IMPACTO CIENTÍFICO EDITORA

LEAN MANUFACTURING IN PRODUCT DEVELOPMENT: CASE STUDY IN A TEXTILE INDUSTRY

MANUFATURA ENXUTA NO DESENVOLVIMENTO DE PRODUTOS: ESTUDO DE CASO EM UMA INDÚSTRIA TÊXTIL

MANUFACTURA ESBELTA EN EL DESARROLLO DE PRODUCTOS: ESTUDIO DE CASO EN UNA INDUSTRIA TEXTIL

https://doi.org/10.56238/edimpacto2025.069-006

Diego Milnitz[1], Glauco Garcia Martins Pereira da Silva[2]

ABSTRACT
The reduction of lead time in the product development process (PDP) is one of the main challenges faced by organizations operating in dynamic and competitive markets, such as the textile sector. In this context, the application of lean manufacturing principles has proven to be a promising strategy to eliminate waste and increase efficiency. This article aims to analyze the joint application of Value Stream Mapping (VSM) and the Gemba Kaizen (GK) method in a multi-project PDP of a textile industry in Santa Catarina, seeking to highlight how these practices can contribute to continuous improvement. Methodologically, the study adopts action research, conducted in two intervention cycles: the first focusing on waste identification through VSM, and the second on implementing improvements via GK. The results revealed the existence of excessive information inventories, rework, and inconsistencies in material and data flows, which directly impacted lead time. The application of lean practices resulted in a 63% reduction in the rework rate in printing and a decrease of two days in the total PDP lead time. As a contribution, the study demonstrates the applicability of Lean Product Development in sectors still scarcely explored in the literature, such as textiles, while also highlighting the relevance of integrating classical quality tools with lean methodologies. It further suggests the need for future research on the digitalization of VSM and GK, aligning product development with the principles of Industry 4.0 and the circular economy.

Keywords: Lean Manufacturing. Lean Product Development. Value Stream Mapping. Gemba Kaizen. Textile Industry.

RESUMO
A redução do lead time no processo de desenvolvimento de produtos (PDP) é um dos principais desafios enfrentados por organizações que atuam em mercados dinâmicos e competitivos, como o setor têxtil. Nesse contexto, a aplicação dos princípios da manufatura enxuta tem se mostrado uma estratégia promissora para eliminar desperdícios e aumentar

[1] Dr. in Production Engineering. Universidade Federal do Paraná (UFPR).
E-mail: dmilnitz@gmail.com
[2] Dr. in Production Engineering. Universidade Federal de Santa Catarina (UFSC).
E-mail: glaucogmpsilva@gmail.com

a eficiência. Este artigo tem como objetivo analisar a aplicação conjunta do Mapeamento de Fluxo de Valor (MFV) e do método Gemba Kaizen (GK) em um PDP multiprojetos de uma indústria têxtil de Santa Catarina, buscando evidenciar como essas práticas podem contribuir para a melhoria contínua. Metodologicamente, adota-se a pesquisa-ação, conduzida em dois ciclos de intervenção: o primeiro com foco na identificação dos desperdícios por meio do MFV e o segundo voltado à implementação de melhorias via GK. Os resultados apontaram a existência de inventários excessivos de informações, retrabalhos e inconsistências nos fluxos de materiais e dados, que impactavam diretamente no tempo de atravessamento. A aplicação das práticas enxutas resultou na redução de 63% do índice de retrabalho na estamparia e em uma diminuição de dois dias no lead time total do PDP. Como contribuição, o estudo demonstra a aplicabilidade do Lean Product Development em setores ainda pouco explorados pela literatura, como o têxtil, além de destacar a relevância da integração entre ferramentas clássicas da qualidade e metodologias enxutas. Também sugere a necessidade de pesquisas futuras sobre a digitalização do MFV e do GK, alinhando o desenvolvimento de produtos aos princípios da Indústria 4.0 e da economia circular.

Palavras-chave: Manufatura Enxuta. Lean Product Development. Mapeamento de Fluxo de Valor. Gemba Kaizen. Indústria Têxtil.

