International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V70I8P244

Volume 70 Issue 8, 435-446, August 2022
© 2022 Seventh Sense Research Group®

Original Article

Application of Mixed Methodologies in the Production Planning of Screw Conveyors for the Flour and Pasta Food Industry

Lucy Casallo[1], Elizabeth Lucero[2], Fernando Maradiegue[3], Eloy Marcelo[4], Jose C. Alvarez[5]

[1,2,3,4,5]*Department of Industrial Engineering, Universidad Peruana de Ciencias Aplicadas, Lima, Peru.*

[1]u201615417@upc.edu.pe

Received: 27 May 2022 Revised: 04 August 22 Accepted: 20 August 2022 Published: 27 August 2022

Abstract *- The continuous growth of the food industry has consequently brought the need for equipment, parts, and pieces to meet the local market demand. One of these parts has a higher demand in the market, which are the screw conveyors of stainless steel 304; these are one of the components that have greater use of hours machines. For this reason, it is required to plan maintenance and repairs in the industry of reference. This article is focused on identifying the most important failure reasons in the agribusiness supply industry; it was identified that the processes of greatest opportunity measure and assembly. These processes increase the delivery time of the final product, which failures should not increase because providing the product outside the agreed time causes high financial impact as penalties and loss of customers. The company manufactures various parts for industrial mills and has a problem with delivery delays because its current fulfilment rate is below correct. This delay causes poor distribution, lack of proper planning, and not having proper cleaning in work areas. To solve this problem, it is proposed to apply mixed tools that include standardizing work to reduce production time and redistributing workstations; and the application of MRP. The proposal shows an increase in the level of on-time delivery service, which contributes to reducing penalties.*

Keywords *- Screw conveyor, On-time deliveries, System layout planning, Standardization work, Simulation.*

1. Introduction

The company under study belongs to the metal-mechanic sector [1]. Total sales from this sector in 2019 were approximately $ 37,525.30 million [2]. Regarding the Physical Volume Index of Manufacturing Production, the variation was -4.8% when comparing 2018 and 2019; the index decreased, which may be caused by the different problems within the production processes [3].

The American company EEMAX has been considered a model to follow, with an average compliance rate of 95% [4]. The increase of the food needs in the market has brought consequently that the machines that make products in the different processes are affected by the performance of the parts or pieces; this performance of acceptance is referred to as the quality of the performance of the machine when it exceeds the working hours of the same. Exceeding these times results in line stoppages, which generates that the plants work very closely with metalworking service providers. In this context, most orders that a metalworking organization works with are urgent. For this reason, the level of service is low because the local and national industry does not have good control of the performance of the machinery, not necessarily because the service provider does not do it on time but because it does not receive the orders with a schedule advantage that allows them to ac. The proposal in this situation is to have the organization's internal processes standardized so that when the requested parts arrive, it can work directly with the customers to detect the anomaly in time.

Currently, the studied company has an average on-time delivery rate of 41% for its main product, which is the screw conveyor. Consequently, it has a low percentage of compliance. Therefore, the problem to be mitigated and reduced is the delay in the screw conveyor production process.

It is proposed to use mixed methodologies; this solution reduces the delay in the productive processes and improves the distribution of the plant. On the one hand, the simulation program Arena will be used to validate the time reduction. In this case, the bottlenecks are the measurement and assembly processes. On the other hand, the AutoCAD program will recommend the new distributions and validate the reduced traveled distances.

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

The organization of this article is as follows: first introduction, second state of the art, third materials and methods, fourth results, fifth discussion and sixth conclusions.

The problem was analyzed in detail in the short article. Next, the results obtained will be indicated. Currently, the average on-time delivery rate is 41%. This represents a total cost of $96,000 per year. In addition, the rate is below the target, reaching a maximum of 75% compliance (Figure 1).

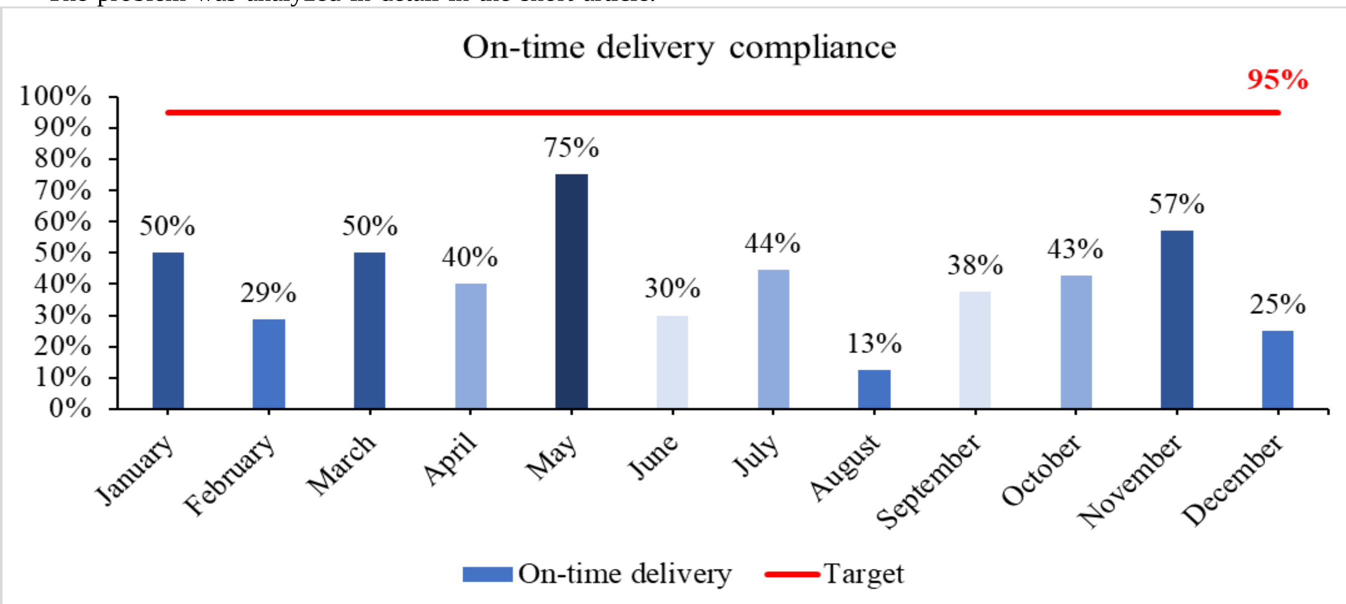

Fig. 1 The figure consists of a bar diagram: a representation of deliveries on time that the company has had each month of 2019. 95% represents the goal to which it wants to reach [5]

