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Continuous improvement through "Lean Tools": An application in a mechanical company

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Abstract

This article results from a work carried out in a company that is dedicated to the production of mechanical equipment. Throughout the production process, with the support of Value Stream Mapping (VSM), it was possible to detect several wastes. This article suggests several lean tools that can be used, indicating the improvements that can be obtained with each of the recommended hardware. This work aims above all to be a guide to support organizations that wish to start their lean road. Smart value creation remains today dependent on the maturity of how lean management tools are applied. Lean, innovative technologies, critical knowledge, talent and big data need other dimensions to be sustainable. I4.0 assumes here a critical pillar for this new journey toward the future of our organizations.

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1. Introduction

In 1988 Tachii Ohno presented in his book "Toyota Production System: beyond large-scale production" [1] the seven wastes that are authors for the low productivity of companies. According to Tachii Ohno the wastes that exist along the production flow are creators of losses and must be removed. The knowledge of their location is crucial for their identification, and this must be performed on *Gemba* (shop floor) because that is where they occur, and it is necessary to remove [2]. Nowadays, companies keep wastes along the production flow and it is more and more important to eliminate them, because they are sources of costs and loss of productivity inside the companies, endangering their future sustainability. Rother & Shook, stated that in all products / services provided to customers there is a determined added value and the challenge is in the visualization of this value stream [3]. Rother & Shook, who were already familiar with the Toyota Production System (TPS), developed the Value Stream Mapping (VSM), which they called a tool with a pencil and paper [3]. The purpose of the VSM design was to help company managers and directors see the flow of material and information in their plants. The utilization of the VSM is essential for any organization [3]. Among other things it allows: flow visualization and visualization of the sources of waste in the value stream. The seven wastes identified by Tachii Ohno in his major work "Toyota Production System: Beyond Large-Scale Production"[1], continues to be a nightmare for all organizations. Masaaki Imaii in his work: "Gemba Kaizen - A Common sense, low cost approach to management" [2] reinforce the need for companies to identify their waste and then eliminate them. Masaaki Imaii to make it easier, uses the term *"muda"* rather than "waste" to define the term "wastage", and reinforce a need to be identified in *Gemba* (on the factory floor) That's where they will have to be eliminated! The need that companies have to eliminate their desires are not adequate for the final value of the final product, but rather, resources are needed. They bring added value to the final product / service. The principles and practices of Lean began in the late 1980s, but in 1988, through a group of researchers led by James Womack who are doing research at the Massachusetts Institute of Technology (MIT).

In 1990, Womack defined the concept of "Lean" as an internal philosophy of the organization, which sought an elimination of change in the book The Machine That Changed the World [4]. Womack in 1996 predicted major changes in the production process for the companies due to the type of orders from the customers and that they would have to adapt to the change. He asserted that the era of standard mass production had ended and that they were now in the era of small quantity and large variety orders. Faced with this new reality, it was necessary to change the production system of the companies to a new production regime based on the detection and elimination of *muda*. Womack, however, found that some companies in the United States, Germany, and England had already embarked on this path due to the fact that there was no growth at the time, that is, they were in a period of economic stagnation. Unfortunately, many companies continued to resist the adoption of this new paradigm of production, since it was sufficient to look at the high stocks that existed in the companies (raw material, product in the process of manufacturing - WIP and finished product) which remained clinging to retrograde concepts. Womack believed that resistance to change was no more than a psychological issue, since the adoption of lean allowed organizations in the short term to improve their resources and eliminate existing change, thereby enabling them to produce the same quantities but with fewer resources. This situation posed a challenge to the top management that could choose to lay off employees or else bet on innovation and create / launch new products / services to the market and keep all existing workforce.

This second situation would be the best option, as it allowed companies to increase the number of products / services they had to offer to the market and, consequently, to increase the volume of invoicing without increasing labor costs. Another aspect to take into consideration, in order to choose the second situation, was the need not to cause any internal social unrest in the company, because it was imperative that employees accept the changes brought about by the implementation of the Lean, They could put it into practice, and consequently improve the organization's performance.

