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Procedia Manufacturing 41 (2019) 1023–1030

Procedia MANUFACTURING

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8th Manufacturing Engineering Society International Conference

Improvement of Production Line in the Automotive Industry Through Lean Philosophy

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Abstract

This work refers to concepts and definitions of Lean Philosophy. The main targets were to study how waste reduction can be achieved on a production scenario, by identifying added-value operations, enhance productivity, levelling and over-processing reduction. The project behind this study is a massive one, which involves the installation of seven final production lines and more seven pre-assembly lines, being considered by the company, a project that must be as profitable as possible. After implementation and validation, costs were evaluated and the savings reached 10,9 % (2 159 000 €) considering all costs of industrialization.

Keywords: Lean; Reducing Costs; Waste; Production Levelling; 5S; Standard Work.

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Peer-review under responsibility of the scientific committee of the 8th Manufacturing Engineering Society International Conference.

1. Introduction

Nowadays, the dynamic nature of the market, with the ever-tightening competition and more demanding clients, companies needs to be focused on reducing costs, in order to remain competitive and adapt to the needs of the market [1]. For some years, many companies have been working on Lean thinking philosophy. They have been implementing actions that reduce significantly the companies' wastes. These days, more than ever, they searching for alternatives that reduce the percentage of activities that don't add value to the product. It is of extreme importance to any company.

The main goal of this scope was to reduce the production costs of a manufacturing plant. This goal was conducted on an existing and recently installed Production Line. This Production Line is part of a customer project which includes a further installation of more six production lines to the current one. This project had a big impact on factory costs. Each cost reduction measure can have a significant impact on the total cost of industrialization and production. In order to accomplish the improvement status, wastes were identified. The diagnosis was performed under support of Lean tools, and measures like optimization of the machines processing time, balancing of the Production Line and reduction of the number of machines were implemented. Several contributions may be associated with this study, however the main contribution for the industry were: 1) Achievement of a big cost reduction without major physical changes on Production Line equipment; 2) Application of this study to similar Production Lines; 3) Contribution to the scientific literature with a scope on improving a Production Line.

2. Literature Review

Womack, in 1992, on the book "The machine that changed the world", used for the first time the expression Lean Manufacturing, doing a retake of the history of automobile production combined the Japanese, American and European production lines [2]. Lean Manufacturing (LM) consists of producing, by maximizing the economy of resources, to represent the products developed in Toyota [2]. Lately, Lean Thinking concept is described as being a philosophy that imposes less time since the order placement (Lead time), obtaining products and services with high quality and low cost, through improvement of production fluxes, by reducing wastes on the flux chain, that we can see through Value Stream Mapping (VSM) or Waste Identification Diagram (WID) [3,4]. Applying this tool brings real advantages, as proved by [5]. The authors stated that it could reduce 2,5 days the Production Lead-Time (PLT), and, the value added-time lowered from 68 minutes to 37 minutes. LM philosophy aims to eliminate wastes, to potentiate (in Japanese called) MUDA that reflects the need to reduce waste in order to increase profitability. It corresponds to everything that is not the minimal quantity of equipment, materials, space and time necessary to add value to a product [6]. The most common wastes that can exist in a production system, are classified in seven types: Overproduction, excessive stock, transport, unnecessary dislocations, waiting, defects and over processing [7-9]. As shown in [10], by applying lean tools it was possible to reduce inventory level, that led to minimization of the other seven wastes mentioned previously. The 5S's main goal is to achieve a state of cleanliness and organization that promotes the efficiency and effectiveness of the production environment in an organization [11]. The great benefit of applying the 5S methodology is the obtained discipline in the productive space. However, there are others, such as standardization and documentation that can lead to reduced cycle times, efficiency gains and less movement, which directly affect transport and inventory waste. This methodology has several benefits for the organization as a whole, of which the most relevant is the reduction of waste, time and space [12,13]. The application benefits of the 5S range from quality to hygiene and safety [9]. A tool in the productive context is the methodology of standard work, which aims to standardize the sequence and execution of activities at each workstation. This ensures that procedures are carried out in the same way, regardless of the employee involved [14]. However, before this can be undertaken, the production levelling must be considered in order to achieve balance workloads in each workstation and smooth production flow, thus meeting the required demand [15]. This methodology was implemented by Rosa et al. [16] in a production line during the peak years of production life cycle leading to an increase in production of 41 %. As shown in [17], a well-designed layout led to reduced cycle times using the same number of operators, better workload distribution, resulting in a 10% raise in productivity.

