Improvement model to increase efficiency levels using Lean tools in a jewelry company in the manufacturing sector

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Abstract The main objective of the study was to evaluate the level of efficiency of a jewelry and precious metals production line. According to this detailed analysis, proposals for improvements were made focused on the efficiency of the production process and, in this way, being able to substantially improve the downtime of the machines and the operators involved in the process. The work presents a robust theoretical framework with the necessary knowledge to better understand the various tools and methodologies that will be used for the analysis and proposal for improvement. The methodology used includes a detailed analysis of current processes, the identification of bottlenecks and the implementation of the aforementioned Lean tools. The TPM tool has been used to ensure proper and continuous maintenance of machines, reducing downtime and improving equipment life. Kanban cards have been implemented to manage and control the workflow, guaranteeing an adequate supply of necessary materials and components at the right time.

The main indicator evaluated is the general efficiency of the machining area, measured before and after the implementation of the improvement model. The results obtained show a significant increase in efficiency levels, reflected in the reduction of cycle times, increased production and decreased operating costs. This study highlights the effectiveness of Lean tools in improving processes within the jewelry industry and its potential application in other manufacturing sectors. The result was a significant increase in efficiency from 48.9% to 67% with the sand simulation.

Keywords— Processes, production, Kan Ban, efficiency, TPM.

I. INTRODUCTION

The jewelry industry, rooted at the intersection of art and craft, has been a cultural and status vehicle throughout time [1]. In today's business world,

Growth is closely linked to political factors and to trade policies and international agreements that facilitate expansion into new markets [2]. In the political sphere, the Ministry of Foreign Trade and Tourism (MINCETUR) in Peru plays a crucial role in promoting collaboration between the public and private sectors.

Through the National Export Strategic Plan (PENX 2025), it seeks to diversify exportable products and improve the country's competitiveness in global markets [3]. At the social level, institutions such as the National Superintendence of Labor Supervision (SUNAFIL) in Peru have the responsibility of guaranteeing compliance with labor and workplace safety provisions [4]. In addition to monitoring compliance, these institutions provide technical advice and propose regulations related to these issues.

Low efficiency in the production of gold chains in the jewelry company is manifested through indicators such as machine downtime, increased waste and rework, as well as decreased customer satisfaction. This problem directly impacts the company's competitiveness in a highly demanding and competitive market [5]. The research being carried out aims to improve efficiency levels in the machine chain area of a jewelry company using Lean tools such as TPM and 5s, it is important to emphasize that improved efficiency translates into a reduction of operating costs, since the waste of raw materials is minimized and the use of labor and machinery is optimized. A company that operates efficiently can offer high-quality products at more competitive prices, putting it in an advantageous position in the market [6].

The main purpose of this research is to improve efficiency levels in the machine chain area of a jewelry company in the manufacturing sector using the necessary tools to improve its efficiency and competitiveness in the market, while ensuring the quality of its products. products [7]. Furthermore, we seek to contribute to the existing body of knowledge in the literature related to the metalworking manufacturing sector for future research. The study proposes a methodology of two Lean Manufacturing tools: TPM and Kanban cards. These tools focus on three fundamental pillars: Autonomous Maintenance, Education and Training, in order to address the causes of low levels of efficiency in the area of machine chains.

This article is structured in four sections. The second part addresses the state of the art, which includes a literature review of the specific industry and the use of Lean Manufacturing tools, as well as their benefits and limitations. The third section defines the contribution of the methodology used in the case study to solve the identified problem. The fourth section details the model validation proposal. Subsequently, in the fifth section the discussion is carried out, where the adaptability of the proposed methodology in different production lines is analyzed. Finally, the conclusions and recommendations derived from the case study are presented.

II. STATE OF THE ART

A. Application of lean tools in the manufacturing sector

Today's large companies, together with fundamental pillars such as technology and sustainability, have been growing, having a greater understanding of how the market works and due to the increase in competition, companies have resorted to the use of competitive advantages and to a greater extent They resorted to optimizing their processes using lean tools and all the advantages that these bring them [8]. Lean tools always have as one of their main focuses the search for sustainability, achieving it in different ways such as reducing activities that do not add value, this makes the process have greater production capacity with the use of fewer resources [9], [10].

