Proposal to optimize the rate of defective products by applying Lean Manufacturing tools in a company in the metalworking sector of stainless steel studs inside the framework of digital and intelligent manufacturing.

Karen G., Carbonel[1], Rodrigo F., Rodriguez[2], and Martin J., Sáenz[3]
[1,3]Peruvian University of Applied Sciences, Peru, u201912297@upc.edu.pe , pcinmsae@upc.edu.pe
[2]Peruvian University of Applied Sciences, Peru, u201910197@upc.edu.pe

Abstract– This article proposes a solution to reduce defective products index a company that operates in the steel study production in metalworking through the implementation of Lean Manufacturing tools. The methodology applied consisted in a revision bibliography of concepts theorists in Lean Manufacturing and tool identification applicable to address the issue. In addition, an analysis of the current situation of the company was carried out to identify the causes root of defective product. The implementation of tools was proposed as job standard, TPM, SMED. The solution proposal focused in defective products index by implementing Lean Manufacturing tools suggests animprovement significant in product quality and decrease of the production costs, leading to an increase in the competitiveness of the company in the market.

Keywords—Lean Manufacturing, defective products, TPM, Standarization work, SMED.

I. INTRODUCTION

Currently, the industry manufacturing this growing so much at the level national as worldwide, so it is positioned as one of the activities that contributes a great impact to the economy of the countries. [1] The industry manufacturing contributes to growth economic. In this case study, the focus will be in the steel sector and problems you have faced on a daily basis. The problem further striking is generated in regarding the quality of the final products, the which are expressed through defective products [2] The importance of detection is highlighted prompt of defective products in the processes productive parts of the supply chain to avoid costs additional and improve customer satisfaction offering quality products of low manufacturing cost. The objective of this case study is to reduce the very high rate of defective products that are generated in manufacturing companies through an optimization proposal based on the implementation of the Lean Manufacturing methodology. [3] Said LM methodology is characterized by seeking continuous improvement by reducing waste and industrial waste and by delivering products characterized by high quality accompanied by low manufacturing costs. Specifically, Total Productive Maintenance (TPM), the tool, will be applied. SMED and the standardized work tool together with a methods study.

II. LITERATURE REVIEW

A. Case study and problems

One of the greater problems that generate greater impact in bliss industry (specifically in the metalworking sector) are the defective products mentioned above. The objective of this case study is power reduce the great high rate of defective products generated in companies manufacturing through a optimization proposal based in the implementation of the Lean Manufacturing methodology. [4] Bliss LM methodology is characterized by seek continuous improvement by reducing waste and waste industrial and deliver characterized products by his high quality accompanied by a low manufacturing cost. It will apply Maintenance Total Productivity (TPM), the SMED to and the work tool standardized together with a methods study.

B. Lean Manufacturing

The Lean Manufacturing methodology, its tools and techniques employees show as the basis of the model proposed. Given this, take a lot relevance know as It works and what it consists of bliss methodology. [5] the Lean Manufacturing methodology is established such as the proportion and delivery of characterized products by his high quality accompanied by a low manufacturing cost of said product. Has as purpose minimize the costs operational reducing waste, waste and defective products.

C. Maintenance Total Productive (TPM)

TPM tool is essential to resolve the causes root of the main problem, the which shot blasting machinery is located in state of deterioration, [6] the TPM tool has as main objective eradicate the time deaths and losses associated with both quality like cost overruns during production process. Bliss tool and the base of its pillars us will allow attack downturn problem availability of machinery (ovens, shot blasting machine, compressor, among the most important) by unplanned stops by breakdowns mechanical Bliss tool will allow Optimize Maintenance Management in regarding the company's machine.

D. SMED

[7] SMED is defined as a technique used in the processes productive to reduce tool change time, improve the machinery configuration parameters and improve the flexibility of the production process.

E. Standardization work

[8] The job standardized is a continuous improvement tool that seeks unify the implementation of activities that make up a process productive to improve the measure of efficiency and effectiveness of these. Furthermore, this Lean manufacturing tool is one of the most used by companies manufacturing.