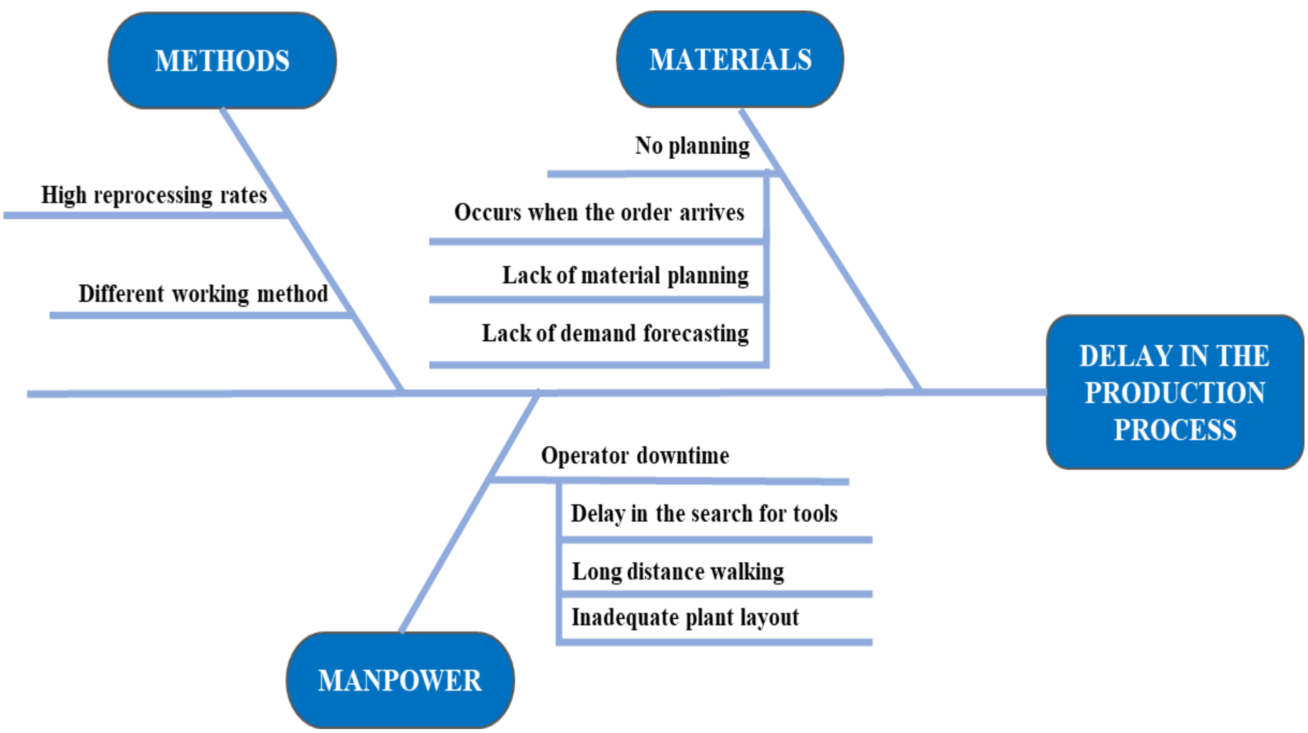

Fig. 2 The figure consists of a root cause analysis representing the main causes of delays in the production process. These causes are divided into three: Materials, Methods, and Manpower [5]

Table 1. Percentage of causes

Percentage share of the causes of the problem	%
Poorly distributed workstations	43%
Delay in finding tools	31%
A different method of working	15%
Incorrectly measured parts due to inadequate calibration	6%
Lack of planning of MP requirements	6%

Figure 2 shows the Ishikawa diagram to identify the secondary causes of the delay problem. In addition, Table 1 placed the causes of the problem and the percentage of each influencing the delay in deliveries corresponding to the period of 2019. The main causes are poorly distributed workstations and delays in finding tools.

The main causes identified are related to delays in deliveries, since the poor distribution of workstations and the extra time it takes for operators to look for their tools negatively add more hours to the production of the final product. For this reason, this research aims to determine the causes of delays in production processes, which are generated in the same production process and even those generated with the different activities that the operators have for the same process. Not having a standardization in the processes generates many problems of delays and even non-compliance in the production processes leading to a bigger and main problem for a company, having losses of money and materials, and not being able to retain customers due to non-compliance with an order.

2. State of the art

State of the art was extensively developed in the brief article. Therefore, in the following paragraphs, a general explanation of the contribution of some authors who contributed to the development of the article will be given.

2.1. Advantages of the redistribution of workstations

Tiacci [6] and Monteiro et al. [7] have delays in the production process as a problem. For this reason, they propose minimizing the number of stations as a solution.

2.2. Benefits of using the MRP tool

About Pooya et al. [8], the author mentions the importance of receiving the correct information for the production schedule since this information allows for determining the quantity to be produced and the time it will take to place the orders.

2.3. Benefits of using the 5s tools

The research of Randhawa and Ahuja [9] showed that applying the 5s contributes positively to the processes of companies. For their part, Neves et al. [10], Veres et al. [11], and Makwana [12] managed to increase productivity. Pombal et al. [13], Makwana [12] and Lastra et al. [14] showed that it is possible to achieve a reduction in the placement time of the materials.

2.4. Benefits of using the 5s and SLP tools

Gutti-Salazar et al. [15] and Rabanal et al. [16] use SLP (Systematic Layout Planning) to improve production lines. Both demonstrated that the joint application of the 5s and SLP contribute to improving processes.

2.5. Advantages of standardizing the working method

Machado et al. [17] and Harari et al. [18] provide the standardization of the work method as a solution to their problems. On the other hand, Desai [19] proposes a design methodology in his solution, with which he manages to reduce the assembly time from 102 seconds to 11.9 seconds.

It is concluded that the application of the 5s helps to reduce the material search delay [13]; however, not only is the application of the 5s sufficient but it must be complemented by SLP [15]. However, material search delay can be reduced with only the application of the 5s tool [12]; moreover, there is an increase in productivity. In addition, no scientific articles have been found where the SLP tools, 5s and work method study are integrated into any company within the metalworking sector. Therefore, the proposed solution of this article is significant both for the studied company and the entire sector.

3. Materials and Methods

To define the tools to be used by the authors, an outline of the causes of the problem and the tools to be used for the proposed solution (Figure 3).