3. Methodology

In order to achieve the proposed goal for this scope, it was followed by a methodology based on Action-Research principles, in which all members involved are investigators, through "learn by doing" [18]. Identification of a problem leads to a solving measure, with further validation of the result, and if it is not enough, a new measure is generated followed by a new validation process [19]. There are five steps on which should an investigation be carried out [20]. The first step is the diagnosis of the problem, which includes the definition of general goals and relevant data collection. The second step is to plan measures, preparation and developing of improvement actions, through observation and mapping of initial status and further identification of problems. The third step is the implementation of measures planned and obtaining results of actions implemented. After on the fourth step, an evaluation is done, and it is determined if it is enough the current status achieved or if there is something more to be done. Finally, in fifth the conclusion, where it is detailed all methodology developed, tools applied to achieve it, as well as the presentation of work done and suggestions for further work.

4. Improvement of a Production Line in the Automotive Industry

The production line on which this study was undertaken is operated usually by ten operators. The line is composed of two different lines. The first stage, which is performed by the first line, is a fully automatic line, that the aim is to glue two parts with very low tolerance. Therefore, there is needed a robust and precise process, which cannot be performed by operators. This line is operated by only one worker, who has to load and unload parts one the beginning of the line. After this process, the assembled part goes to the next line, final assembly. This one is operated by nine operators. There are standard works for working from seven to nine workers since is not always needed the line at full capacity, due to lower order quantities from a customer or lack of material supply. According to Fig.1, the processes installed in the line are screwing, glueing, plasma surface activation, inspections and manual assembly of parts and electronic components. Fig.2 shows the Cycle Time (CT).

