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Production management model through MPS and line balancing to reduce the non-fulfillment of orders in lingerie clothing MSEs in Peru

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Abstract. The focus of this research is to establish control and planning management in the sewing production process of lingerie clothing to better prepare companies for demand growth. The lack of improvement tools in this sector, the lack of staff training and a lack of quality culture has led to companies, especially MYPES, not being able to meet the established delivery times and non-fulfillment of orders with the customers, which represents 80% of dissatisfied orders due to the limited production capacity and non-productive time in the plant. This problem is due to limited production capacity, deficient production planning, and lack of materials. In order to solve this problem, industrial engineering tools were used. The application of these tools improved production from 79% to 95%.

1. Introduction

Textile companies have grown exponentially within the informal market, becoming commercially dynamic without the required accompanying strategic development. The textile industry is very important for the country's economy because it accounts for 1.3% of the GDP. Furthermore, this industry is considered the second most important industry within the manufacturing sector, which accounts for 7.4% of the GDP [1]. According to National Society of Industries, 87.5% of textile products are consumed in the domestic market, and demand for 12.5% of textile products is from the external market. Thus, the national market is the biggest consumer of textile products. Most textile industries are made up of microenterprises, which represent 95% of the total number of companies within this sector [1]. Most textile companies engaged in garment production (MSEs) are managed according to the owner's basic knowledge, without proper planning and control.

The companies' production is not aligned with demand, which causes problems related to non-fulfillment of orders [2]. Currently, the market has begun appreciating the time taken and the quality of the product's delivery [3]. This is related not to cost reduction but rather to the elimination of its

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cause. Non-fulfillment of orders is the most important problem of the sector. Non-fulfillment or delay of orders affect the profitability of the company; as a result of the root causes, they lead to an excess of working hours for the workers and a stagnation of raw material. "Poor management will result in unsatisfied demands and will lead to the failure of organizations" [4].

Lingerie clothing production has increased from 2012 to 2017 by 52% [4]; therefore, an opportunity to improve can be observed, considering that companies must be prepared for the increase in demand for this kind of garments. For this reason, companies, especially MSEs, need to be well organized in order to satisfy growing demand and correct existing problems. Without discipline and culture to shape the company, the results of any search for improvements will be circumstantial and are likely to fail. Therefore, several techniques that contribute to the improvement of fulfilling orders in companies have been used. This model suggests ways for reduction of such non-fulfillment of orders by means of a production planning and control model in Peruvian lingerie clothing MSEs. For such purpose, the value of the customer and the fulfillment of orders should be maximized in order to increase the final value of the products. The Deming cycle (PDCA) and other tools that may contribute to the company should be used in each phase including master production schedule, material requirements planning (MRP), line balancing, and training, focusing on the improvement of quality in organizations. These tools will be used to solve a problem existing in lingerie clothing MSEs of the textile industry.

2. State of the art

2.1. Master planning schedule and material requirements planning
The non-fulfillment of orders is due to poor estimates regarding production capacity, performance of raw material resupply, and production control. Lack of production control also causes thefts, recounting errors, misplacement, and damage of raw materials. This inaccuracy costs 10% of profits in retail companies [5].

In one study, the MRP system is used because it is more flexible and adaptable to the changing conditions of the market. This model allows a faster and more consistent delivery of a mix of products with different volumes [6]. However, other authors have stated that the MRP has some limitations with respect to production capacity and fixed delivery periods. Therefore, they present a model that includes material requirements planning (MPS) for a more competitive production planning [7][8]. Another study applied the MRP tool under a mixed integer linear programming model, which allowed for the estimation of net requisites of products in processes and the amount of batches [9].

