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Implementing Lean Tools in the Manufacturing Process of Trimmings Products

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Abstract

The increasing requirements regarding quality assurance and processes traceability require the implementation of continuous improvement procedures, with a view of maintaining the company's levels of competitiveness and satisfaction for its customers in terms of quality. The optimization of information flows and manufacturing processes are, in general, extremely important factors in any company's life. It is therefore important that companies quickly self-adapt to this kind of reality and adopt policies of product innovation and standardization of its production processes, in order to allow rapid adaptation to the constant market changes. The present work aims to identify problems and finding solutions through a combination of PDCA (Plan-Do-Check-Act) cycle, 5S (Seiri, Seiton, Seiso, Seiketsu, Shitzuke) and 5W2H (5 Whys + 2 Hows) tools those can be implemented into a program of continuous improvement, with a view of standardizing of processes, ensuring real profits in products typically with critical added-value. The combination of tools was implemented and the results have been checked, showing a significant impact in the Weaving production process, with gains of 10% in the useful available time by the operator.

Keywords: Lean; Trimming; Industry/Textile Sector; Methodologies; Information Flow; Continuous Improvement.

1. Introduction

Nowadays, internal enterprise information plays a key role in the functioning of organizations [1]. Information lacks cause severe impact on companies, such as customer dissatisfaction and loss of business opportunities [2].

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Provided with high flexibility and usually purchased at low cost, recent computer applications allow for solving these problems [3]. However, the computer applications do not solve the problems by themselves: the company must ensure that information is entered into the computer, being reliable and previously validated, avoiding the use of wrong data. Thus, both perfectly described procedures and flowcharts are needed in order to define what can be done at each moment, allowing the company to reply assertively to the market demand in a competitive sense, showing high flexibility, agility and very good quality/price ratio [4]. The textile industry has known significant changes in different worldwide locations. Starting by the UK in the 18th century, it moved away to Japan in 50's and 60's, subsequently to Hong-Kong, Taiwan and Korea in the 70's and 80's, going forward to developing countries such as China, India, Pakistan Sri-Lanka, Bangladesh, Indonesia, Malaysia, The Philippines and Thailand. Nowadays, the textile industry is flowing to Kenya, Nicaragua, Myanmar, Madagascar and Ethiopia, searching for places with low labour cost [5]. In Portugal, the North is the main region devoted to textile industry [6], contributing in a significant manner to the Portuguese GDP (Gross Domestic Product) and employment, according to the Association of Textiles and Clothing of Portugal (ATP) [7], taking into account data from 2015. The textile industry is divided into several types of products and processes and within each one, companies select its preferred segment: high volume and low cost, or customized products and large yields, playing with the markets, quality and way to conduct their business. The automotive industry is also a strong customer, usually requiring high levels of quality, such as ISO-TS 16949 [8], and judicious delivery times at affordable costs.

This work aims to contribute to the processes optimization in a trimmings industry using a combination of Lean tools, with a focus on two main problems: information flow and waste of time problems in the manufacturing process.