Womack advocated the idea that top management should instill the spirit of teamwork in its employees through a clear focus on Lean tools and techniques, in order to create a culture of polyvalence within the organization's internal structure / Employee turnover [4]. Another idea pointed out by Womack was that organizations should reinforce to the employees the importance of identifying the problems and their causes, without this being a reason for later reprimand, but a moment of congratulation because the employee of the company Opportunity for improvement in your company. In 2003 Womack, J.P. and Jones D.T., present the concept of "Lean Thinking" in their work [5], in order to present the key ideas developed by Taiichi Ohno in the Toyota Production System (TPS). McDonald et al. (2002) reported that James-Moore & Gibbsons had already defined the key areas of Lean Manufacturing as follows:

Flexibility; Elimination of waste; Optimization; Monitoring of processes and Involvement of people. Several authors defined tools / techniques to help organizations implement the Lean culture. Among them, we highlight the work developed by Rother, M. and Shook, J., with the presentation of Value Stream Mapping (VSM), which aimed to design the flow of value of a product [3]. The use of VSM as a tool for the detection of waste as a support for the implementation of the Lean philosophy, has reached the most diverse sectors of activity and has contributed to eliminate some outdated concepts. This paper aims to be a contribution to the organizations, showing how they can detect the wastes in the productive flow through VSM. In addition to the detection of waste, this article intends to show several lean tools that can be applied in different situations, as well as the wastes that each can eliminate, and the benefits that are obtained from each one.

2. Case Study

2.1 Presentation of the current situation of the company

The company selected for the case study in 2010, is a company that is dedicated to the production of mechanical equipment. Currently the manufacturing process is oriented by production orders, which are issued by the production manager, taking into account the existing orders and the estimate of new orders. The production is subdivided into four main areas of work: reception of materials; conformation (cutting, drilling, bending); welding (longitudinal welding by submerged arc, laying of the bottoms, circular welding of the bottoms by submerged arc, manual assembly of the boiler); painting (pickling, manual painting); assembly, packaging and storage of the final product.

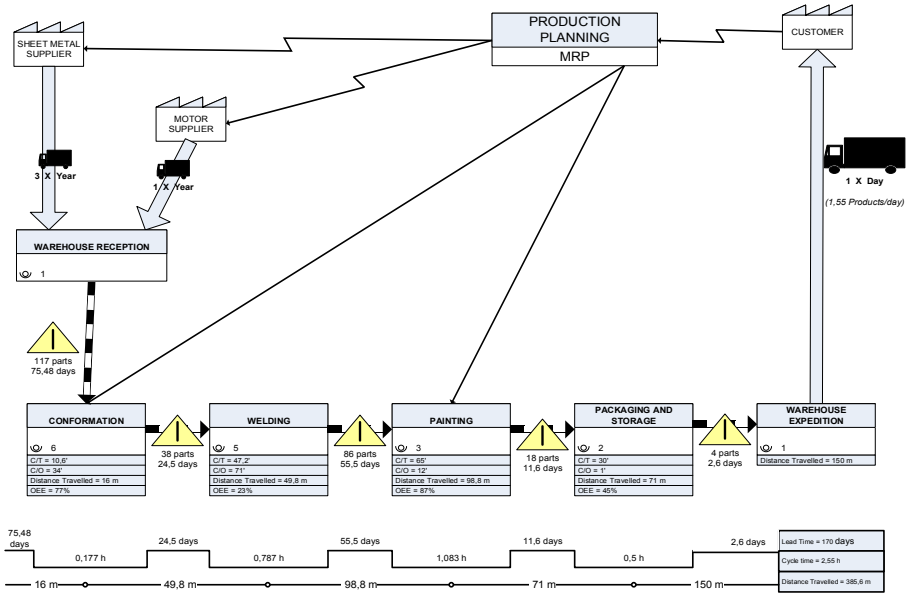

Fig. 1. The VSM of the current situation

The most outstanding wastes throughout the company were: WIP and high stocks, equipment shutdown and large distances between jobs. When the production managers were questioned about the situations recorded, the response was that the company had always worked in this way and that because of the type of article produced, with all the productive operations associated, there was no other way to do it. The way to show how the productive part of the company could be reorganized was to show clearly to the top management the wastes that exist along the productive flow, as well as the costs that these have for the company. Since the concept of lean philosophy consists of producing only what the customer needs when he needs it (Womack and Jones), the first step was to know which product had the highest customer demand and the average monthly demand. The information obtained was that the products that had the most output had an average monthly demand in the order of 34 products per month, and the unit cost of this article stood at 300 €. This information allowed us to calculate the takt time that defines the cadence with which