RESUMEN

La reducción del lead time en el proceso de desarrollo de productos (PDP) es uno de los principales desafíos enfrentados por las organizaciones que actúan en mercados dinámicos y competitivos, como el sector textil. En este contexto, la aplicación de los principios de la manufactura esbelta se ha mostrado una estrategia prometedora para eliminar desperdicios y aumentar la eficiencia. Este artículo tiene como objetivo analizar la aplicación conjunta del Mapeo de Flujo de Valor (MFV) y del método Gemba Kaizen (GK) en un PDP multiproyectos de una industria textil de Santa Catarina, buscando evidenciar cómo estas prácticas pueden contribuir a la mejora continua. Metodológicamente, se adopta la investigación-acción, conducida en dos ciclos de intervención: el primero enfocado en la identificación de desperdicios a través del MFV, y el segundo orientado a la implementación de mejoras mediante el GK. Los resultados señalaron la existencia de inventarios excesivos de información, retrabajos e inconsistencias en los flujos de materiales y datos, que impactaban directamente en el tiempo de atravesamiento. La aplicación de las prácticas esbeltas resultó en una reducción del 63% en el índice de retrabajo en la estampación y en una disminución de dos días en el lead time total del PDP. Como contribución, el estudio demuestra la aplicabilidad del Lean Product Development en sectores aún poco explorados por la literatura, como el textil, además de resaltar la relevancia de la integración entre herramientas clásicas de la calidad y metodologías esbeltas. Asimismo, sugiere la necesidad de futuras investigaciones sobre la digitalización del MFV y del GK, alineando el desarrollo de productos con los principios de la Industria 4.0 y de la economía circular.

Palabras clave: Manufactura Esbelta. Lean Product Development. Mapeo de Flujo de Valor. Gemba Kaizen. Industria Textil.

1 INTRODUCTION

The time interval from product idea to market launch is one of the most important factors in maintaining an organization's competitiveness and increasing its chances of market expansion (WHEELWRIGHT and CLARK, 1992; CLARK and FUJIMOTO, 1991). Among so many possible strategies to be applied in order to improve its performance, Lean Manufacturing has been used with greater emphasis due to its character of valuing human resources as a means of reducing waste through continuous improvement.

According to Wechsler and Torre (2009), several studies demonstrate the application of EM concepts in the product development process, however, these examples show the reality in the conception of one, or few, complex products, as is the case of the automotive industry. Also according to the same authors, studies of the effects, or relationships, of the application of the concepts of Lean Manufacturing in the development environment of simple or multi-project products, as is the case of the textile industry, are little explored in academic works.

In this research, value stream mapping and the *gemba kaizen* method were applied in a PDP with the objective of demonstrating, through a case study, the potential application in the joint use of these tools in the development of textile apparel products. Since the process to develop textile products is complex and highly dynamic, with a diversity of types and quantities of products being developed simultaneously in a short period of time.

This article first presents the methodology used to carry out the work, and then a brief theoretical review on the concepts of Lean Manufacturing in the product development environment, on the value stream mapping and on the concept of continuous improvement. Then, the application of these tools in the researched company is presented and finally the results are presented along with the final considerations of the work.

2 METHODOLOGY

It adopts action research as a methodological approach, and suggests the application of Lean Manufacturing tools in a product development process. The action research method was adopted in order to support the use of EM tools within the researched organization. To this end, the article uses the framework for the application of the action research proposed by Cauchick *et al*. (2010), in this structure the authors indicate five steps, which are: i) action research planning; ii) data collection; iii) data analysis; iv) implementation of actions; and v) evaluation of the results of the work. This framework proposed by Cauchick *et al*. (2010) was used in two cycles, the first cycle being applied during the use of the value stream mapping technique and the second cycle being applied during the use of the *gemba kaizen method*.

3 VALUE STREAM MAPPING

The application of industrial process mapping began at the beginning of the last century, through the work of Frederick Taylor and Frank Gilbert (MARTINS and LAUGENI, 2006; LEE and SNYDER, 2006). According to Soliman (1998), the important element for the process approach is its mapping, as it makes it easier to identify where and how to improve. It also allows you to determine and focus on the customer, eliminate activities that do not add value, and reduce the complexity of processes. Process flow analysis is a tool to evaluate an operation from the resources of entry into the system to the output as a final product (GOMES, 2008).