F. Digital and Intelligent Manufacturing and Managament

[9] The digital and intelligent framework of management and manufacturing has great relevance in the proposed model. In this way, [10] is defined as the way to carry out a precise and reliable design within a production process, which generates energy savings, reduction of consumption, and a significant improvement in quality and efficiency. Likewise, [11] smart manufacturing also has the focus of reducing costs and increasing efficiency through the unification of manufacturing, intelligence, digitalization and finally information technology.

III. PROBLEM ANALYSIS

The company on which it is based present studio is dedicated to the manufacture of parts based on steel , that is, it is found in the manufacturing sector , but specifically in steelmaker. For him present study was taken in consideration the main family of products which is the asparagus . Having a high rate of defective products represents an impact economical of $. 21 797.70 which is reflected in the cost overruns generated by reprocessing waste , waste and overtime.

Image 1 shows the comparison between the average of the index of defective products in the sector and the company index. Bliss comparison was obtained based on the defective product rates from period from 2021 to 2022. This high index display of defective products generates a significant impact on the company negative in the profits net.

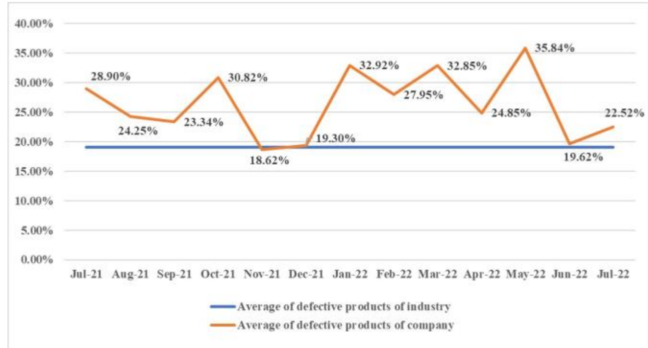

Fig 1: Graph statistic of % of defective products of the company vs. sector.

As shown in Table I, it can be observe the number of reasons that make up the problem initial and the frequency with which they appear to produce defective products.

TABLE I
Motives

Item	Motives	Quantity
1	Deterioration of shot blasting	91
2	Lack of work procedures in the coating process.	50
3	Low quality raw material.	9
4	High staff turnover.	6
5	Errors in cutting steel.	2
	Total	158

To determine the main reasons that cause the problem in the company, an analysis of the current situation of the company was carried out, as shown in Fig. 2, the Pareto diagram shows that one of the main problems are the machine deterioration shot blasting machine defective 57.59 %, lack of work procedures in coating area 31.65 % and other reasons representing 10.76 %. [12]

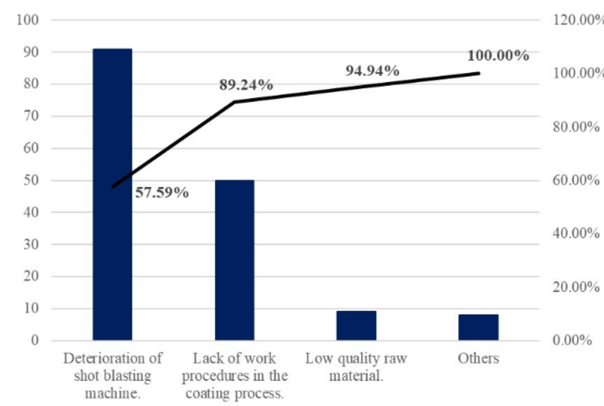

Fig 2: Pareto diagram.

Likewise, to identify the main problems of the high rate of rework was carried out the problem tree he which one is shown in Fig. 3, said problem tree contains the gap technique (the index of defective products of the company and the sector), the impact negative generated for the problem economically (in dollars), their motives (each one with its percentage based on your importance), its causes root and its possible solutions tools .