2.2. Line balancing
On the one hand, the stage presenting the most deficiencies is thought to be sewing because in this stage, several operations having different cycle times to be performed are involved [10]; on the other hand, some authors claim that the sewing process is the most important and crucial stage among all processes of garment production [11]. As a result, the problematic areas, commonly known as the bottleneck, appear in the production line, work, or operation station. The bottleneck operation has the longest cycle time, and this is where the sewing process slows down because not all the workers are experts in carrying out the whole process. Bottleneck problems are the main reason for efficiency reduction in the production line [10]. The delivery period for this process is fixed according to the time taken to move the material, seeking to eliminate this waste, that is, the waiting time in processes. Reorganizing internal processes in the production process alone is not enough to ensure the fulfillment of orders. Deficiencies within the supply chain should be identified, and strategies must be adopted accordingly [12].

Line balancing is a type of technique used to balance the production line. However, the application of this technique is not ideal without meeting the standards of working faster while achieving better quality [10]. In the study, observation and description of the work method will provide insights

regarding how the work is done and identify how to improve the process and how long it should actually take [13].

Line balancing helps to assign tasks in workstations, so as to achieve optimal assignment. With this method, the elimination of bottlenecks and reduction of activities with no added value in each workstation is sought, that is, a method to share tasks. The research methodology includes estimates on the hourly production capacity; the cycle time of each process; and identifying bottlenecks, activities with no added value, and the production line balance by means of the work-sharing method. Line balancing through the work-sharing method provides higher efficiency in the line of production as well as the workforce [14].

3. Contribution

3.1. Proposed model
An outline of the model can be found in Figure 1. The design for the solution model is presented, which is divided into the four phases of PDCA.
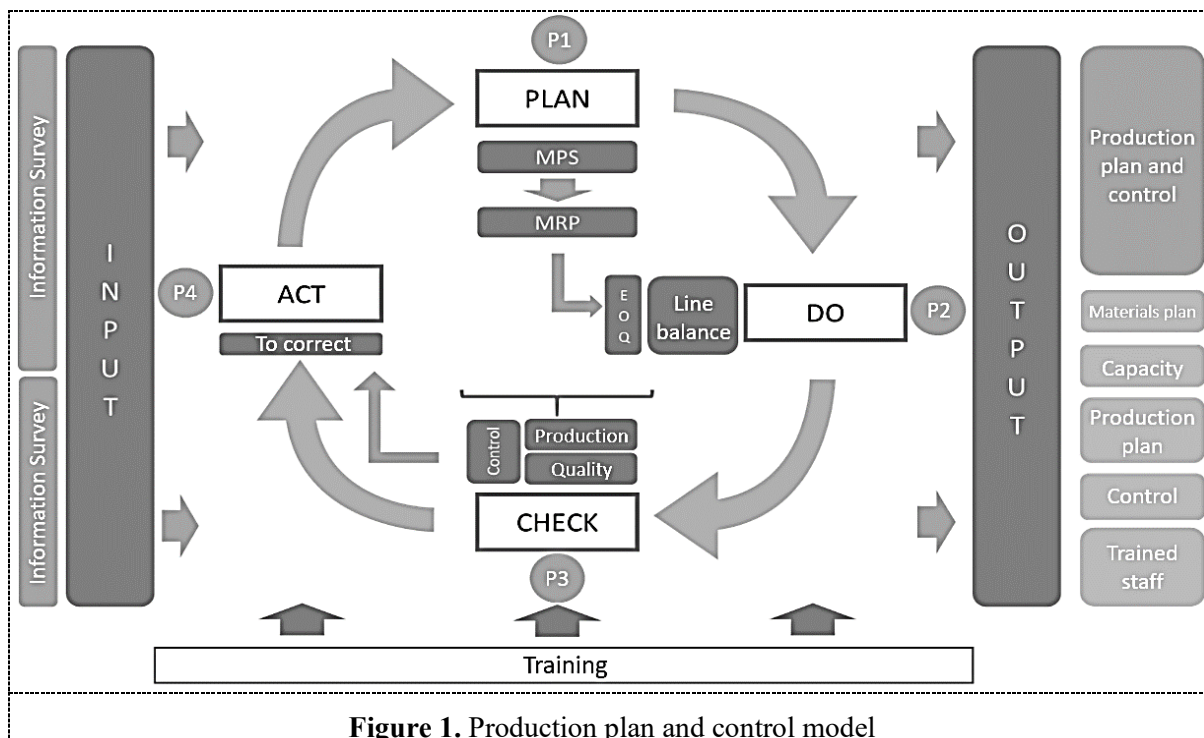

