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Production management model based on LEAN, TPM, DDMRP, and change management tools to reduce lead times in an SME in the garment manufacturing sector

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***Abstract*– Currently, SMEs are unable to meet the needs of customers, presenting problems for the delivery of complete orders on time. Based on an analysis of continuous improvement tools and integration of change management within the organization, a new production management model is proposed that manages to reduce delivery times; This model uses tools such as: DDMRP, 5S, JIDOKA, TPM and integrates change management with the Kotter model as a base. The proposed model was carried out in a pilot test of an SME in the textile and clothing sector, obtaining as results: an increase in Total (IF) and inventory precision of 87.77% and 95% respectively; in addition to the reduction of defective products by up to 2%.**

***Keywords*-- Demand Driven, MRP, Change management, PDCA Cycle, 5'S, Jidoka, Total Productive Maintenance.**

I. Introduction

According to figures from the BCRP, the utilization rate of the installed capacity of the textile and clothing sector has fallen drastically to 42.6% at the end of 2020. This indicator has not yet recovered its pre-pandemic level (63.3% in 2019) and is far from reaching its highest values recorded in 2011 (92.1%) and 2012 (91.1%). These results show that the Textile and Apparel sector presents some operational restrictions that limit the production and growth of the company, which prevents satisfying the projected demand.

The problem identified, according to the literature, leads us to the case study of a textile company where the main problem detected was the level of orders fulfilled late, this is generated by the lack of productive planning, activity times, defective and in other studies they affirmed that this problem has its origin in the delayed deliveries of raw material, as well as the frequent replacement of defective garments [1]. In another case study of the same textile sector of a small company in the fashion center of Gamarra, it was identified that the central problem was low production capacity due to difficulties in fulfilling orders, including incomplete orders and late orders, causing not only impediments in the growth of the company but also low levels of production [2].

Therefore, to solve the main problem of On Time In Full in orders, a production management model was developed and implemented combining the 5'S, JIDOKA, DDMRP, autonomous maintenance and preventive maintenance tools based on the Kotter model. - Change management. Faced with the main problem of the Study, it is proposed to optimize the inventory management with the application of DDMRP [4], integrate quality control points to increase the complete orders with JIDOKA [5], in terms of the maintenance of the machines that are require in the production system integrates TPM [6] and 5's [7] in key work areas, Finally, all this is integrated by change management – Kotter Model focused on the integration of workers with the aim of motivating them so that this implementation is carried out not only once but applied continuously. This management model was developed based on success stories that presented similar problems to the study, this research not only satisfies the need to solve the sector's problems but also contributes to the scientific community.

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II. Literature Review

A. Production management model to reduce delivery times in the textile and clothing sector

Various authors [1][7][8] agree that companies in the textile and clothing sector have opted for the application of lean tools such as 5's and Kanban to improve information management, production planning and work method. Likewise, the implementation of standardization methods, process designs with correct planning through the application of the theory of restrictions and 5's focused on reducing production times.

On the other hand, different authors [1][7][8] agree that the application of lean tools in the textile and clothing sector allows quantifiable results through indicators in a practical way in companies, improving the percentage of late compliance, productivity, and cycle time with an average of 35% for each indicator. Lean application in the textile and clothing sector.

B. Demand driven MRP application in the textile and clothing sector

Different authors [4][9] agree on the practical application of DDMRP for good production planning and control, thus allowing integration of order coordination systems, management of the supply chain and reduction of inventories. In addition, other authors [10][11][12] agree on the development of MRP algorithms that allow having an optimal inventory and anticipated material requirements with a capacity to adapt to any industry and according to the particular characteristics of each SME in the world. textile and clothing sector.

On the other hand, the correct planning of inventories within the SMEs of the textile and clothing sector has allowed the increase in the use of the required materials and the reduction of over-inventory in the warehouses; Likewise, it is reflected in the reduction in costs on average of 25% [9][10].

C. *TPM application in the textile and clothing sector*

Companies in the textile sector frequently present low efficiency in their production lines, this is due to unexpected stops and unproductive times recorded by the machines, which generates a breach in customer demand [13][14][15]. Likewise, in the manufacturing industries they register low availability of production equipment, this is caused by the high frequencies of breakdowns and periods of inactivity [16][17][18]. To reduce this, it is essential to implement systematic procedures of the TPM methodology as a maintenance strategy to improve performance, thus avoiding equipment failure [13][14][15].