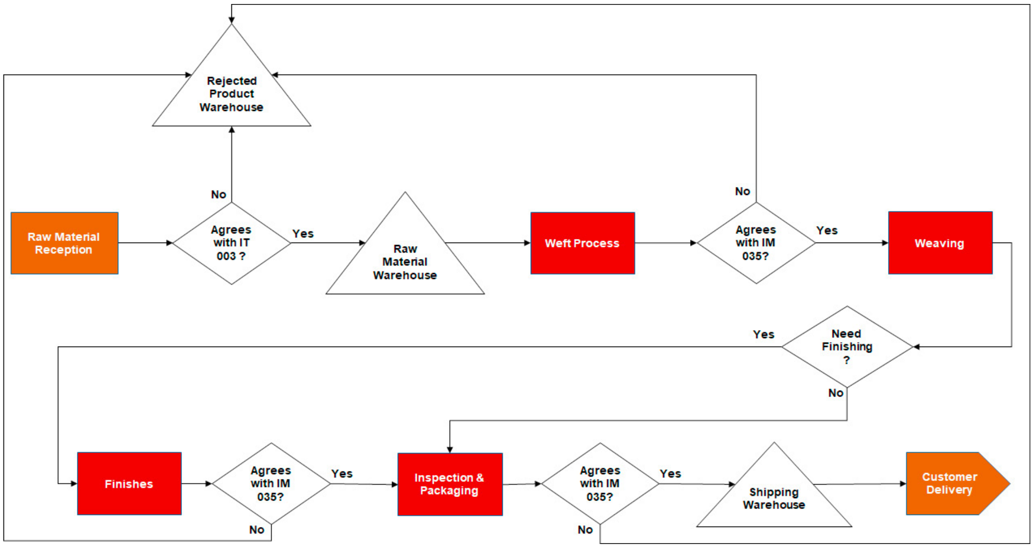
2. Literature review

Quality is usually an imperative issue to any company survival in this competitive market [9]. The worldwide experts have postulated different definitions for Quality, such as: suitability to use (Juran) [10, 11], predictable degrees of uniformity and dependence at a low cost and appropriate to the market (Deming) [11], compliance with requirements (Crosby) [11], customer satisfaction (Ishikawa) [12], among others. On the other hand, it is possible to define Non-Quality as the failures occurred directly or indirectly during the production process, which generates added costs not adding value to the product and usually implying deliver delays [13]. In order to comply with the quality criteria, delivery deadlines and keep the company economically healthy, all waste detected during the production process must be identified and eliminated [14]. Lean Thinking is a philosophy that has emerged as a management system aiming for developing processes with a view to continuous reduction of waste throughout the process [15]. Lean Thinking is based on Toyota Production System (TPS) but which principles can be applied to any industrial activity.

Recent investigations related to the textile industry have been focused mainly on raw materials [16], chemicals improvement and their impact on the environment [17]. Moreover, under the sustainable consumption trend, the reuse and recycling of discarded textile products have been also studied, saving the consumption of energy, water and chemicals [18]. Nevertheless, the textile industry is continuously growing up in terms of business, being disseminated worldwide but with higher predominance in Asian countries. In fact, merchants strategically located in countries practising low labour costs are the most attractive to highly demanding customers searching response at low cost for large production volumes, distributing the huge demand by small companies [19]. In order to survive, companies need to have structured strategic plans in order to keep their competitiveness [20]. Companies and regions are creating characteristic products and brands in order to distinguish their products on the market, generating by this way more added-value. However, Europe has a huge tradition in the textile industry and need to manage properly their companies with a view to preserving employment in this sector. Thus, European companies have been focused in the last decade in technical textile [21]. However, in the last years, a new focus has been created for the productive sector: its preparation to incorporate Industry 4.0 technology, in order to increase their competitiveness [22]. The implementation of the principles linked to this industrial revolution together with Lean principles can surely boost the European textile industry, combining technology with a careful management of manufacturing processes.

3. Project methodology

This work is focused on identifying and eliminating wastes throughout the production process of small textile products, such as zippers, Velcro, helmet belts, amongst others, considering in this particular case the weaving manufacturing process. With a view to describe this manufacturing process, a flowchart was drawn as the first approach, which can be seen in Figure 1, letting to understand the different steps involved in the process. This process was selected based on the huge number of internal complaints generated.



Label:
IT 003: Inspection of material received
IM 035: Record of production control

Fig. 1. Flowchart relatively to the weaving manufacturing process.

Thus, the methodology used to develop this study consisted of four main stages. In the first stage, the manufacturing process was dissected. In the second stage, the wastes and quality problems were identified. Then, on the third stage, root-causes were mitigated. After that, in the fourth stage, some Lean tools appropriate for this kind of industry were applied. In the fifth stage, the results were analyzed and compared with the initial ones. Finally, in the sixth stage, the advantages were listed and new procedures were drawn. At the final stage, some conclusions about the methodology used and achieved results were drawn.