Figure 1. Production plan and control model

3.1.1. Phase 1: PLAN. The members of the senior management and the workers involved in the production process should be committed. Furthermore, an identification of the process answering the five Ws should be made. After its application, the MPS is applied to the preliminary capacity and the MRP, thus achieving the plan for materials, purchases, and production.

3.1.2. Phase 2: DO. The line balancing tool is applied, which will be used from the moment products and orders are requested. With the application of this tool, workers' request and capacity optimization will be achieved. Throughout its application, quality training should be made to raise awareness among workers in order to create knowledge in terms of quality.

3.1.3. Phase 3: CHECK. The third phase involves a verification of production control and quality training. The production control activity is related to the MPS and line balancing, in which planning compliance is controlled. Furthermore, a follow-up of the specifications made by the customers

ordering products is carried out, in which surveys are conducted to identify whether workers need to have more training.

3.1.4. Phase 4: ACT. The carried-out process needs to be assessed in order to constantly improve its performance. If any defect, error, or reduction is found, the PDCA stages should be applied in order to solve it.

3.2. Proposed method. The proposed method is presented with a flow chart, which can be seen in Figure 2, of processes describing in detail each activity that needs to be performed.
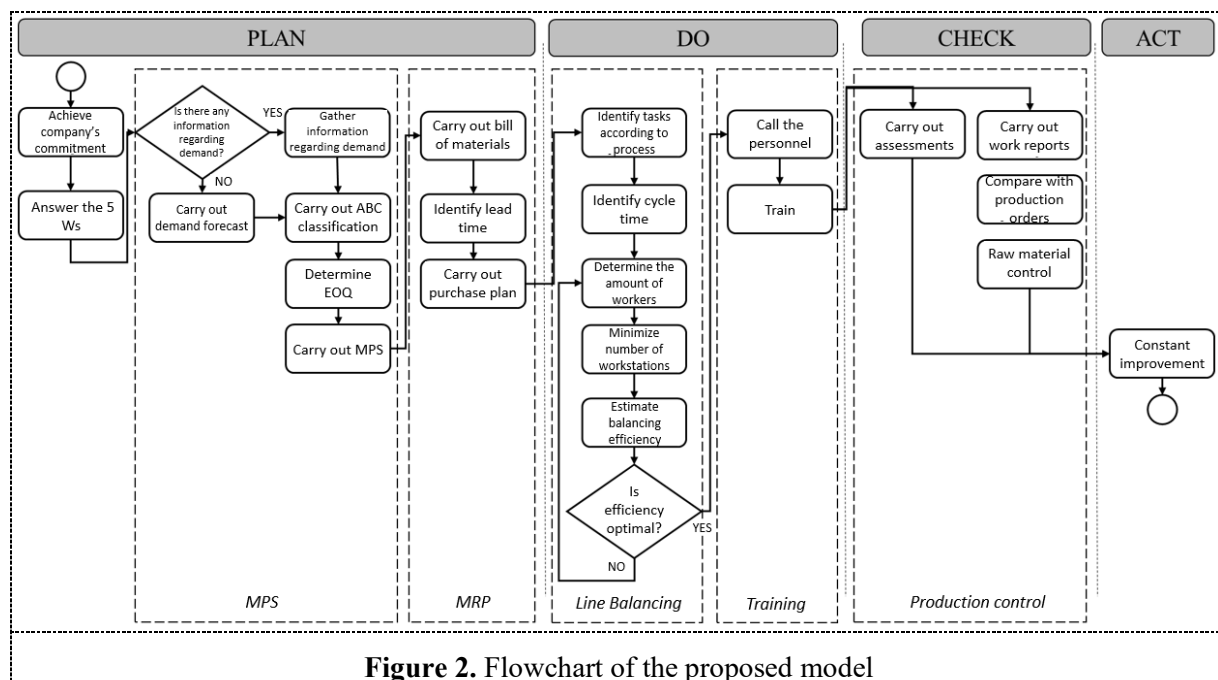