D. *Lean applications, demand driven MRP and TPM in the textile and clothing sector*

Integration models of lean manufacturing tools such as the 5'S methodology, autonomous maintenance and planned maintenance achieved a reduction in production time in the textile industry with the aim of increasing the efficiency and availability of production equipment [19][20]. On the other hand, other contributions from researchers showed that it is possible to improve the efficiency of the machines by implementing autonomous, preventive, and predictive maintenance strategies and with the integration of the 5'S tool in order to reduce the breakdown times that impede the competitiveness of the machines. companies in this industrial sector [21][22][23].

E. *Change management in the textile and clothing sector*

One of the most effective corporate applications in the integration of new elements, improvements and/or restructuring of the work carried out in companies in the manufacturing sector is change management, whose main purpose is to establish a simple but efficient method that allows identifying the disadvantage that the organization has by not adapting to change and encouraging continuous evolution for its growth [41] [42]. In the case study that the textile manufacturing company has, it shows that 15% of the collaborators improved their work methods, allowing a 5% increase in productivity by not having failures and encouraging the continuous quality control that was sought [43].

III. CONTRIBUTION

A. *Proposed model*

According to the research of the scientific articles, a production management model is proposed based on DDMRP, "Lean manufacturing" tools such as JIDOKA, 5's and TPM. It is based on change management, the Kotter model to reduce delivery times, delivery times of an SME in the textile and clothing sector. For the implementation of the engineering tools, a Deming cycle model was used which aims to increase the productivity of the company and implement constant