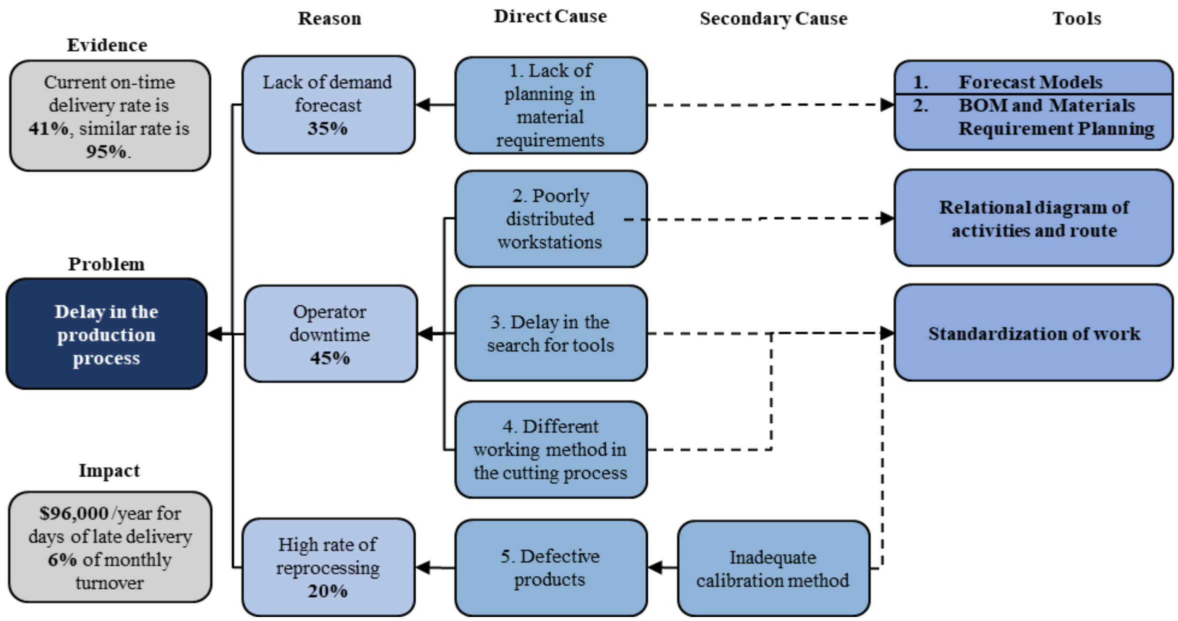

Fig. 3 The figure consists of the analysis of the problem, the causes, and tools to be used: a representation of the tools that will solve the delays in the production process. These are divided into three: Forecast Models, BOM and Materials Requirement Planning, Relational diagram of activities and route and standardization of work

The first cause identified is the lack of planning in the materials requirements. To solve it, a Master Production Plan was developed to know when to order the materials. The second cause is poorly distributed workstations; in this case, it is proposed to redesign the layout using the Relational and Path Diagram tool. The third cause, the delay in searching for tools caused by the disorder, will be solved using standardization of work to establish order. The fourth cause identified is the different work methods in the cutting process, and the fifth cause is the inadequate calibration method; both will be solved by standardizing the work method.

The proposal consists of 4 phases, PLAN, DO, VERIFY and ACT. Each step of the tools is detailed in the short article [5]. For the proposal, a continuous improvement model has been made (Figure 4).

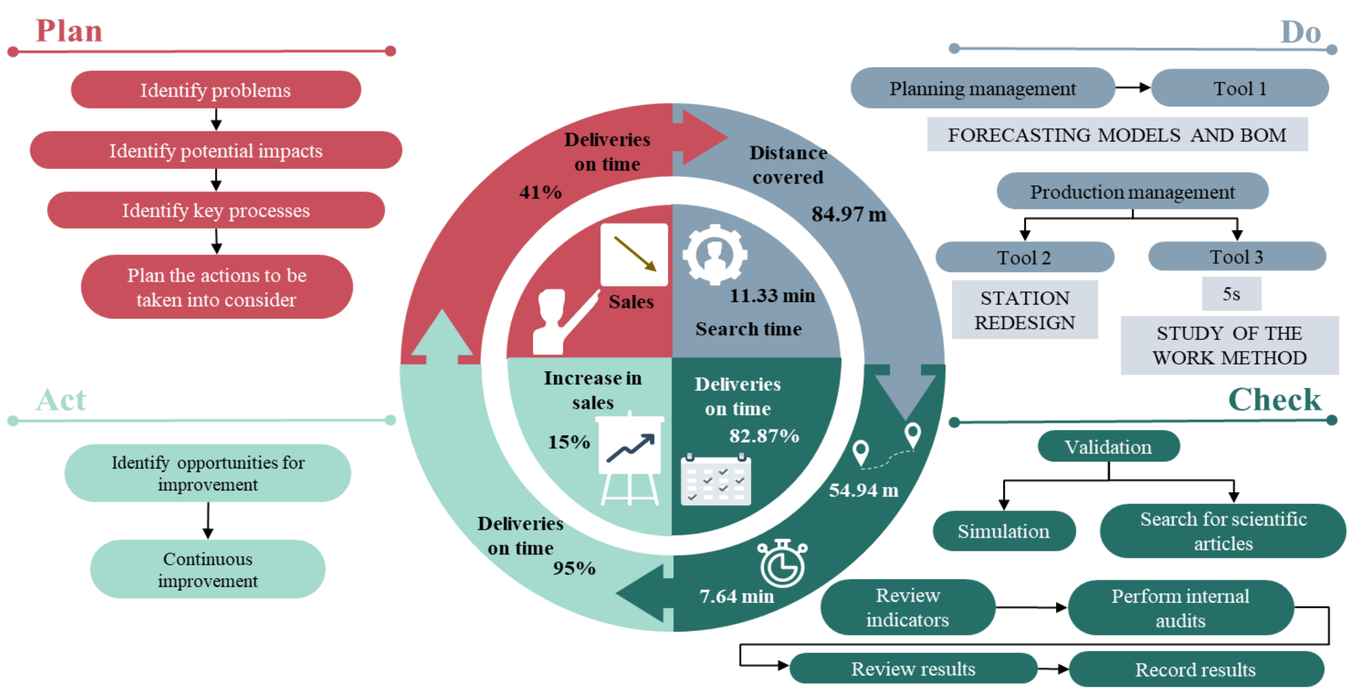

Fig. 4 The figure consists of a continuous improvement model: a representation of the specific model of the proposed model to solve the problem

3.1. Relationship between the proposed tools

The link between planning and production is that both focus on reducing product delivery delays. On the one hand, it will forecast and establish the times to order the materials and meet the demand. Also, the plant layout will be redesigned to reduce travel time, and workstations will be back-to-back. On the other hand, the method of layout and calibration of the manual cutting machine will be standardized. Also, discipline is linked to implementing the proposed methods because if it is not disciplined and maintains the solutions, it will incur the same problem again.

3.2. First phase of the proposal

The first phase is PLAN, where the problems and potential impacts on the company, whether quantitative or qualitative, are identified. It also identifies the key manufacturing processes of the stainless-steel conveyor wires; finally, it plans the actions to be considered. At this point, it is concluded that on-time deliveries are 41% below expectations on average.

