Preventive Maintenance Development: A Case Study in a Furniture Company

Bruno. A. Carvalho, Isabel. S. Lopes, *Member, IAENG*

Abstract— **This article intends to present a project in a furniture manufacturing factory, carried out to improve the efficiency of preventive maintenance actions, decreasing the number of failures and downtime of equipment, and maintenance costs.**

An initial diagnosis allow identifying the main weaknesses of the maintenance department, especially concerning preventive maintenance, one the pillars of TPM methodology and on which the factory is based for maintaining their equipment. There was a small percentage of planned preventive interventions actually performed and an unbalanced allocation of tasks by the available resources.

In order to improve the efficiency of maintenance staff, standard preventive maintenance instructions was developed. An approach to the planning and allocation of tasks throughout the year by service technicians was also defined.

There was a positive impact of the improvement actions and the new way of tasks allocation led to a better balance of the tasks among service technicians, as well as an increase in the number of performed preventive interventions.

Index Terms— **Maintenance management; Preventive maintenance; Tasks planning; Total Productive Maintenance.**

I. Introduction

The globalization of markets and the rising competitiveness between organizations leads them to seek costs reduction, to be more dynamic and quick in responding to requests. With this increase competitiveness, the maintenance department has been playing a very important role in achieving the objectives of the organizations. However, the maintenance function was not always be properly developed and utilized by organizations, as indicated by Chand and Shirvani [1], it has been seen as a cost and the cost of corrective maintenance actions (maintenance performed after the occurrence of failure) was one of the highest percentages of total maintenance costs.

According to Rodrigues and Hatakeyama [2], there is no time to improvise when dealing with issues related to industrial management, where the impact of inadequate and inefficient maintenance operation can set the profitability of the business and compromise the survival of the organization. More recently, companies have come to recognize the significant role of the maintenance function, and assign it a strategic potential for increasing competitiveness and strengthening operational excellence [3].

For continuous improvement of production processes, it is imperative to intervene in the organization's equipment that stops too often due to unforeseen events in order to increase their availability and efficiency. To obtain this improvement, it is advised to implement the Total Productive Maintenance (TPM) methodology. For Chan, Lau, Ip, Chan, and Kong [4], TPM is a maintenance system that covers all stages of the life of the equipment. This includes planning, manufacturing and maintenance, where the intervention of top management of the maintenance department in the development of TPM and Lean philosophy is essential for the involvement and commitment of everyone involved in the project.

As stated by Smith and Hawkins [5], Lean Maintenance concept is relatively new since it follows the principles of TPM. The Lean thinking's mission is to eliminate all forms of waste in manufacturing processes, including wastes in maintenance [5]. This philosophy is originally based on manufacturing processes, however, many of the Lean tools used in production can be adjusted and also applied to maintenance operations.

The purpose of TPM, developed by Nakajima, is to increase equipment efficiency and to maximize productivity, reaching and maintaining their optimal conditions in order to avoid unexpected breakdowns, speed losses and defects in the product being processed [6]. One of the major responsibilities of the maintenance department at TPM methodology is to guide and support, not only autonomous maintenance activities carried out by operators but also the preventive maintenance activities carried out by service technicians, the latter to be planned and programmed effectively and efficiently so that the work of the technicians is really done quickly and correctly.

Ben Ali, Sassi, Gossa, and Harrath [7] define preventive maintenance as a schedule of planned maintenance actions aimed at preventing failures and unexpected stops of production equipment and, its main objective is to prevent the occurrence of equipment failure and is designed to preserve and improve equipment reliability, replacing damaged components before they fail.

The management of technicians is also an important issue in the management of maintenance. The planning of the workforce includes decisions and issues often difficult and important to be taken, such as the number of appropriate technicians corresponding to the workload over time and the management of these technicians taking into account the constant changes typical of production and maintenance.

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Bruno. A. Carvalho is with Centro Algoritmi, University of Minho, Campus de Gualtar, 4710-057, Braga, Portugal (e-mail: bagcarvalho@gmail.com).

Isabel. S. Lopes is with Centro Algoritmi, University of Minho, Campus de Gualtar, 4710-057, Braga, Portugal (corresponding author phone: +351 253 604762; fax: +351 253 604741; e-mail: ilopes@dps.uminho.pt).