4. Project Analysis, Results and Discussion

Looking at the flowchart shown in Figure 1, it is possible to understand that there are essentially two Departments that coordinate the processes, Logistics and Industrial. The raw material is initially provided by Logistics in coordination with the Quality department. After approval, it enters into the current production, where the yarn passes through the weft process, which consists of transferring the wound wire coiled in cones from the supplier to the warp beams (large rolls) with the number of yarns necessary to form the webs, according to the specifications defined in the datasheet. For example, for a product which web has 20 threads, the 20-cone threads are woven into a single warp beam. Also, only the amount of yarn required to produce each order is processed. After this process, the webs are sent to the loom (the process through which the webs are assembled by passing the wires along the loom), beginning the weaving process. When ready, if any additional treatment is needed (thermo-fixture, flame retardant, gum, water repellent treatment), it is directed to the Finishing section and undergoes a calendering process (similar to ironing). Otherwise, it is directly rewound and placed in the dispatch warehouse, returning again to the care of the Logistics Department.

Throughout the whole process, it is easily detectable that there are several inspection stages, in order to ensure greater production control and hence the detection of failures, as well as their causes. The inspection stages (IT 003 and IM 035) are different according to the way they are performed, so there are different instructions for each type, i.e.:

- Inspection according to IT 003 is carried out by the Logistics Department in coordination with the Quality Department when the Logistics do not have the equipment required for the Inspection.
- Inspection according to production register IM 035 is carried out by the machine operators concerned (in this case, warp, loom, finishing and winding) through measurements at the different production stages (start, middle and end), in order to validate the product. This inspection allows for some failures detection and recovery rework.

Non-quality approach was started consulting Incidents Report and Actions Database regarding the year 2016 in which the information is classified by type (Complaint, Quality Alert, Improvement Action, Non-Conformity), date, its origin, incidence description and product involved, a brief analysis about the causes, as well as improvement action plans implemented in each case and, finally, the associated costs. The data treatment can be seen in Figure 2.

Observing the Figure 2, it is possible to conclude that the most frequent type of incident is the Complaint, which entails higher costs. This situation arises from a large number of complaints received, whose when sent by the customers, could lead to additional costs because the product needs to be scrapped, reworked and/or reprocessed, giving also rise to additional transportation and administrative costs. Thus, the mitigation of root-causes linked to this kind of non-quality problem assumes particular emphasis. Subsequently, the study was focused on the origin of the Complaint, being divided into two groups: Complaint from the customer to the company and Complaint from the company to its suppliers. It must be referred that, in addition to the industrial activity, the company also commercialize products provided by other companies. The results can be seen in Figure 3.

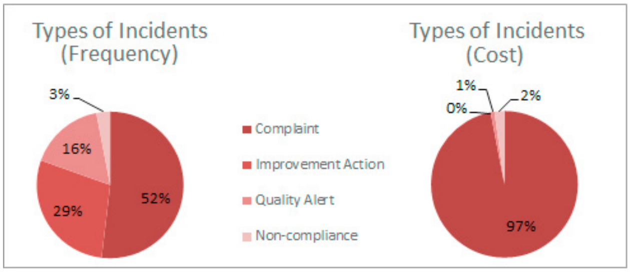


Fig. 2. Graph distribution of non-quality reports by type and corresponding cost.

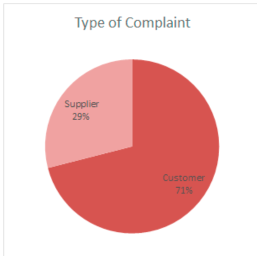


Fig. 3. Complaint classification by origin.

A deeper analysis of the data was needed creating three new groups of factors, corresponding to specific groups as follows: "Department" (which caused the complaint), "How" (causes of inspection or communication failure) and "Why" (causes of non-compliance). Thus, each group was divided into subgroups as pointed out in the graphs of Figure 4.