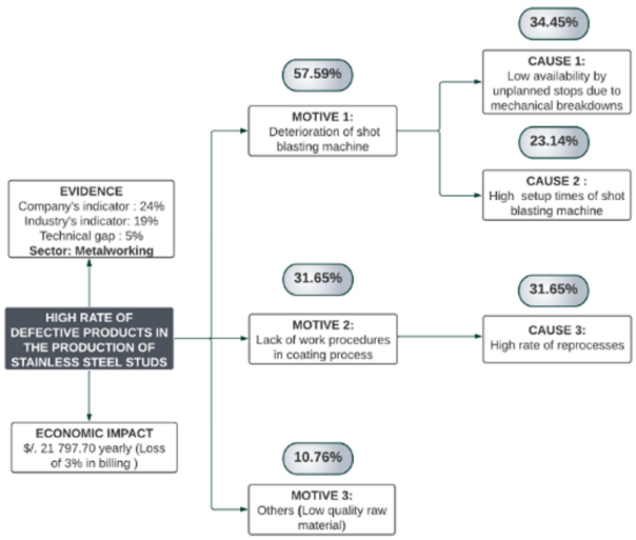

Fig 3. Analysis Tree Diagram.

They have definite diverse indicators to evaluate the current situation of the company in as for your productivity. As indicated in Table II, these parameters focus in function to the problems of the company. The indicator matrix presents the As Is (Current Scenario) and To Be (Target Value) values . Such way , it is presented he general problem and issues specific.

TABLE II
Table Indicators

Indicator	Formula	As Is
% Availability.	$\frac{MTBF}{MTBF + MTTR}$	82%
Average setup time.	$\frac{Sum\ of\ taken\ time\ for\ each\ activity\ in\ coating\ process}{Quantity\ of\ taken\ time\ for\ each\ activity\ in\ coating\ process}$	30.69 min
% Reprocesses.	$\frac{Reprocessed\ steel\ studs}{Completed\ steel\ studs}$	21%

$$Rate\ of\ defective\ products = \frac{Defective\ products}{Completed\ products}\ x\ 100\%$$

In fact, it is observed that the high rate of defective products is due to mainly to the deterioration of the machine shot blasting machine and lack of work procedures in coating area.

IV. INNOVATE PROPOSAL

A. Model rationale

The model proposed has as aimimprove the efficiency in area productive of the company and is based in the adoption of Lean Manufacturing methodology tools (specifically Total Productive Maintenance or also called TPM, SMED (Single-Minute Exchange of Die) and the job standardized in conjunction with the study of methods) and the implementation of Digital and Intelligent Manufacturing and Managament.

Likewise, the novelty of this proposal is the sequence of the implementation of tools with the approach of Digital and Intelligent Manufacturing and Managament presented in the principal indicators. It is important to mention that the model proposed is based on a set of tools which together they work to reduce the main problem which is a high rate of defective products in the company, TPM tool (Autonomous Maintenance and planned), the SMED tool and standardized work together each of them with their indicators which they are availability, set up times and reprocessing respectively. Each of the components of the proposed model has as objective the following:

Continous improvement in shot blasting machine", its main objective is to increase the availability of the shot blasting machine through the implementation of the TPM tool specifically pillars of autonomous and planned maintenance. Likewise, the reduction in the setup time of the machine through the implementation of the tool SMED. The "New work method design in coating" component process", its main objective is the reduction of reprocessing in the coating area through Standardization work tool

B. Proposed model

The model presented has as particularity the unification of the Digital and Intelligent Manufacturing and Managament and the selected tools of the Lean Manufacturing methodology before mentioned. [13]. Likewise, each one of the tools they will be implemented in area productive of the company. The tools by implement were considered after one investigation in different databases and articles scientists based on studies carried out to reduce the high rate of defective products in companies manufacturing. The model established It consists of 2 components , the which are detailed by its implementation phases. The TPM tool (maintenance autonomous and planned) is a fundamental tool to be able implement and increase the low availability by unplanned stops by breakdowns mechanics, the which It represents 34.45 % of the general problem.