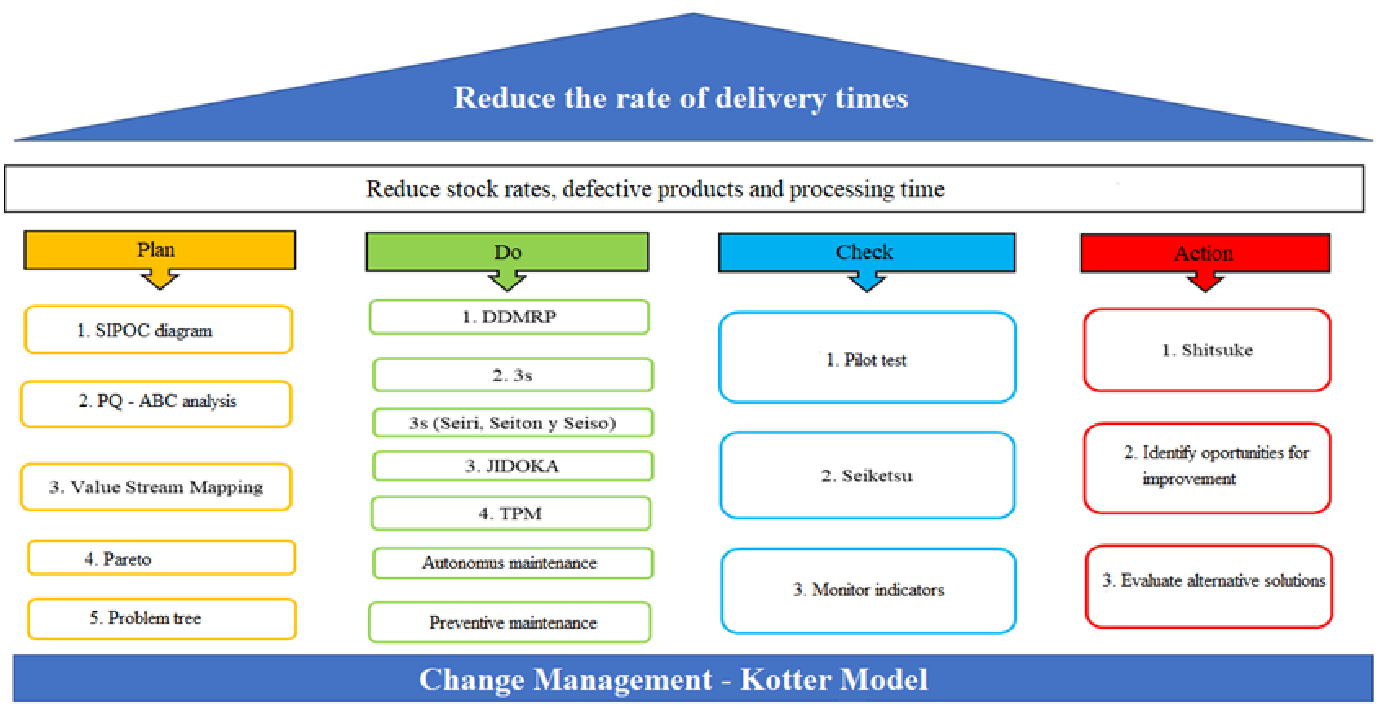


Fig. 1 Proposed model.

solutions due to the continuous improvement of the cycle correctly represented in Figure 1.

B. Model components

1) Phase 1: Plan

In the first phase, the necessary tools are developed to establish an initial diagnosis of the problem. To achieve what has been proposed, first the SIPOC diagram is elaborated, which analyzes the production processes of an order for the case study company. According to the diagram, the PQ and ABC analyzes are developed, which identify the standard product of the company. After the analysis of the indicators and the determination of the central problem, the VSM is elaborated where the problems that the case study presents in its production processes are identified with the objective of carrying out the Pareto analysis to determine the immediate causes. Finally, the root causes are identified through the problem tree.

2) Phase 2: Do

DDMRP: Considering that the case study presents supply shortages in raw materials and also considering that planning scenarios are increasingly complex, a manufacturing strategy driven by demand planning is necessary. The objective of implementing this methodology is to achieve careful planning, programming, and execution of the consumption of raw materials. To achieve this, the DDMRP is composed of five stages which are: Strategic inventory positioning, profiles and storage levels, dynamic adjustments, demand planning and visible and collaborative execution.

3) Phase 3: Check

5's: In this stage, the first 3's of the 5'S methodology are implemented. The implementation begins with the 1st (classification), for this it is necessary to inspect the workplace where surplus or unnecessary elements will be eliminated with the help of red cards and a list of unnecessary materials to achieve immediate continuous operations. Once the classification is done, the 2nd (Order) will proceed, where the work elements will be ordered through efficient methods such as the limitations of the work areas and the labeling of the elements. Finally, the 3rd (cleaning) will be carried out, where the aim is to eliminate clutter, keep the place clean and free of waste. To achieve this, cleaning checklists were used in order to record the activities in the established formats.

Jidoka: The application of this tool will be developed in two activities which seek to implement a process detection system to identify the appearance of the problem and communicate to the operators about the processes that are being intervened to solve the problem by correcting the root cause.

TPM: At this stage, a maintenance team will be appointed to help keep equipment running to avoid unplanned downtime during daily operations. This maintenance includes the repair, replacement, and maintenance of equipment to avoid unexpected failures. The main objective is to achieve high equipment reliability and minimize maintenance costs, such as inspection and repair, and equipment downtime.

4) Phase 4: Action

Change Management: Considering the case studies of the literature review on change management with the Kotter model that is divided into different steps that involve the participation of the entire corporation that will be affected by the proposed changes, either directly or indirectly. Groups of leaders are established that generate a commitment with the other collaborators so that a continuous change can be maintained in the company and thus be able to provide feedback on the cycle of steps for future improvements in the areas, becoming a way of working in the organization.

C. Indicators of the proposed model

The proposed indicators are intended to improve supply management, machine processing time and reduce defective products in the areas of planning, printing and sublimation respectively as shown in Table 1.

TABLE 1
PROPOSED INDICATORS

Components	Indicators	Formula
DDMRP	Inventory Accuracy	$\left(\frac{\text{MP total} - \text{MP required}}{\text{MP total}}\right) \text{x } 100\%$
5'S	Lead Time	$\sum \text{Processing times}$
Jidoka	Defective Products	$\left(\frac{\text{Number of defectives}}{\text{Total production}}\right) \text{x } 100\%$
TPM	Stops	$\left(\frac{\text{Total Hours} - \text{Hours stopped for maintenance}}{\text{Total Hours}}\right) \text{x } 100\%$
Change Management	Acceptance	$\left(\frac{\text{Number of Acceptance}}{\text{Total Workers}}\right) \text{x } 100\%$

IV. Validation

A. Initial diagnostic

The problem of the case study is due to the low rate of delivery of complete orders. Currently the company has 73.88% which is 13.89% below the industry average. For 2021, the economic impact of the low rate of complete orders was PEN 82,280 equivalent to 18.70% with respect to revenues. The main causes were the high rate of supply breaks, the high rate of defective products and the high print processing time. For each of these, indicators were identified and measured and compared with the industry average, as shown in the following Table 2.