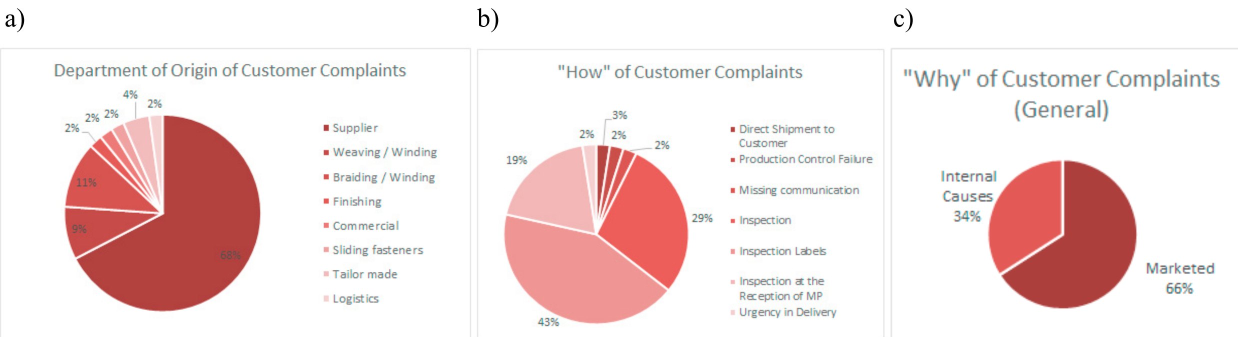


Fig. 4. Distribution of the failures by root-cause.

Analysing the Figure 4a), one can find easily that 68% of the complaints can be attributed to the Supplier, within the Commercial activity. Looking at the graph of Figure 4b), it is clear that a large number of non-compliances reached the customer - corresponding to failures in the inspection, in particular by the Marketed Product Inspection (62%) and General Inspection (29%). This situation is due to several factors, on the one hand, due to the difficulty to make a 100% inspection regarding the huge number of products commercialized and different specifications, being done by sampling, and on the other hand, only from the mid-2016, with the implementation of the laboratory, it became possible to perform certain tests that allow a better inspection of the product received. When analyzing the "Why" of Customer Complaints (Figure 4c), it can be concluded that most of them are related to marketed products (72%) without the direct responsibility of the company in the non-quality of the products. Thus, the main "Why" of Customer Complaints internal root-causes showed in Figure 4c) also deserved the attention of this study with a view to implementing an action plan, as depicted in Figure 5, because they respect to internally manufactured products.

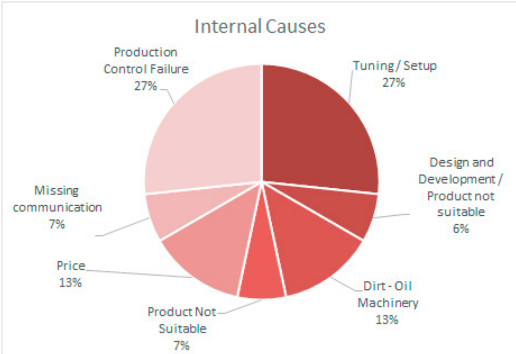
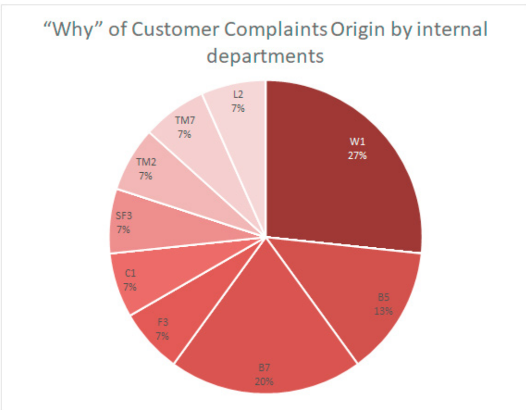


Fig. 5. Distribution of the Internal Causes.