3.3. Second phase of the proposal

Next, the OD is carried out. At this point, it starts with the planning management, including the first tools, the forecast and bill of materials models. In addition, the MRP of the production process is elaborated where it indicates in which week to start manufacturing each piece at the end. Then, the tools are executed within the production management, where the second and third tools will be used. The second executed tool is redesigning the current layout and proposing two alternative solutions. The third and last tool includes the application of the 5s and the study of the work method. For the application of these tools, an initial audit was first performed, resulting in a search time of 11.33 minutes and a travel distance of 84.97 meters.

3.4. Third phase of the proposal

Then, the CHECK phase will be executed, where the simulation and search of scientific articles will be carried out for validation. In addition, the indicators and results will be reviewed; the improvements obtained are the increase in the percentage of on-time deliveries to 82.78%, the reduction of the distance traveled to 59.94 meters and the search time to 7.64 minutes.

3.5. Fourth phase of the proposal

The last phase is the ACT, in which opportunities for improvement will be identified, and continuous improvement will be carried out. These phases can be repeated as a cycle, starting with PLAN, then DO, etc. Repeating the cycle is expected to achieve a 95% on-time delivery rate.

4. Results

The results stage is divided into two sections, planning management and production management, based on the authors' success stories in scientific articles. The validation planning can be visualized in Figure 5.

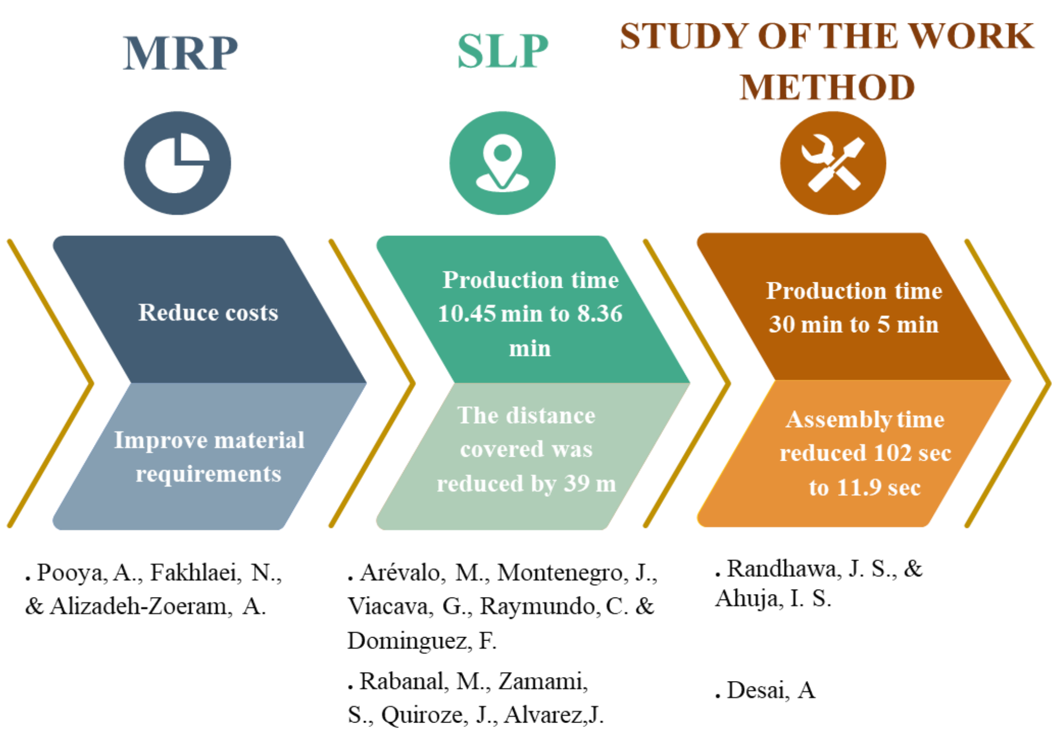

Fig. 5 The figure consists of a presentation showing the authors of each successfully executed tool and the respective results

4.1. Planning management

In the case of MRP, according to the authors Pooya et al. [8], they improved the instability of the material requirement planning system, thus reducing costs. They also mention the importance of receiving the correct information for the production schedule since this information allows for determining the quantity to be produced and the time it will take to place the orders. The authors introduced 3 scenarios, the first, stochastic demand-stochastic lead time; the second, stochastic demand-deterministic lead time; and the last, the company's suggestion. The results of these three scenarios showed that in scenario 2, the nervousness of the MRP system was the highest. Also, the lowest total cost in scenarios 1 and 2 has occurred in the batch-by-batch policy, while it is for the company suggestion related to the fixed-period order policy.

The first results were obtained by applying the first tool, which is the MRP. First of all, the demand forecast was elaborated, which is shown in Figure 6. The forecast shows that there is a strong variability and that there is not meeting the schedule.

Second, the explosion of the material or BOM was elaborated, indicating what is needed to produce a stainless-steel conveyor wire. Next, the MRP was made and, for this, considered the physical stock and the safety stock. The order was considered to be 60 conveyor wires for week 12. The MRP results help them to know when to start production and order the materials to manufacture the product and have it on time. To meet the delivery schedule, orders for materials such as screws, electrodes, metal plates and gear motors must be issued at least two weeks before the delivery date. Also, manufacturing orders for the thread assembly, flanges, hopper, bracket, flange base and covers should be issued two weeks in advance. In addition, tubes and discs must have their production order issued three weeks in advance to meet the delivery date.