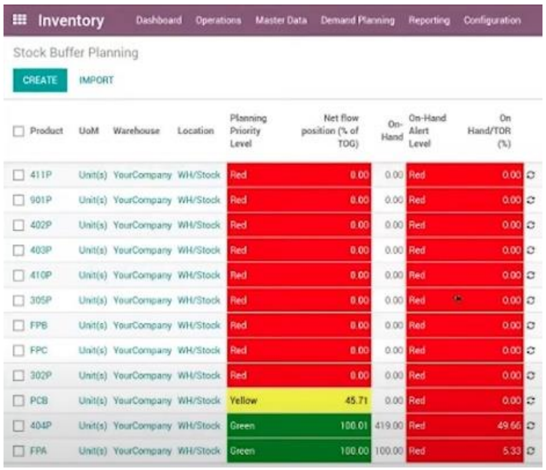
TABLE 2
COMPARISON OF INDICATORS

Indicators	Current	Objective	Variation
OTIF	68.75%	83.38%	14.63%
In Full	73.78%	87.77%	13.99%
Inventory Accurancy	72.58%	95%	22.42%
Defective Products	10.36%	5%	3.36%
Lead Time (min)	14.20	< 8	50.70%

B. Validation design

1) DDMRP

Regarding the implementation of the DDMRP in the case study, it was possible to implement it with the calculation and sizing of the buffers that are the warehouses that it has destined. For this, the calculation was made with the history of the company in the year 2021 and the green, yellow and red zones were calculated. As can be seen in the Figure 2 below, the 2021 buffer without having integrated DDMRP and only by reading the data obtained in that year it was possible to identify that most of the time they were out of stock, therefore there were too many stock breaks for the production. Likewise, once the buffer and the corresponding calculations have been created, which are updated with the Odoo software, which allows the forecasts obtained on a daily basis to be entered through the GMDH Streamline and can be updated as often as required, the data obtained in 2022 They are better because the inventory level is between the green and red zones, which indicates that the amount of inventory is correct and is maintained on average, giving continuity to the acceptance of orders and keeping consumption constant without over-inventorying.



Product	UoM	Warehouse	Location	Planning Priority Level	Net flow position (% of TOG)	On-Hand	On-Hand Alert Level	On Hand/TOR (%)
411P	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
901P	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
402P	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
403P	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
410P	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
305P	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
FPB	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
FPC	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
302P	Unit(s)	YourCompany	WH/Stock	Red	0.00	0.00	Red	0.00
PCB	Unit(s)	YourCompany	WH/Stock	Yellow	45.71	0.00	Red	0.00
404P	Unit(s)	YourCompany	WH/Stock	Green	100.01	419.00	Red	49.66
FPA	Unit(s)	YourCompany	WH/Stock	Green	100.00	100.00	Red	5.33

Fig. 2 Buffer de SB-002.

2) 5's

The considerations that were taken for the action plans of the 5'S methodology were focused on the management of order and cleanliness.

In the first place, with the development of the red cards, it was possible to identify those materials that were outside the workplace and were considered unnecessary. Among the most important details that were on the red cards, the category of the material and its person in charge were mentioned. Therefore, an adequate limitation of the work was developed where the operators can find the materials and equipment at their disposal to avoid crowds. Then, to implement a correct cleaning of the workplace, a checklist was proposed where the parts and/or materials that were working normally were considered, this due to the prevention of failures in the production of impressions and to eliminate reprocessing.

Once the order and cleaning procedures were finished, a final audit was carried out that consisted of the development of forms where compliance with these activities was evidenced as seen in the Figure 3. After the meeting with the supervisor, opportunities for improvement and alternative solutions were established.

