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Lean and Ergonomics decision support tool assessment in a plastic packaging company

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Abstract

This paper intends to apply and improve a workstation assessment tool called ErgoSafeCI. Lean manufacturing methods and guidelines, together with safety and ergonomics aspects, were thoroughly researched with the ultimate objective of finding a way to improve the workplace by considering the efficiency and well-being of workers. The assessment tool was applied in the plastics packaging sector, in a process which relied on both practical and theoretical ideas. This tool originates in the notion that for a successful Lean implementation, managers should start the Lean process with a Lean assessment which is then repeated on a regular basis. In addition, it is also important to integrate ergonomic conditions in this journey because ergonomic risks can sometimes result in Lean wastes and vice versa, so workplace ergonomics and Lean manufacturing are to a great extent inter-related. This tool aids practitioners in the assessment of the implementation of Lean principles and safety matters in their processes.

Keywords: Lean Manufacturing, Process improvements, SMED, Ergonomics, Packaging industry, Model application

1. Introduction

Nowadays, due to globalization, strong competition and demanding customers, every industry and business which wants to achieve excellence is committed to making and delivering flawless products, solutions or services, promoting first-time-right production and the zero defects concept, training people and motivating staff, keeping environmental protection integrated in every activity and involving staff members [1,2]. To confront these challenges, many companies update their traditional management style [3] and adopt methods that lead to improvements in cost, quality, productivity and operational performance, such as Lean manufacturing (LM) [4]. LM is based on consistent elimination of wastes. It is characterised as a system that uses less from the viewpoint of all inputs to generate similar deliverables as made possible by a conventional mass production system, with more variants for the client [5]. Liker and Rother [6] pointed out that numerous Lean programs have not succeeded as a result of the superficial approach of the organizations. Numerous organizations focused on the implementation of only hard Lean tools and techniques and neglected soft Lean practices (human-related practices) [6, 7]. Gupta and Kundra [8] claimed that this failure has to do with the consideration of Lean as a manufacturing strategy or process, instead of as a long-term philosophy. Some other factors for Lean failure are the underestimation of Lean by the top management [9,10]; resistance to change and organizational culture [11,12]; insufficient management support, inadequate training, and opposition to change [4]; and low understanding, use of incorrect tools, application of one tool to solve all the organizational problems, and a poor decision-making system [12]. Naranjo-Flores and Ramírez-Cárdenas [13] claim a methodology of intervention is needed

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which focuses on the correct application of Lean concepts under the premise of achieving results without forgetting the human factor. Nunes [14] argues companies do not realize the potential for further improving productivity gains if ergonomic principles are integrated and implemented at the same time as Lean Systems. The integration of the needs for effective production and a healthy workforce in the analysis and development of production systems could be the way to unblock the apparent conflict of interest between ergonomics and rationalization, according to [15]. Totorella *et al.* [16] stated that the LM approach brings forth the human element as a key factor for continuous improvement sustainability. From a Lean perspective, ergonomics leads to increases in productivity, improves quality, and makes safe human performance greater by aligning products, tasks, and work environment to people. From an employee's point of view, taking into account ergonomic issues having to do with workstation design, such as access to materials, equipment and tools and communication between workers, is absolutely essential for operator safety while working in the cell [17]. The Lean team has to view ergonomics and safety, in the same way as waste reduction and value creation, as basic values of the Lean process [18] for instance, by bringing risk assessments into the value stream mapping process [19] and thinking of ergonomics values in the context of a Lean implementation process in a Kaizen event [20]. Among the gigantic group of Lean tools, the majority were created to solve specific issues, namely high work-in-process levels, low availability of equipment or long setup times. Not more than a few of these (e.g. value stream mapping and Lean assessment tools) support Lean practitioners in pinpointing problematic areas to be worked on [21]. According to Wan and Chen [21], more attention has been given to the efforts made to address "how to become leaner" than to the matter of how Lean the system is. Liker [22] claimed that Lean implementation is at the same time a process and a journey, with no end state. He suggested that a company implementing Lean had to continuously monitor itself to identify the current level of leanness and future path of improvement: they needed to understand "where to start" and "how to proceed", as well as be aware of the available tools. With this in mind, Lean training and value stream mapping are the key actions to think about when executing a Lean implementation cycle [21]. The number of studies in the literature on leanness assessment, it must be said, cannot be compared to that in the area of Lean implementation. In the current study, an existing assessment tool, ErgoSafeCI, previously developed in the metallurgical sector, was tested and improved in the plastic packaging sector. ErgoSafeCI's goal is to improve ergonomics and safety conditions while simultaneously keeping productive performance indicators in focus [23]. It comes from the insight that when we put Lean and worker well-being together in a workstation improvement project, productivity goes up while work accidents and absenteeism go down. Brito *et al.* [23] claim that "this instrument aims to be a systematic long-term self-assessment model and was designed to be used in manufacturing companies by practitioners". To support the application and improvement of ErgoSafeCI in the plastic packaging sector, both research papers and practitioner works were examined to improve the existing tool. The questions were analysed and then the tool was used in three workstations/production areas of a plastic packaging company. Based on the results obtained, improvements were introduced to enhance productivity and worker well-being. This study is organized in the following way: Section 2 covers the analysis of existing research articles connected with assessment audits based on Lean tools and the integration of human factors in Lean assessment audits; Section 3 details the methodology followed in this study and the assessment tool suggested; Section 4 depicts the results of the study and Section 5 highlights the conclusions of this study.