In the case study of a metallurgical company, lean tools such as 5S are used together with the PDCA cycle to improve the efficiency of its workshops and increase the percentage of dispatches by 14.5% [8]. In another case study, lean tools were used together with the DMAIC, in addition to diagnostic tools such as the 5-why and the Ishikawa diagram, which made it possible to increase the efficiency of the line from 78 to 95% [11]. Likewise, in the case of a construction machinery manufacturing company, the lean methodology was applied, within the case the Value Stream Mapping and spaghetti diagram were used as main tools, by identifying activities that do not generate value in the process. productive, they were eliminated, the results of the use of lean tools were an improvement in the process cycle efficiency by 25.59% and a reduction in lead time by 23.66% [12], [13].

For the correct use of Lean Manufacturing tools, a cultural change is necessary in the organization. Furthermore, for the implementation of the Lean methodology to be sustainable, leaders need to have the ability to internalize lean thinking in their employees and promote them to them. Use that thinking in the processes of your position [14]. The tools of the Lean methodology, in addition to generating a direct impact within companies, also imply a cultural change, thereby solidifying issues such as occupational health and safety and, in this way, improving the lifestyle in society, With all the advances and tests made, it has been shown that Lean tools greatly help the company become sustainable [15], [16].

B. Application of Kanban as a process control tool

Considering Taichi Ohno as the father of this tool, Kanban is considered a vital piece in the process flow, this being the tool that communicates the needs of the different workshops or work areas, likewise, it has been quite useful in the field of control and scheduling of demand, since it is emphasized as a pull production system, in order to minimize the inventory levels to be managed [17], [18]. For the case study of a car seat construction company, the use of Kanban was proposed, adapting it to an electronic system that they called online E-Kanban. Prior to this implementation of the electronic Kanban, a VSM analysis was carried out to find The bottleneck, the use of E-Kanban, will also be to prioritize tasks, through a comparison of multiple criteria, as a result of the use of this tool, lead time could be reduced by 38.99% [19]. In the case of another vehicle maintenance and repair company, the use of Kanban is proposed, along with the use of other tools. This mainly, through the use of colored cards on a Kanban board, will be able to indicate the urgency of a workshop. in obtaining some material or to indicate the initiation of a new project, previously using the VSM, and Lean tools that focus on visual identification, the result was a reduction in lead time by 26% and the minimization of losses around 47% [20]. Also, with the use of Kanban, through a multiple decision system, in a laboratory, with the use of Lean Thinking, it was possible to improve indicators such as the reduction of times in search and assembly activities by 93% and 31% respectively [21].

Despite being a very useful tool, it is not always possible to work in an environment where demand is constant, so the validation of this tool through simulations brings many alternatives for improvement [17]; Furthermore, with respect to the correct use of the tool, it must always be taken into account that it works in a fairly simple and logical way, since it decrees that nothing will be produced until it is needed, being a simple form of application and the most common, color charts, mentioning established quantities for process flow improvement [18]. Likewise, Kanban is not only limited to the operational part of organizations, but, with its continuous advancement, Kanban has been able to adapt, forming part of project management, this thanks to the implementation of continuous improvement of several flows that are easy to continue [22].

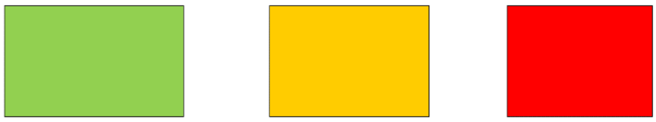


Fig 1: Kanban Card Models

C. TPM in improving efficiency

Quality has always been a complex issue to address and comply with, and in modernity, and more specifically in business practice, it refers to how a product complies with standards, technical rules, and details: therefore, a company that has not maximized its resources and internal competencies, it cannot be considered competitive; in this highly competitive environment that exists today, maximizing the capacity of its teams is key to being part of the leading companies [23]. It is also important to emphasize that process standardization is essential within specialized TPM, to achieve maximum efficiency of a process [24].