Figure 2. Flowchart of the proposed model

3.3. Indicators

3.3.1. Indicator 1. Fulfillment of Orders (FOO): Fulfillment of orders at a level higher than 90% is expected to be achieved.

$$FOO = \frac{Orders\ fulfilled}{Total\ orders} \times 100 \tag{1}$$

Interpretation: If the result is higher than 85%, it is considered optimal; between 60 and 84%, it is considered regular; and finally, if the result is 59% or lower, it is considered deficient.

3.3.2. Indicator 2. Production Capacity (PC). Production capacity at 95% efficiency is expected to be achieved.

$$PC = \frac{Actual\ capacity}{Suggested\ capacity} \times 100 \tag{2}$$

Interpretation: If the result is higher than 95%, it is considered optimal; between 70 and 94%, it is considered regular; and finally, if the result is 69% or lower, it is considered deficient.

3.3.3. Indicator 3. Production Efficiency (PE). Production efficiency of 95% is expected to be achieved.

$$PE = \frac{Finished\ products}{Requested\ products} \times 100 \tag{3}$$

Interpretation: If the result is higher than 95%, it is considered optimal; between 70 and 94%, it is considered regular; and finally, if the result is 69% or lower, it is considered deficient.

3.3.4. Indicator 4. Raw Material Handling (RMH). Less than 5% of waste is expected to be achieved.

$$RMH = \frac{Raw\ material\ used}{Raw\ material\ received} \times 100 \tag{4}$$

Interpretation: If the result is lower than or equal to 5%, it is considered optimal; between 6 and 10%, it is considered regular; and finally, if the result is 11% or higher, it is considered deficient.

4. Validation

4.1. Case study
The pilot plan will be applied in a company called Sensualidad y más EIRL, identified with the taxpayer number 20600864387. This company is engaged in the design, production, and sale of female lingerie garments. The key processes are design, cutting, sewing, and packaging. The company's demand is seasonal; it sells more products in January, February, July, November, and December. This company sells products as per request, but it also has three stores located centrally in Gamarra. The production is carried out in a workshop located in the district of La Victoria.

4.2. Initial diagnostic
A diagnostic was carried out in the case study, generating the following initial results:

Table 1. Initial diagnostic

Indicator	Diagnostic
1. FOO	78 %
2. PC	79%
3. PE	89%
4. RMH	11%

4.3. Contribution development within the context

4.3.1. Component 1. The ABC classification is carried out in order to find the most important product:

Table 2. ABC Classification

	Units	Sales (S/.)	% of sales	Accumulated %	ABC Classification
Line 1	25632	S/. 812,021.76	64.00%	64%	A
Line 2	10269	S/. 329,883.84	26.00%	90%	B
Line 3	4110	S/. 126,878.40	10.00%	100%	C
TOTAL	40011	S/. 1,268,784.00	100%		

As can be seen, Line 1 is most important for the company.

After the MPS is carried out, the size of the batch is needed to develop it:

$$Qpoq = \sqrt{\left(\frac{f}{f-d}\right) * \frac{2*D*S}{H}} = \sqrt{\left(\frac{93}{93-92.8}\right) * \frac{2*25632*11}{276*0.51}} = 1683 \; unidades \qquad (5)$$