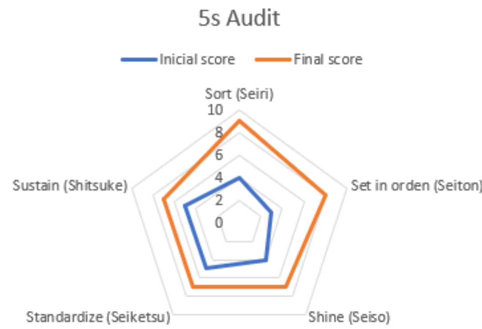


Fig. 3 5'S Audit.

C. Jidoka

Within the implementation of the Jidoka tool, the Poka Yoke and Andon methods were considered. To improve quality within the textile company, a series of steps were followed:

First, the error was identified, which was found in the sublimation area, and to identify the errors, a defect registration form was made, which collected information for a period of 3 months. Then we proceeded to prioritize the problems with a Pareto diagram, resulting in burned sublimated polo shirts and the error in the sublimation color. Both have as their root cause the confusion on the part of the operators in the manual digitization and the increase in temperature of the sublimation plate.

Finally, the Poka Yoke and Andon tools were developed, where a thermostat was applied that helps to identify if the internal temperature of the plate is equal to the programmed one, in case of an increase, this Poka Yoke will launch an alert and the management of this is through an Andon system, specifically a bicolor control tower.

In this case, the system detected an error and proceeded with the analysis where the coordinator and the operators identified that it was an error in the manual digitization of the temperature. For this reason, as a definitive solution, stickers were implemented to classify each garment, which had to be attached to the corner of the sublimated paper and a visual aid board for time and temperature control that had the colors of the stickers.

D. TPM

1) Autonomous Maintenance

For the development phase of the TPM methodology, the implementation of Autonomous Maintenance was carried out, carrying out training plans so that operators and supervisors consider optimal cleaning, ink changes and printer heads assigned around Print. Next, we proceeded with the development of the procedures that the operators must follow for a correct maintenance of the machines with the aim of avoiding unscheduled stops.

2) Preventive Maintenance

One of the main causes that was observed in the initial diagnosis of the company, revealed a high processing time in the printing area, for which preventive maintenance activities were developed to guarantee that the printers operate in their best conditions without presenting breakdowns. The first step to develop this pillar was to carry out a time study to record the failures in the printing machines. In the Pareto diagram, it was recorded that the obstructions of the heads and the cartridges without ink represented 80% of the failures, which is why it was decided to measure them through the indicators of Mean Time Between Failures (MTBF) and the mean time of Repair (MTTR).

With the registration of the indicators, it was possible to show that the month of June was the month with the greatest failures, because it represents the lowest value of the MTBF with a mean time between failures of 84.35 hours. This means that, on average, for every 84.35 hours, a failure occurred in the equipment on this line. Likewise, the MTTR indicator showed a positive trend that indicated that the repair time of the equipment has been increasing.

V. DISCUSSION

With the implementation of the improvements for the company, it was possible to increase to an OTIF of 75% because of complying with the inventories as indicated by the authors [1] [7] [8] who indicate that the improvement of the inventory varies up to 5 % additional to the one already had with the correct inventory planning.

Likewise, the correct inventory was increased to 90% with the application of DDMRP where the applications of the authors are considered [4] [9] and according to the algorithms of the authors [10] [11] [12] with the correct application of DDMRP in the planning and production line, the percentage of healthy inventory should not drop below 89% finding the correct result. Finally, the defectives were reduced to 4.4% as indicated by the authors [19] [20] the percentage cannot be greater than 5’s after applying the 5's and TPM as fault elimination methodologies and therefore dead times where the author [21] indicates that it obtained 4.9% of defectives.

VI. CONCLUSION

It is concluded that the improvements proposed for the case study were effective to such an extent that they exceeded the objectives that were set for the indicator product of the literature review, which allowed establishing a Benchmarking by other authors, who among them carry out improvements; however, they fail to relate the improvements they propose. Therefore, in this article the implementation of DDMRP is proposed as two of the main scientific contributions, which are not usually considered in other case studies in a practical way in small organizations; however, in this case study a 17% increase in inventory accuracy was proposed and successfully implemented. Likewise, no change would have increased, as in the case study, if the concept of change management had not been considered and implemented corporately, since it focuses on a commitment of employers and the employee with continuous improvement and flexibility to improvements, since the level of acceptance by the collaborators reached 95%, this indicates that the effects of engineering improvements increase because they share the same objective of continuous improvement.

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