Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Industrial

Tesis

Waste Reduction with Lean Manufacturing Model in an Alpaca Wool Workshop

Jazmin Magaly Cristobal Quispe

Para optar el Título Profesional de
Ingeniera Industrial

Huancayo, 2020

IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Waste Reduction with Lean Manufacturing Model in an Alpaca Wool Workshop

To cite this article: J Cristobal *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **999** 012014

IOP Conf. Series: Materials Science and Engineering **999** (2020) 012014 doi:10.1088/1757-899X/999/1/012014

Waste Reduction with Lean Manufacturing Model in an Alpaca Wool Workshop

J Cristobal[1], G Quispe[2], F Dominguez[3], G Zapata[4] and C Raymundo[4]

[1] Facultad de Ingenieria, Universidad Continental, Huancayo, Peru
[2] Universidad Nacional Autonoma Altoandina de Tarma, Junin, Peru
[3] Escuela Superior de Ingenieria Informatica, Universidad Rey Juan Carlos, Madrid, Spain.
[4] Direccion de Investigacion, Universidad Peruana de Ciencias Aplicadas, Lima, Peru

Email: 72674845@continental.edu.pe; gquispe@continental.edu.pe; carlos.raymundo@upc.edu.pe

Abstract. This paper proposes the design of a quasi-experimental time-series model comprising lean manufacturing tools—such as the value stream mapping and 5S's—with the aim of reducing the level of waste and losses in a micro-company dedicated to the production of Alpaca wool clothing in Junín, Perú. The model implementation managed to reduce the level of waste by 7%, increase the efficiency in material consumption, and reduce the cycle time and total supply time. The implementation of the model allowed reducing the level of waste in the production process and creating an organizational culture based on order, cleanliness, discipline, and teamwork.

1. Introduction

The Peruvian textile industry represents 1.3% of the GDP and 8.9% of the country's productive sector [1]. This industry includes companies that work with Alpaca fiber, with a large percentage of their production being destined for export due to the quality of their yarn. Thus, in 2018, exports grew by 22.1% with respect to the previous period, equivalent to more than USD 12,000,000.00 [2].

As Alpaca yarn accounts for 70% of the total production costs, it is vital to keep the percentage of waste or excess material to a minimum. The variation in waste and excess material directly impacts the final quality of the products and profits of the organization [3]. Nowadays, the maximum limit of waste accepted in the Alpaca fiber sector is 4.4% [4].

The importance of reducing the level of waste within the textile industry has been recognized by several authors. Extensive research has been conducted regarding the same, of which the umbrella model stands out. This model has managed to reduce waste resulting from overproduction, reprocessing, non-value-added work, and non-compliance in cost movement [5]. Another study verified the use of lean manufacturing tools for reducing the total supply time and the waste generated, with minimal investment in machinery, training, and technology [6]. In addition, it has been demonstrated that the integration of Kanban tools and 5S's manages to reduce not only the total supply time and flow of information but also defects [7] [8]. Finally, it has been shown that its use promotes a work environment that motivates the worker to achieve sustainability in the organization and increase productivity [9].

Thus, a model that, supported by the integration of VSM and 5S's, allows for a reduction in the level of waste throughout the production process is desired. The objective is not only to contribute to increasing the profits of industrial micro-enterprises, by reducing waste, but also to create sustainable work environments that promote continuous improvement.

2. State of the Art

2.1. Application of lean manufacturing in the textile industry

The implementation of Lean manufacturing tools in the textile industry aims to reduce waste and increase the level of customer satisfaction. Therefore, a scheme was developed with the following necessary steps for waste reduction: first, reduce the response time; then, allocate the materials and resources necessary for production; and finally, execute production according to demand, seeking cross-cutting management of information.

The results showed a reduction of 80% and an index of 75% of workers informed and trained for the design execution. However, the time required for its implementation is approximately one year. In addition, other tools are needed for a successful implementation [10].

Some other studies proposed the joint application of Kanban, 5S's', and PDCA cycle to reduce downtime, information flow, and through the continuous improvement cycle, defects and waste. The results demonstrated an 84% increase in the organization's income and a 25% reduction in the level of defects, reducing the associated production costs [7].

Likewise, it has been demonstrated that a Lean manufacturing model formed of three tools—layout redesign, source quality, and line balance—can achieve similar results. Thus, its implementation shows a 96.7% reduction in waste and 43% reduction in the total delivery time [6].

3. Methodology

As there is no control over all the variables that are part of the research, a quasi-experimental model was developed. This model requires periodic measurements on a group of Y variables, described in table 1, before and after introducing the X improvements, to determine the effect of the latter on the variables described [11]. The implementation stages are described in figure 1.