According to Pereira (2009), in the framework of the literature there are dozens of possibilities for representing the flow of industrial processes. Among so many possibilities, the VSM technique is the most used in the context of Lean Manufacturing. This is because it allows a real understanding of the current situation, the identification of waste and potential points for improvement of the mapped processes (MACMANUS, 2003). In addition, it enables a more integrated visualization between processes, providing the implementation of systematic and permanent improvements (ROTHER and SHOOK, 2003).

Similarly, other authors highlight the importance of VSM in the implementation of Lean Manufacturing (KEYTE and LOCHER, 2004; WOMACK and JONES, 2004; DENNIS, 2008; LIKER and MEIER, 2007; ÁLVAREZ *et al*., 2008; FERNANDES, 2001; SALZMAN, 2002). In this sense, the mapping of the value stream is the most appropriate tool to achieve part of the objectives of this research, which is the understanding and survey of waste in the PDP.

This technique was created by Rother and Shook (2003), consisting of a diagram with figures and boxes, used to represent a process or a production flow. The diagram is divided into three basic parts: the flow of information, the flow of process, and the process times. VSM has evolved, and today the distances between processes are represented in the diagram itself (NASH and POLING, 2008).

Rother and Shook (2003) propose some steps for the application of the value stream mapping method. Figure 1 illustrates the steps for carrying out the value stream mapping in the processes, namely:

- Selection of the product or product family to be mapped. Rother and Shook (2003) attribute to the family a group of products that go through similar stages and use common equipment in their processes.

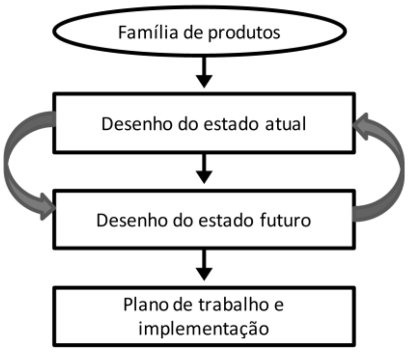
- Mapping of the current value stream of the family or product. To carry out the design, it is necessary to go to the factory floor and personally verify how the flow of product and information happens.

- Mapping the future value stream. This is the most important part of VSM, according to Rother and Shook (2003) a situation without a future state is not very useful. At this stage, the concepts and tools that will be developed in the process are planned in order to provide a leaner flow.

- Planning of improvement actions. A schedule of actions to be carried out to reach the desired situation must be made. Thus the future map becomes the current one, and the cycle begins again.

Figure 1

Steps for Value Stream Mapping



Source: Rother and Shook (2003).

Group work is usually used to carry out the planned improvement actions in the VSM. In the next item, the *Gemba kaizen* method will be presented, used to systematize improvement actions through group work.

4 GEMBA KAIZEN

One of the ways to develop and apply the suggested improvements in VSM is through the use of the *gemba kaizen method*. According to Araujo and Rentes (2006), *gemba kaizen* can be defined as a continuous improvement of the value stream or of an individual process, in order to add more value with less waste.

The application of the KM methodology must be carried out in an organized, planned and systematic manner. Thus enabling the implementation of Lean Manufacturing practices in a coordinated and structured manner. For this, the Deming Cycle, also known as PDCA, has generally been used (LIKER, 2005).

Silva (2009) proposes a methodology to apply *gemba kaizen* based on the Deming cycle. The effectiveness of this method is proven through a practical application in an assembly cell of a company in the metal-mechanic sector. Like these, there are other works that demonstrate the benefits and gains of applying *gemba kaizen* in organizations. Among them are the publications of Araujo and Rentes (2006), Briales (2005), Jugend, Silva and Mendes (2006), Freire and Alarcon (2002), Neto and Barros (2007), Costa (2007), Hanashiro (2005). In addition to the results of the application of the KM concept, all authors comment that the involvement and commitment of everyone in the organization is an essential factor to ensure its perpetuation. Table 1 shows the summary of the procedure used in the study by Silva (2009). In this process, the author defined five steps to apply the tool called *gemba kaizen*. Each step is related to the *PDCA cycle* as a way to facilitate understanding and ensure the structure in the application of the improvement.

