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DIGITAL TRANSFORMATION MODEL BASED ON BUSINESS PROCESS MANAGEMENT AND LEAN MANUFACTURING TO INCREASE THE PRODUCTIVITY OF THE ADMINISTRATIVE AREA OF A PERUVIAN AERONAUTICAL COMPANY

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Digital Transformation Model Based on Business Process Management and Lean Manufacturing to Increase the Productivity of the Administrative Area of a Peruvian Aeronautical Company

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ABSTRACT

The aviation sector has suffered the effects of the pandemic as the industry's problems have become more evident due to operational constraints. The challenging and uncertain scenario has made the airline industry adapt its business to innovative alternatives based on efficient and digital strategies associated with the sector's low productivity and the efficiency of each process. According to the reports, a series of failures were observed in the Maintenance Administrative Area, which is in charge of managing the work shifts of each technician in charge of aircraft maintenance, identifying that the most significant productivity problem in the area is based on the inefficient attention of requests to technical personnel. Therefore, a new model based on digital transformation was established by applying Business Process Management and Lean Manufacturing, in which the implementation of an ERP system connected to a self-service digital platform stands out. The main objective of this research is to increase productivity through the proposed new model and reduce unproductive times. Initially, the current case was analyzed, the improvements were identified, and the simulation was performed in the Arena software version 16; giving as a result of the validation, the increase of attention rate by 26.4%, the reduction of the rejection rate by 2.09%, the increase of the registration efficiency by 32.59%, and a significant reduction of the cycle time by 87.37%; obtaining as a key result the increase of productivity by 18.62%, achieving a precedent that contributes to the optimization of the processes in the aeronautical sector.

CCS CONCEPTS

• **Applied computing** → Supply chain management.

KEYWORDS

Aircraft industry, Digital transformation, BPM, standardized work, Line balancing, VSM

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1 INTRODUCTION

Before the pandemic, the international air transport sector contributed significantly to Peru's economy, with 341,000 jobs generated, directly and indirectly, and contributing USD 5 billion in gross value added to the economy, representing 2.6% of GDP. In addition, the air market offered benefits such as the contribution of USD 3.7 billion from foreign tourists, foreign direct investment (FDI) reaching USD 98.2 billion, and exports generating USD 51.3 billion [1]. However, in the following years, the Peruvian aeronautical sector suffered a 77% loss of revenue, equivalent to USD 2.5 billion, and market demand fell by 64%, putting at risk approximately 229,000 jobs related to air transport. In addition, one article identified a direct impact on GDP contribution of USD 500 million and USD 2.93 billion in the sectors involved in the supply chain, workers' expenses, and tourism [2].

This analysis further evidenced the problems presented by the aeronautical sector industries, as they reported a loss in their total income due to their operational restrictions, so it was necessary to give innovative alternatives associated with the low productivity of the sector and the efficiency of its processes.

Under this premise and according to the research literature, the case study of a transnational aeronautical organization is presented, where it has been identified as a potential problem the lack of process optimization, the absence of methodologies that integrate digital transformation and Lean manufacturing models in their maintenance areas. Therefore, to solve the issues described, this

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research aims to implement tools to increase productivity in the administrative area of company maintenance through a digital transformation model using the Business Process Management and Lean Manufacturing methodology.

In this sense, the academic articles analyzed contain various information on organizations with agile organizational structures and the highest level of technology implementation. Likewise, research related to the health sector and the inefficient use of its resources and time in the development of its processes concludes that it is of utmost importance to optimize operations, understand how to increase productivity, how to reduce costs or in which procedures there is an excessive investment and how to reduce waiting times, through the Business Process Management and lean manufacturing methodology [3]. In another research, it was determined the importance of implementing Lean Manufacturing practices to reduce time in the processes of textile companies. Also, implementing this methodology generated an increase of 23% to 40% in productivity, and the busy time in each cycle of the company went from 32% to only 11% [4]. For all the above mentioned, it is necessary to carry out this research related to the administrative area of maintenance of the aeronautical sector because it presents similar problems in its organizational processes, so it is necessary to continue investigating solutions to this problem.

Under this context, this article proposes an innovative proposal that focuses on the solution to the low productivity index of the Maintenance Administrative Area in the aeronautical sector, presents the analysis of the problems identified in the area, and offers the combination of a digital transformation based on Business Process Management and Lean applied in traditional maintenance administrative areas. According to the analysis, some researchers use these methodologies separately in different sectors with administrative processes; however, it is difficult to find a method that combines them in the administrative area of the aeronautical industry.