In the case study of a metal industrial company, through the use of TPM and the pillar of autonomous maintenance, I managed to increase the OEE of its different workshops by more than 10%. In another case study, with the use of autonomous maintenance, an increase in machine availability by 6.12% was achieved [25]. In another case study of a Chinese company, which focuses most of its activities on the use of a CNC machine, its maintenance was carried out, applying knowledge of TPM, the fundamental step in improving the maintenance process. was the reduction of steps that were carried out when maintaining the machine, this was reduced from eight to six steps, greatly reducing the preparation time, this improvement proposal had the most notable result: the increase in availability of the machine from 80 to 92.22% [26]. The next case is a company in the automotive sector, in which the aim is to increase the reliability of its equipment. To begin with, various data were recorded such as the setup time, the failure time and the preventive maintenance that was carried out each year. Then we proceeded to create the 6-step plan with autonomous maintenance as a key pillar. The main activities of this autonomous maintenance were cleaning prior to activating the machine and constant training for those involved, in addition to defining the positions and the responsibilities of each position, with the use of autonomous maintenance, the preparation times at the workstations were reduced in addition to the OEE of each of the stations by up to 6% [23].

The main objective of TPM is to reduce the failure time or downtime of equipment and reduce defects that may occur in equipment [24]. A key aspect for the adaptation of tools such as TPM that occurred in the third industrial revolution was the change in needs, from needing more work force, to now requiring more technological and technological machine management and administration skills. computing, and the fourth revolution only increases the need for the previously mentioned skills, so more advanced ideas for the implementation of maintenance in industries 4.0 would be the implementation of control panels and digitization of data and maintenance programs [27], [28].

D. Alternative solution models

In current times, the industrial sector is facing the fourth industrial revolution, so the requirements of the market requirements are closer to flexible manufacturing, which merits constant adaptation to varied volumes of demand, which implies intervention. of a person's work; Therefore, to reduce resources in these processes and optimize time and resources, the use of robots and advanced intelligence is proposed, so that they demonstrate their great functional intelligence and ability to adapt to the unpredictable [29]. In a case study to solve the problem of failures in detection and classification, Machine Learning is used, which, the latter will be achieved through an artificial neuron that has the same functionality as human neurons thanks to an algorithm that will allow it to take decisions according to the inputs provided, the result of the use of this advanced artificial intelligence tool resulted in a 2% reduction in Down time [30].

Likewise, along with the advancement of technologies, tools created a long time ago are adapted and/or modified to new needs. A clear example is Kanban, which, in a case study carried out in a company in the sector manufacturing was integrated with a security system to minimize the time it takes for the system to operate and the communication between plants or stations, with the digitization of the data, and the constant checking of information and quantities in movement, mishandling or incorrect data reception; With the use of this improved tool, the production time of the work line was reduced between 5% and 7% [31].

In the field of production in industries, a tool that has been widely used is Kanban, which focuses on reporting on production, containing parameters such as the production order or batch and the quantity to be produced [25].

III. INPUT

A. Model overview

In fig. 1 shows the methodology to be implemented based on the reviewed literature. This is based on the application of 5S to be able to organize and leave the work area impeccable and thus, with a clean and organized environment, be able to implement the other tools. Once the concept of 5S is well established in the company's culture, the Kanban cards will be implemented and used in order to improve the workflow and increase the production of the line and, finally, The autonomous maintenance TPM pillar will be implemented, with the aim of technical operators performing tasks more related to maintenance during calibration and, in this way, being able to increase the availability of the equipment. It should be noted that within each step, the respective training on the tool will be carried out and at the end there will be an analysis of the impact that the application of the methodology had.

B. Detail view

Step 1: Formulation and calculation of indicators

As a first step, the indicators that will be used to measure whether the tools will be effective in the case study are formulated. These indicators will be better presented in the following sections of this article.

Step 2: Kanban

Kanban is a tool to control the flow of different objects and production through the use of cards and visual material. Thanks to this tool, waiting times for materials can be reduced and bottlenecks avoided [32]. To use Kanban cards, first a training program will be carried out on the tool and its advantages, then Kanban cards for raw materials, work in process and finished product will be implemented, with the main objective of informing the previous areas about the amount of material to use in the machine chain process.