Likewise, the tool of the standardization work his implementation of procedures manuals and guides prior to the study done the amount of rework will help in coating area, the which It represents 31.65 % of the total. Finally, the SMED technique will be used to reduce the set up times in machinery the which have a representation of 23.14%. The next proposal has as aim implement two pillars of the TPM tool (Maintenance Autonomous and Maintenance Planned), SMED tool and the work tool standardized presenting these 3 phases that will allow development of optimization proposal. [14]

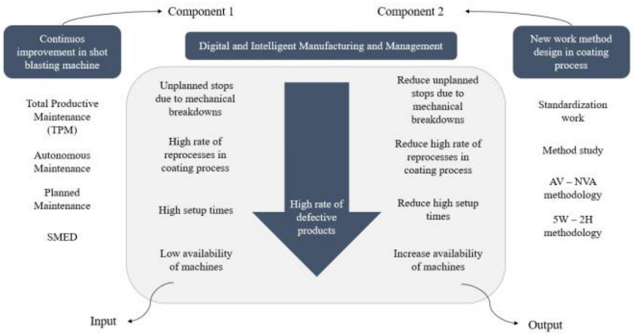

Fig 4. Proposed model.

Saying model shows the unification of 2 components proposals that have as aim achieve a reduction in the rate of defective products.

- **Implementation of component "Continuous improvement in shot blasting machine"**

The first phase focuses in the implementation of maintenance Autonomous and Maintenance Planned (TPM pillars). [15] Bliss phase is done within the production process (specifically in shot blasting of the two steel products stainless). The solution proposal It begins with the implementation of the second pillar of the TPM: Maintenance Autonomous. Bliss tool has as aimimplement a maintenance plan autonomous in the machine shot blasting machine, due to the deficiency with the that says equipment and results will be measured through incident rate reported in the shot blasting machine. Subsequently, it is implemented Maintenance Planned. This pillar of the TPM has as function optimize availability indicator. [16] To validate the TPM tool, pilot tests were conducted focusing on autonomous and planned maintenance, as well as worker training. In autonomous maintenance, workers take responsibility for routine machine maintenance, with specific formats for training and machine inspection. Planned maintenance aims to keep equipment in good condition to avoid unnecessary downtime, supported by theoretical and practical training for employees. [17] The validation process for the SMED technique involves three phases aimed at reducing the setup times of the shot blasting machine. The first phase involves using Input Analyzer and Arena software to represent the production process, prepare initial setup times, and simulate the production scenario. Data from 19 setup activities were evaluated, resulting in various distributions. In the second phase, a setup activities diagram was created in Arena and simulated, showing an initial average setup time of 30.63 minutes per batch. Improvements were made by externalizing certain activities, eliminating others, and implementing parallel activities with an additional operator, reducing the average setup time to 16.67 minutes.

- **Implementation of component "New work method design in coating process"**

It continues to implement the SMED tool as second phase in the implementation of the proposed solution. [18] SMED is defined as a technique used in the production processes that have the goal of reducing setup and changeover time of tools on machinery when not found working. The last phase applies through the application following 3 phases based in the observation and recording of method procedures to implement, its subsequent development and the standardization of the new procedures of the new method developed. [19] This tool is established as a fundamental tool (in the Lean methodology Manufacturing) with the objective of reducing the rate of defective products. Its main focus is continuous improvement. [20] Bliss tool has as function standardize the procedures in the steel activity with the support of the study of methods (focused in the times). Finally, for the measurement of the implementation results, will be used as indicator to the reprocessing index (reworks) of the steel studs. The next tool that follows the SMED to give solution to the problem of defective products is the standardized work of the Lean methodology Manufacturing. Standardized work will be complemented with the method study technique (time study) in the coating process. For carry out the validation of said tool in the solution proposal will use a pilot test with the objective of verifying the effectiveness. This pilot test It consists of 3 phases that will detail the validation process. Initially, the first phase consists of carrying out a observation and recording of procedures and times of the method with which the jobs. Given this, initially a time is obtained observed 73.58 minutes of the 9 activities previously established. Next, the valuation system is established Westinghouse for the calculation of normal time (TN) thus achieving a valuation 24% above the average thus obtaining 91.24 minutes. [21] The system Westinghouse has a direct positive relationship to the time to evaluate team performance. In this way, a standard time of 113.14 is achieved minutes.