This academic article is divided into Introduction, Literature Review, Contribution, Validation, and Conclusions.

2 LITERATURE REVIEW

2.1 Digital Transformation model to increase productivity

According to the authors of this category, there are models to improve the productivity of processes; the first research refers to the 11-step digital transformation model for a manufacturing company focusing on employees who, according to the data investigated, are the ones that present the challenge when it comes to the adoption of new technology [5].

On the other hand, it was determined that medium-sized companies use at least 2 Industry 4.0 technologies to improve the productivity and efficiency of their manufacturing processes, having augmented reality and additive manufacturing as good practices to improve the maintenance process of airplanes. Also, the main limitation is the lack of regulation for the aeronautical sector, which could become a problem if a new technology enters this field; another limitation would be the significant investment needed to implement these technologies as they are usually used in multinational companies due to the high cost they present [6].

In conclusion, the level of digitalization that companies have is classified on a scale of 1 to 5, having a value of 2.3, which indicates that, although there is a certain number of companies that are implementing these technologies, the percentage is still deficient and therefore it is not possible to take full advantage of the benefits that these tools can provide to companies, however, it should be taken into consideration that more and more technologies are being adopted. For its correct application, it is necessary an evaluation of barriers and digital maturity in the organization. [7]

2.2 BPM – Business Process Management

The authors of this second category sought to use the methodology within the organizations, having as main benefits: the increase in the quality of the services offered and the decrease in the waiting time for their requests in the clinic or hospital under study, in addition, the analysis of this methodology identified that to have a digital tool that improves the order and optimization of each process it is necessary to identify the main parts of this using the BPM methodology [8].

The researchers conclude that the BPM methodology is adequate to determine the processes that need to be improved, besides being a valuable tool to order and optimize the processes and thus have greater control of the activities [9]. In addition, implementing this model means increasing the organization's capacity for digital transformation.

2.3 Lean Manufacturing

We can visualize in the third category the importance of implementing Lean Manufacturing practices to reduce time in the processes of textile companies. Likewise, implementing the Lean Six Sigma methodology led to improvements in the manufacturing processes of the paper manufacturing company, such as productivity increased from 23% to 40% [4].

This typology aims to reduce cycle time through a standardized work chart; the optimization based on this Lean Manufacturing technique seeks to boost quality control and reduce failures in the field. Given this situation, it is necessary and essential for companies to observe and identify non-value-added tasks and activities through the use of a chart that combines the Standardized Work and Operator Balance Chart (OBC). In addition, non-value-added processes are called waste elements: Defect, Overproduction, Waiting, Transportation, Inventory, Movement, and Excess process [20].

On the other hand, it is concluded that the feasibility of implementing these Lean methodologies within a medium-sized company is possible and also profitable since, according to the literature articles investigated, after the implementation of the methods, the companies present higher productivity, thus fulfilling the main objective of the research, even though there is broad resistance to the changes on the part of the company's collaborators.

2.4 Digital Transformation model with BPM and Lean Tools

This category seeks to analyze the results of the implementation of Industry 4.0 technologies in conjunction with methodologies such as BPM and Lean Manufacturing, the first research results that the company implements a total of five technologies as a first phase to simplify the processes of information, maintenance, and efficiency in the transfer of knowledge within the company. Also, as part of the second phase, eight additional technologies are implemented to allow the company to complete the strategy, resulting in revenue growth, agility, and predictability for the company's processes [10].

Based on the Lean methodology, we took as primary tools standardized work and online balance because it offers critical tools such as takt time, which corresponds to the rate at which the units must be produced to meet customer requirements, determination of the process sequence, defined times, establish resources and order of execution to avoid unnecessary stops. The results indicate the impact of the socio-economic context where the companies are located and the possibility of implementing the Lean methodology. However, this does not impede companies in emerging economies from implementing these methodologies and also obtain benefits such as improved productivity, competitiveness, time reduction, and the creation of digital processes [11]. Furthermore, it is also essential to consider the dynamic reconfiguration of the company since the commitment of top management and workers is vital for the successful development of the tools [21].