To obtain the best results in maintaining with an increasingly limited budget, the collection of historical maintenance data on equipment became in recent years of high importance. Such data must be collected and analyzed properly, and maintenance plans prepared starting with the critical equipment and focusing up those that are really important for production.

The production unit where the project described in this article took place was, at the beginning of the project, the target of several process improvements using Lean methodology, and it became necessary to improve the procedures to carry out effectively preventive maintenance interventions as well as the efficient allocation of necessary resources, material and human to realize them. This project appears with the intention to develop and improve preventive maintenance activities at the plant, through the application of Lean tools in the management of maintenance.

The article is divided into five chapters. The next chapter presents the analysis of maintenance management at the plant, and describes the classification of maintenance work used at the plant, the procedures to a request for assistance, the maintenance support software and a review of preventive maintenance management. Later it sets out the proposals for improvement that were implemented. In the fourth chapter the results obtained are shown and, finally section V presents the conclusions and proposed some future work.

II. Analysis of Maintenance Management in the Organization

A. *Classification of maintenance works*

Maintenance work at the factory resides in performing systematic preventive interventions, condition-based maintenance and corrective maintenance actions, as reported by Cabral [8] and shown in Figure 1.

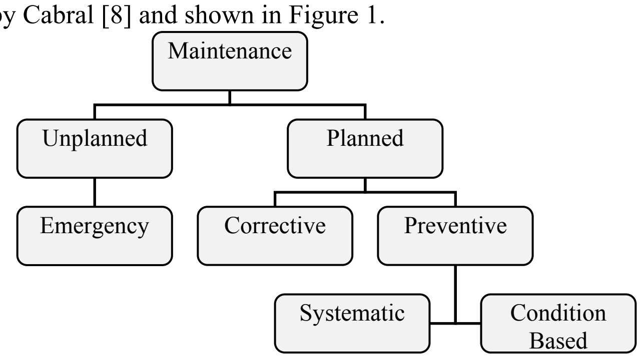

Fig. 1 - Maintenance activities

Maintenance works at the factory can be classified as planned and unplanned and, concerning priority may be classified as emergency work (which requires the production stoppage), works with high priority, with regular or low priority. Regarding the level of participation of production operators, maintenance works are classified as first level maintenance (designated in TPM methodology by autonomous maintenance), and these maintenance interventions by operators consist of simple and planned regulations, using commonly used tools and the support work instructions.

B. *Response to a request for repair*

Currently in the factory, the response procedure to a request for a corrective action is performed as follows (Figure 2). The operator, after detecting an anomaly in equipment or the need to carry out a maintenance work, communicates personally, or by phone, to the maintenance technician of the same area the need for intervention. Subsequently, the technician analyzes the fault and if he is not the most appropriate person to solve the problem, requests the assistance of another service technician or thus requests the intervention of an external team. Then, if replacement parts are required in the equipment, its existence in stock warehouse is checked. If there is a part or parts in stock, they are used to replace inoperable, and if there are none in stock, it is made a request by the maintenance department to warehouse, which subsequently performs the order. Finally the equipment is repaired and the intervention is recorded in maintenance support software with the following information:

- Equipment where the operation was performed;
- Brief description of the event, indicating if it was resolved or whether if it is necessary to intervene again, opening a work order (WO);
- Materials applied in the operation;
- Description of the replaced parts;
- Time used in the intervention.

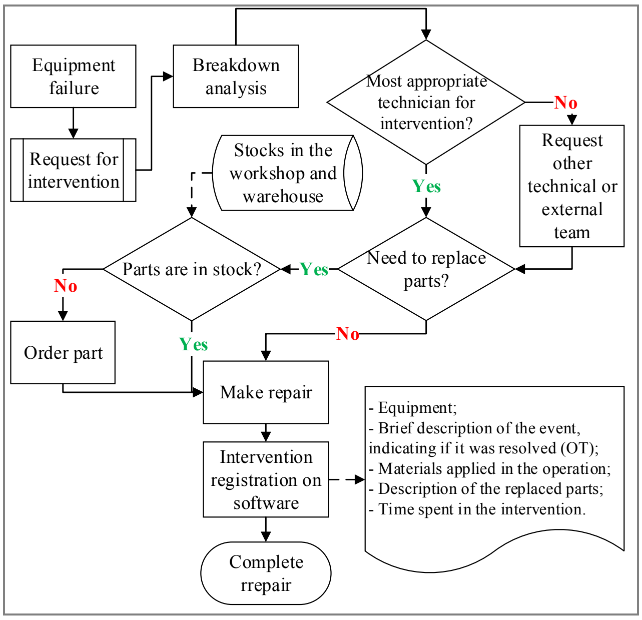

Fig. 2 – Flowchart of a request for action

C. *Software maintenance support*

The maintenance department has a software application whose main objective is to support management of maintenance.