Table 1

Structure of the gemba kaizen method

Stage	Deming Cycle	Gemba *kaizen method*	Responsible
1	P	Opening and recording of *gemba kaizen*	Gemba *Kaizen Facilitator*
2		Pre *Gemba Kaizen*	Gemba Kaizen *facilitator* and leader
3	D	Gemba *kaizen event*	Gemba kaizen *facilitator*, leader and collaborators
4		Operational action plan	Gemba kaizen *facilitator*, leader and collaborators
5	C The	Post *gemba kaizen*	Gemba Kaizen *facilitator* and leader

Source: Adapted from Silva, (2009).

The initial stage of the GK is the opening and registration, the objective is to start the improvement event, enabling a direction of the company's strategies, with the collection and registration of information relevant to the improvement. Once the first stage is done, you can move on to the *pre-gemba kaizen*. At this stage, all the information necessary to carry out the improvement is collected and analyzed. It is in the phase that precedes the event that the leveling of knowledge about the problem and the lean tool to be used is made, as well as what is the goal to be achieved and the control item to be monitored.

At the *gemba kaizen event* , improvement is discussed and carried out. The event should start with the presentation of a workshop on *pre-gemba kaizen* to the participants, then a goal is launched to direct the improvement and then the discussion begins with the proposed solutions to the problem presented. After the application of the new actions and suggested tools, the goal established for the indicator is met.

Once the goal is reached, the new work method is documented and assumed by the group in the workplace, so that the indicator can be controlled and monitored. Otherwise, the process is repeated with the discussion of new tools and methods, keeping the *gemba kaizen* open until the goal is reached.

The last stage is the *post-gemba kaizen*. It is initiated when the *gemba kaizen* event is finished, i.e. the new working method has been documented and taken over by the group at the workplace. During the monitoring of the improvement, walks are carried out in the place where the *gemba kaizen was applied* in order to verify the effectiveness of the results that were previously analyzed through the control indicators of this improvement.

In the following item, the application of VSM and *gemba kaizen* in the PDP of a textile industry will be presented.

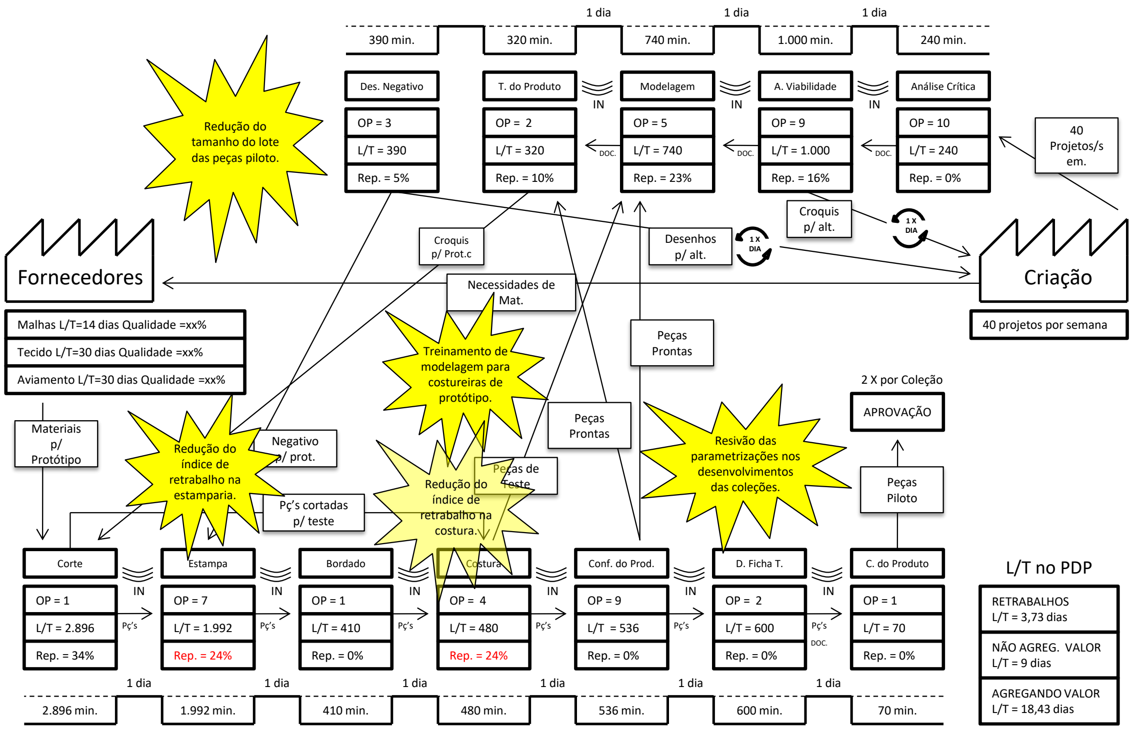
5 VALUE STREAM MAPPING IN THE PDP IN THE RESEARCH COMPANY

The application of value stream mapping (VSM) in engineering marked the beginning of lean work on PDP. This tool helped in the identification of potential improvements in the flow of material and information, and was also used as a management tool in the application of improvements.