products should go out to the customer. Knowing the monthly demand, and considering that a month on average has 22 business days, you get the average daily demand of the customer:

Daily demand = (34 products / month) / (22 working days / month) = 1,55 products / day

That is, the average daily demand is 1.55 products. From this value, we calculate the takt time that gives us the information on how often the company should have an end product ready to satisfy customer demand. The takt time value will then be: Takt time = (8 hours) / (1.55 products / day) = 5.16 hours

With this information, we now know that the company has to have a product ready, of 5.16 hours in 5.16 hours. *Gembutsu* (Masaaki Imai) should be used to collect the information for the value stream mapping process. It should always be done in *Gemba*, because that is where the problems happen and there is nothing like going there to see what is really going on – *Gembutsu.* The most appropriate set of actions. As can be verified through VSM, there is a high level of stock and several workplaces which can be reduced through the implementation of a pull system [1]. However, existing stocks may result from the fact that production is not synchronized with customer demand [3], but may have emerged because there are a large number of unplanned breakdowns due to malfunctions, which could be reduced through the implementation of the TPM (Total Productive Maintenance) [6]. The disorganization and lack of existing standards has been one of the main sources of waste, which can be eliminated through the implementation of 5S [7] [8]. There is also a high changeover time, which can be reduced substantially through the SMED (Single Minute Exchange of Die) application [9]. It was also analyzed the implementation of the standardized work, with the purpose of optimizing production processes and reducing process variability [10].

2.2 The use of lean tools

The following tools will allow this organization to achieve continuous and valuable propositions for their key stakeholders. A lean manufacturing initiative is focused on cost reduction and increases in turnover by systematically and continuously eliminating all non-value-added activities. In a competitive market, lean is the "the solution" to manufacturing industries for survival and success. Lean manufacturing helps organizations to achieve targeted productivity by introduction of easy-to-apply and maintainable techniques and tools. Its focus on waste reduction and elimination enables it to be engrained into organization culture and turns every process into profit.

2.2.1 Standard work

Standard work is a lean tool developed by Onho in the fifties. According to Jang & Lee [11], it is defined as the degree of rules and operational procedures which are formalized and executed. Furthermore, the authors argue teams require autonomy to establish a set of specific rules which facilitate their work. The method aims to eliminate the variation and inconsistency of results by instructing workers to execute manufacturing activities following clearly defined procedures. This goal can be achieved by both defining an optimal procedure and ensuring its performance. There is no room for improvisation. Therefore, the operations are often referred as an inflexible work standard. They are used as a training auxiliary tool as well [5]. Benefits: Variability reduction – The work effort becomes stable and measurable; Cost reduction – By means of waste reduction derived from inefficient work procedures, the system becomes more cost-effective; Quality improvement - If the same operation were to be executed differently depending on the person, the probability of defects would increase; Worker involvement – Standard work shifts the blame for errors from the worker to the system. Thus, people tend to start being more honest about improvement opportunities; Continuous improvement – This tool is essential for continuous improvement, since it facilitates change to improved standards, making it easier, faster and more efficient overall.

2.2.2 Value Stream Mapping

Value Stream Mapping (VSM) is a method developed by Rother and Shook [3], which permits an overview of the material flow from the raw material acquisition to the final product expedition. Abdulmalek & Rajgopal [12] define VSM as a map to identify waste, improvement opportunities and which lean tools to use. In order to apply the VSM methodology, four steps should be followed: 1 – Selection of the product or family of products to use as improvement subject; 2 – Drawing of representation of current state; 3 – Drawing of the future state, without the inefficiencies previously pinpointed. This is referred as value stream design (VSD); 4 – Elaboration of a work plan to achieve the

future state. The use of VSM helps on the identification of waste sources, provides a common language for its analysis and facilitates the understanding of the connections of the material flow. It is also an effective way of registering lead times, setup times and other indicators, in a way which enables the responsible to clearly visualize the system's performance.