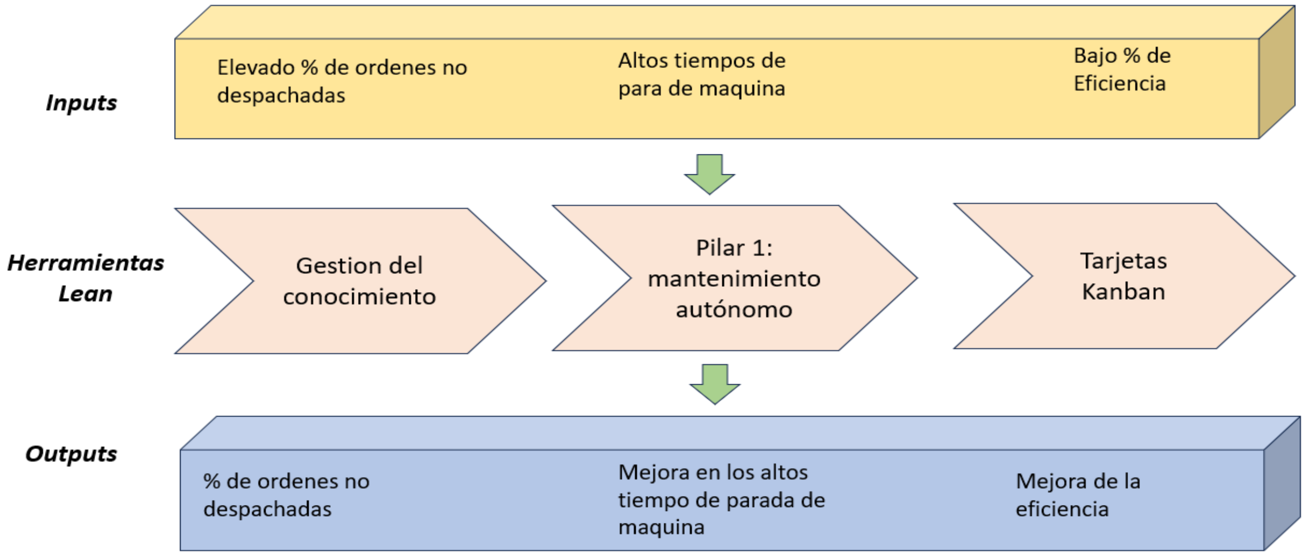
Step 3: TPM

<u>Autonomous maintenance:</u>

With the advancement of technology in industries, the degree of automation and production equipment has increased in addition to the costs involved in this technology, so the deterioration of this equipment translates into increased production costs and lower quality. and longer delivery time [33]. Due to this, the use of autonomous maintenance is proposed, which involves operators participating in the maintenance of the machine in their charge through simple processes [23]. In the case study, booklets will be implemented on the machines and the component with the highest deterioration factor to take it into account when recalibrating the machine.

<u>Training and education:</u>

Operator training is a critical factor in TPM, as it focuses on increasing operator morale and educating them to increase their knowledge regarding maintenance and their machine [33]. Therefore, a continuous training system on TPM, its approach and correct implementation was proposed, in addition to generating booklets so that operators can guide themselves whenever they require it.



Step 4: Analysis of the results

Monitoring and control are almost mandatory steps in an investigation to prevent the system from suffering recurrences with respect to the model that was managed before implementing the improvement proposal [34]. So, as the last step, there is the analysis and monitoring of the results that, as its name indicates, will evaluate the results obtained from the implementation of the previously mentioned tools. We can achieve this through the use of evaluation sheets. results of each tool implemented in the previous steps.

C. *Methodology indicators*

In this section we can view the key indicators for the case study presented.