2. Literature Review

Hines and Rich [24] suggested seven tools and a five-stage approach, the Lean processing program (LEAP), in the UK. This toolset, however, has not gotten much attention due to the complexity of the approach. The value stream mapping (VSM) technique created by Rother and Shook [25] has, in turn, become one of the most widely used Lean tools. Current and future state maps visually show the flow of value streams along with time-based performance, which results in a sense of urgency and indicates improvement possibilities. Karlsson and Ahlstrom [26] created a Lean assessment tool in which they identified nine variables to be assessed, which were: elimination of waste (EW), continuous improvement (CI), pull of materials (PULL), multifunctional teams (MFT), decentralization (DEC), integration of functions (IF) and vertical information systems (VIS). Soriano-Meier and Forrester [27] assessed the degree of leanness of manufacturing companies by resorting to these nine variables. Several other Lean assessment surveys, among them Feld [28] and Conner [29] have been introduced to guide users through the Lean execution. The scores in these surveys indicate the differences between the current state of the system and the goal levels of several Lean indicators predefined in the survey [21]. According to Nakajima [30], OEE (Overal Equipment Effectiveness) measurement is an effective way of analyzing the efficiency of a single machine or an integrated manufacturing system. It is a function of availability, performance and quality rate. An OEE of 100% means that only good parts are produced (100% quality), at the maximum speed (100% performance), and without interruption (100% availability). Sanchez and Perez [31] formulated a checklist of 36 Lean indicators in six groups to evaluate alterations towards Lean and Allen *et al.*[32] classified the metrics (performance actions for tracking effectiveness of improvements strategies) into productivity, quality, cost and safety. These assessment Lean tools are quite familiar but its focus is on assessing the whole sytem and not in the evaluation of the workstation specific features. Saurin *et al.* [33] realized that the existing systems were essentially designed to evaluate the level of Lean production implementation in the entire plant and not in specifc units of the manufacturing system, such as cells, job shops or assembly lines. Thus, they brought forth a framework for evaluating the use of Lean production activities in manufacturing cells. However, until then they did not consider human aspects. Jarebrant *et al.* [34] suggested the application of the ergonomic value stream mapping (ErgoVSM), a tool whose goal is to improve ergonomic conditions while at the same time monitoring productive performance indicators. This work is directed to providing academics and practitioners with a tool capable of meeting current needs in manufacturing environments in relation to cognitive ergonomics assurance in workplaces. The use of ErgoVSM in its cognitive modality tries to acknowledge the importance of evaluating health risks within each workstation at companies. Gonçalves and Salonitis [35] state workstation design evaluation needs to focus on both Lean and ergonomic aspects. Lean assessment usually leads to waste reduction in workstations and an ergonomic assessment ensures employee safety and comfort. This link is key to long-term success. Gonçalves and Salonitis [35] listed seven workstation design considerations – "health and safety", "work environment, cleanliness and orderliness", "waste elimination", "inventory and material logistics", "Improvement assessment tool ", "exibility", "visual management" and "quality". These authors created an evaluation model and a tool to evaluate every requirement based on Lean and ergonomic aspects which was designed for workstation design. This model takes the form of a checklist based on the best available practices in workstation design of assembly lines. The validation of the assessment tool took place in an automotive assembly line and, taking its results into account, improvements in the associate working zones, workstation dimensions, storage areas or parts feeding system, were implemented to improve "waste elimination" and "inventory and material logistics." Although this tool connects the elements of safety, ergonomics and Lean, its main use is the design of the workstation and it does consider some other key requirements, namely indicators of performance and continuous improvement [23]. Totorella *et al.* [16] devised a method that consists in a combination of techniques which make possible the identification of deficiencies connected with the adoption of Lean manufacturing practices which may support socio-technical practice implementation, indicating which improvement opportunities should be prioritized to better sustain them. The divergence between these tools and the ErgoSafeCI assessment is in the assessment of jobs by resorting to a combination of these basic dimensions: continuous improvement, productivity, safety, ergonomics, quality, visual management, work organization, and materials flow [23].