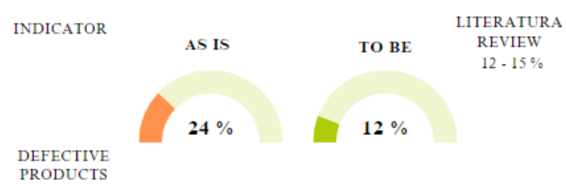

Fig 5. As Is – To Be.

As shown in the image, the main indicator for measurement and evaluation of the model proposed is the defective product index. Given this, at the beginning saying indicator was presented at 24%, representing this the As Is. In comparison, it was established the expected value (To Be), after implementing proposed model at 12%.

V. CONCLUSION

It is feasible and viable to carry out the proposed project due to the integration and obtaining results. It was possible to reduce the rate of defective products through the development of the solution proposal: increase in machinery availability (90%), reduction in setup times (16.54 minutes per batch) and reduction in reprocessing (14.89%). The contribution generated in the company is reflected through the innovative integration of the TPM tool (Autonomous Maintenance and Planned Maintenance), SMED and standardized work. Through the implementation of the total productive maintenance (TPM) tool, it was possible to reduce unplanned stops due to mechanical failures through the pilot test of the tool, which has as an indicator the availability of the machinery, which before implementation was 82.86 % and after implementation it was 90.52%, managing to increase availability and avoiding unplanned stops of machinery. Through the Arena software simulation technique, it was revealed that the SMED technique can reduce the average setup time of the shot blasting machine, achieving from 30.69 to 16.54 minutes. For this, 30 iterations and two simultaneous scenarios were used.

REFERENCES

[1] Haddad, MA, & Silva, LCE (2022). Experimental analysis of TIG welding of 304 stainless steel sheets. Journal of Manufacturing Processes, 76, 246-253. https://doi.org/10.1016/j.jmapro.2022.03.023

[2] Bartolomeu, F., Fernandes, J., Oliveira, MC, Baptista, AP, & Rocha, LA (2021). Paint coatings on stainless steel: a review. Coatings, 11(6), 656. https://doi.org/10.3390/coatings11060656

[3] De Sousa, J. P., Santos, S. P., & Ferreira, J. R. (2021). Lean manufacturing and the environmental performance of firms: A review of empirical evidence. Journal of Cleaner Production, 306,127097. https://doi.org/10.1016/j.jclepro.2021.127097

[4] De Sousa, JP, Santos, SP, & Ferreira, JR (2021). Lean manufacturing and the environmental performance of firms: A review of empirical evidence. Journal of Cleaner Production, 306,127097. https://doi.org/10.1016/j.jclepro.2021.127097

[5] Shahin, M., Chen, F.F., Hosseinzadeh, A., & Zand, N. (2023). Using machine learning and deep learning algorithms for downtime minimization in manufacturing systems: an early failure detection diagnostic service. The International Journal of Advanced Manufacturing Technology, 128(9-10), 3857-3883.

[6] Sarir, E. B. (2021). Fuzzy based failure mode and effect analysis towards risks of autonomous maintenance activities: As a TPM implementation. Ege Akademik Bakis,21(1),17-27. https://doi.org/10.21121|eab.873999

[7] Prasad, MRN, Murugan, K., & Kumar, VK (2020). A comparative study on the application of SMED and TPM tools for productivity enhancement in an automobile component manufacturing industry. International Journal of Industrial Engineering Computations, 11(1), 21-36. https://doi.org/:10.5267/j.ijiec.2019.11.002