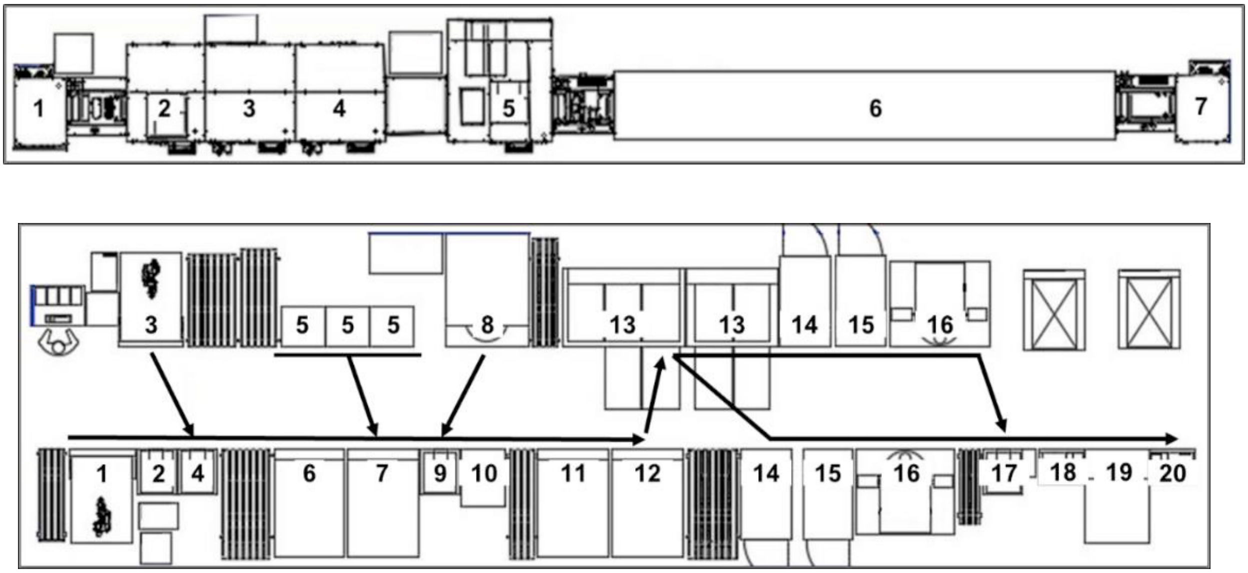

Fig. 1. Process Description and Workflow

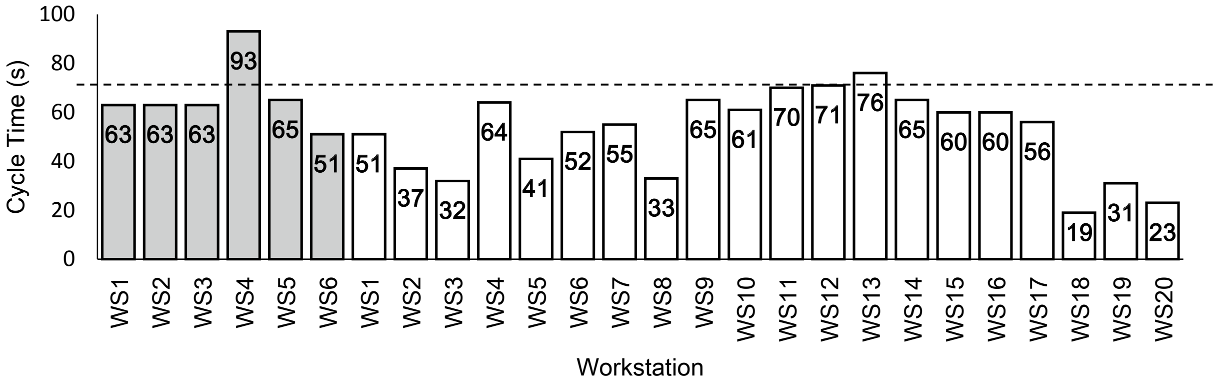

Fig. 2.Cycle Time

4.1. Problems Identification / Opportunities for improvement

Based on the process analysis, undertaken through observation of the production flow, table 1 presents a detailed description of the problems identified on the line. It is important to point out that this line was a first of a kind since it was a new product for the plant, therefore it is expected that after a period of samples production, opportunities for improvement are found. This involved evaluating which resources and specifications were required, reducing wastes and adjusting production flow between workstations. The main purpose was to reduce costs for the plant.

Table 1 Identified Problems / Opportunities for Improvement

Problem	Description
CT of Gluing Line above target	The CT needed to meet with the customer needs is 72s. Time measurements were obtained and were verified that there was one workstation with 93s of CT. All the rest equipment was under the target CT. This deviation on the CT means that is produced less 76 000 parts per year, 22% of total production. In this scenario, from a production point of view, there is a lack of capacity in production, not matching the needs pulled by Logistics and failing in meeting the customer demand and workstations are not balanced which means that resources installed are being wasted because of the big bottleneck deviation in CT.
Stock between lines	Both lines have a similar target CT. If target CT is achieved on the Gluing line, it is possible to supply directly the Final Production line, without creating stock between the lines. Generating stock means money stuck, Work in Progress, more unnecessary movements to storage and pick materials and production area that is occupied with non-adding value infrastructures.
Transportation on Gluing Line process	Analyzing the glueing process that was established for the Gluing line, is realized that there is more transportation than the necessary. Transportation is a non-adding value action, so it should be reduced to the minimum needed for production
Workstation removal	On the Final Production line, there are two workstations that perform the same process but in different parts. These workstations are physically the same. The workstation just differs on the tool that is specific to the part. Each workstation has two tools. The tool was built considering a quick changeover.
Workstation CT reduction	This workstation is the bottleneck of the Final Production Line, with 4s more than the target of 72s. It is a workstation that is duplicated in the line and it is the most expensive equipment installed in the line. This workstation is test equipment and its main function is to heat the product till a stable functionally working state. This time of heating the product is the CT of the workstation. The heating time was defined based on the know-how acquired with other products previously produced in the plant.
Inspection reduction	The workstation in analysis performs a material dispensing in a part. After the dispensing, in the same workstation, there is an inspection of this dispensed material. But, since the part is assembled only in the workstation after there is another inspection right before assembling in the product. The same inspection is performed two times and inspection doesn't add value in the product. The process itself generates more costs of production, there is over processing, one of the workstations is more expensive because there is installed inspection equipment.

4.2. Proposed solutions

Based on the process analysis presented in Table 1, were proposed solutions for each identified problem.

CT of Gluing Line above target

As mentioned the Gluing line was not producing according to the target established. Its CT is 93 s and the target is 72 s. This CT was set at this value due to one bottleneck workstation, that had a CT much higher than what was planned. The workstation in analysis performs automatically a precision assembling of two parts with a robot. It was proposed to improve robot movements until achieving a state of art process, having no wastes and not adding any risks on the quality of the assemble. After listing all steps performed in the workstation and counting its times, it was defined which steps should be shorted in time, eliminated or performed in parallel. After all improving actions were implemented, CT was measured again and the workstation CT was set in 68 s.