Thus, Figure 5 shows that the main causes behind the occurrence of nonconformity are related to Production Control Failures (27%) and Tuning/Setup (27%). It should be noted that 13% of the non-conformities relate to low-cost products, being supposed they do not include higher levels of Inspection. Increasing the Inspection of these products would entail an increase in costs, which would make the business unfeasible. Finally, it was also considered important to carry out a final analysis of the "Why" of Customer Complaints regarding the products manufactured into the company, allowing for identifying the departments responsible for the non-quality root-causes, as well as the most relevant cause within each department. Figure 6 depicts the detailed situation regarding the decomposition of the “Production Control Failure” slices in the graph of Figure 5.



Label:
W1: Weaving - Tuning / Set up;
B5: Braiding - price;
B7: Braiding - failure production control;
F3: Finishing - soiling oil machines;
C1: Commercial - Lack of commissions;
SF3: Sliding fasteners - Dirt oils machines;
TM2: Tailor made - Design and development (not suitable product);
TM7: Tailor made - Production control failure;
L2: Logistics - Not suitable product

Fig. 6. Graph distribution of "Why " of Customer Complaints by internal departments regarding the products manufactured into the company.

Regarding the graph of Figure 6, it can be concluded that there are two departments that stand out in this regard: Weaving (27%) and Braiding (33%). Within the Weaving Department, only the pitch is detected as a cause of non-quality - four occurrences corresponding to 27% of internal causes. The problems in the tuning will then be subject to further study, through the cause and effect diagram. In the Stranded Department, two causes stand out: Failures in Production Control (three occurrences - 20%) and Price (two occurrences - 13%). The price situation again has the same justification presented previously, and the shortcomings in the control of production, similar to what happens with the weaving adjustment, will be studied in more detail later in this paper. Another department with some relevance is Tailor Made, with a total of 14% of the causes, being equally divided into problems in the product design and development, as well as in the failure of production control. The remaining departments have only one occurrence each, throughout the year 2016 (6.66% each). It should be noted that in the graph there are percentages of 6% and 7% indiscriminately, for situations in which only one occurrence was detected. This is justified because whenever one occurrence is detected, this represents 1/15, that is, 6.66%. Therefore, showing the percentage rounded to the unit, it is sometimes necessary to round by default and others by excess.

As stated before, an Ishikawa diagram was drawn and analysed, trying to identify the causes behind the non-conformities with origin in Weaving, as depicted in Figure 7. A subsequent Brainstorming was carried out, hearing the people (operators and others) with high know-how about the process, leading to make a list of potential cases.

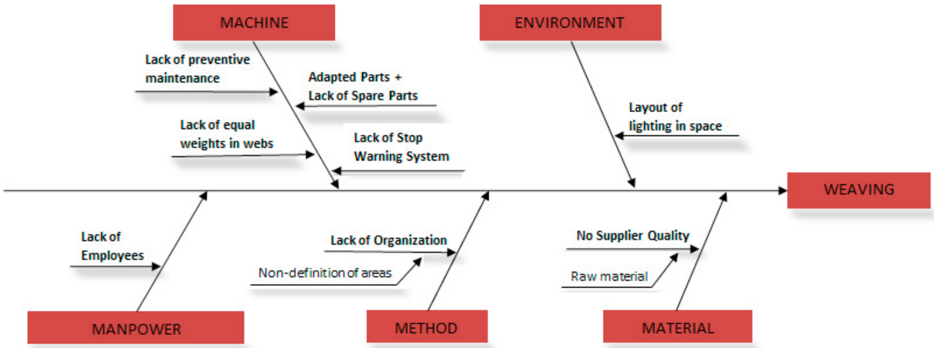


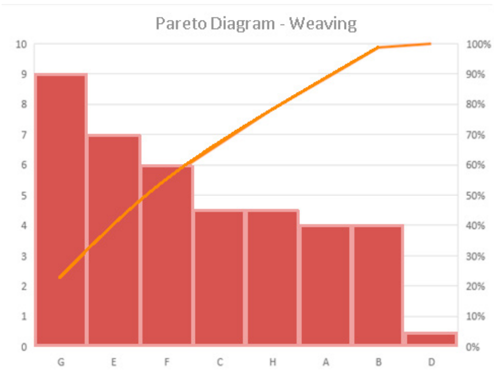
Fig. 7. Ishikawa Diagram regarding the Weaving process.