3 CONTRIBUTION

3.1 Model Justification

The proposal focuses on redesigning the current process of attending requests under a digital transformation approach focused on self-service, Lean, and BPM for the processing of the extensive database of technical staff and the implementation of a tool that facilitates the worker the registration of absences and quick attention of requests to reduce waiting times and bottlenecks in the process.

The purpose of the redesign of the process is to avoid excess time in the attention of requests, regularizations out of the time of personnel shifts, and inefficient management in the issuance of these, at the same time avoiding inconsistencies in the lack of personnel for the operation and reducing inconveniences on the part of the technicians when waiting so long for the attention of a request; avoiding costs of overtime and reimbursements, which are caused by an inefficient resolution or a late registration in the system.

The ideas implemented can be easily adapted to various sectors, as they can be applied in companies seeking to improve their processes in digital transformation and application of Lean tools. Currently, many companies in the aeronautical sector have low productivity compared to the standards of other sectors due to the significant investment needed by the aeronautical company to implement these technologies, as they are usually used in multinational companies and would include a high cost, however, by performing a correct analysis, the implementation of digitized tools reduces delays, rework and unnecessary stops. In this sense, we find the proposal possible to apply and with broad benefits in the long term.

As a proposal, we have considered the tools with the best re- sults in various investigations and industries with low productivity problems, focusing mainly on the processes in operation, knowing the root causes, study, and consequences of each analyzed research. Likewise, the following input table is presented where a comparison of the mentioned tools was made [12]-[17].

3.2 Proposed Model

The generation of value of our proposal was formulated through the tools proposed in state-of-the-art. For the highlighted problem, we presented as the primary solution a digital transformation model based on Lean Manufacturing-BPM, which is represented in Figure 1 The proposed model comprises four components, which employ the Deming Cycle or PDCA as a strategy based on continuous improvement.

3.3 Model Components

3.3.1 Phase 1: Plan. In this phase, the company's current situation was analyzed to determine the objectives and action plans to be implemented for improvement. A Pareto diagram and a VSM were carried out to make a holistic diagnosis and identify opportunities for improvement. Therefore, a Pareto diagram and a VSM (Figure 2) were made to identify opportunities for improvement. Then, the analysis of the objectives tree determined the indicators for measurement and follow-up. In addition, the research identified the root causes of the problem and the tools to be implemented, using historical company data to calculate the indicators.

3.3.2 Phase 2: Do. The first methodology implemented was Operator Balance Chart (OBC), based on optimizing work times during the process. Based on this tool, the necessary processes were considered for the attention of requests, knowing the sequence from data entry to the notification of acceptance or rejection, defining times, and making a calculation of the necessary activities in the process; in order to join processes, eliminate waiting times, set rules in each activity and calculate the cycle time [4]. The second tool was the standardized work, which systematizes the processes focusing on the production time to meet the demands and optimize the processes. This tool proposes implementing all processes correctly without waste, so standardizing processes helps improve operations' efficiency within an area [18]. The other tool used was the Business Process Management (BPM), which derives from the combination of two approaches: Continuous Improvement and Lean Six Sigma, providing companies with a crucial tool to focus and optimize processes and create more excellent value for the customer [9]. Finally, the last methodology proposed was the digital transformation model, where the first step is the identification of processes that present a lack of digitization to be more productive and optimal; for the second step, a process that needs to be improved must be found, for the third step the process is analyzed based on the fulfillment of numerical objectives set by the organization, In the fourth step, the process has to be redesigned based on technological methodologies that allow the reengineering of the process; in the fifth step, areas that are affected by the implementation of new technologies are determined, and the impact is studied; in the sixth step, risk management is performed in the event of a problem [5]. Then, the necessary skills of employees to develop the digital transformation model are analyzed; in the eighth step, the implementation of the digital transformation based on BPM and Lean is proposed, and the staff is trained in both methodologies; for the ninth step, a cost-benefit analysis is performed, and finally, the validation, monitoring, and control of the redesign is determined [8].