3. Methodology

The Action-Research methodology was selected for this work, which is now routinely used amongst researchers because of its ability to involve all the intervening parties in the problem-solving process, which is very important to all [35]. It differs from other methodologies in its practical section, given that it is described as research in action rather than research about action [36]. The Action-Research methodology can be executed in a project through a cycle consisting of five main phases [37]: Diagnosis, in which analysis of the detected problems and data collection takes place; (2) Action Planning, where the improvement measures to be taken are identified; (3) Implementation of measures, during which the planned actions are put into practice so as to resolve the problems identified beforehand; (4) Evaluation, where the outcome of the implementation phase is looked through; and finally, (5) Conclusions, in which the changes derived from the implemented improvements are pinpointed, and an assessment of the learning and difficulties during the process of research is undertaken. Fig 1 shows the Action-Research spiral.

During the study it was also necessary to use the ErgoSMED tool, developed by [39] to support the implementation of SMED (Single Minute Exchange of Die) considering ergonomic aspects.

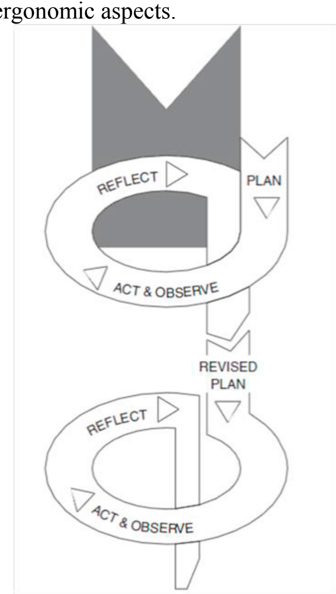

Fig 1. Action Research Spiral [38].

4. Results

The application of this tool was in a plastic packaging company. This is a plastic material processing company which is dedicated to the production of Polypropylene Film (PP) Cast, Polyethylene Sleeve (PE) in High and Low Density and also plastic packaging for different applications. Currently works for different markets (food, textiles, among others). The production area is divided into three sectors: extrusion, printing and cutting. The results were divided into two phases. First, ErgoSafeCI tool was analysed in order to adapt it to this sector and improve it through a bibliographic review. The second step was the application of the tool in the three productive sections of this company.

4.1. ErgoSafeCI tool improvement and review

This tool was developed with the ultimate goal of finding a way to improve the workplace, taking into account the efficiency and well-being of workers.