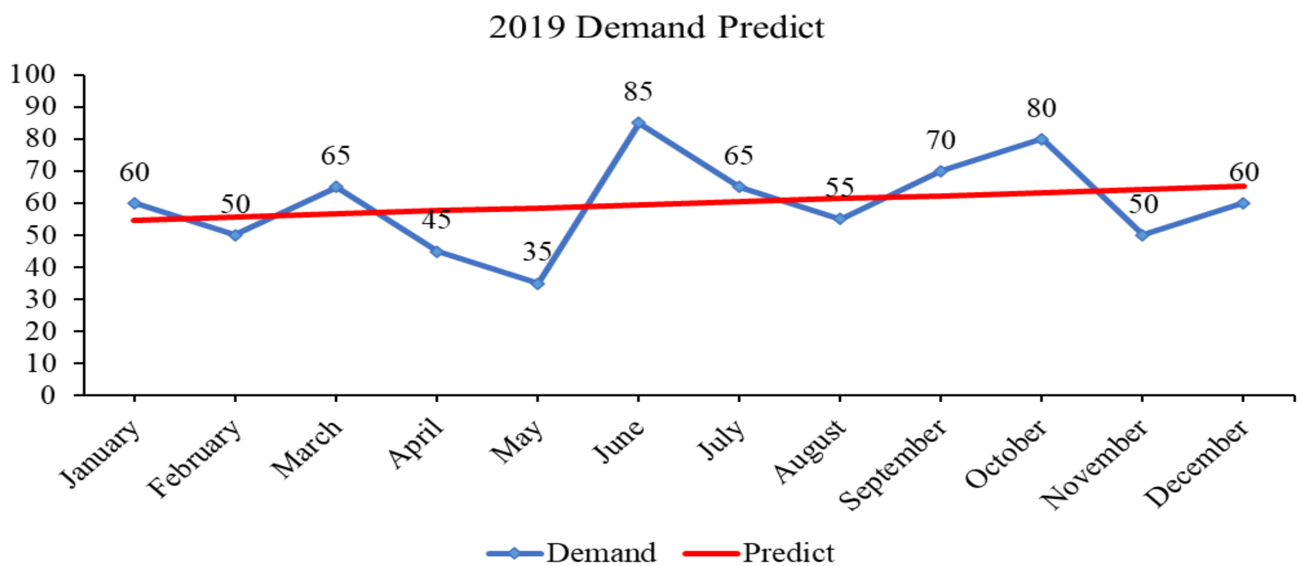

Fig. 6 The figure consists of a continuous improvement model: representation. The figure consists of the 2019 demand forecast: a representation of the number of products demanded (blue line) versus the forecast (red line)

For the planning of the materials, the expert judgment validation method was used since two successful cases have been found in the same sector that obtained good results with the application of this tool. In addition, the current demand of the company would be atypical due to the pandemic, and the pre-pandemic demand is different from the current one. Therefore, it was concluded that considering the current demand would not be acceptable because it would be considering high costs, low demand, months without production and loss of profits. Table 2 shows the analysis of the success cases.

Table 2. Success stories that applied material requirements planning

Authors	Objectives	Results
Pooya et al. [8]	Improve the instability of the MRP system and reduce costs.	Reduction of the fixed order cost by 10.76% and system stability of 62,742 min.
Velasco et al. [20]	To assess the applicability of DDMRP in a complex manufacturing environment regarding customer satisfaction and stock levels.	Reduced delivery time by 41%, and stock levels decreased by 18%.

They conclude that applying this tool in the company studied is feasible because, according to the experts, it would reduce lead time by up to 41%. Thus, the production time of 60 conveyor threads from 17.68 days is reduced to 10.43 days. Likewise, the penalty cost of $8,000 per month is reduced by 10.76%, equivalent to $7,139.20 per month. In addition, the joint implementation of forecasting and material requirements will help to meet on-time deliveries.

4.2. Production management

According to Arevalo et al. [21], the SLP's main problem is high production times, reprocesses and economic losses. The author's contribution to this case was a new distribution in the workstations, consisting of 3 production lines. It will help accelerate the flow of materials and personnel and increase annual production. The result was an increase in production to 5,445 units, which represents 16% of current production, and the cost of implementation is equivalent to 4% of sales revenue in the year of implementation. Delays in order requirements were eliminated. The new standard production time was found through the time study and the redistribution of the plant using the SLP method; it was possible to reduce the production time by 20%, from 10.45 min to 8.36 min.

Another successful case was for Rabanal et al. [16], applying the systematic design planning tool to reduce rework and increase profits. Their proposal has four stages: diagnosis, preparation and design, implementation, and validation. The validation technique they used was through a simulation in Arena, considering the improvement in the employees' performance and the physical changes in the distribution of the area. As a result, the cycle times were reduced to 120.46 min, and the current simulation was compared with the proposed improvement, revealing that the time was reduced to 18.28 min, and the distance traveled was reduced by 39 m.

In their case study, Randhawa and Ahuja [9] evaluated 5S audits in different areas of the organization and obtained the cumulatively after implementing 5S. Their study facilitated the organization to achieve considerable improvements in plant performance. So, the practice of the 5S technique began to produce improvements in the early stages of implementation. The most considerable result was reduced production time from 30 min to 5 min. Likewise, the hours per month of machine breakdowns were reduced from 800 to 95 hours.

For the last tool, which is the work method study, according to Desai [19], the methodology for his case study was based on standard time data. This system facilitates the time to assemble a product before it is designed. The assembly time is a direct function of the product design attributes. The validation technique consisted of 4 steps, from evaluation to an organization of action taking, design alternatives, and costing. This successful case resulted in the reduction of assembly time from 102 sec. to 11.9 sec. reducing up to 88%.

The final results were obtained by applying the second and third tools. The validation of the redesign of the workstations to reduce the distances traveled and the mobilization time from one workstation to another will be validated using the block diagram together with the AutoCAD program. As a first step, they requested the measurements of the plant and the work areas of each activity so that they could elaborate manually and in AUTOCAD the block diagram of the current distribution to know the distances traveled. The route starts in the Raw Material warehouse; then, the operator goes to the Measure and Trace area. Then, he leaves the Measuring area and moves to the Cutting area, then he leaves the Cutting area and goes to the Bending area. Next, he moves to the Weld area, next to the previous area, then he leaves the Weld area and goes to the Assembly area. Finally, it leaves the area, positions itself in the middle of the aisle and takes the finished product to the PT warehouse. The time workers take to go from one station to another is 13.25 (Table 3), and the total distance they travel is 84.97 meters (Table 4).

Table 3. Current travel time

Area covered	Time
warehouse MP → area of measure and trace	1.50 min
area of measure and trace → area of Cut	2.50 min
area of → Court area of fold	3.00 min
area of fold → area of solder	0.75 min
area of solder → area of assembly	1.50 min
area of assembly → warehouse of PT	4.00 min
Total transfer time	**13.25 min**

Table 4. Current distance traveled

Area covered	Distance traveled
warehouse MP → area of measure and trace	12.03 m
area of measure and trace → area of Cut	10.97 m
area of → Court area of fold	19.60 m
area of fold → area of solder	7.00 m
area of solder → area of assembly	14.37 m
area of assembly → warehouse of PT	21.00 m
Meters traveled in total	**84.97 m**

After validation of the current design, they made two new distribution proposals. It should be noted that the proposals were made considering the meters available for each specific area. The Cutting area was moved next to the

Layout and Measurement area in the first proposal. In addition, the Assembly area was relocated to the right of the Cutting area, and the Bending and Welding area was positioned in front of these areas. They considered that the Warehouse area should not be relocated since they are close to the loading and unloading area. In the second proposal, the Assembly and Welding areas were placed next. In addition, the Measuring and Plotting area, the Cutting area and the Bending area were relocated in sequence. The results obtained are shown in Table 5.