Stock between lines

Both lines are working with similar CT, so, instead of having stock between them, it was proposed to have a direct flow of material, by connecting physically the two lines. In this scope, there were two proposals. First one, it was proposed to unify both lines in line, and, so, have one production flow only (Fig. 3). Though, and due to space factors, it is not possible to implement this solution in a short-term date, and, so, it was abandoned.

Fig. 3. Proposal Layout 1

The second proposal was to have a conveyor unifying both lines and even eliminate one machine from the final production line, and perform that production step in a similar machine of the Gluing Line (Fig. 4). The cons of this proposal are Lead Time of first part being produced for the Gluing Line. Time is too high and has risks of quality for the part that is being produced.

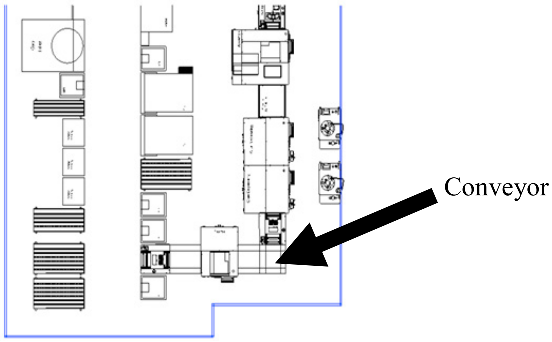

Fig. 4. Proposal Layout 2

Resuming, both ideas were abandoned due to the cons of their implementation. Besides abandoned, both ideas have the potential for further implementation in future or in other projects.

Transportation on Gluing Line process

In Gluing Line there are three machines which its main function is the transportation of parts (Fig. 5). Transportation is identified as a waste, so, the analysis started in order to check and decide if this is necessary.

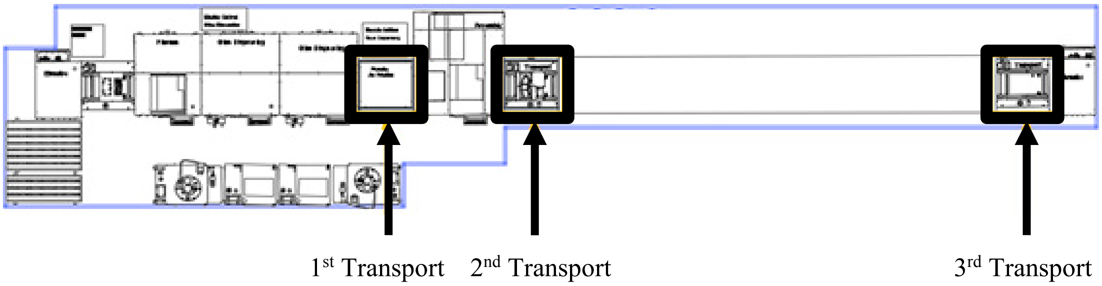

Fig. 5. Transportation on Gluing Line

First transport has as its main function transportation of parts and removal of parts from the previous process. Second transport is located after the assembly machine and before a long oven. Its main function is to transport and allow removal of NOK (Not Okay) parts of the assembly process. The third transport its's located at the end of the oven and before a lift, and besides transportation, it also has the capacity to hold one part while the lift is moving, so that is not needed to stop the oven when a part is coming out and the lift is on the lower level. From the analysis, it's the third transport is crucial for a good working of the Gluing Line. Though, there is a possibility for improvements between the first and second transportation. The proposal was to eliminate the first transport and the removal of NOK parts starts to be done also in the second transport, having the assembly machine working in bypass mode when it happens to have a NOK part passing through.

Workstation Removal

In the final production line, there are two machines that are physically equal and perform the same process but to different parts. Each machine has two fixtures to place the part that goes to inside the machine and has the job is done (Fig. 6)

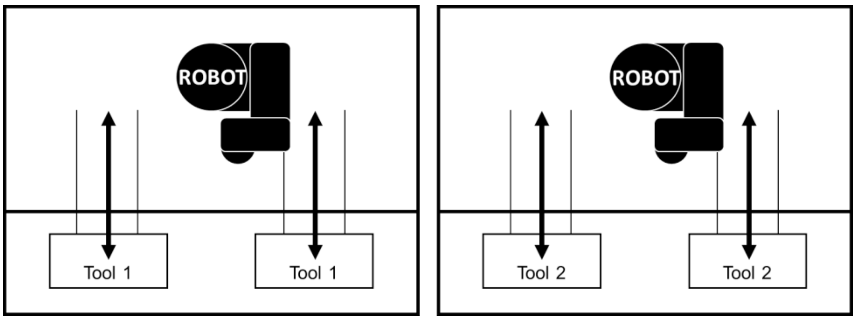

Fig. 6. Workstation Scheme

There are two machines, each with two fixtures due to CT. There is potential to merge these two machines in a single one, working with one fixture for each part. The target CT is 72 s. If a merge was made in this status, CT would be 83 s. The same improvement activity that was performed in assembly workstation of the Gluing Line was made to this workstation too. After listing all steps performed in the workstation and counting its times, it was