2.2.3 5S

The 5S lean tool was developed in Japan by Sakichi Toyoda, Kishiro Toyoda and Taiichi Ohno in 1960 [1]. This tool aims to achieve a clean and organized workspace in order to maintain an outstanding organizational environment [13]. The method consists on the sequential following of five steps: *Seiri* (Sort) – Consists on the removal of everything deemed unnecessary. The workplace should only have what is needed to perform the activities; *Seiton* (Set in order) – There must be a place for everything and everything should be in its place. Quick and visual identification of tools and areas saves time and facilitates processes; *Seizo* (Shine) – Cleaning the workspace is essential. It reduces the risk of accidents and aids on the inspection of products; *Seiketsu* (Standardize) – In order to optimize the first three S's, standards must be created and followed; *Shitsuke* (Sustain) – The last step consists on developing a method to ensure the 5S technique is followed. It requires discipline and focus. Usually, audits are performed to assure the sustainability of the methodology. 5S bring several benefits to a company, being the most relevant one the decrease of waste of time and space. According to Hirano [13], the rewards of applying 5S are extended to quality, security and hygiene.

2.2.4 Visual Management

According to Galsworth [14], visual management is a "self-ordering, self-explaining, self-regulating, and self-improving work environment where what is supposed to happen on time, every time, because of visual devices". It is the basis of several other lean tools, such as 5S and standard work. Hall defines it as communication with no words nor voice [15]. It consists on the utilization of fast and intuitive means of communication. There are several visual management systems such as informative boards, space delimitations, *andons* and work instructions. The goal is to empower workers to manage their own work environment, reducing errors and further forms of waste.

2.2.5 Kanbans

Developed by Ohno on Toyota production lines, *kanbans* [1] emerged as a solution to the tendency of factories to overproduce. He looked for a way of reducing this waste by finding a means of delivering only what is necessary when necessary. Kanban can be translated from the Japanese as card or signal, and is a visual input used in pull systems [16]. Arbulu, Ballard & Harper define *kanban* as a lean approach developed in the automotive industry to "pull" materials from the production line in a "just in time" mindset [17]. The concept of this method consists on promoting the restock of materials only when required, by receiving and sending signals, usually in the form of cards. This process can be either internal or external to the company [18]. In order to assist this practice, supermarkets and milk-runs are utilized. The former is a structure filled with organized product components. The latter is a transport vehicle which provisions the assembly lines with the components they necessitate from the supermarket.

2.2.6 Line balancing

Line balancing is the procedure of allocating tasks to workstations inside an assembly line distributing the amount of work evenly. In order to achieve this goal, the concepts cycle time and takt time must be understood. Takt time is related to demand and its value represents how often it is necessary to produce one item. The cycle time is the amount of time required to complete one cycle of an operation. Since different workstations usually have different cycle times, the output frequency of the system corresponds to the slowest workstation's cycle time, the bottleneck [19]. In order to properly balance an assembly line, the work effort must be distributed in a way that cycle time is inferior to takt time. However, the efficiency increases if these two metrics are as close as possible [20].

2.2.7 Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) means autonomous, planned, and preventive maintenance of machines and facilities. TPM becomes one of the foundations for operational performance stability and improvements and is a key tool that allows production management to achieve higher levels of efficiency and effectiveness. It also brings to