Table 1. Description of variables

Variable	Description
Y_1	Raw material waste and loss
Y_2	Defective product
Y_3	Production cycle time
Y_4	Total supply time
Y_5	Added value activities

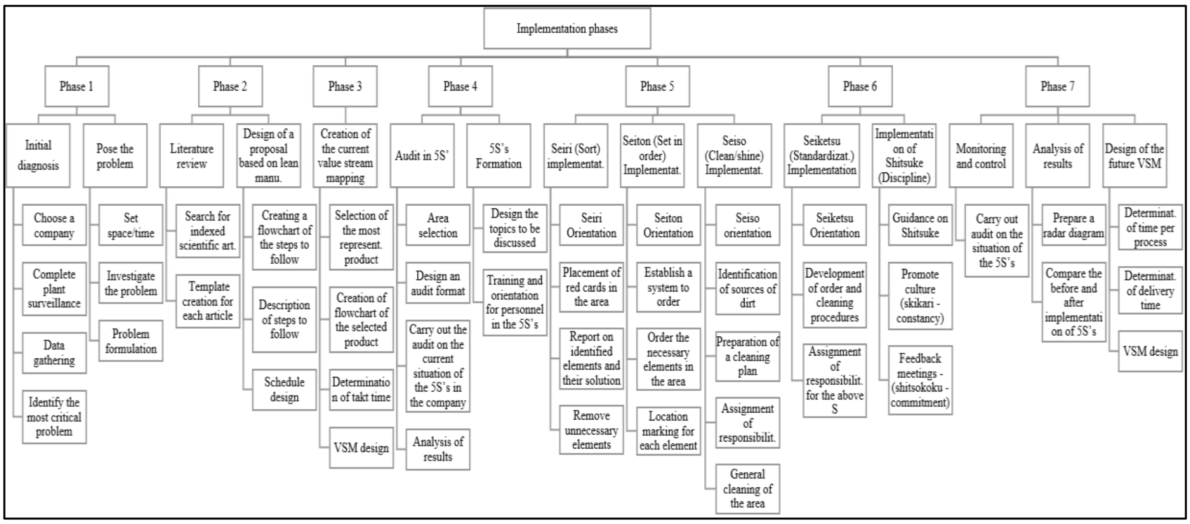

Figure 1. Implementation Design

3.1. Phase 1. Initial diagnosis and problem statement
Select the company and carry out the initial diagnosis to identify the main problems and, after analysis, define their causes. Finally, the scope of the project is defined in terms of space and time, the problem is investigated in depth for its solution and finally the scope of the problem is formulated.

3.2. Phase 2. Bibliographic sources review and design solution proposal
Compare and contrast previous results from lean methodology used in previous researches focused on both waste reduction and its implementation methods. Finally, the solution model is proposed and the implementation schedule is made official.

3.3. Phase 3. Set up Value Stream Mapping
Determine the product or product family most relevant to the organization. Identify the materials and information flow in the selected process. Determine the takt time and the activities with the highest level of waste.

3.4. Phase 4. Carry out a 5S´s audit and form working teams
Select the area, perform the assessment formats and carry out the 5S's audit to know the current state of the organization. Subsequently, train and guide workers in the implementation of 5S's.

3.5. Phase 5

3.5.1. Sort (Seiri). After workers were trained in the element classification in the working area, unnecessary elements were separated using visual control labels, called "red cards." The name of the object, its classification, the reason for removing it, the type of action to take, and observations were recorded. All useless items were removed or relocated.

3.5.2. Set in order (Seiton). After removing the unnecessary objects, the workers were trained in the order of the necessary tools and elements. Workstations were arranged considering the criteria described in table 2 [12].

Table 2. Elements' location criteria

Frequency of use	Location
Hourly	Locate it beside the person
Several times a day	Locate it near the person
Several times a week	Locate it in the workspace
A few times a month	Locate in a labeled place easy to reach

In addition, the equipment, tools, and materials were labeled and located according to their use.

3.5.3. Shine (Seiso). The staff were trained on cleaning the workspace. Subsequently, the sources of dirt were identified and a cleaning plan for assigning responsibilities was prepared. Deep cleaning of tools and machinery for optimal operation was also carried out.

3.6. Phase 6

3.6.1. Standardize (Seiketsu). The personnel were trained in the standardization of activities and procedures and standards were established to eliminate the previously identified the dirt sources at the workspace. Responsible parties were assigned and a schedule was prepared to carry out the specific cleaning.