The software allows accessing to a database which contains all the equipment of different production areas, as well as the history of corrective interventions in the respective equipment.

The software has the following features:

- Registration of operators;
- Registration of suppliers;

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• Creation and registration of instructions of first level, preventive and predictive maintenance. In addition to these generic functions, it still has several features directly related to maintenance activities, such as:

• Registration of all maintenance interventions;

• Creation and registration of a checklist of operations of each type of intervention;

• The programming of the various types of interventions and allocation to maintenance technicians;

• Registration of conditional preventive maintenance operations;

• Calculation of costs associated with interventions in equipment.

D. *Preventive Maintenance*

Practically all plant equipment are subject to preventive maintenance work.

For equipment subject to preventive maintenance works, there are maintenance tasks defined to each type of equipment and corresponding intervals, as indicated by the manufacturer. However, some interventions were defined through the experience gained by technicians and approved by the maintenance manager.

From the analysis of the maintenance registration, it was observed that not all planned preventive tasks are performed, with a high percentage of activities not carried out. This is due to a high load on the existing production plant (24 hours a day) and there are no planned stops in any of the areas of the plant for the realization exclusively of maintenance tasks. Therefore, the technicians make use of stop hours for eating and other small downtime to perform the tasks, and also weekend and stops for holidays, since the production load is smaller on these occasions.

Preventive maintenance instructions

To carry out preventive maintenance works, a template is used indicating the production area and the line of the equipment for intervention. This standard document allows indicating the frequency of interventions, the sequencing of tasks that must be performed by technicians, the tools needed for the intervention, the expected time and some images and schemes to help technicians. Located at the bottom of the document, the symbols related to Environment, Hygiene and Security are presented indicating the technical safety equipment that must be used in maintenance work.

Use of hand labor

The analysis of hand labor used in maintenance allows understanding its occupation and distribution by types of maintenance. Figure 3 shows the number of hours used by service technicians in preventive and corrective interventions since January 2012 to December 2013. Based on this analysis it can be said that technicians are dedicated mainly to corrective interventions.

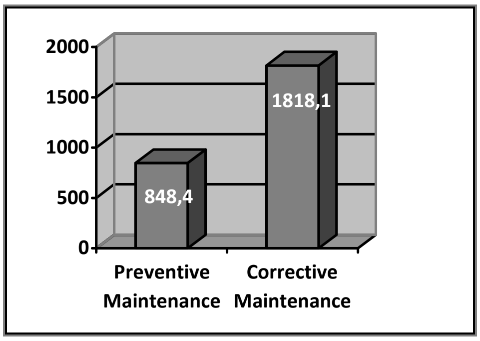

Fig. 3 - Hours expended on maintenance

Allocation of preventive maintenance

The planning of preventive maintenance works is carried out monthly with the use of an Excel sheet where the various equipment in the area are distributed by the respective technicians. Figure 4 shows an extract from the allocation of preventive maintenance in the months of May, June and July.

Equipment	May	June	July
U2000005	Technician A	Technician B	Technician C
U2000006	Technician A	Technician B	Technician C
U2000007	Technician A	Technician B	Technician C
U2000008	Technician A	Technician B	Technician C
U2000338	Technician C	Technician A	Technician B
U2000339	Technician C	Technician A	Technician B
U2000352	Technician C	Technician A	Technician B
U2000380	Technician C	Technician A	Technician B
U2000381	Technician C	Technician A	Technician B
U202000430	Technician B	Technician C	Technician A
U202000431	Technician B	Technician C	Technician A
U202000547	Technician B	Technician C	Technician A
U202000548	Technician B	Technician C	Technician A

Fig. 4 - Scheduling of preventive maintenance

By observing the figure we can see that there is a turnover in the tasks. The equipment allocated to technician A and the respective maintenance tasks will be assigned in the following month to technician B, the tasks allocated to technician B will be allocated the following month to technician C, and the tasks allocated to technician C will be allocated to technician A.