production technologies, efficiency and profitability. Planned and unplanned downtimes should be minimized systematically and maintenance and repair activities quickly and easily completed, based on standardization of processes. TPM is relevant to maximize the effectiveness of the equipment, improving its overall efficiency, helping organizations get benefits with this approach based on a role model comprehensive productive-maintenance system that helps the entire life of the equipment in a good condition to support their business [21]. TPM implementation helps organizations have a smart preventive and productive maintenance and involves every level, from top executive to the floor operator [22]. TPM has been a key pillar for helping them increase the productivity and overall equipment effectiveness. There are benchmarked key performance indicators to monitor the equipment as Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR). Machine operators carry out maintenance work independently, including the continuous improvement of the machinery. Associates are actively involved and are jointly responsible for their production facilities. TPM is one of the most valued tool [23] with high added value to achieve high standards of efficiency for all organizations. There are eight pillars for the TPM implementation. Each pillar has specific targets to achieve higher levels of performance in each organization. It is necessary to check the implementations on the shop floor and results have to be measurable. The associates involved with TPM activities, are responsible for driving and overseeing TPM activities factory-wide [25]. The following tasks for the planned maintenance are critical for the TPM success: Clear definition of the best sequence of activities, separating the activities/time for each equipment and operator in the complete production line; Work descriptions per equipment, specifying tools, equipment spots and visual instructions for all activities; training the operators in maintenance, change over and standard work activities. Increase the operators' involvement in designing the best sequence of activities and implementation of standards: cleaning, inspection, changeover, maintenance activities, process confirmation with analysis of deviations, continuous improvement and standards optimization. These points are relevant to value their operators and create a culture of empowerment for achievement of both organizational and personal targets.

2.2.8 Overall Equipment Effectiveness (OEE)

The strategic goal of TPM implementations is the reduced occurrence of unexpected machine breakdowns that disrupt production. [24] Overall equipment effectiveness (OEE) indicator includes results from all equipment manufacturing into a measurement system that helps manufacturing and operations teams improve equipment performance and, therefore and reduce equipment costs. The OEE Key Performance Result offers a starting-point for developing quantitative variables for relating maintenance measurement to plant strategy. OEE can be used as an indicator of the reliability of the production network. [24] Forming cross-functional teams to solve the root causes/problems can drive the highest improvements and generate real bottom-line benefits. A comparison between the expected and current OEE measures, can deliver the needs for the manufacturing organizations to improve the maintenance policy and affect continuous improvements in the manufacturing systems. OEE offers a measurement tool to evaluate equipment performance [24] and ensure relevant information for productivity improvement. OEE is a productivity improvement process that starts with management consciousness of total productive manufacturing and their commitment to focus the factory work force on training in teamwork and cross-functional equipment problem solving. A key objective of TPM is to eliminate or minimize all losses related to manufacturing system to improve overall production effectiveness. The OEE measure is fundamental to the formulation and execution of a TPM improvement strategy.

2.2.9 Single-Minute Exchange of Die (SMED)

Shingo invented the Single-Minute Exchange of Die system for Toyota, helping the companies reducing their changeovers and can achieve quickly improvements in their results as: lead time reduced, lower inventories that will improve quality, productivity, profits and global results. Single Minute Exchange of Dies, is a methodology used to reduce the time machines are down during changeovers. First, the SMED approach looks to identify the steps that can be performed while the machine is running (external setup operations) and those that can only take place while the machine is stopped (internal setup operations). The strong way to get value with this methodology is to start to transform internal operations to external operations, reducing the down time during changeovers and standardize the process. SMED methodology distinguishes in a changeover two types of operations: Internal Operations (I.E.D.) - Input Exchange of Die that can only be performed with the machine immobilized and External operations (O.E.D. - Output Exchange of Die) that can be performed while the machine is running. The SMED method has allowed

numerous companies to considerably reduce their changeover times. Companies can now go from several hours to a few minutes. The definition of the standards for changeover plays here a key role. The application of SMED is indispensable, since the long changes of a production series are critical problems to guarantee the fluidity of the circulation of products. Improve maintenance quality by establishing periodic inspection and replacement criteria based on provisional cleaning and inspection standards.