3.6.2. Sustain (Shitsuke). The workers were trained on tool implementation. Due to the inherent difficulty in measuring this step, given its close relation with the organizational culture and employee behavior, two more steps were implemented: consistency (shikari) and commitment (shitsokoku). The first seeks to ensure that workers comply with the steps previously implemented through periodic visits to the workspace, mainly to the activities identified as having the greatest waste. Regarding commitment, it was obtained progressively, holding periodic meetings to receive suggestions and observations from the workers.

3.7. Phase 7

A final audit was carried out to verify compliance with the tool. The results were then analyzed and the impact generated on the level of waste in each activity was measured, using a radar chart. Finally, a future VSM was elaborated to evaluate the impact of the implementation in time per the process and delivery time.

4. Validation

4.1. Initial diagnosis

The jerseys were identified as the family of products with the highest seasonal demand for the company, representing 21.32% of the total production volume. This product was established as the most relevant for the organization, developing its value stream mapping.

The percentage of waste generated in the jersey production was analyzed considering the models with the highest demand. It was found that, for the production of a sample total of 200 units, comprising 10 units per design, the total weight of the waste was 16.24 kg, which represents 11.67% of the total material entered.

For the development of VSM, the takt time was first determined as 38.64 min/unit. Subsequently, the material and information flow were established to draw the current process of jersey production, as shown in figure 2. A total cycle time of 41.6 min and a total supply time of 3.44 days were obtained. This clearly shows that the supply time was greater than the takt time, which resulted in delays in deliveries.

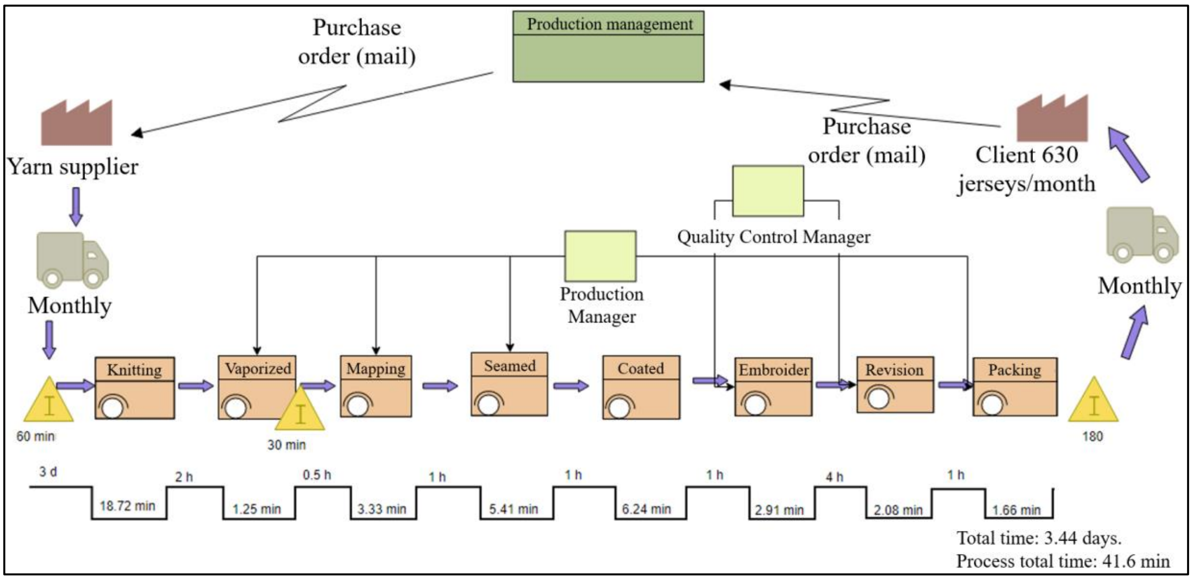

Figure 2. Initial VSM of jerseys in the company

An audit was conducted to determine the level of compliance with 5'S methodology in the workspace. The results showed the little commitment and culture focused on order and cleanliness, obtaining only 32% compliance with the 5S's methodology.

4.2. Implementation

IOP Conf. Series: Materials Science and Engineering **999** (2020) 012014 doi:10.1088/1757-899X/999/1/012014

The workers were trained in the objectives and benefits of the project, as well as in the steps for the 5S's tool execution. The implementation was conducted in the following steps:

4.2.1. Sort. Red cards were placed on unnecessary elements in the workspace. As shown in table 3, 103 elements were found, and were relocated to other areas. The item removal was carried out within two days.