Since in the engineering sector of the company studied, all the products developed go through all processes, it was not necessary to use an ABC classification to identify product families. As a way of trying to bring the map closer to the reality of the sector, weightings with the degree of difficulty of the product *portfolio* were used that were added to the time data of each VSM activity. During the survey of the information used in the preparation of the flow map, interviews were conducted with all employees in the engineering sector in order to verify how the development process behaved and, together with the analysis of the reports, form the current VSM of part of the product development process, which can be seen in Figure 2.

Figure 2

Value stream mapping in product engineering (current state)



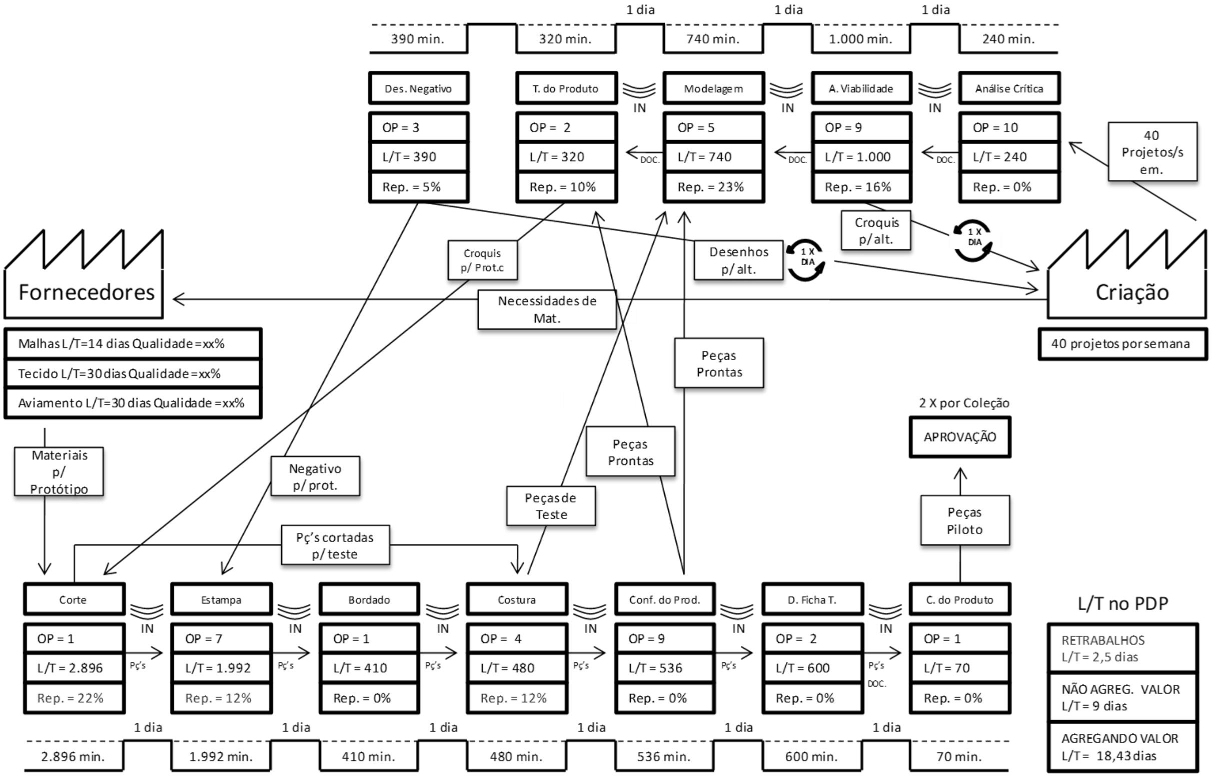
Source: The authors.