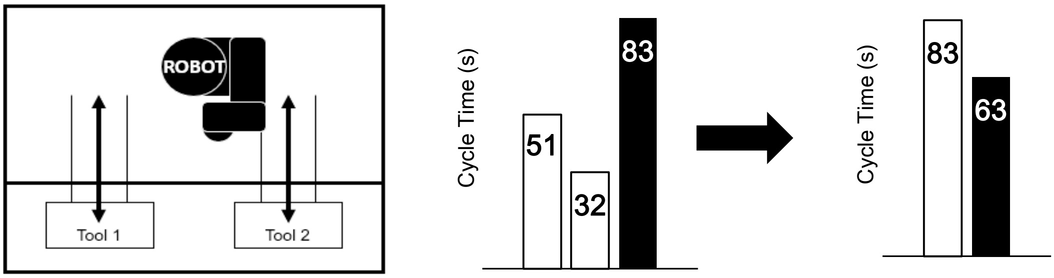

Figure 7 Merge of Workstations

defined which steps should be shorted in time, eliminated or performed in parallel.

After all improving actions were implemented, CT was measured again and the workstation CT was set in 63 s (Figure 7).

Workstation CT Reduction

This workstation is the bottleneck of the final production line, with 4s more than the target of 72 s. It is a workstation that is duplicated. This is test equipment and its main function is to heat the product till a stable functionally working state. This time of heating the product is 30 minutes and there is a capacity for 18 parts in one machine. Any improvement can reduce the CT and lead to a state where is only one equipment needed in the line. A scope with 125 parts was made, and it was concluded that the behaviour of parts is stable after 700 s, in other words, after 700 s of heating the part, all display parameters are stable. With 700 s of heating each part, this equipment is no longer a bottleneck. Further talks were made with the customer.

Inspection Reduction

The workstation in analysis performs a material dispensing in a part. After the dispensing, in the same workstation, there is an inspection of this dispensed material. But, since the part is assembled only in the workstation after, there is another inspection right before assembling in the product, because human handling increases the risk of damaging the dispensed material. The same inspection is performed two times and inspection does not add value in the product. The process itself generates more costs of production, there is over processing and one of the workstations is more expensive because there is installed inspection equipment.

4.3. Results Analysis

After analysing problems and improvement opportunities, a financial evaluation should be done to enlighten how each measure was effective in reducing the cost for production. For the first problem identified there was no immediate saving with CT reduction of the Gluing Line because it was only planned to have one line, that is worth around 1 million €. The second opportunity was not implemented. The third measured proposed was to reduce the transports in Gluing Line. It was possible to take out one equipment from the line, resulting in a saving of 12 000 € for each line. Since there will be 7 lines, the saving for this project is around 84 000 €. The fourth measure was to merge two workstations that were the same. Each one of these machines costs 100 000 €. Since it was possible to remove one workstation of the final production line, and being this one usable for the next line, the savings for this measure were around 700 000€. The fifth measure was the reduction of a CT of test equipment. This reduction leads to a reduction of equipment units in the line, from 2 to 1. Each test machine costs 175 000 €, meaning a total saving of 1 225 000. For last, the inspection elimination on a standard machine reduced the cost of the machine in 25 000 €. Since there is already one machine installed, it will only be saved investment on future lines. The total amount saved will be around 150 000 €.

5. Conclusion

Lean philosophy provides to companies' strong tools for low-cost solutions, enhancing productivity. It was possible to optimize the production process by observation on the field, identifying improvement points and thinking "Lean". Wastes like over-processing, transportation, motion and others were eliminated. The maximization of workstations was achieved, resulting in more efficient usage of the production area. From total investment planned for this project, it was possible to save 2 159 000 €. This is equivalent to 10,9 % of total investment planned for this project.

6. References

[1] U. Dombrowski, T. Mielke, and C. Engel, "Knowledge management in lean production systems," *Procedia CIRP*, vol. 3, no. 1, pp. 436-441, 2012.