With regard to the Weaving Department, it is possible to detect that a great part of the root causes mentioned are related to the machine, namely lack of (a) preventive maintenance (b) spare parts - which causes the use of adapted parts, (c) lack of the stop sign system in some of the looms and also (d) lack of equal weights in the webs - which causes small variations in the speed of the yarns arrival to the needles, causing different stresses in the tapes, or different elasticity values in the case of the elastic products. In addition, the lighting could be better distributed in the looms area, because it is not centred in the corridor, but rather sideways, which implies that some of the looms do not receive much light, thus enhancing the occurrence of errors in the setting or Failure in detecting defects due to visibility deficit. In relation to labour, facing a peak of production demand, there is essentially a lack of staff. In the Method, there was a lack of organization, essentially disarray in the surrounding area, a situation that is related to the ongoing layout redesign. Regarding the Raw Material, it is pointed out the non-quality of the Supplier, because the raw material received does not present a constant quality. Regarding the previously presented Ishikawa diagram, it was necessary to understand the occurrence frequency for each cause, in order to detect which ones need more attention and faster intervention. Since the time available for this study did not allow one to account for the real numbers of these occurrences, it was chosen to draw on the opinion and experience of those who work daily in this sector, namely to the Industrial Director of the Textile Area and to the head of Weaving department.

In order to quantify these opinions, a brief quiz was carried out based on a system of assigning scores to each cause pointed out in the Ishikawa Diagram, where:

- 0 points → NEVER causes non-conformities;
- 10 points → ALWAYS cause non-conformities.

Once the questionnaires were collected, the scores and their respective averages were recorded. Data allow for drawing the Pareto's Diagram shown in Figure 8.



Label:
A: Lack of Preventive Maintenance
B: Adapted Parts + Lack of Spare Parts
C: Lack of Equal Weights in the webs
D: Lack of Stop Warning System
E: Lack of Employees
F: Lack of Organization
G: No Supplier Quality
H: Layout of lighting in space

Fig. 8. Pareto diagram of weaving.

Attending to the Pareto's Diagram of the Weaving Department, it is clear that all causes indicated are currently generating non-quality resulting in customer complaints, some of which stand out, with a score higher than 5, namely Supplier's Quality, Lack of Employees and Lack of Organization. Concerning the Pareto's Law, also known as 80-20 rule, it is possible to confirm that this rule is not verified. In fact, 80% is only reached at approximately 60% of the causes, since the red line in the chart only reaches 80% in the range of the 5th cause (5 x 12.5% = 62.5%). Thus, there is a high dispersion in the root-causes of the non-quality internal problems related to the manufacturing Weaving process. Therefore, there is no just one cause which can be really responsible for a majority of non-conformities in the Weaving Department, deserving each a similar attention, always taking into account their variability of occurrence. Subsequently, some continuous improvement methodologies will be applied to one of the causes detected previously, since even though it was not the most important cause, it was thought as one that can allow faster and more efficient application.

Weaving: Lack of Organization as Root-Cause

Among the eight causes able to induce non-quality in the Weaving Department, Lack of Organization was chosen, namely regarding the organization of the warp beams. The following figure shows the current state of how the warp beams are stored, in a place that is not suitable for this purpose. This situation is due to the current process of redesigning the Weaving layout area. Regarding this situation, it was considered that the best continuous improvement methodology to be applied would be the 5S, accompanied by the PDCA cycle and the 5W2H cycle. The PDCA cycle trailed the following steps:

- PLAN

1. Problem: Lack of warp beam storage site;
2. Objective: Creation of a proper place for the warp beams (Deadline: End of December 2017);
3. Problem characterization: Now, the warp beams are being stored in a random place for this purpose;
4. Causes of the problem: There is no defined place for the warp beams' organization;
5. Action Plan: Use of the 5W2H methodology, as shown in Table 1.

Fig. 9. Current situation of organ upkeep.

Table 1. 5W2H.