In this flow, it is possible to see that the total time that the batch takes to be developed is about 31.16 days, and the time spent on rework is 3.73 days, which directly affects the product development time. An important point shown in Figure 2 is the amount of document inventory between each process, in the execution of activities there is an advance of one working day before each process, so if these stocks are added between each process, there will be an increase of nine days in the product development time in this sector. The total percentage of rework of activities generates an increase of 12% in total work time.

After drawing and analyzing the current map, the future state was drawn – see Figure 3 – one of the most important parts of the mapping process. For the construction of the future VSM, the concepts of Lean Manufacturing were used, adjusted to the reality of the organization.

Figure 3

Value stream mapping in product engineering (future state)



Source: The authors.

One of the wastes identified in the map of the current state that must be combated in the product development process is rework, that is, every time the sector generated a rework, the processes involved stopped producing a new product to remake a non-conforming product. One way to improve this situation in the company was to apply some tools such as Pareto Analysis, Cause and Effect Diagram, *Brainstorming*, among others, to analyze and propose solutions to reduce the percentage of rework and, thus, reduce product development time.

Another improvement identified was the training on product modeling in the sewing process, thus reducing the time spent by the employees of the modeling process assisting the seamstresses, that is, the assistance that the modeling process performed in sewing reduced the available time used for product development. Therefore, the qualification of the employees of the sewing process in product modeling made it possible to reduce the requests for help that indirectly reduced the *lead time* of the modeling process.

Reducing the batch size of the pilot parts of each product, which is related to the total product development time, was one of the suggested opportunities. This opportunity for improvement consisted of verifying the possibilities of reducing the number of parts developed for each product without harming the development process as a whole. It was understood that the smaller the size of the batch of pilot pieces of each product, the shorter the time needed to develop a collection.

Finalizing the proposals for improvements in the flow of information and material in product engineering, it was suggested to carry out a review of the product development parameters, since the control and adequacy of the parameters influence the development and production of the product in general in the company. The development and application of the improvements suggested in Figure 2 helped to reduce the product development lead time by more than two days, as well as improved the standardization and control of data relevant to the process, increasing people's involvement in the practice of continuous improvement.

6 APPLICATION OF GEMBA KAIZEN IN PDP

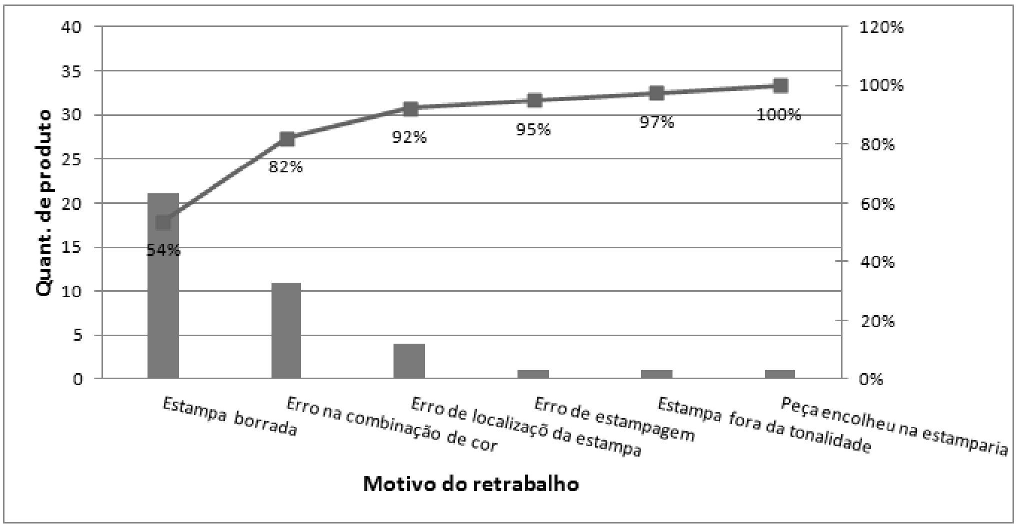
The mapping of the value stream in the engineering sector had the purpose of identifying opportunities for improvement and planning actions in order to direct the application of EM concepts. Gemba kaizen, on the other hand , is the phase of effective changes in the place where value is added to the product, when improvements and results begin to materialize. To illustrate the execution of the GK method, the improvement in the reduction of the rework index in the stamping process will be presented.