This type of scheduling, assigning approximately the same number of equipment to every technician is inadequate since it does not guarantee a monthly schedule of fair work by the technicians, once every month there are different types of interventions to be executed in equipment with different durations.

Figure 5 shows, according to the plan and distribution of tasks established and specified in Figure 4, the number of hours that the three technicians have to perform at the end of the year. Examining the figure aforementioned, you can see that there is no equity in terms of workload among technicians, existing at the end of the year a difference of 187 hours between the technicians with the most and the lowest workload.

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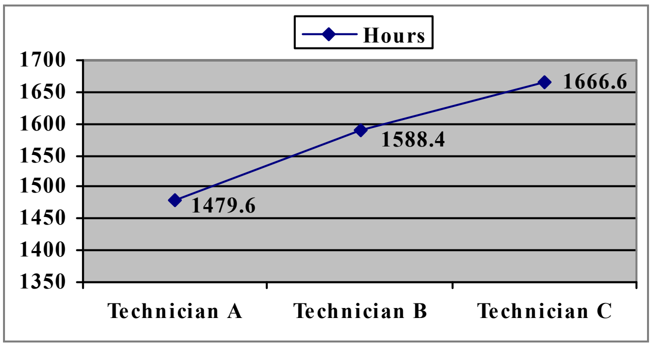

Fig. 5 - Annual workload of each service technician

III. Implementation of Improvement Proposals

The analysis of the model of organization and management of plant maintenance and of operations records allows identifying opportunities for improvement, including:

- Using the analysis of the interventions historical and failures records for continuous improvement of maintenance service and equipment performance;
- Adjustment and creation of preventive maintenance work instructions;
- Changing the timing and allocation of preventive maintenance tasks;
- Improve the planning of preventive maintenance works.

The changes identified by the analysis are expected to increase the percentage of preventive maintenance realization.

The implementation of changed in the maintenance system took into account the potential of the maintenance support software.

A. *Standardization of preventive maintenance instructions*

Due to the need to standardize the process of preventive maintenance work, in order to optimize the use of human resources [9], new standards were created for carrying out work orders. These new sheets are designated by Standard Operation Sheet (SOS) and Work Element Sheet (WES) and will replace the old maintenance work instructions.

Replacing the old maintenance work instructions by SOS and WES are intended to improve interventions of preventive maintenance by separating the simple interventions and maintenance interventions whose realization requires more detailed processes.

The main objective of SOS is to describe preventive maintenance tasks with little complexity and the main objective of the WES is to describe in detail SOS tasks that need to be performed according to a series of more detailed procedures.

In this project a total of 1174 preventive maintenance instructions using SOS and WES format were created, by consulting the maintenance plans recommended in technical manuals of equipment manufacturers and taking into account the opinions of service technicians.

In addition to the creation of SOS and WES, the actions described were also divided into intervention and inspection type. This division in intervention tasks and inspection tasks allows maintenance technicians having a better management of the tasks that they have to perform, since the inspection tasks can be performed with the equipment in operation, which could increase the percentage of realized preventive interventions.

B. *Allocation of preventive maintenance tasks*

As shown in Figure 4, the distribution of maintenance tasks was performed by dividing the number of technical equipment by the number of the respective areas of production, and each technician performed all the instructions that were allocated to the equipment that were attributed to him in respective month. This originated an imbalance of workload between maintenance technicians making the percentage of lacking preventive interventions high.

For the reallocation of preventive maintenance tasks, a division was held in each month so that each technician performs the same workload in terms of inspection and intervention.

Table I shows the example of preventive maintenance tasks to be held in June in the A1 area and the respective workload. As shown by table I, in June 112 preventive maintenance interventions, corresponding to a total of 217.6 hours had to be carried out.

TABLE I
TASKS TO BE HELD IN JUNE IN THE A1 AREA

Intervention Category	Number of interventions	Hours
Monthly - Inspection	32	70,4
Monthly - Intervention	12	7,2
Quarterly - Inspection	34	71
Quarterly - Intervention	34	69
Total	112	217,6

In order that all the area's technicians perform about the same workload of inspection and intervention tasks, the workload was evenly distributed by the three service technicians considering each category of tasks presented in Table I.

