaining lithographed plans from the previous MO, placing the new reel on the shaft and supplying the machine with the new planes to be back-shifted. It was also possible to observe that the operations carried out in the setups vary according to the previous MO, which means that there are operations that are more time consuming than others. It was also verified that the operations are not carried out sequentially by all operators, i.e., the setup is not performed following a defined order, but rather according to the operator's will and the location of the materials.

3.3. Shop floor environment

The organization of the workspace is important because it allows better conditions and consequently an increase of productivity and quality. Thus, analyzing each workstation and its surrounding area individually, the points that need more organization and cleaning were identified. In the three machines there are some tools that help the operators to perform the adjustment of the machines, but these are scattered, not having a site of their own. As it is possible to verify in Fig. 2 the section presents pallets that are leaning against the machines, the micro coils are scattered in the corridors, etc.

Fig. 2. Messiness and lack of cleaning

3.4. Synthesis of identified problems

After a critical analysis of the section and its production process, some problems were detected affecting the quality of the products. These problems led to some improvement proposals being presented to the company. The main problems identified were:

- the low availability of the machines resulting from various changes of MOs
- high setup times due to lack of standardization of operations
- lack of organization of the section, work areas are messed up with scattered materials and there is no definition for tools location.

4. Improvement Proposals

Some improvement proposals are presented below for the problems encountered in the bonding section. These proposals are based on the implementation of Single Minute Exchange of Die (SMED) methodology, visual management and 5S technique.

4.1. SMED Methodology Implementation

In order to reduce the high setup times of the machines, an improvement proposal was elaborated that consists in the implementation of the SMED methodology in the section. The implementation was done for the three machines, but the development of the various stages (Preliminary Stage; Stage 1; Stage 2; and Stage 3) will only be presented for CC1.

Preliminary Stage - Observation and description of setup operations

The first phase of this methodology consisted in filming various setup operations and thus it was possible to identify the unnecessary ones to execute the change of MO. The operators were asked about the method that was currently used to perform the setup, but only stated that the way they did it was how they were taught, not knowing if it was the right way to do it. The setup movie of the machine CC1 has the duration of 699 seconds, time corresponding to the total duration of the setup. Based on this film the sequence-performer flowchart shown in Fig. 3 was elaborated, where it is possible to verify the time spent in each of the activities that make up the setup operation: operation, transport, storage, control and wait.

Sequence Chart		Summary		
Chart 1	Sheet 1 of 1	Activity		Current Values
Objective: To reduce the setup time of the machine under study **Activity:** Change manufacturing order **Location:** Countertop Section **Operator:** 1 **Equipment:** Scaffolding 1		Operations	⬭	453
		Movements	⇨	246
		Storage	▽	0
		Control	□	0
		Waiting	D	0
		Distance (m)		184,14
		Time (s)		699

Nº	Description of Operation	Distance (m)	Time (s)	⬭	⇨	▽	□	D	Operation type
1	Stop the machine to change MO	3,3	5	●					Internal
2	Arrange the plans that are left over from the previous MO	8,42	12		●				Internal
3	Record the quantity produced in the previous MO		26	●					Internal
4	Check which is the next MO	4,96	27	●					Internal
5	Cut the micro in the machine inlet	6,66	6	●					Internal
6	Remove the micro and place it on the waste pallet	6,65	12		●				Internal
7	Wrap the remaining bobbin and identify it	3,6	30	●					Internal
8	Lower the shaft coil		19	●					Internal
9	Pack the micro coil in the hallway	5,7	8		●				Internal
10	Search for a pallet truck	16,7	18		●				Internal
11	Find the plans and transport them to the machine	15,23	30		●				Internal
12	Arrange the pallet truck	26,6	19		●				Internal
13	Load the machine with the planes to be	36,67	217	●					Internal
14	Find the bobbin and transport it to the machine	11,4	17		●				Internal
15	Raise reel to shaft		33	●					Internal
16	Remove the 1st turn from the reel		8	●					Internal
17	Take the 1st turn to the waste pallet	7,2	4		●				Internal
18	Run the micro through the machine inlet		36	●					Internal
19	Tuning machine (wheels and suction cups)	1	15	●					Internal
20	Pass the micro through the machine rollers	0,85	31	●					Internal
21	Search for a pallet truck	13,4	79		●				Internal
22	Arrange the pallet with the contracted planes	8,1	23		●				Internal
23	Turn the machine on and remove the trash	7,7	24		●				Internal
	Total	**184,14**	**699**	**453**	**246**	**0**	**10**	**0**	

Fig. 3. Sequence flowchart for CC1 setup

In order to understand the movements that operator 1 performs, the spaghetti diagram (Fig. 4) was performed, showing the entire path made by the operator 1 in the setup of machine CC1.