Therefore, the first step of the GK stage was to open and register the improvement and reduction of the rework rate in the printing shop. At that moment, the group and the leader who would be responsible for the development and application of this improvement were defined. After recording the improvement, the group started the *pre-gemba kaizen* stage, so they met to level the knowledge about the problem and discuss which tools could be applied to help in the analysis of the problem and in the generation of possible solutions. Figure 4 shows a graph that was used for the analysis of the most relevant reasons for the rework generated by the printing process.

The analyzed data were extracted from reports from the company's last collection and the information contained in these documents was worked on by product engineering analysts in order to enable an objective evaluation of the problem. In this figure, a Pareto Analysis is presented, where it is seen that a blurred print generates more than half of the rework, and if it is added to the error in the combination of the colors of the print, together the two types of reprocessing are responsible for 82% of the amount of reprocessed product, in this way, the group focused the studies on reducing these two types of problems.

Figure 4

Graph of the rework reasons generated by the stamping

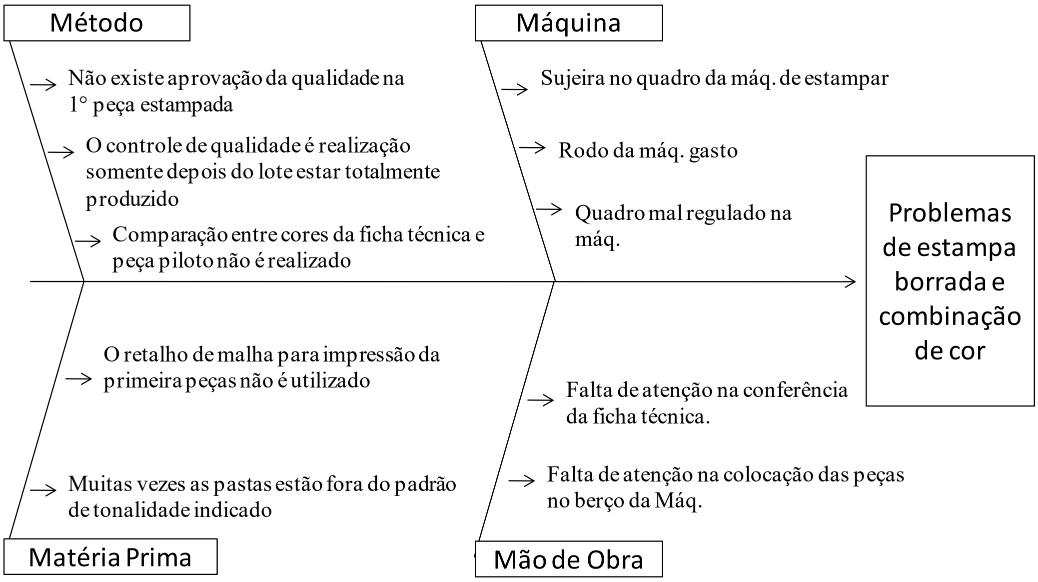


Source: The authors.

Still in the *pre-gemba kaizen* stage , meetings were held with support areas and technicians of the printing process, to get information about the potential reasons that could be causing the problems of blurred print and error in the combination of colors. After some meetings and discussions on the subject, it was possible to prepare a map of the causes that generated the two irregularities, these reasons were arranged in Figure 5 in the format of a Cause and Effect Diagram, being classified as problems caused by the method applied, by the operator (labor), by the raw material and by the machine.

Figure 5

Diagram of the causes that generated the problems in the printing plant



Source: The authors.

During the analysis of the information generated in the discussions, the group considered that the method applied was the cause of a considerable part of the rework, highlighting the lack of approval at the beginning of production, and the performance of the quality control of the batch only when all the parts of the product were ready. Carrying out these processes left room for the late identification of errors, generating a large amount of rework.

A similar problem occurred when checking the colors of the folders, since this activity was not performed before starting to print the images on the pieces. When the difference between the colors was identified in the quality control inspection, usually the entire batch had to be redone, generating rework again. Problems caused by machinery and raw materials could be mitigated if the method was adequate to enable the identification of abnormalities in advance. In the monitoring of the stamping process, it was identified that some problems occurred due to the lack of attention of the operators themselves (labor). According to the testimony of the stamping technicians themselves, one of the causes of this lack of commitment on the part of the employees was the lack of information and clarification of their importance in the development of new products.