5W	What?	Create a place to store warp beams
	Where?	Next to the warp beams
	Why?	To make space more organized and lesser potential failure modes
	When?	During the month of December 2017
	Who?	Industrial Textile Department with assistance from the Quality Department
2H	How?	Assembling a shelf that is dismantled and tidy
	How Much?	If it is possible to reuse the shelf, it will have no material costs. The only cost will be associated with the time spent on this task by operators

- DO
  6. Inform those involved in the implementation of the plan;
  7. Implementation of the established plan:
     5S Methodology
     - The sense of Use: Select between the warp beams which are actually used, excluding those that are not. Separate the most used from the less used ones, so as to put "those at hand more frequently";
     - The sense of Storage: Define in the shelf proper places for each warp beam type (size);
     - The sense of Cleaning: Keep the shelves tidy and clean;
     - The sense of Standardization: The identification of the warp beams and their specific location on the shelf should be easy to understand and similar to the identification of the lots and their storage places, in order to standardize this situation;
     - The sense of Self-discipline: Whenever it is necessary to use new types of warp beams, try to define a place of storage before acquiring them, in order to avoid repeating the current scenario.
- CHECK
  8. Throughout the execution, check constantly if the plan is being fulfilled and if there are no unforeseen circumstances that imply the change of the same;
  9. After execution, verify if the plan has been fulfilled and the objective reached, as well as the deviations (errors or failures) that have occurred.
- ACT
  10. Try to apply the same action in other areas of the factory, in order to promote the organization (standardization of the storage system).

Regarding the warp beam storage, the expected results are related to the implementation of the stipulated plan, especially if this is possible with the reuse of the shelves that are stowed. With the potential engagement of a new Maintenance Manager, it is expected that the overall production of the company will be increased, as several operators will not have to worry about the maintenance of their machines, spending their time effectively producing.

It was then sought to analyze and present improvements in several problems that are the origin of customer complaints, two of which have been the subject of further study. After detecting the sectors that generate more non-conformities, it was important to understand the causes that are in their origin, in order to minimize them. It is notorious that the major source of non-conformities is the Suppliers. Being something external to the company, it will be necessary to promote a better suppliers' selection or to help develop them, namely by assisting them to improve their quality in order to avoid these problems, ensuring a higher level of conformity with the specifications.

5. Conclusions

This work intended to apply a combination of Lean methodologies to a Textile Industry, which was successfully achieved. Methodologies such as PDCA cycle, 5S and 5W2H were combined departing from the PDCA cycle, producing excellent results solving just one problem, proving that the methodology can be extended to other identified problems, improving significantly the company functioning and competitiveness. Based on the data previously collected by the company as properly treated and sorted, the following concluding remarks can be drawn:

- Problem identification was successfully achieved using Ishikawa diagram and the graphs analysis;

- After identification, some problems were solved: intensification of the Suppliers control, better Suppliers selection, adjustment of workload among internal sectors, hiring of a new Maintenance Manager, a better compartment in shop floor, need of Preventive Maintenance.

The actions undertaken during this work allowed saving four hours per operator weekly, which corresponds to a gain of 10% of the available time per week and operator, representing a considerable productivity improvement in this kind of industry. Moreover, this work can now be expanded to the overall activity of the company, mainly to the other items identified as containing wastes liable to be eliminated.

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References

[1] V. Zaharia. The Entreprise Network, a Managerial Assumption in the Social Market Economy. Procedia - Social and Behavioral Sciences 62 (2012) 545-547.

[2] B. Preifssl. Strategic use of communication technology – diffusion processes in networks and environments. Information Economics and Policy 7 (1995) 75-99.

[3] G. Dragoi, S. M. Rosu, I.-B. Pavaloiu, A. Draghici. Knowledge Applications Development at the SMEs Level in a Virtual Business Environment, Procedia Technology 9 (2013) 431-441.

[4] K. Amoako-Gyampah, M. J. Maffei. The adoption of flexible manufacturing systems:strategic considerations. Technovation 9 (1989) 479-491.