Table 5. Current distance traveled

Current Distribution	Distance of 84.97 m
	Travel time of 13.25 min
Proposal 1	Distance of 65.99 me
	Travel time of 10.29 min
Proposal 2	**Distance of 59.94 m**
	Travel time of 9.35 min

They compared both proposals with the current layout and selected proposal 2. The reason is mainly that this proposal reduces 29.43% of the current travel time. In addition, the meters traveled by the operator would be reduced by 25.03 meters, reducing the production time of a conveyor thread and reducing tiredness and fatigue in workers. The validation of the reduction of the material search time by applying the 5s was done by expert judgment since, due to the pandemic situation, the company does not allow the entry of outsiders. Therefore, a search was made for scientific articles that had applied this tool and obtained excellent results. Table 6 shows the analysis of the success cases.

Table 6. Success cases in the reduction of time spent searching for tools

Authors	Objectives	Results
Barzola et al. [22].	Combining various Lean Manufacturing techniques improves productivity and the level of compliance.	Compliance with delivery times increased from 52% to 87%, and penalties for non-delivery decreased from 53% to 17%.
Randhawa and Ahuja, [9].	Evaluate the quantitative and qualitative benefits through strategic initiatives to implement the 5S.	The most considerable result was reduced production time from 30 min to 5 min.
Neves et al. [10].	Optimization of information flows and manufacturing processes.	15% reduction in tool delay time per week and operator.

At the end of the analysis of the authors' results, they conclude that if the 5S is implemented in the company studied, they can reduce the search time by up to 40%. Barzola et al. [22] manage to increase the fulfillment of deliveries by 35%. On the other hand, Randhawa, and Ahuja, by cleaning and arranging the workstations, reduce the search time by 20.67% [9]; likewise, Neves, Silva, Ferreira, Pereira, Gouveia, and Pimentel, by arranging the tool area, achieve a 15% reduction in the time available per week and operator [10].

First, tidying and cleaning the workstations would reduce the search time from 11.33 min to 8.99 min. Next, tidying the tool area would reduce the tool search time from 8.99 min to 7.64 min. Finally, the on-time delivery rate of 41% by applying this improvement increases to 54%.

4.3. Simulation

The last validation method considered to demonstrate the proposal's effectiveness is the simulation of production time. The simulation will consist of simulating the real aspects of the company with the times provided by the organization; for example, the real-time that an operator takes to find his tools, currently is 11.33 min due to the disorder in the work area, the times given by the company were simulated and with the implementation carried out what is expected to be obtained in the simulation is to reduce this time to approximately 6 min. The proposal simulation will indicate how feasible it is to implement it.

The first step to simulating the Arena program is to present the actual system. Then, it analyzed the distribution of each process time using the Input Analyzer program. In addition, 11.59% were considered as the number of parts in reprocesses due to failures in the measurements of the parts. The distributions obtained for each process used for the simulation in Arena were calculated with a sample size of 50.

For the arrival time, a uniform distribution, UNIF (10;13), was obtained as a result. For the Measurement and Tracking time, a normal distribution, NORM (53;0.813), was obtained as a result. For the Cutting time, a triangular distribution, TRIA (40;43;43.8), was obtained. Arrival time resulted in a uniform distribution, UNIF (3;4). Welding times resulted in TRIA's triangular distribution (33,2;35,3;36,4). The assembly times have a uniform distribution, UNIF (51.1;54.8). Once the distributions for each process were obtained, the system was plotted (Figure 7).

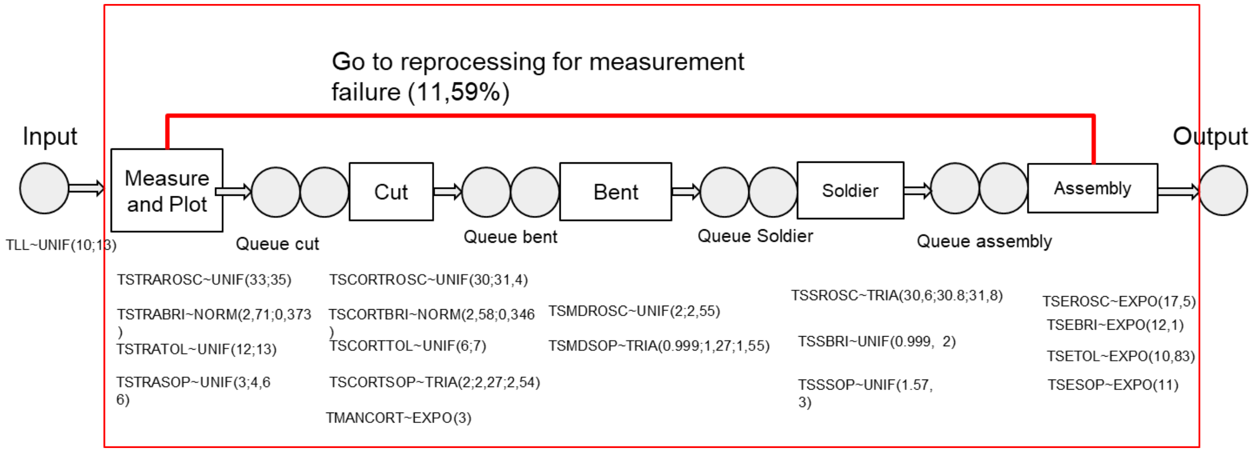

Fig. 7 The figure is a representation of the initial system of the production process that was simulated in the Arena program

After the system representation, the simulation is performed. The result effectively showed that the measurement, tracking, and assembly activities have the longest production time. By running the Arena program, considering the reduction of the time of the runs obtained in the previous validation method, they obtained that the current time of the system is 45534.60 min or 31.62 days for a monthly demand of 60 units of conveyor threads. In addition, it was observed that the percentage of on-time deliveries increased from 41% to 60.15%. It is concluded that the process improved, but if the daily demand of 3 units is considered, it would not be fulfilled since, with the time obtained, it is possible to produce up to two threads per day. Figure 8 shows the simulation in execution with the proposed improvements.

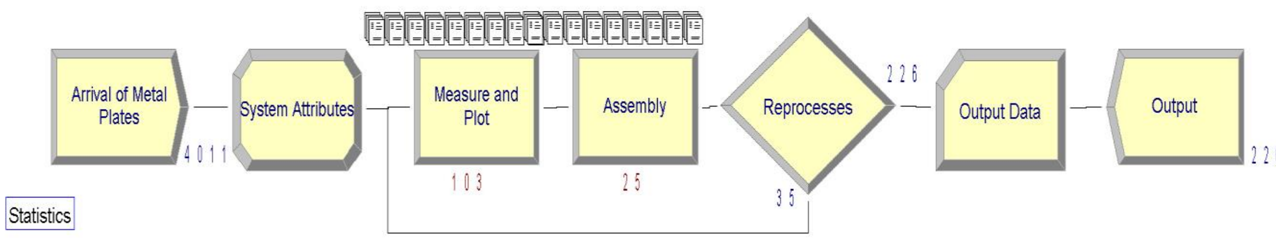

Fig. 8 The figure is a representation of the simulation of the system improvements

It was simulated again with the time improvements. With the first improved simulation, it obtained a time reduction of 22.34% for each process, and the second improvement it simulated resulted in an improvement of 9.14%-time reduction; these percentages were the result of the support of the articles of the authors Barzola, Randhawa, Neves, and Rabanal. The results obtained by simulating the first and second improvements are summarized in Table 7.