After surveying the reasons causing rework in the printing process, discussions were held to try to eliminate them. Therefore, some *Brainstorming sections were carried out* with the objective of generating possible solutions for the causes compiled in Figure 5. In general, the actions had a greater impact on the change in the production method and quality control of the pieces, as well as a greater involvement and commitment of the machine operators and their supervisors during the production of the collection products.

Table 2 shows in detail the actions planned and executed by the group. This plan was already put into practice in the subsequent collection that was used as a basis for data collection and analysis. Items two, three and four are related to the way to carry out the activities, thus trying to minimize the impacts caused by equipment problems, raw materials, or operator errors. Items one, five, six, and seven are related to the behavior of supervisor operators, trying to increase everyone's involvement and commitment to product development.

Table 2

Action plan applied in the printing process

	Sector: Printing		**Leader:**	**Sup. Stamping**
	Improvement: Reduction of the rate of rework caused by printing		**Date of Elab.:**	**April 2011**
No.	**Activity**	**How to do this activity**	**Accountable**	**When to perform**
1	Leveling actions for sample production	Meeting with all those involved in the production of the showcase to pass on responsibilities and the new production method	Stamping Supervisor	Before the start of the production of the showcase
2	Evaluate the quality of the print	Before starting the production of the batch the reference, the operator must print the image on a test body to check if the print has any problem that may classify the part as blurred	Operator responsible for printing the stamp	Before the start of each sample production
3	Check the color stamped on the part with the color of the technical sheet	Use the color Table of the collection to compare the color of the printed piece with the color of the technical sheet	Operator responsible for printing the stamp	Before the start of each sample production
4	Release the 1st stamped piece from the showcase	Before starting the production of a certain reference, stamp a part and compare it with the standard (prototype), checking the size of the panel in relation to the mold, location and the quality of the print in all aspects.	Facilitator of the printing	Before the start of each sample production
5	Analyze the rejections that occur during the production of parts in the stamping process	Whenever there is a rejection due to quality problems in the print, immediately return the pieces to the stamping shop where the investigation of the causes that originated the rejection should be carried out. Use the "5 whys" methodology and draw up an action plan to prevent this problem from occurring again.	Engineering Analyst	During the production of the showcase

6	Make changes in the production of ref. On display	Make the record in the production form of the showcase, informing the need for repique, duplication of frames and machine options during production.	Facilitator of the printing	During the production of the showcase
7	Prioritize flocking samples.	Prioritize samples with the flocked effect in the stamping shop, stamping them as soon as they enter the phase, to avoid delays in case there is a problem in production.	Facilitator of the printing	During the production of the showcase

Source: The authors.

It was observed that at the beginning of the implementation of the actions, the rate of rework in the printing reduced by more than 50%, reaching close to 80% at the end of the collection. The overall reduction in this improvement was 63.4%, which directly impacts the product development lead time in the engineering sector. This gain was greater than the 50% planned in the future map in Figure 3, that is, the reduction in lead time was greater than two days in the processes of this sector.

7 FINAL CONSIDERATIONS

In order to explore the possibilities of reducing product development time (*lead time*), this work applied two tools of Lean Manufacturing, MFV and GK, thus making the product development process of the studied organization more agile and efficient. As a main result, a 63% reduction in the rework rate in the stamping process was obtained, which generated a two-day reduction in the total *lead time* of product engineering.

The mapping of the process was essential for those involved to understand the interrelationships of the activities within engineering and later to be able to identify the waste that did not add any value to the product. The application of improvement in the printing through a structured method, allowed the group to study the process to be improved and thus develop solutions through specific tools of total quality in an organized and planned way.

Due to the results obtained, it is suggested as a future work in the company the application of a system of pulling the inventories of information between the engineering activities, since 30% of the time of crossing information and materials in this sector are generated by this type of inventory.

Also, through this research, it is possible to reflect on the gains that can be obtained in other development processes in organizations in this segment, as well as in PDPs of companies that have similar characteristics, such as the complexity and dynamism of the process, and its diversity of types and quantities of products being developed simultaneously in a short period of time, As is the case with technology, footwear, cosmetics companies, among others.

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