Metricas	Formula	As is	To be
% de ordenes no despachas	$Order\ Fulfillment\ rate = \frac{Orders\ fulfilled\ on\ time}{Total\ Orders} \times 100$	25.42%	11%
Tiempos de paradas de maquina	$Unplanned\ down\ time\ (Due\ to\ failures\ /Day) = Failures\ per\ month\ working\ days/month$	5.08 h/dia	3.5 h/dia
Eficiencia	$Eficiencia = \frac{Producción\ Real}{Capacidad\ Efectiva}$	48.90%	67%

Tab. 1 indicators to evaluate

- % Orders not shipped

$$1 - \frac{Ordenes\ despachadas}{Total\ de\ ordenes\ de\ Cadenas\ a\ maquina}$$

With this indicator it is possible to calculate the percentage of orders that did not reach the machine chain area based on the total orders ordered. In this way, there will be control of the production flow, which is expected to achieve a greater quantity of products entered to feed the machine. It is expected that the improvement in this indicator is approximately 13% to demonstrate that the tool was appropriate [11].

- Machine downtime

$$Tiempo\ parada\ de\ maquina = Tiempos\ por\ calibracion$$

This indicator allows measuring the time that the machine operates, based on the total time of the machines, where production outside of time is excluded; With the use of the tools, it is expected to reduce downtime by 1.6 hours/day [26].

- Efficiency

$$\frac{Producción\ Real}{Capacidad\ efectiva}$$

This will be the main indicator of the case study, and focuses on indicating the number of hours that the machines in the machine chain area work in the company, for this it will be based on the effective or total capacity of the machines.

IV. VALIDATION

A. *scenario validation*

The company under study with more than 35 years in the jewelry industry specializes in the manufacture of chains and jewelry using materials such as gold and silver, the company has a team of highly trained professionals, from designers to mechanics specialized in the jewelry manufacturing, the company is made up of a total of 327 employees and the study area is machine chains, which has 11 operators.

B. *Initial diagnostic*

One of the many products that the study company manufactures are machine chains. By analyzing its production process in the machine chain line, it was possible to identify the low efficiency in the machining process. In the initial diagnosis, it was obtained that the efficiency of the process is 48.9%, the main causes being the high level of orders not dispatched on time due to lack of control in production and the high time of machine downtime due to poor calibration.

The process efficiency of the last 12 months that represents the current situation is presented in table 1.

Año	Meses	CAPACIDAD REAL (Hr)	CAPACIDAD EFECTIVA (Hr)	EFICIENCIA
2022	SETIEMBRE	6892	14400	47.9%
	OCTUBRE	7246	14400	50.3%
	NOVIEMBRE	7141	14400	49.6%
	DICIEMBRE	7100	14400	49.3%
2023	ENERO	7263	14400	50.4%
	FEBRERO	6905	14400	48.0%
	MARZO	6700	14400	46.5%
	ABRIL	6890	14400	47.8%
	MAYO	7023	14400	48.8%
	JUNIO	7376	14400	51.2%
	JULIO	6988	14400	48.5%
	AGOSTO	6969	14400	48.4%

Tab. 2 current situation

In the current situation of the case study we were able to observe that the real production capacity was very low with respect to the effective capacity, this due to different causes such as the calibration of the machines, the high unproductive times and the high level of undispatched orders. . The efficiency of the area could be verified with the following formula [26]:

$$Eficiencia = \frac{Capacidad\ Real}{Capacidad\ Efectiva}$$

Finally, a comparison was made with the average efficiency of the sector (x) and it can be concluded that that of the company under study was below the average with a difference of 30% .

Indicador	Situacion actual
Eficiencia	48.90%
Tiempos de parada de maquina	5.08 h/dia
% de ordenes no despachadas	25.42%

Tab. 3 current situation of the indicators

In the current situation of the case study, the company had a record of the current machine downtime that was 5.08 h per day and in addition, the orders not dispatched to the machines in the area are at 25.42%. Finally, the efficiency of the machine chain line was 48.9%.

C. *Validation method*

To validate the solution proposal, a simulation was carried out in the Arena software which allowed us to make a comparison of the current indicators with those of the improvement proposal. The simulation method is the most suitable for modeling solution proposals with Lean tools, this because the program provides a robust platform to model complex processes such as simulating the number of Kanban cards, the average arrival time of the demand and the locations. of performance bottlenecks in the integration of flexible manufacturing, assembly and disassembly JIT systems [35]. In addition, the simulation can give results in calculations by assigning a variable, which can give as results indicators or key values in the evaluation of the impact of tools such as time and distance traveled [36], [37].