Table 7. Simulation results

	Current	First improvement	Second improvement
TSystem	45534.6 min	35362.8 min	32130 min
Daily production	1.90 units	2.44 units	2.98 units
Cost	$ 308.01	$ 307.63	$ 290.98
Level of care	60.15%	78.33%	82.78%

The simulations conclude that the demand of 3 units per day can be met by applying the proposed tools. In addition, the cost of reprocessing will be reduced from US$ 308.01 to US$ 290.98; the percentage of deliveries on time will increase from 41% to 82.78%. Finally, Table 8 shows the results obtained with the validation methods to verify that the current state has improved.

Table 8. Final results of the validation methods

Reason	Indicator	As is	To Be			Fountain
		Current Situation	First Result	Second Result	Final Goal	
Delivery compliance	% Of delivery compliances	41%	60.15%	78,33%	82.78%	Barzola-Cisneros et al. [22]
Travel time	Minutes it takes the worker	13.25 min	10.29 min	9.35 min	9.35 min	Rabanal et al. [16], Randhawa and Ahuja [9]
Distance travelled	Meters that the operator travels in meters	84.97 m	65.99 m	59.94 m	59.94 m	Ali Naqvi et al. [23], Gutti et al. [15]
Tool search time	Tool search (units/sec or min)	11.33 min	8.99 min	7.64 min	7.64 min	Barzola-Cisneros et al. [22]
Number of defective parts	% Of parts in failures in the cutting process	10 units	8 units	5 units	2 units	Randhawa and Ahuja [9]

4. Discussion

It is necessary to discuss some important aspects regarding the results obtained in the research project. As a specific objective, requesting the necessary resources for the production process was essential. The application of MRP, material requirements planning, consists of supplying and producing in correct quantities and when to do it. Another specific objective is to reduce travel times; the application for this is the SLP, systematic planning of distributions; according to Bocanegra [24], this tool aims to redesign the areas in a company to reduce distribution times, improving the workflow in the operators. Another specific objective is to reduce the number of defective parts generated in the cutting process; the application for this is the standardization of work using the study of work methods; this allows standardizing processes avoiding various methods for the same activity. And as a general objective is to reduce the delay in the production process.

Another article that applied the SLP presented the problem of a poorly designed plant, which caused low productivity, high material handling and poor effective use of machines, labor, and material. By applying this tool, the author improved the plant's design with greater efficiency and systematic layout [25]. This contribution, like the previous ones, reinforces the solution of using the tools proposed by the authors of this article.

Table 8 shows the results obtained from the application of the improvements, detailing the current situation, the first result, the second result, the final goal, and the source of support for each indicator considered for the results obtained. The results of the present investigation coincide with those mentioned by the following authors; the on-time delivery rate was 82.78%, i.e., a reduction of 41.78%. Barzola et al. [22], by applying their 5s and SLP, delivery times increased from 52% to 87%, and penalties for non-compliance with delivery decreased from 53% to 17%.

Randhawa and Ahuja [9] reduced the production time from 30 min to 5 min, a reduction of up to 25 min. By applying the improvements, a reduction of 3.9 min is achieved. Still, it is impossible to reduce time because the company's processes are mostly manual, and the maximum reduction is from 13.25 to 9.35 min, the time the operator travels to produce a conveyor thread.

In addition, the distance traveled was reduced from 84.97 m to 59.94 m and 25.03 m. Ali Naqvi et al. [23], by applying their proposed improvements, managed to reduce the production time from 22 to 16.9 hours. Gutti-Salazar et al. [15] increased the operating efficiency to 82% and reduced the cycle time from 57.2 minutes to 49.1 minutes.

The tool search time when applying the simulation and with the support of Barzola et al. [22] was reduced from 11.33 min to 7.64 min; this reduction was very helpful in improving the percentage of on-time deliveries because it was reduced by 3.69. In total time, if it considered the improvements in the delay in the path and tool search, a reduction of 7.59 min for each piece produced per month will save 455.4 min. Randhawa and Ahuja [9], by applying the 5s, reduced the production time from 30 min to 5 min. Also, the hours per month of machine breakdowns were reduced from 800 to 95 hours. As a result of the applied improvements, the parts with failures are reduced from 10 units to 2 units, and more than half of the improvement is achieved.

The background of the present work evidence that the tools used to solve the main problem reduce the delay in the production process achieving on-time deliveries to its customers.

5. Conclusion

When applying the planning tools, it was concluded that it is indispensable to order the necessary materials at the right time and produce the products on time, thus avoiding delays or waiting to start production. With the implementation of MRP and the standardization of work, the result was an increase in on-time delivery compliance from 41% to 82.78%. Operator travel time between stations was reduced from 13.25 min to 9.35 min. Likewise, the distance traveled between workstations was reduced from 84.97 m to 59.94 m. As for the time it takes operators to search for tools, it was reduced from 11.33 min to 7.64 min, the number of defective parts generated in the cutting process was reduced from 10 units to 2 units, and finally, the penalty percentage, which currently represents 6% of the company's total turnover, was reduced to 2.5%.

The application of the tools of the proposed model will help improve the production processes of the company under study, providing multiple benefits for the company. Likewise, applying the 5s and SLP tools helps reduce delivery times, which will increase profits and the level of customer satisfaction. By complementing the 5s and SLP tools, it is possible to reduce the distance traveled by operators, clutter in the work area and waiting time. The SLP helps restructure workstation positions, helping to reduce downtime caused by poor work zone layouts.

Funding Statement
The research and publication of this article were funded by Universidad Peruana de Ciencias Aplicadas, with the study company's support.

Acknowledgements
To Universidad Peruana de Ciencias Aplicadas, and the studied company.

References
[1] "Metal Mechanics is Key to Development," *Lima Chamber of Commerce*, 2019.

[2] Data from the Annual Diagnostic and Evaluation Report on the Business Activity of Micro and Small Enterprises in Peru, Ministry of Production, Lima, Peru.

[3] Data from the Production Report, Ministry of Production, Lima, Peru.

[4] "Engineering & Operations," *Eemax*, 2017.

[5] L. Casallo, E. Lucero, F. Maradiegue and J. C. Alvarez, "Proposal of Work Standardization to Improve a Metal-mechanical Process," in *IEEE International Conference on Industrial Engineering and Engineering Management IEEM,* Conference Paper, pp. 668-672, 2021.