[8] Bartnicka, J., Kabiesz, P., & Kaźmierczak, J. (2020). Standardization of human activities as the component of a workflow efficiency model‐ a research experiment from a meat producing plant. Production Engineering Archives, 26(2), 73-77

[9] Xue, Y. & Zang. J. (2022). Evolution and Innovative Implementation of Industrial Model for Intelligent Manufacturing. Journal of Mechanical Engineering, 58, 303-318. https://doi.org/10.3901/JME.2022.18.303

[10] Ding, M. & Liu, X. (2023). Design, Manufacturing, Management and Control Technology of Cutting Tools for Intelligent Manufacturing Process. Journal of Mechanical Engineering, 59, 429-459. https://doi.org/10.3901/JME.2023.19.429

[11] Zhang, W. & Meng, F. (2023). Digital Economy and Intelligent Manufacturing Coupling Coordination: Evidence from China. Systems, 11, 521. https://doi.org/10.3390/systems11100521

[12] Liu, X., Li, Y., Sun, W., & Li, D. (2022). A new multivariate Pareto chart with improvedperformance. Quality Engineering, 34(1), 30-48. https://doi.org/10.1080/08982112.2021.1996867

[13] Jaquin, C. , Rozak,A. , Hardi ,H. (2020).Case Study in Increasing Overall Equipment Effectiveness on Progressive Press Machine Using Plan-do-checkact Cycle. InternationalVolume 33, Issue 11. Journal of Engineering. https://doi.org/10.5829/ije.2020.33.11b.16

[14] Arroyo Huayta, C. A., & Cruces Raimundis, E. S. (2020). Modelo para mejorar la eficiencia en el área de extrusión de una pyme manufacturera del sector plástico basado en SMED, Mantenimiento Autónomo y 5s. Universidad Peruana de Ciencias Aplicadas (UPC). https://repositorioacademico.upc.edu.pe/handle/10757/651811

[15] Conde, J. & Gonzales, D, (2020). Reducción del número de devoluciones en empresas del sector gráfico mediante la aplicación de herramientas del Pensamiento Esbelto. Universidad Peruana de Ciencias Aplicadas (UPC). https://repositorioacademico.upc.edu.pe/handle/10 757/65363

[16] Suryaprakash, M., Gomathi Prabha, M., Yuvaraja, M., & Rishi Revanth, R. V. (2021). Improvement of overall equipment effectiveness of machining centre using tpm. Materials Today: Proceedings, 46, 9348–9353. https://doi.org/10.1016/J.MATPR.2020.02.820

[17] Pinto,G. Silva,F. , Fernandes,O. Casais,R.(2020). Implementing a maintenance strategic plan using TPM methodology. International Journal of Industrial Engineering and Management. Recuperado de: https://doi.org /10.24867/IJIEM-2020-3-264

[18] Prasad, M. R. N., Murugan, K., & Kumar, V. K. (2020). A comparative study on the application of SMED and TPM tools for productivity enhancement in an automobile component manufacturing industry. International Journal of Industrial Engineering Computations, 11(1), 21-36. https://doi/10.5267/j.ijiec.2019.11.002

[19] Santos, B., Janixa, L., Zacarias, O., & Wendy, L. (2020). Modelo de mejora de proceso productivo para incrementar la eficiencia en pymes del sector calzado en perú aplicando 5s, SMED, TPM y estandarización de trabajo. Universidad Peruana de Ciencias Aplicadas (UPC). https://repositorioacademico.upc.edu.pe/handle/10 757/655273

[20] Bouzitouna, F., Dridi, D., & Boujelbene, M. (2021). An integrated approach for product quality control based on statistical process control and quality inspection. International Journal of Industrial Engineering and Operatio ns Management, 12(3), 323-336. https://doi.org/10.30857/ijieom/21041

[21] Rizkya, I., Sari, R. M., Syahputri, K., & Tarigan, U. (2021). Evaluation of total productive maintenance implementation in manufacture. IOP Conference Series.Materials Science and Engineering, 1122(1) doi:https://doi.org/10.1088/1757-899X/1122/1/012059