On the other hand, it is possible to simulate the impact of long-term changes in the system, which provides a holistic view of the effects of the improvement proposal. This is crucial for Lean tools like TPM, which involve changes in organizational culture and long-term work processes [38], [39].

For the simulation of Kanban cards in Arena, 3 parameters will be used with the following names: Kanban number (CPED), Reorder point (PTOREP) and initial stock (STOCK). Once the initial parameters are defined, the configuration proceeds. of the workstations with their respective times. It should be noted that the timing data was processed in the arena plugin called Input Analyzer. Once the workstations and processes with which the simulation will be carried out are configured, the final model in Figure 2 is obtained.

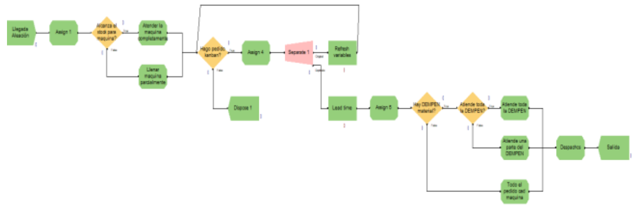


Fig . 2 Sand model of Kanban cards

As the last necessary step of the model, a variable dispatches is assigned, which would represent the dispatches made. With this variable created, it will be possible to obtain a result of the dispatched orders indicator. Finally, we have as the OUTPUT of the model the dispatched orders indicator, which uses the generated orders and dispatched orders variables, which is composed of the following formula:

$$Nivel\ de\ ordenes\ despachadas = \frac{Despachadas}{Ordenes} \times 100$$

Finally to validate the improvement model of the TPM tool with sand. The data will be processed with the Input Analyzer tool. This plugin allows us to understand and analyze input data, as well as determine probability distributions that accurately represent the behavior of random variables in a simulation model. The input data is presented below in table 4:

Estaciones	Distribucion
Llegada de MP	EXPO (1.94)
Almacen de MP	TRIA (0.3;1;1.5)
Area de fundido	NORM (3.5;5.4)
Area de maquinado	TRIA (1.3;3.2;4.6)
Rope Chain	TRIA (16;18;20)
Spike	UNIF(18;20)
Veneciana	NORM (15.7;18.9)
PopCorn	NORM (16;19.4)
Franco	TRIA (12;16.7;19.2)

Tab. 4 times workstations for TPM model

Once the processes, stations and times that will be used to model the TPM proposal have been defined, the model is built taking into account two factors, the first being the availability of the machines. For this, a mathematical expression will be used (figure 4) that allows for a fluid distribution of material and prevents any material from being out of stock, bellow we show the mathematical expression formulated in arena, this expression makes that the distribution of every machine can be even.

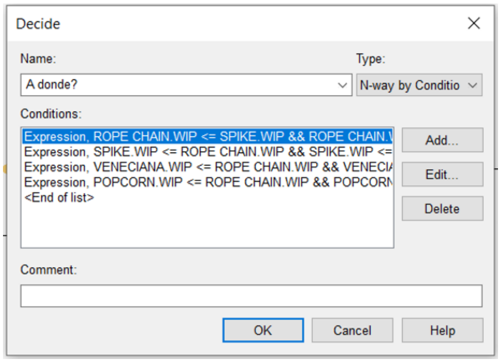


Fig. 4 Mathematical expression

We have also considered the simulation of the recalibration time of the machines. It should be noted that each machine handles a different recalibration time which is shown in table 5.