[6] L. Tiacci, "Mixed-Model U-Shaped Assembly Lines: Balancing and Comparing with Straight Lines with Buffers and Parallel Workstations," *Journal of Manufacturing Systems*, vol. 45, pp. 286-305, 2017.

[7] C. Monteiro, L.P. Ferreira, N.O. Fernandes, F. J. G. Silva, and I. Amaral, "Improving the Machining Process of the Metalwork Industry by Upgrading Operative Sequences," *Standard Manufacturing Times and Production Procedure Changes, Procedia Manufacturing,* vol. 38, pp. 1713–1722, 2019.

[8] A. Pooya, N. Fakhlaei, and A. Alizadeh-Zoeram, "Designing a Dynamic Model to Evaluate Lot-Sizing Policies in Different Scenarios of Demand and Lead Times in Order to Reduce the Nervousness of the MRP System," *Journal of Industrial and Production Engineering,* vol. 38, no. 2, pp. 122-136, 2021.

[9] J. S. Randhawa, and I. S. Ahuja, "5S – A Quality Improvement Tool for Sustainable Performance: Literature Review and Directions," *International Journal of Quality and Reliability Management, Emerald Group Publishing Ltd,* vol. 34, no. 3, pp. 334-361, 2017.

[10] P. Neves, F. J. G. Silva, L. P. Ferreira, T. Pereira, A. Gouveia, and C. Pimentel, "Implementing Lean Tools in the Manufacturing Process of Trimmings Products," in *Procedia Manufacturing*, vol. 17, pp. 696-704, 2018.

[11] C. Veres, L. Marian, S. Moica, and K. Al-Akel, "Case Study Concerning 5S Method Impact in an Automotive Company," in *Procedia Manufacturing,* vol. 22, pp. 900-905, 2018.

[12] A. D. Makwana, and G. S. Patange, "Strategic Implementation of 5S and its Effect on Productivity of Plastic Machinery Manufacturing Company," *Australian Journal of Mechanical Engineering*, vol. 20, no. 1, pp. 111-120, 2019.

[13] T. Pombal, L. P Ferreira, J. C. Sá, M. T. Pereira, and F. J. G. Silva, "Implementation of Lean Methodologies in the Management of Consumable Materials in the Maintenance Workshops of an Industrial Company," in *Procedia Manufacturing,*vol. 38, pp. 975-982, 2019.

[14] F. Lastra, N. Meneses, E. Altamirano, C. Raymundo, and J.M. Moguerza, "Production Management Model Based on Lean Manufacturing for Cost Reduction in the Timber Sector in Peru," in *Advances in Intelligent Systems and Computing,* vol. 971, pp. 467-476, 2019.

[15] C. E. Gutti-Salazar, F. Segura-Chavez, F. Maradiegue-Tuesta and J. C. Alvarez-Merino, "Kanban-CONWIP Hybrid Model for Improving Productivity of an Electrostatic Coating Process," in *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Conference Paper*, pp. 1295-1299, 2019.

[16] M. Rabanal, S. Zamami, J. Quiroz, and J. Alvarez, "Systematic Layout Planning: A Research on the Third-Party Logistics of a Peruvian Company," in *Advances in Intelligent Systems and Computing,* vol. 1018, pp. 988-993, 2020.

[17] R. H. C. Machado, A. L. Helleno, M. C. de Oliveira, M. S. C. dos Santos, and R. M. da C. Dias, “Analysis of the Influence of Standard Time Variability on the Reliability of the Simulation of Assembly Operations in Manufacturing Systems,” *Human Factors,* vol. 61, no. 4, pp. 627-641, 2019.

[18] Y. Harari, R. Riemer, and A. Bechar, “Factors Determining Workers' Pace While Conducting Continuous Sequential Lifting, Carrying, and Lowering Tasks,” *Applied Ergonomics,* vol. 67, pp. 61-70, 2018.

[19] A. Desai, “Ease of Product Assembly through a Time-Based Design Methodology,” *Assembly Automation,* vol. 39, no. 5, pp. 881-903, 2019.

[20] A. P. Velasco Acosta, C. Mascle, and P. Baptiste, “Applicability of Demand-Driven MRP in a Complex Manufacturing Environment,” *International Journal of Production Research*, vol. 58, no. 14, pp. 4233-4245, 2020.

[21] M. Arévalo, J. Montenegro, G. Viacava, C. Raymundo, and F. Dominguez, “Proposal for Process StandarDization for Continuous Improvement in a Peruvian Textile Sector Company,” in *Advances in Intelligent Systems and Computing,* vol. 1026, pp. 909-915, 2020.

[22] V. Barzola-Cisneros, J. Calderon-Tirado, G. Viacava-Campos, and D. Aderhold, “Production Model to Increase Productivity and Delivery Compliance in the Peruvian Textile Sector by Applying Value Stream Mapping, 5S and Flexible Production Systems,” in *Advances in Intelligent Systems and Computing*, vol. 1253, pp. 599-605, 2021.

[23] S. A. Ali Naqvi, M. Fahad, M. Atir, M. Zubair, and MM Shehzad, “Productivity Improvement of a Manufacturing Facility using Systematic Layout Planning,” *Cogent Engineering*, vol. 3, no. 1, 2016.

[24] A. Bocanegra, “*Proposal to Improve Production Management to Increase the Profitability of a Publishing Company*,” Thesis to obtain the Professional Degree of Industrial Engineer, Universidad Privada del Norte. Trujillo, Peru, 2018.

[25] G. Goyal, and D.S. Verma, “Optimization of Plant Layout in Manufacturing Industry,” *International Journal of Recent Technology and Engineering IJRTE,* vol. 8, no. 2, pp. 3115-3118, 2019.

[26] Tushar Kapratwar, Siddhi Jadhav, Harshvardhan Uttarwar, Nirmity Bomidwar, Shubham Patil, "Layout Improvement at a Printing Press," *International Journal of Industrial Engineering*, vol. 7, no. 3, pp. 9-24, 2020. *Crossref,* https://doi.org/10.14445/23499362/IJIE-V7I3P102

[27] Haftu Hailu and Tewedros Hailu, "Reduction of Long Delivery Time by Implementing Advanced Kaizen (Problem Solving Approach)," *International Journal of Industrial Engineering*, vol. 4, no. 3, pp. 26-48, 2017. *Crossref,* https://doi.org/10.14445/23499362/IJIE-V4I6P103

[28] Debaleena Chatterjee, Supriya Pandey, "A Time Study on Dispatch and Delivery of Material in the Food Processing Sector," *International Journal of Economics and Management Studies*, vol. 7, no. 2, pp. 52-58, 2020. *Crossref,* https://doi.org/10.14445/23939125/IJEMS-V7I2P108