[5] U. Nimkar. Sustainable Chemistry: A Solution to the Textile Industry in a Developing World, Current Opinion in Green and Sustainable Chemistry 9 (2017) 13-17.

[6] L. Meira. Degradação de Corantes Indigoides com Reagente de Fenton para tratamento de efluentes na Indústria Têxtil (in Portuguese). MSc Thesis, Instituto Politécnico de Portalegre, Portugal; 2012. https://comum.rcaap.pt/handle/10400.26/17078 [Online]. Retrieved on 29th January 2018.

[7] Associação Têxtil e Vestuário de Portugal. A Indústria Têxtil e Vestuário Portuguesa (in Portuguese) 2013. http://www.atp.pt/fotos/editor2/2015/ITV%20Portuguesa_BRASIL_19.02.2015.pdf . [Online]. Retrieved on 29th January 2018.

[8] ISO/TS 16949:2002. Quality management systems-Particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organizations. ISO - International Standard Organisation, Geneva, Switzerland.

[9] T. Costa, F. J. G. Silva, L. P. Ferreira. Improve the extrusion process in tire production using Six Sigma methodology. Procedia Manufacturing 13 (2017) 1104-1111.

[10] J. M. Juran, A. B. Godfrey. Juran's Quality Handbook, 5th Edition, McGraw-Hill, NY, U.S.A.; 1999.

[11] J. G. Suárez, Three experts on quality management: Philip B. Crosby, W. Edwards Deming, Joseph M. Juran. Department of the Navy, Total Quality Leadership Office, VA, U.S.A.; 1992.

[12] K. Ishikawa. Guide to quality control. Asian Productivity Organization, Tokyo, Japan; 1976.

[13] C. Rosa, F. J. G. Silva, L. P. Ferreira. Improving the quality and productivity of steel wire-rope assembly lines for the automotive industry. Procedia Manufacturing, 11 (2017) 1035-1042.

[14] R. J. S. Costa, F. J. G. Silva, and R. D. S. G. Campilho. A novel concept of agile assembly machine for sets applied in the automotive industry, International Journal of Advanced Manufacturing Technology, 91 (9–12), (2017) 4043–4054.

[15] I. Antoniolli, P. Guariente, T. Pereira, L. P. Ferreira, F. J. G. Silva. Standardization and optimization of an automotive components production line. Procedia Manufacturing 11 (2017) 1120-1127.

[16] M. N. Alam, L. P. Christopher. A novel, cost-effective and eco-friendly method for preparation of textile fibres from cellulosic pulps, Carbohydrate Polymers 173 (2017) 253-258.

[17] H. Yukseler, N. Uzal, E. Sahinkaya, M. Kitis, F.B. Dilek, U. Yetis. Analysis of the best available techniques for wastewaters from a denim manufacturing textile mill, Journal of Environmental Management, 203(Pt3) (2017) 1118-1125.

[18] Helena Dahlbo, Kristiina Aalto, Hanna Eskelinen, Hanna Salmenperä. Increasing textile circulation—Consequences and Requirements, Sustainable Production and Consumption, 9 (2017) 44-57.

[19] L. Norris. Aesthetics and ethics: Upgrading textile production in northern Kerala, Geoforum, 50 (2013) 221–231.

[20] M. Kýzýloglu, C. Serinkan. Perception of Strategical Management in Textile Sector, Procedia - Social and Behavioral Sciences, 207 (2015) 306 – 314.

[21] B. J. McCarthy. An overview of the technical textiles sector, Handbook of Technical Textiles (Second Edition), Volume 1 – Technical textiles Processes, A. R. Horrocks and S. C. Anand (Eds.), Woodhead Publishing in Textiles, Elsevier, 2016, pp. 1-20. ISBN: 978-1-78-242465-9.

[22] D. Küsters, N. Prass, Y.-S. Gloy. Textile Learning Factory 4.0 – Preparing Germany's Textile Industry for the Digital Future, Procedia Manufacturing, 9 (2017) 214 – 221.