Maquina	Recalibracion (minutos)
Rope chain	63
Spike	60
Veneciana	50
PopCorn	60
Franco	55

Tab. 5 recalibration time

Finally, once all the stations and their respective times have been configured, the model that the TPM tool simulates is as follows:

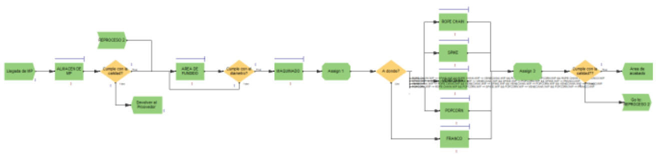


Fig. 5 Sand model of the TPM tool

On the other hand, to obtain the appropriate number of replicates and validate the model correctly in both models in sand, we proceeded to work with two indicators with which sand works. First, it starts with an average number of replicates (30 replicates); then the software provides us with the average and Ho data. Finally, the following formula is applied:

$$N = No \times (\frac{Ho}{H})^2$$

Where:

N=Number of replicas

No=Initial number of replicas

Ho=Margin of error obtained

H=Desirable margin of error

Finally, this formula will give us the appropriate number of repetitions, having to repeat it as many times as necessary until the largest is found [40].

D. Results

Indicador	Situacion actual	Simulador Arena
Eficiencia	48.90%	67%
Tiempos de parada de maquina	5.08 h/dia	3.3 h/dia
% de ordenes no despachadas	25.42%	13.35%

Tab 5 . Current Situation vs Arena Simulation

Maquina	Situacion actual (Horas)	Simulador Arena (Horas)
Veneciana	2380	840
Rope Chain	1800	1540
Spike	720	480

Tab 6 . Machine downtime

Indicador	Situacion actual	Simulador Arena
% de ordenes no despachadas	74.58%	86.65%

Tab 7 . % of orders shipped

After applying the simulation in sand for both the TPM tool and the Kan Ban tool, we obtain the following results which can be seen in Table 5.

As a first result for the TPM tool, we obtained that the efficiency of the machines increased from 48.9% to 71.12%, obtaining a considerable improvement in the production process from chains to machines. Likewise, the recalibration time of the machines could be reduced, this was a very common cause in their maintenance. In addition, with the simulation carried out it was possible to improve the downtime of the machines shown in table 6.

On the other hand, to simulate the Kanban tool, we proceeded to work with the % of orders shipped indicator. The results obtained were that the percentage went from 74.58% to 86.65%, observing a significant improvement when correctly applying the software. These results can be seen in Table number 7.

To sustain long-term efficiency improvements in a jewelry company within the manufacturing sector, it is essential to implement continuous control and monitoring strategies. The integration of Lean tools such as 5S, Value Stream Mapping, and Just-In-Time facilitates the reduction of non-value-added activities and the optimization of processes [41]. The implementation of real-time monitoring systems simplifies the identification of deviations and supports data-driven decision-making [42] while key performance indicators (KPIs) enable the evaluation of the impact of improvements [43]. These measures ensure that the achieved results not only endure over time but also generate lasting value for the organization.

V. DISCUSSION

A. *New Scenarios vs Results*

Scenario 1: Decrease the number of replicas

To obtain more reliable results in the simulation and therefore in improving efficiency in the machine chain line using the Arena simulation software, it is crucial to perform an adequate number of replications. Each replica of a simulation in Arena is an independent realization of a stochastic model. Due to the variability inherent in stochastic processes, a single replica may not adequately represent the behavior of the real system. By increasing the number of replicas, results can be averaged, which reduces statistical variability and provides a more accurate estimate of system performance metrics such as cycle time, resource utilization, and inventory levels. By making changes such as the number of replicas from 84 to 30, we were able to notice an improvement in efficiency by 5%, machine downtime improved by 0.7 h/day and the % of undispatched orders did not vary. We can conclude that a variation in the number of replicates that is not appropriate for the simulation substantially improves the indicators, but these are not optimal for their total improvement.

Scenario 2: Increase the number of replicas

Complex systems, such as a jewelry company, can have many sources of variability (different product types, variable processing times, variations in demand, etc.). A greater number of replicas helps to better capture this complexity, providing a truer representation of the system's behavior under different operating conditions. For our case study we decided to expand the number of replicas to the next largest of 84, which was 174, which produced a varied result with respect to the original, obtaining an efficiency of 58%, machine downtime of 4.5 h/day and a % of undispatched orders of 23.4%, however the data that draws the most attention is the machine downtime. When the results of each machine are shown, we can see that the Venetian machine is the one that will work the least of the 5 machines. in total, because their total hours in the current situation have not had a great variation.