ErgoSafeCI, which consists of 83 evaluation questions, consists of 10 sections: efficiency, continuous improvement, safety, standards and visual management, process and operations, material flow, zero defects, physical ergonomics, organizational and cognitive ergonomics and discipline. Brito *et al.* [23] state these nine requirements where each one is considered as a way to have a productive, safe, ergonomic and Lean workstation.

The answers to these questions resulted in a visual indicator in the form of a radial graph with the score of each evaluation element. This tool aims to be a systematic long-term self-assessment model and was designed to be used in manufacturing companies by professionals.

The improvement of the tool consisted of three phases:

- The first phase was the analysis of all questions in the tool in order to understand whether they should be adapted or not to the productive reality of the plastics packaging sector. However, at this stage it was not necessary to make any adaptation;
- The second phase consisted of a bibliographic review on Lean, safety and ergonomics with a view to improve the tool's questions. This analysis led to the separation of ergonomics into two parts:
  - physical ergonomics;
  - organizational and cognitive ergonomics.

This separation was important in analysing the results and identifying improvements.

There was also a need to add some questions with the aim of improving workstation evaluation. In the health and safety section, the following questions were added:

- Have there been accidents or medical appointments?
- Is the layout of the workplace likely to cause accidents?

In the physical ergonomics the following questions were added:

- Does the worker have to use a non-adjustable chair?
- Does the job require the frequent use or manipulation of hand tools?

Finally, the organizational and cognitive ergonomics section suffered the most changes, with the following questions added:

- Is the work rate controlled by the worker himself/herself?
- Are work tasks or methods completely restricted by machines?
- Is the level of attention required by the job high?
- Are there frequent complaints from workers due to stress or pressure caused by work?
- Are workers' mistakes frequent?
- Is the training time for this job too long?
- Is the work made up of unambiguous tasks with information clearly displayed?

The third phase consisted of improving the software tool with the aim of making it more user friendly.

In order to make the tool more user friendly, it was necessary to make the process of conducting the questionnaire simpler and more intuitive, with the introduction of automatic processes and leaving aside "manual" processes, where the probabilitty of making mistakes is greater as well as the time of accomplishment. It was also essential to automate the method of obtaining the radial graph so that the user only needs to press a button to obtain it.

The initial purpose for the development of this tool was to conciliate two great existing tools, which are Microsoft® Forms and MS Excel® through the use of VBA (visual basic), macros and graphs. The initial idea was to use the Microsoft® Forms to realize the questionnaire at *Gemba*, due to the fact that it is a simple, practical and easy to access tool that can be used on a desktop computer, smartphone or tablet. The second step was to load the data obtained from the completed form, through Microsoft® Forms, and then make the treatment of them using a macro developed in VBA, wich automatically returns, by selecting a button, a spider graph that indicates the scores obtained by área as well as the average score and the goal to achieve. Fig 2 shows an example of the interface used in Microsoft Forms.

Fig 2 Microsoft® Forms interface.

Visual Basic is a programming language created by Microsoft®, which differs from the others by the fact that it is a more visual language in contrast to the textual aspect of the others. The comands used in Visual Basic® are extended to meet the needs of an application oriented to graphic environments. This programming language is considered a revolution in the computer world due to its versatility and relative ease of learning when compared to other languages. However, even though the applications created by VBA be more friendly to the final user, these are more difficult to make from the point of view of those who create them.

A macro (Fig. 3) is nothing more than a sequence of commands and functions stored in a VBA module, being used as a kind of shortcut to repetitive tasks, aiming to achieve a lesser "loss" of time in long stages through its automation. The macro recorded in MS Excel®, stores the information related to each step performed as a series of commands is executed. There are two ways to create a macro, one of them using the "Macro Recorder" in the MS Excel® menu, consisting of a process in which several steps are recorded, which the macro is intended to do and then it automatically performs these steps itself. Another way is to use a VBA code, creating a programming code that performs the intended tasks. After the macro is realized, it is possible to associate it with a "button" to facilitate its execution.