[2] "The machine that changed the world: By James P. Womack, Daniel T. Jones, Daniel Roos," Bus. Horiz., vol. 35, no. 3, pp. 81–82, May 1992..

[3] M. Rother and J. Shook, "Learning to see: Value stream mapping to create value and eliminate muda," Lean Enterprise Institute. 2003.

[4] J. C. Sá, J. D. Carvalho and R. M. Sousa, "Waste Identification Diagrams" in CLME'2011-IIICEM – 6º Congresso Luso-Moçambicano de Engenharia – 3º Congresso de Engenharia de Moçambique, Moçambique, Maputo, 2011, pp. 1-7. Available: https://repositorium.sdum.uminho.pt/bitstream/1822/23930/1/Artigo%2520%255BWaste%2520Identification%2520Diagrams%255D.pdf.

[5] J. M. Rohani and S. M. Zahraee, "Production Line Analysis via Value Stream Mapping: A Lean Manufacturing Process of Color Industry," *Procedia Manuf.*, vol. 2, no. February, pp. 6-10, 2015.

[6] S. J. Pavnaskar, J. K. Gershenson, and A. B. Jambekar, "Classification scheme for lean manufacturing tools," *Int. J. Prod. Res.*, pp. 3075–3090, 2003.

[7] C. Marques, N. Lopes, G. Santos, I. Delgado, and P. Delgado, "Improving operator evaluation skills for defect classification using training strategy supported by attribute agreement analysis," *Measurement*, vol. 119, pp. 129-141, Apr. 2018.

[8] T. Ohno, *Toyota Production System: Beyond Large-Scale Production*. Oregon: Productivity Press, 1988.

[9] S. Shigeo, *A Study of the Toyota Production System: From an Industrial Engineering Viewpoint*. CRC Press, 1989.

[10] N. Norani and U. Utara, "Lean Manufacturing Implementation in Malaysian Automotive Industry : An Exploratory Study Lean Manufacturing Implementation in Malaysian Automotive Industry : An Exploratory Study," vol. I, no. January, pp. 6-10, 2011.

[11] S. K. M. Ho, "The 5-S auditing," *Manag. Audit. J.*, vol. 14, no. 6, pp. 294-301, 1999.

[12] J. Oliveira, J. C. Sá, and A. Fernandes, "Continuous improvement through 'Lean Tools': An application in a mechanical company," *Procedia Manuf.*, vol. 13, pp. 1082-1089, 2017.

[13] C. Costa, L. P. Ferreira, J. C. Sá and F. J. G. Silva, "Implementation of 5S Methodology in a Metalworking Company" in DAAAM International Scientific Book 2018, vol. 17, Vienna, Áustria: DAAAM International Vienna, 2018, pp. 001-012.

[14] G. Santos, J. Afonseca, N. Lopes, M. J. Félix, and F. Murmura, "Critical success factors in the management of ideas as an essential component of innovation and business excellence," *Int. J. Qual. Serv. Sci.*, vol. 10, no. 3, pp. 214-232, Sep. 2018.

[15] J. P. Pinto, *Pensamento Lean - A Filosofia das Organizações Vecedoras*. Lidel - Edições Técnicas, lda., 2009.

[16] C. Rosa, F. J. G. Silva, and L. P. Ferreira, "Improving the Quality and Productivity of Steel Wire-rope Assembly Lines for the Automotive Industry," *Procedia Manuf.*, vol. 11, no. June, pp. 1035-1042, 2017.

[17] S. S. Gnanavel, V. Balasubramanian, and T. T. Narendran, "Suzhal – An Alternative Layout to Improve Productivity and Worker Well-being in Labor Demanded Lean Environment," *Procedia Manuf.*, vol. 3, no. Ahfe, pp. 574-580, 2015.

[18] C. P. Coutinho, A. Sousa, A. Dias, F. Bessa, M. J. Ferreira, and S. R. Vieira, "Investigação-acção : metodologia preferencial nas práticas educativas," *Revista Psicologia, Educação e Cultura*, vol. XIII, no. 2. pp. 445-479, 2009.

[19] W. Carr, "Philosophy, methodology and action research," *J. Philos. Educ.*, vol. 40, no. 4, pp. 421-435, 2006.

[20] G. I. Susman and R. D. Evered, "An Assessment of the Scientific Merits of Action Research," *Adm. Sci. Q.*, vol. 23, no. 4, p. 582, 1978.