B. *Analysis of results*

The simulation by decreasing the number of replicas showed that the implementation of TPM together with kanban cards resulted in a reduction of 0.7 h/ day in machine downtime. This translated into a 5% increase in operational efficiency, increasing chain production per week, and a reduction in costs associated with corrective maintenance.

Indicador	*Situacion actual*	*Simulador Arena*
Eficiencia	*48.90%*	*53.90%*
Tiempos de parada de maquina	*5.08 h/dia*	*5.01 h/dia*
% de ordenes no despachadas	*25.42%*	*25.42%*

Tab 8 . Scenario 1 indicators

On the other hand, the simulation, by increasing the number of repetitions, shows results such that efficiency improves by almost 10% and the % of undispatched orders by 2%. However, the data that most attracts attention is the hours. machine since we can see that the Venetian machine has not undergone a considerable improvement like its peers Rope Chain and Venetian, this is a special case that must be treated in greater depth to understand this type of situation.

Maquina	*Situacion actual (Horas)*	*Simulador Arena (Horas)*
Veneciana	*2380*	*2240*
Rope Chain	*1800*	*1440*
Spike	*720*	*620*

Tab 9 . Scenario 2 machine stops indicator

C. *Future Jobs*

Next steps should focus on exploring other potential solutions to address machine chain production line challenges in a jewelry company. One possible solution is the integration of Industry 4.0 technologies, such as the Internet of Things (IoT), which can provide real-time data on machine performance and machine downtime. This information can be used to make more informed decisions and improve operational efficiency. Additionally, utilizing data analytics and machine learning can help predict equipment failures and optimize preventative maintenance, thereby reducing downtime.

Another promising area is the automation of maintenance and inventory control processes. The implementation of robots and automated systems can reduce dependence on human intervention, minimizing errors and improving accuracy in materials handling. Automation can also streamline workflow and increase responsiveness to changes in market demand.

Additionally, it is important to consider adopting agile project management methodologies to improve the flexibility and adaptability of the production line. Agile methodologies such as Scrum can foster greater collaboration between work teams and enable faster response to operational problems. This agility can be crucial to maintaining competitiveness in an ever-changing market.

Finally, research should focus on evaluating the impact of external factors, such as changes in the supply chain and variations in the quality of raw materials. The resilience of the production line in the face of these factors is essential to ensure operational continuity and customer satisfaction. Strategies must be developed to mitigate these risks and ensure a constant supply of high-quality materials.

VI. CONCLUSIONS

The search for efficiency in production processes is a fundamental objective in any industry, and jewelry is no exception. In this context, the implementation of Total Productive Maintenance (TPM) tools and Kanban cards has proven to be an effective strategy to improve operational efficiency in the machine chain production line in a jewelry company. This article analyzes the significant impacts of these tools, supported by simulations performed with Arena software, and how their adoption has transformed the company's work environment and competitiveness.

The implementation of TPM in the jewelry company has proven to be highly effective in reducing machine downtime. This systematic maintenance approach has not only increased equipment availability, from 83% to 92.7%, but has also improved the operational efficiency of the machine chain line, raising it from 48.9% to 67%. This significant improvement is due to TPM's ability to keep equipment in optimal operating condition, ensuring greater continuity in production and a reduction in unplanned interruptions.

In parallel, the implementation of Kanban cards has optimized the workflow by providing more effective control of the inventory of raw materials and parts in process. This tool has allowed a 12% reduction in undelivered orders, evidencing an improvement in inventory management and greater synchronization between the stages of the machining process. Complete visualization of the process, from receipt of raw materials to delivery of finished products, has facilitated better planning and scheduling of production, as well as faster response to changes in market demand.

Finally, we can conclude that the combination of TPM and Kanban has not only improved efficiency, but has also provided the company with greater flexibility to adapt to fluctuations in internal demand. This ability to quickly adjust according to the needs of the internal customer has significantly improved efficiency in the process, the standardization of maintenance and production procedures through these tools has contributed to the reduction of errors and defects in the machining process, resulting in a notable improvement in the quality of the final products.

VII. REFERENCES

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