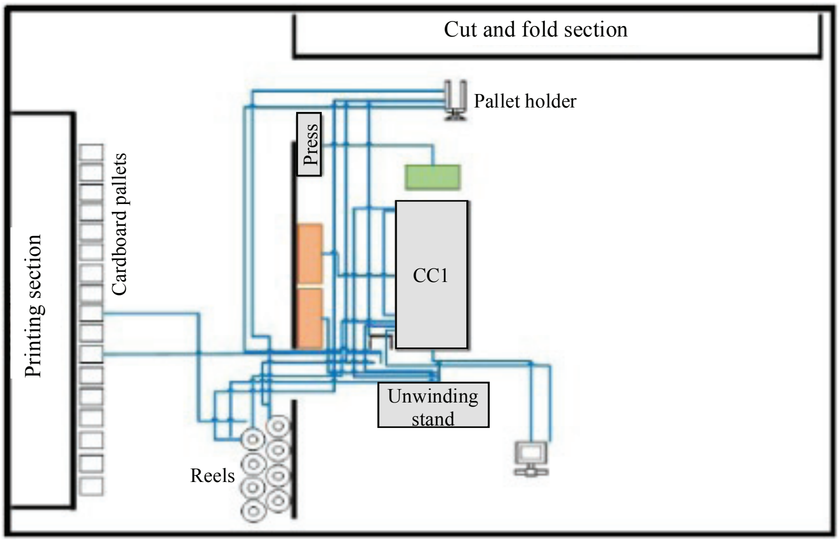

Fig. 4. Spaghetti diagram for CC1

As shown in Fig. 4, Operator 1 performs many moving operations which obviously do not add value to the product. These movements represent a total distance of 184.14 meters, most of which are due to the disorganization of the tasks to be performed.

Stage 1- Separation of internal setup and external setup

The operations are classified as internal or external, if the machine is stopped or in operation at the time of the setup, respectively. Through the sequence-executing graphic performed in the previous stage, it is verified that a great part of the operations are internal, being that only the operation "Inspection the first parts produced after change MO" is carried out with the machine in operation.

Stage 2 - Conversion of internal operations in external operations

At this stage of the SMED methodology it was tried to convert internal operations to external ones. In the preliminary stage, operations 3, 4, 9, 11, 14 and 22 (Fig. 3) were detected as being operable with the machine CC1 in operation. Additionally, these internal operations (on machines CC1, CC2 and CC3) started to be executed by another employee (operator A) who accumulated these functions with the ones he did until then.

After these changes were implemented, along with information and training of the operators, new filming was carried out to evaluate the new setup times, and the construction of new sequence flowchart. For the CC1 machine, a setup time reduction of 699 seconds to 452 seconds was verified, representing a setup time reduction of 35%.

Stage 3 - Improvement of setup operations

The continuous improvement of MO change operations was pursued. Several operations were improved through standard work and changes were introduced in the sequence of operations to be performed. Proposals for improving other operations in this section have also been made, in particular the definition of a place for the pallet stand and the purchase of a new pallet stand, given its high utilization rate.

4.2. Visual Management and 5S Application

Pallets are indispensable for the transport and supply of machines, especially for CC2. Whenever operators load the plans on a pallet to be produced, they must first check that the pallet measure fits the plane measure. For this operation to be as fast as possible, it is proposed to identify the pallets using the visual management technique. Thus, this improvement proposal follows the following steps:

- Carry out a survey of all the pallet measures that exist in the section;
- Know which measures are most used, so as to remove from the section those that are unusable;
- Give each measure a different color;
- Paint the pallets with the color assigned to them.

An example for identification is shown in Fig. 5, where the measurement of the pallet (L x W) is represented and is assigned with the respective color. Thus a pallet storage location should be defined in the section, which should be as close as possible to the three machines.

In order to combat the lack of organization and cleanliness, it is proposed to apply the 5S technique. In this first phase it is necessary to carry out a general assessment in the section, so that all the irrecoverable and obsolete tools and materials are removed. Thus, in conjunction with each machine operator, all tools and materials present in the work area must be identified. With this identification, it is also important to define the functions of each one and to make an evaluation of the state of the same, and those that are damaged should be replaced.