C. *Turnover of preventive maintenance tasks*

For technicians to be versatile and able to perform all preventive interventions, existing turnover was maintained and the rotation began to be made, not by the equipment of the respective area, but by the frequency and category of each instruction.

Figure 6 shows the balanced distribution in terms of hours of preventive maintenance instructions in the A2 area in June.

Preventive maintenance plans have also been established to be printed and placed in the maintenance workshops, in order to register and verify what tasks were or were not made each month, for a greater focus on not performed tasks.

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Equipment	Monthly - Inspection	Monthly - Intervention	Bi-Monthly - Inspection	Quarterly - Inspection	Quarterly - Intervention
U2000005	Technician A			Technician A	Technician A
U2000006	Technician A			Technician A	Technician A
U2000007	Technician C				Technician A
U2000008	Technician A			Technician B	Technician C
U2000338	Technician B	Technician A	Technician A	Technician C	Technician A
U2000339	Technician C	Technician A	Technician B	Technician C	Technician A
U2000380					
U2000381	Technician C	Technician C		Technician C	Technician C
U202000430	Technician B				Technician A
U202000431	Technician C				Technician A
U202000547	Technician C				Technician C
U202000548	Technician C	Technician B		Technician B	Technician B

Fig. 6 - Distribution of preventive maintenance tasks

D. Setting priorities in carrying out maintenance works

Monthly as it is not possible to complete preventive maintenance plan, intervention priorities should be stated for equipment with longer track record of failures, since this fact is indicative of a low reliability of equipment, which can lead to high loss of production costs. Besides, the time used in corrective and preventive interventions is also an important factor, since it shows equipment with the highest hand labor maintenance costs.

Another issue raised in the performance of preventive maintenance instructions was that when certain interventions were not made, this information was not available and taken into account in the planning and realization of the following month interventions. The solution is to indicate a high priority for that information, so that it is subsequently presented in the "tasks list" that technicians print to carry out the instructions, and in the top of the list will appear tasks with higher priority to be performed in the first place.

E. Standard checklist for maintenance instructions

One of the observed improvement opportunities is the change of the "tasks list" template that the service technician prints to make the registration of the performed tasks.

The template of the "tasks list" proposed is a list of the tasks that the technician has to make per month, which discriminate the instruction number, the start date of the task, the name of the equipment, its location in the factory, the expected time for completion of the task, the frequency of the task and its priority. The main difference between the new template proposed and the one used in the factory is the possibility of recording the starting and ending date and time of maintenance intervention. Since it is not possible at the moment to make directly the registration into the software, the information could be subsequently introduce into the software to calculate the average length of time for performing each maintenance intervention (corrective and preventive).

In the "tasks list", the service technician notes if the listed tasks have been realized or not, the time (in minutes) it took to perform each of the tasks and other observations considered relevant.

IV. Impact of Implemented Changes

With the new implemented distribution of tasks, it was possible to reduce the annual time difference between the technician with the most and the lowest workload, balancing the workload among technicians and getting that the technicians carry a higher percentage of tasks. This distribution also contributes to reducing the sense of injustice among the technicians, since there were technicians with reduced workload compared to colleagues in the same area.

As seen in Figure 7, the new distribution originates at the end of the year a difference of only 15 hours between the technician with the most and the lowest workload, a small difference compared to the 187 hours of difference observed in the old distribution

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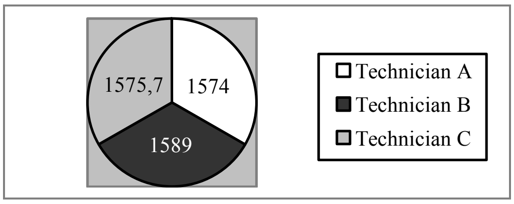

Fig. 7 – Hours spent by each maintenance technician

The modifications allow increasing the number of preventive interventions actually performed from 21% to 29% at the end of the project. However, the impact will be more visible at the end of the year since it continues to increase with the full implementation of the changes. Figure 8 shows the expected increase in the percentage of implementation of preventive interventions in each area of the plant at the end of the year.