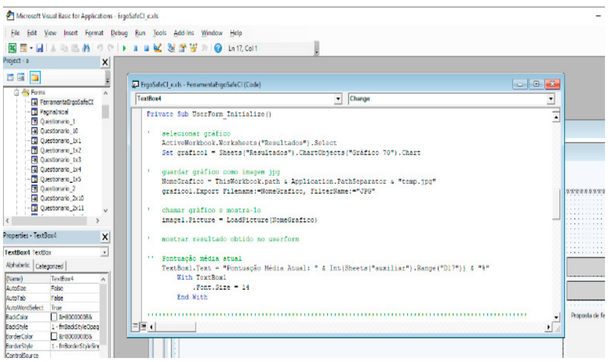

Fig. 3. Example of a macro.

With the conclusion of the initial idea for reconciling the Microsoft® Forms tool with a macro (MS Excel®) to handle the data, it was found that the transfer of the data obtained from the questionnaire to the MS Excel® tool, makes the process slower, which does not fit in the Lean mentality. This combination submits the user to more laborious tasks, and they do not add extra value to the "final product".

Thus, it was concluded that it would be better to integrate the questionnaire itself in the file of the MS Excel® tool, eliminating the intermediate step of transferring data from the questionnaire to MS Excel®. For this, it was necessary to resort to UserForms, where the end user can carry out the questionnaire in a simple and intuitive way, assimilating to the process performed in Microsoft® Forms.

A UserForm is a window or dialog box that makes up part of an application's user interface and also makes a user data entry more controllable and easier to use. Fig. 4 shows the interface with the evaluation results.

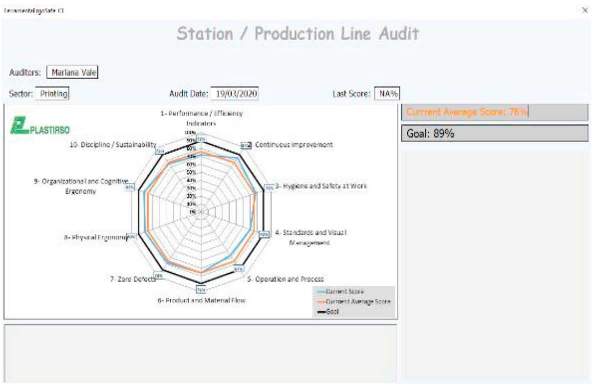

Fig. 4. Interface with the evaluation results.

After a few attempts it was then possible to achieve a cleaner and user friendly tool, thus, any user less "instructed" can carry out an assessment to an industrial sector and identify its strengths and points to improve, using the obtained radial graph.

4.2 ErgoSafeCI tool application

The score of the workstation /production area assessed was given in the form of a percentage, which represented the level of Lean implementation considering safety and ergonomic aspects. The final percentage was calculated from the average of the percentages of each item, according to the answers given: 100% if it was OK, 0% if it was NOK. In case of a not applicable question, this question was ignored for the calculation.

After improving the ErgoSafeCI tool, it was used to evaluate the three production areas in the plastic packaging company.

After the process was concluded, the company took the results obtained in the assessments and put them in practice to help identify the most critical areas, especially the ones with the worst assessment scores. The members of the assessment team, were then asked to analyse the process of these critical production areas, thoroughly and suggest some changes which could improve ergonomics and safety conditions, and simultaneously improve indicators using Lean principles, such as reducing wastes. To do this, it was important to analyze the radial graph of each section (Fig. 5, 6 and 7).