After the separation of tools/materials useful for the section, proper locations must be defined for them. During the observations made to the production changes, it was possible to verify that the operator needed the help of some tools to adjust the machine, but they were not always available. This led the operator to move to another section, for example the section of cut and fold, to get the material he needed. In addition, the tools present at the workstation do not have a specific place, being scattered and mixed, making the setup process of the machine even more difficult and time-consuming, Fig. 6.

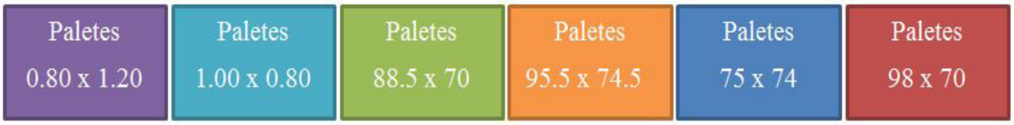

Fig. 5. Identification of pallets through visual management

Fig. 6. Tools support

5. Results and Discussion

An analysis of the results obtained after the implementation of some of the presented improvement proposals will be carried out.

5.1. Gains from the implementation of the SMED methodology

With the implementation of this methodology it was possible to reduce the total setup time for machines CC1, CC2 and CC3. Table 3 shows the results of several indicators evaluated before and after the implementation of SMED methodology. The average reduction in the setup times of the three machines is 47%.

Table. 3. Results before and after the implementation of the SMED methodology

Indicators	Machines					
	CC1		**CC2**		**CC3**	
	Before SMED	After SMED	Before SMED	After SMED	Before SMED	After SMED
setup time (min)	11.65	7.53	12.88	5.10	14.02	7.63
average number of setups/day	13.00	13.00	9.00	9.00	6.00	6.00
daily time spent in setup (min)	151.45	97.93	115.95	45.90	84.10	45.80
daily production time (min)	298.55	352.07	334.05	404.10	365.90	404.20
daily amount produced (plans)	16122	19012	21379	25862	21588	23848
added value (€/day)	806	951	1069	1293	1079	1192
profit (€/day)		144		224		113

Thus, with the reduction of setup time the availability of the machines and, therefore, the daily quantity of plans produced (the output of the machines CC1, CC2 and CC3 are called plans) has been increased.

Knowing that:

- the daily working time are 450 minutes (1 shift of 8 hours)

- the performance of CC1 is in average of 54 plans per minute
- the performance of CC2 is in average of 64 plans per minute
- the performance of CC3 is in average of 59 plans per minute
- the company adds a value of 0.05 € to the final product for each plan produced in the bonding process,

the added value obtained by the machines from the bonding section is estimated before and after the reduction of setup times. The sum of the daily profits after the reduction of setup times is given by: 144+224+113=482 €/day or 10114 €/month.

5.2. Reduction of total distance traveled

It was also possible to reduce the movements of the operators in the three machines (in CC1 there was a reduction of 47%, in CC2 of 48% and in CC3 of 6%). The initial distances traveled by operators were justified by the lack of standardization of operations and the disorganization in the work area.

6. Conclusions

The bonding section was identified as the section that most contributes to the production of nonconformities throughout the process. The analysis of the current situation of this section was carried out using the cause-effect diagram, Pareto's analysis, study of setup times, and also the creation of some performance indicators such as OEE and waste quantification.

To overcome the lack of organization in the section, it was proposed to use visual management and 5S technique. With this, it was intended to carry out a general evaluation of the section in order to eliminate all the irrecoverable and obsolete tools. With the implementation of these improvement proposals, it is expected a greater organization of the work area, thus facilitating the work of all employees.

With the reduction of setup time, the machine has a higher availability, since the production time has increased.

The case study showed how, in an SME, lean and quality tools can be used to involve employees on data gathering and providing improvement suggestions. This allowed the identification of improvement actions which resulted in setup reductions and reductions in operators' traveled distance. These improvements alone resulted in monthly gains of 10114 € in the studied section. From the three indicators studied (availability, speed and quality) the focus of this work was machine availability, but the other two remain to be analyzed and improved. The company administration perception on the activities developed and the results was positive and decided to continue the adoption of this method and also apply it to other company sections.

The low level of use of quality tools and lean practices suggested by Sousa et al. [5] and Lopes et al. [8] was also confirmed in the studied SME. Despite the existence of many improvement opportunities for SMEs with low level of quality maturity they can significantly benefit from the adoption of Lean and quality tools usage.

Acknowledgements

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