The number of units produced in each period is 1,683. Once the EOQ and initial inventory (421 units) is known, the MPS is carried out. As a result, the monthly MPS should be of 2,000 products.
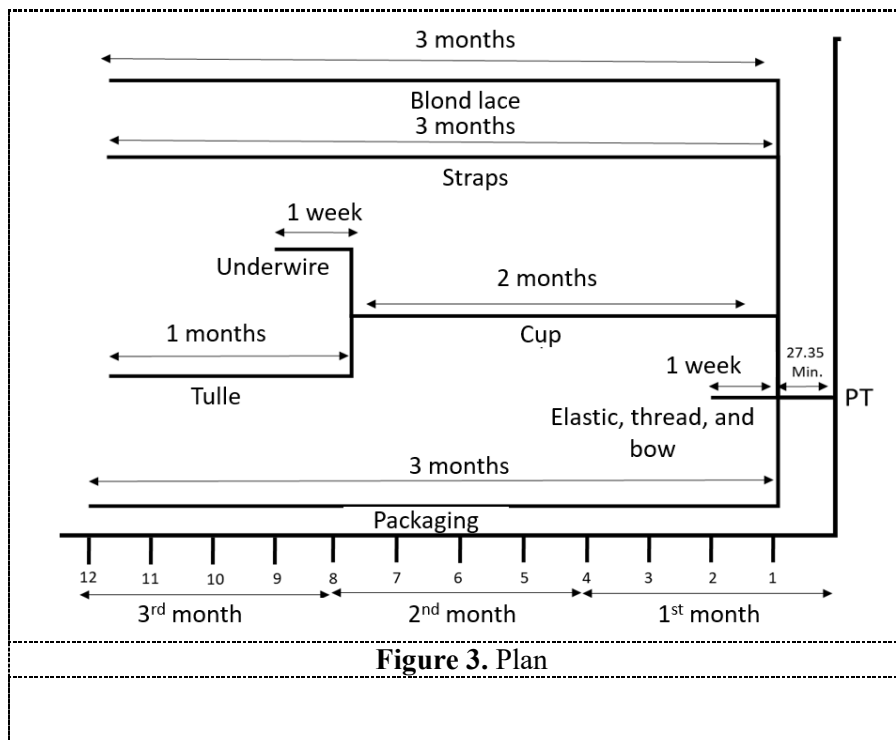
4.3.2. Component 2
Once the production planning is established, the material requirements planning (MRP) is carried out. The BOM is carried out for materials acquisition.

Afterward, the lead time for each material is carried out:

Table 3. Materials' Lead Time

Material	Requirement	Time
Finished product	1 unit	22.83 minutes
Parts	1 unit	15 minutes
Thread	1.5 meters	1 week
Tulle	2 meters	1 month
Blond lace	2 meters	3 months
Elastic	1 meter	1 week
Underwire	1 pair	1 week
Cup	1 pair	2 months
Straps	20 cm	3 months
Bow	25 cm	1 week
Packaging	1 unit	3 months

Finally, the purchase plan is carried out at this stage, in which the estimated time needed to acquire the raw materials before production starts is three months.

Figure 3. Plan

4.3.3. Component 3

In order to perform line balancing, first the tasks to be carried out in the production process need to be detailed and subsequently grouped.

Table 4. Tasks

Description	Means / Equipment	Distance (m)	Time (min/units)	Precedence
1. Design product	Computer		1	-
2. Inspect and cut fabric	Scissors		0.5	-
3. Transport		2	0.25	-
4. Mend	Mending machine		2.5	2
5. Mend basting stitch	Mending machine		1.5	1
6. Inspect blond lace			1	1
7. Cut blond lace	Scissors		0.5	6
8. Inspect elastic			1	1
9. Cut elastic	Scissors		0.5	8
10. Transport		0.5	0.25	
11. Sew	Regular sewing machine		2.5	9
12. Inspect cup			1	1
13. Line cup			2	12
14. Sew	Regular sewing machine		3	13
15. Inspect straps			1	1
16. Cut straps	Scissors		0.5	15
17. Place straps			0.5	16
18. Inspect bow			1	1
19. Cut bow	Scissors		0.5	18
20. Sew	Regular sewing machine		3	19
21. Transport		0.5	0.25	
22. Sew frayed edge	Flatlock sewing machine		2.5	20
23. Place underwire			1	22
24. Transport		0.5	0.25	
25. Sew straps	Coverstich machine		1.25	23
26. Sew elastic	Coverstich machine		1.25	25
27. Transport		0.5	0.25	
28. Sew bow	Knitting machine		2	26
29. Pack			1.25	28
30. Store			1.25	29
TOTAL:		4	33.25	

The line balancing is carried out to define the optimal number of workers to perform the sequence of tasks.