As the three areas had the same score, the indicators with the lowest score were analyzed. OEE indicator is one of the indicators evaluated in the tool and it is calculated by machine

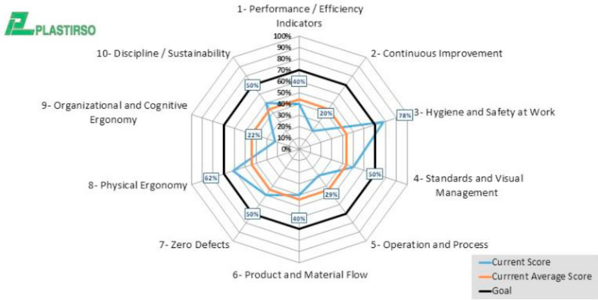

Fig. 5. Radial graphic of printing.

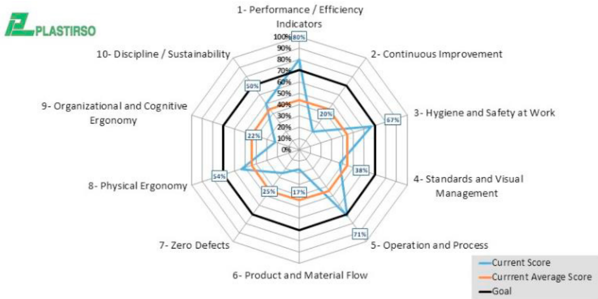

Fig. 6. Radial graphic of extrusion

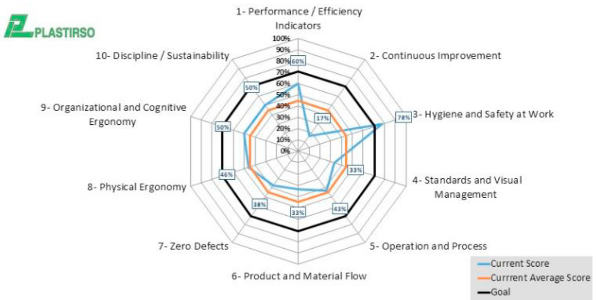

Fig. 7. Radial graphic of cutting.

through the average of the six previous months, considering quality, velocity and avaliability. OEE in the printing sector is presented as the lowest of the three items, so it was selected this area for optimizing. Analyzing the radial graph of this sector, it is detected that the areas of Continuous Improvement, Organizational and Cognitive Ergonomy and the Operations and Processes obtained low scores. The area of organizational and cognitive ergonomics shows also a low score due to errors in the introduction of production records on tablets. These errors arise due to worker distractions, because they are doing several tasks at the same time. One of the problems is also linked to the fact that there is no job rotation and no rest breaks, leading to psychological exhaustion and tiredness. Other problems were also identified after an analysis of the current situation:

- Execution of external tasks during the setup, which includes the preparation of raw materials, preparation of clichés and ink;
- Time lag between the operator and the shift manager leading to waits. The shift manager took too long to search for the material, as there were no locations in the warehouse, the material was scattered throughout the factory.

In order to reduce these kind of wastes, reduce the setup time, and improve the working conditions at the same time, the team proposed the use of the ErgoSMED tool.

The equipment selected to implement this tool was Imp.03 because it had the longest setup time (Fig. 8) and it is also responsible for producing the reference with the highest current volume.

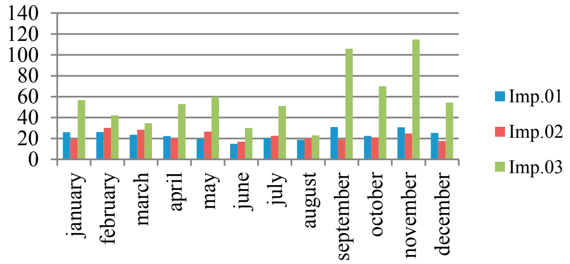

Fig. 8. Average Setup time (min) of the Impression machines.

Before the implementation of the ErgoSMED tool, the project team held some training sessions in the classroom, within the scope of several Lean Manufacturing concepts and Ergonomics. The first step was the separation of the internal and external tasks of the setup [41,42]. It was identified a total of 13 tasks, 8 external and 5 internal tasks (Table 1).