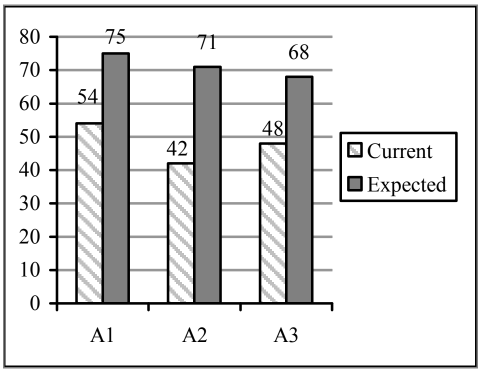

Fig. 8 – Percentage of performed preventive maintenance

V. Conclusion

In this project, preventive maintenance instructions were developed, its allocation by three technicians and their planning throughout the year in order to balance the workload by technicians and increase the percentage of implementation were studied.

The structure of the new instructions were well received by the technicians and they were quickly familiar with the division of instructions in intervention and inspection type, as well as the creation of SOS for simple tasks and WES for more specific and detailed tasks.

The planning of preventive interventions also had great reception and acceptance by the maintenance manager and respective technicians since the monthly load was evenly distributed.

The recommended and implemented actions are expected

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to improve the efficiency and effectiveness of maintenance function without the involvement of significant investment for the organization.

Part of the practical project was also to explore, develop and improve the use of maintenance management software by the department, since its potential is not fully explored.

In this project the improvement of interventions were implemented gradually and it was not possible at the end of the project evaluating the effect of these new improvements in the maintenance indicators.

This project was only the beginning of a process of continuous improvement. From its development have emerged various ideas for improving the performance of the area and to be explored in the future. To continue this work and as part of the implementation of Lean Concepts and TPM methodology, the following proposals are considered:

• Development of Maintenance Value Stream Mapping (M-VSM) for the purpose of determining the efficiency of the plant maintenance process [10] and identifying the activities with the lowest percentage of added value to the process and thus be able to improve these same activities [11];

• Application of SMED tools [12] for the reduction of the duration times of preventive interventions;

• Adjustments to the times indicated in the preventive maintenance instructions based on registration of durations in the tasks performed by the technicians;

• Evaluation of critical equipment, since preventive maintenance interventions must be made according to its level of importance of equipment to the factory and the consequences of its failure.

References

[1] Chand, G., & Shirvani, B. (2000). Implementation of TPM in cellular manufacture. Journal of Materials Processing Technology, 103 (1), 149-154.

[2] Rodrigues, M., & Hatakeyama, K. (2006). Analysis of the fall of TPM in companies. Journal of Materials Processing Technology, 179 (1-3), 276-279.

[3] Cigolini, R., Fedele, L., Garetti, M., & Macchi, M. (2008). Recent advances in maintenance and facility management. Production Planning & Control, 19 (4), 279-286.

[4] Chan, F. T. S., Lau, H. C. W., Ip, R. W. L., Chan, H. K., & Kong, S. (2005). Implementation of Total Productive Maintenance: A case study. International Journal of Production Economics, 95 (1), 71-94.

[5] Smith, R., & Hawkins, B. (2004). Lean Maintenance: Reduce Costs, Improve Quality, and Increase Market Share (Butterworth-Heinemann Ed.). Oxford, UK: Elsevier Science.

[6] Ahuja, I. P. S., & Khamba, J. S. (2008). Total Productive Maintenance: literature review and directions. International Journal of Quality & Reliability Management, 25 (7), 709-756.

[7] Ben Ali, M., Sassi, M., Gossa, M., & Harrath, Y. (2010). Simultaneous scheduling of production and maintenance tasks in the job shop. International Journal of Production Research, 49 (13), 3891-3918.

[8] Cabral, J. P. S. (2006). Organização e Gestão da Manutenção: dos conceitos à prática (5ª ed.). Lisboa: Lidel.

[9] Dennis, P. (2007). Lean Prodution Simplified (2ª ed.): Productivity Press.

[10] Rother, M., & Shook, J. (1999). Learning to See: Value Stream Mapping to Add Value and Eliminate Muda (pp. 102): Lean Enterprise Institute.

[11] Kannan, S., Li, Y., Ahmed, N., & El-Akkad, Z. (2009). Developing a Maintenance Value Stream Map (pp. 1-8). Knoxville: University of Tennessee.

[12] Shingo, S. (1985). A Revolution in Manufactuing: The SMED System. Cambridge: Productivity Press.