Table 5. Sequence of Tasks

N°	Task	Name of the task	Minutes	Estimated time (Sec/units)	Units/minutes	Workers	Total Units			EFFICIENCY
1	A	Inspect and cut	7.5	450	0.133	2	0.267	225	310	73%
2	B	Remesh	4	240	0.25	1	0.25	240	310	77%
3	C	Sew	15.5	930	0.0645	3	0.194	310	310	100%
4	D	Sew frayed edge	3.5	210	0.285	1	0.286	210	310	68%
5	E	Packaging	1.25	75	0.8	1	0.8	75	310	24%

It has been recorded that eight workers are needed for a demand of 75 units per shift. With this number of workers, 92 units were produced per shift. Also, an increase in productivity is achieved with 11.5 garments per worker.

Table 6. Productivity

		Workers	Per./hour	Perf. /shift	Productivity
75 8	Units Hours	8	11	92	11.5
63 8	Units Hours	6	8	63	10.5

However, it can be seen that the efficiency of the tasks is not adequate, and therefore, an improvement is needed. Next, the last two activities are grouped in order to be performed by a single worker to improve efficiency:

Table 7. Sequence of tasks

N°	Task	Name of the task	Minutes	Estimated time (Sec/units)	Units/minutes	Workers	Total Units			EFFICIENCY
1	A	Inspect and cut	7.5	450	0.133	2	0.267	225	310	73%
2	B	Remesh	4	240	0.25	1	0.25	240	310	77%
3	C	Sew	15.5	930	0.0645	3	0.194	310	310	100%
4	D+E	Sew frayed edge+ Packaging	4.75	285	0.211	1	0.211	285	310	92%

It has been recorded that seven workers are needed for a demand of 75 units per shift. With this number of workers, 92 units were produced per shift. Also, an increase in productivity is achieved with 13.14 garments per worker.

Table 8. Productivity

		Workers	Perf./hour	Perf./shift	Productivity
75 8	Units Hours	7	11	92	13.14285714
63 8	Units Hours	6	8	63	10.5

By producing 92 units per shift, 2484 garments can be produced per month, with a cycle time of 27.85 minutes/garment, achieving an average efficiency of 85.5%.

$$Cycle\ time = \frac{69,195\ \frac{minutes}{month}}{2484\ \frac{garment}{month}} = 27.85\ \frac{minutes}{garment} \tag{6}$$

- **Indicator 1:** According to the measurement, a result of 95.90% was obtained, which indicates that the capacity for efficiency is optimal.
- **Indicator 2:** A result of 89.7% was obtained, which indicates that according to the measurement, the actual production capacity is optimal in respect to the one suggested.
- **Indicator 3:** A result of 95.3% was obtained, which indicates that according to the measurement, the production efficiency is optimal.
- **Indicator 4:** A result of 4.3% was obtained, which indicates that according to the measurement, the raw material handling is optimal.

5. Conclusions

After production planning, it was concluded that according to the PMP, 2,000 units need to be produced monthly for the three months in which demand is higher. The production master plan is used to set the production plan for the company.

Line balancing is carried out, which helps to know the number of workers needed and also to establish the number of workers for each task. According to the results, seven workers are needed for production in the plant.

An efficiency of 71.5% was obtained in the line balancing of the tasks.

Between the current situation and the pilot plan, an improvement with respect to the production capacity and creation of knowledge about the quality of workers in a period of time can be observed. If these levels of efficiency and productivity continue, the expected production levels can be achieved, and customer satisfaction can be met.

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