Table 3. Actions taken on unnecessary elements

Element	Number	Classification	Action
Thread	22	Raw Material	Relocate
Plastic lid	7	Container	Eliminate / dispose
Carboard box	12	Container	Recycle
Mannequin	2	Equipment	Relocate
Tub	1	Equipment	Eliminate / dispose
Rags	18	WIP	Relocate
Radio	2	Equipment	Repair
Scissors	8	Tool	Repair
Notchers	6	Tool	Eliminate / dispose
Needles	25	Tool	Eliminate / dispose

4.2.2. Order. A specific location was established for each element necessary for production and containers were labeled to facilitate the identification of each element.

4.2.3. Clean. The main sources of dirt were identified in the activities that generated maximum waste. The activities that generated the maximum lint were identified to make the machines to dirty faster and break down more frequently. Walls, floors, machines, shelves, and tools were thoroughly cleaned (See figure 3 and figure 4).

Figure 3. Object labeling at the workspace.

Figure 4. Cleaning of machines and equipment

4.2.4. Standardize. To maintain proper compliance with the implemented steps, a cleaning schedule was developed for the area and responsible parties were appointed.

4.2.5. Sustain. Work was done to reinforce the organizational culture and discipline of the staff.

4.2.6. Consistency. A schedule of periodic visits was set up to monitor and reinforce the order and cleaning habits of the personnel.

4.2.7. Commitment. A schedule of meetings with plant personnel was established to encourage them to continue with good performance and receive feedback on the current situation, as well as opportunities for improvement.

4.3. Results

As shown in figure 5 and 6, after carrying out the final audit, the percentage of compliance with the implementation from 5S's was increased by 84%. Furthermore, the percentage of waste was reduced from 11.67% to 5.00%, with a total waste of 5.82 kg for the production of 200 units of jerseys divided into 20 models.

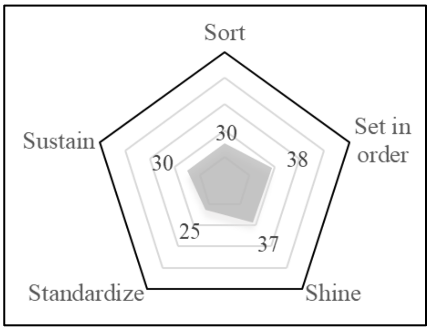

Figure 5. 5S's initial audit radar chart.

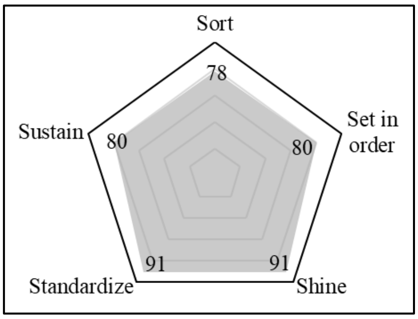

Figure 6. 5S's radar chart after tool implementation.

The Takt Time was also determined taking into account the most recent:

$$Takt\ Time = \frac{Production\ time\ availablee}{average\ demand\ per\ customer} = \frac{12\ 480\,\frac{minutes}{month}}{323\,\frac{sweater}{month}} = 38.64\,\frac{minutes}{sweater} \tag{1}$$

Subsequently, the future VSM was prepared—as shown in Fig. 7— to analyze the impact on material flow in the process. This evidences that the cycle time was 38.6 min, with a total delivery time of 2 days. These times are less than the initial values, allowing the on-time delivery of the products, as it is less than the takt time of 38.64 min/jersey.