2.3 TMP and a connected industry (I4.0)

The internet of things is already a reality. Industry 4.0, otherwise known as the fourth industrial revolution, integrates people and digitally- connected machines with the internet and information technology. Associates are key players in this concept, and their work is facilitated to a greater degree than ever by software-based systems. The I4.0 applications play today a strong role for the TMP implementation. Mobile IT solutions support the operators and maintenance engineers to increase the speed and quality of all kinds of maintenance. The I4.0 connected industry approach is connecting sensors that observe the equipment functions in a real time, and the maintenance will be done if it is necessary. With this, there are clear benefits: maintenance employees and operators will be informed about the current state of the equipment's and the availability will be increase. The big data available for the TPM teams, helps them make quick decisions in order to maintain higher availability and higher outputs in production lines. In Industry 4.0, people are the key players. Real-time big data will not take away people's power to make decisions or their responsibility, but it will support people by providing relevant information in real time, thus enabling continuous improvement of the production processes. The well-organized management of information is a critical pillar in a global performance of the modern organizations that means the quality of the information can affect results [27]. To implement successfully quality systems, organizations need to have the adequate information system that provides transparent information that supports the business development in an adequate way.

2.4 Leading Excellence with TQM

In 1980, the new management practices linked to the TQM philosophy began to emerge in the U.S., in a response from its industrial sector to a global competition where the Japanese companies with its management methodologies, supported by high quality of their products and services, disrupt the US companies' market shares [26]. TQM became an interesting concept in the beginning of the 1990s in order to describe how organizations should work to obtain better performance and customer satisfaction. In addition, TQM is often associated with the figures within the field of quality management, for example, Deming and Juran. TQM is perceived as a targeted methodology to adding value to the customers by producing outstanding products and services and by improving their satisfaction [26]. TQM can also be seen as a philosophy where the whole organization is involved in continuous improvement processes. The main pillar of TQM is recognizing that associates are the organizations' main assets that means their commitment with the continuous improvement process is imperative [26]. EFQM Model is a well-known TQM approach and is a common framework that helps all organizations to improve their businesses. The EFQM Excellence Model offers a holistic view of the organizations, highlighting its strengths and areas for improvement [27]. The EFQM excellence model is adaptable and can be used to assess, to improve an entire organization or just segments, improving their competitiveness of the organizations and deliver value propositions based on their needs, delighting their customers beyond expectations. To achieve the demanding targets regarding quality of services and products the organizations have to understand the basis for managing with agility, and attract new talents to enable them to anticipate and understand their external environment.

3. Conclusions

Lean management includes a set of tools that allow companies to receive strong benefits when they implement them properly. The use of lean tools is a simple way and low cost solution to achieve productivity and profitability, using a continuous focus on the elimination of waste through all the organization. Lean Tools are easy to used tool´s , they engage all the organization and assures the commitment of all from top to down, they assure are way to empower the collaborators and turn visible all the results of theirs work. With TPM implementation, the organizations collect several benefits, because TPM is a world-class approach, which involves everyone in the organization, working to

increase equipment effectiveness. TPM implementation in an organization can ensure higher productivity, better quality, fewer breakdowns, lower costs, reliable deliveries, motivating working environments, enhanced safety, and improved self-confidence of the employees.

The ultimate benefits that can be obtained by implementing TPM are enhanced productivity and profitability of the organizations. TPM aims to increase the availability of existing equipment in a good condition, reducing in that way the need for further capital investment in a new equipment's. To maximize the results, the TPM involves everyone at every level of the organization, from top management to front line employees using overlapping small group activities to achieve the target of zero losses and higher OEEs. With TPM implementation, organizations get high quality products, optimization of costs through stable processes, and short lead time due to flexible production. Aims to create a culture and environment that constantly tries to maximize the effectiveness of the entire production system (increase OEE). TPM is a key pillar in the success of lean management. The lean's purpose is to develop critical skills and competencies in organizations. New innovative products and services are coming for our organizations, new critical knowledge is necessary. Critical knowledge is one of the critical success factor to sustain the competitiveness of our organizations. In the world of Industry 4.0, people, machines, and products communicate with each other directly. Manufacturing processes and services are smart and connected across the boundaries of organizations to make manufacturing and services more efficient and flexible. But the success of I4.0 depends largely on the maturity of organizations and knowledge regarding the application of traditional lean tools such as TPM.

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