Table 1 - Distribution of changeover time in external and internal activities

Tasks	Percentage	Time (min)
External	42%	29.5
Internal	58%	41
Total		70.5

Next step was the implementation of measures to reduce the time of the internal tasks by automate several manual tasks, such as: placing the cylinders in the machine and cleaning the ink cartridges. In this step, the team used the ErgoSMED tool in order to improve productivity by reducing the setup time, considering ergonomic aspects at the same time. After the implementation of these improvements, there was a 50% reduction in setup time (Table 2).

Table 2 – Results of the setup stime after improvments

Tasks	Percentage	Time (min)
External	49%	29.5
Internal	51%	31
Total		60.5

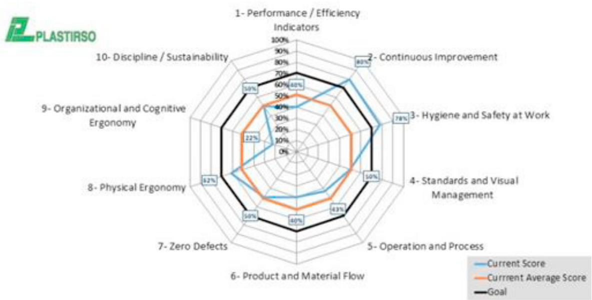

Fig. 9. Radial graphic of Impression after improvements

The final step was the implementation of standards in this area, such as: Work Instructions and 5S Audits. The team returned to use the ErgoSafeCI tool in the printing area, to verify if the score exceeded in the areas where the improvements were made (Fig. 9). The score went up to 51%, through the implementation of Continuous Improvement, Physical Ergonomy and Operations and Process areas. Next step will be the implementation of increasing measures in Organization and Cognitive Ergonomy, the area with the lowest score at the moment.

5. Discussion and Conclusions

Aqlan et al. [43] claim ergonomics can be the basis for Lean transformation by cutting the related wastes, and Lean transformation can lead to the lowering of ergonomic risk. Effective ergonomics methods can increase productivity, lower work injuries and make workstation design and layout better. Ergonomic intervention may at the same time be seen as a tool in bringing wasteful motion levels down, through identifying ergonomic risk factors while working [44]. "Waste" motions in ergonomics, for instance stretching, bending, awkward postures and extreme reaches may not only impact the safety and health of workers negatively but at the same time reduce productivity and efficiency Yusuff et al [45]. During this study, there was an opportunity to apply and improve the ErgoSafeCI tool (shorter assessment execution time, more user friendly and more cleaner) and also support studies previously carried out, which demonstrated that ergonomic risks could lead to Lean wastes and vice versa, which means that workplace ergonomics and Lean manufacturing are very closely connected to one another [44]. From the results, it can be concluded that certain improvements can reduce the setup time by 15% which translates into an increase in productivity by changing some work methodologies.

Correia et al. [46] state that there are many residues that can be eliminated with simple and dry tools. It is not very complicated, but it would bring essential benefits.

Ergonomics can be the basis for a Lean transformation and a Lean transformation can in turn result in the reduction of ergonomic risk [43]. In fact, this work made it possible to prove that through the implementation of Lean tools and considering the ergonomic aspects it is possible to improve a company's productivity as well as the work conditions of the worker.

Morgado et al. [47] state that it is necessary to encourage companies to reflect on OSHMS (Occupational Safety and Health Management System) and its influence on the company can guarantee its success and sustainability.

The ErgoSafeCI tool has gone through several improvement cycles, manual operations have become automatic to simplify the auditor's work. The process of carrying out the assessment in the workplace becomes simpler, reducing the time of about 15 min to 10 min and also reducing or even cross off potential response input errors in the evaluation survey. It was also possible, during this work, to improve the assessment tool. However, it is necessary to validate it in other productive and non-productive sectors at same time. The team also identified some areas for improvement in the tool. It should not only show results but also guide the user in choosing the tools or methods to be used to improve critical sectors, that is, the ones evaluated with the lowest scores. One possible solution would be for the tool to suggest other Lean tools or more specific methods of ergonomic analysis.

Acknowledgments

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