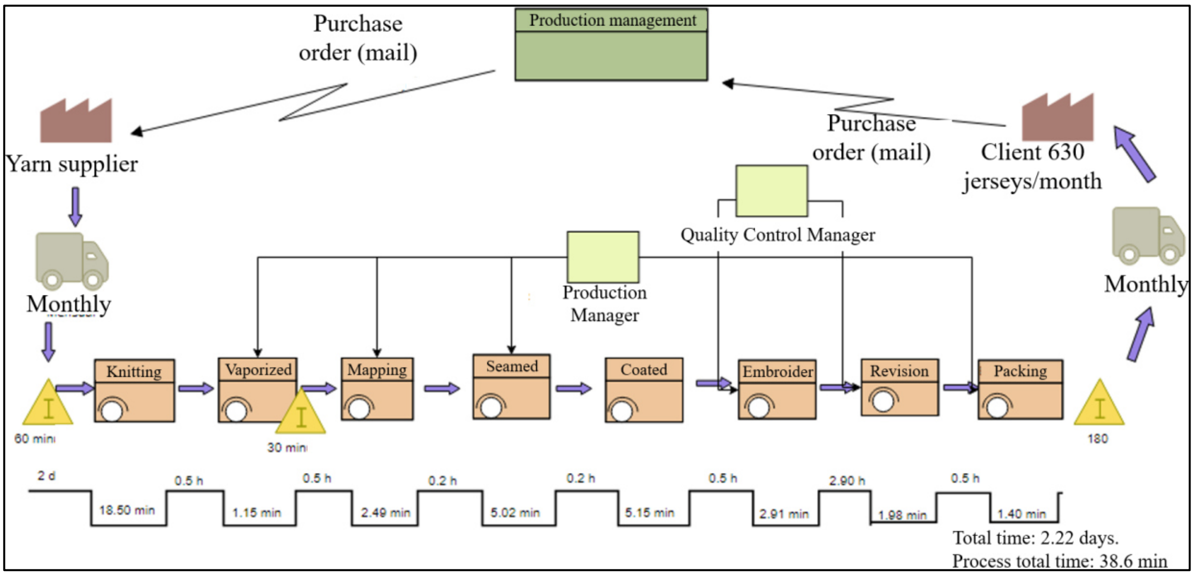

Figure 7. Future VSM for the jersey line production.

5. Conclusions

The research helped to determine the jersey as the most relevant product family, as it represents 21.32% of the total monthly production in the season.

The company's current VSM revealed that there is a cycle time of 41.6 min per garment and a delivery time of 3.44 days; these times are greater than that required to satisfy the demand (takt time = 38.64 min), which causes the late delivery of the orders. A positive result was obtained with the application of the 5'S methodology, as it reduced the level of waste by 7%, besides reducing the cycle time and delivery time, and therefore, the efficiency of the system also improved.

We conclude that lean manufacturing tools reduce the level of waste generated in production and have a positive impact in the workplace. This is because they promote the creation of a discipline-based culture that allows for a cleaner work environment, and encourage the staff to practice teamwork.

References

[1] García JM 2017 Research study of the textile and clothing sector. Ministry of Production [online] Available from: http://ogeiee.produce.gob.pe/index.php/oee-documentos-publicaciones/documentos-de-trabajo/item/725-textil-y-confecciones
[2] Mincetur 2018 Peru: Alpaca textile exports grew 48% in the first half. Peru Retail [online].
[3] Socconini L 2008 The foundations for world-class leadership and culture. In: Lean manufacturing step by step: the Japanese business management system that revolutionized manufacturing and services. ISBN 9789700919324. ISBN 9789700919324
[4] Sáenz RL 2013 Proposal to reduce waste in the garment sector in the textile industry. Institutional Repository - UNI [online]. Available from: http://cybertesis.uni.edu.pe/handle/uni/7049
[5] Cueto G, Caldas Y, Viacava G, Quiroz, J And Alvarez J 2020 Waste Reduction Model in a Small Clothing Company-Umbrella Model. In. ISBN 9783030256289. ISBN 9783030256289
[6] Obeidat M, Al-Aomar R and PEI ZJ 2014 Lean manufacturing implementation in the sewing industry. Journal of Enterprise Transformation. 4 (2), p. 151–171. DOI 10.1080 / 19488289.2014.890980.
[7] Andrade Y, Cardenas L, Viacava G, Raymundo C And Dominguez F 2019 Lean manufacturing model for the reduction of production times and reduction of the returns of defective items in textile industry [online]. Springer International Publishing. ISBN 9783030204433. Available from: http://dx.doi.org/10.1007/978-3-030-20444-0_39ISBN 9783030204433.
[8] Becerra, A., Villanueva, A., Núñez, V., Raymundo, C., Dominguez, F., "Lean manufacturing model in a make to order environment in the printing sector in Peru", Advances in Intelligent Systems and Computing, 971, pp. 100-110.
[9] Laura M, C Alvez A And Celina L 2016 Imece2012-89048 Design of a Lean Methodology for an Ergonomic and Sustainable. Proceedings of the ASME 2012 International Mechanical Engineering Congress & Exposition IMECE 2012. P. 1–10.
[10] Cortez C, Di Laura N, Viacava G, Raymundo C, Dominguez F 2020 Lean Manufacturing Model Based on Knowledge Management to Increase Compliance in the Production Process in Peruvian SMEs in the Textile Garment Sector Advances in Intelligent Systems and Computing, 961, pp. 103-111. DOI: 10.1007/978-3-030-20154-8_10
[11] Valderrama S Steps to evaluate scientific research projects and thesis. Lima, 2007. ISBN 978-9972-38-041-9. ISBN 978-9972-38-041-9
[12] Villaseñor, A. Y Galindo, E. System 5 Ss: Implementation Guide. México : AUTOR-EDITOR, 2010. ISBN 9786070502545. ISBN 9786070502545