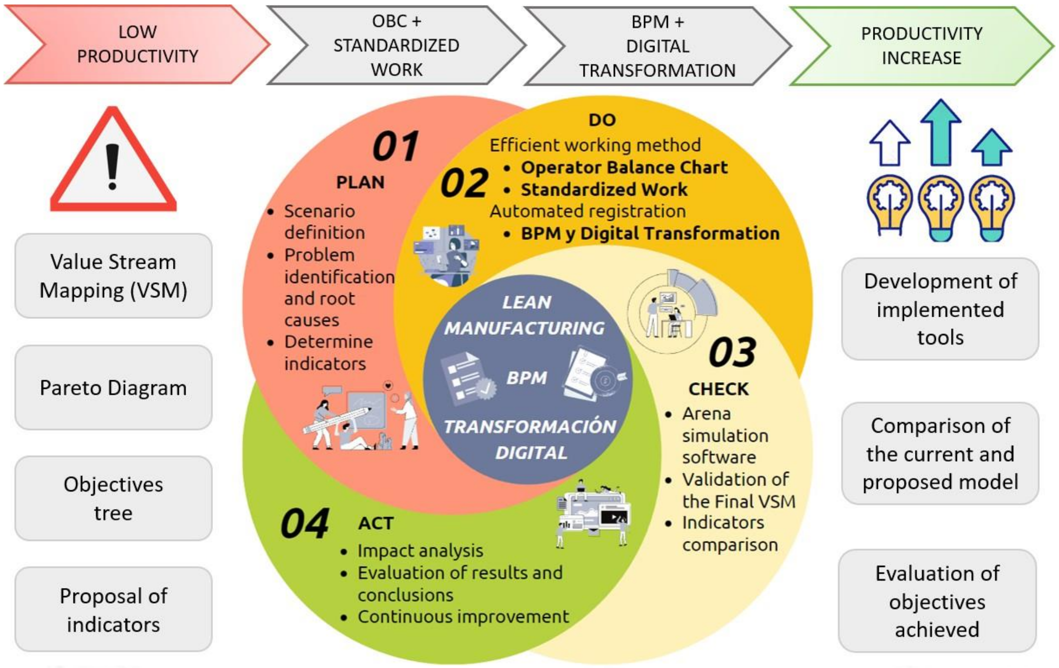

Figure 1: Proposed Improvement Model

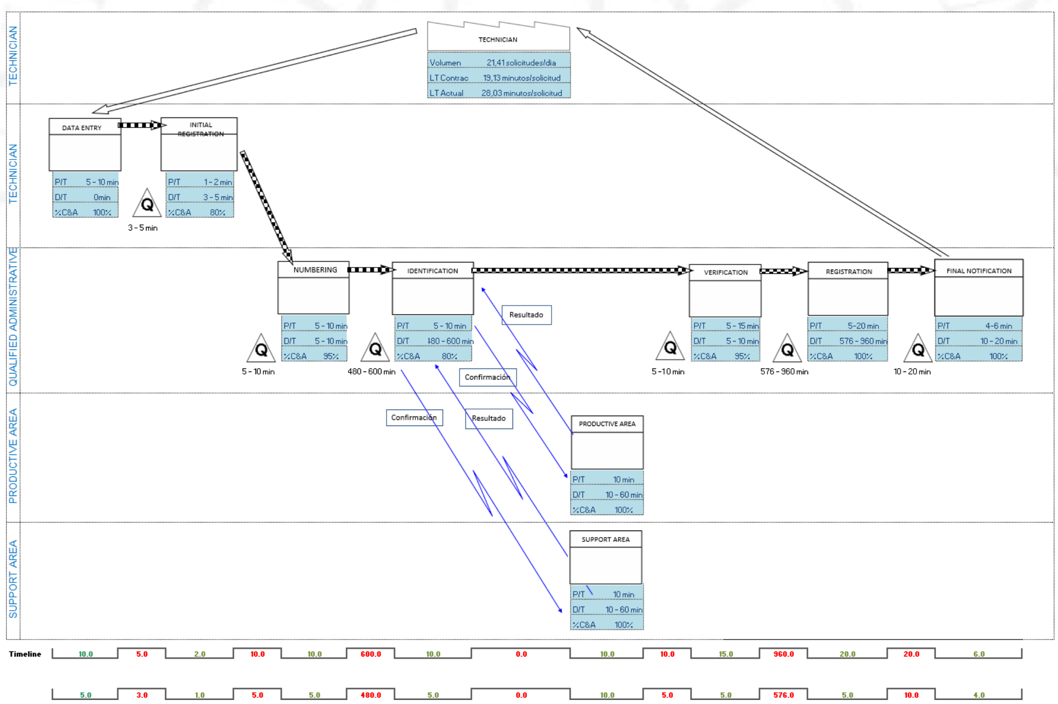

Figure 2: Initial VSM of the process

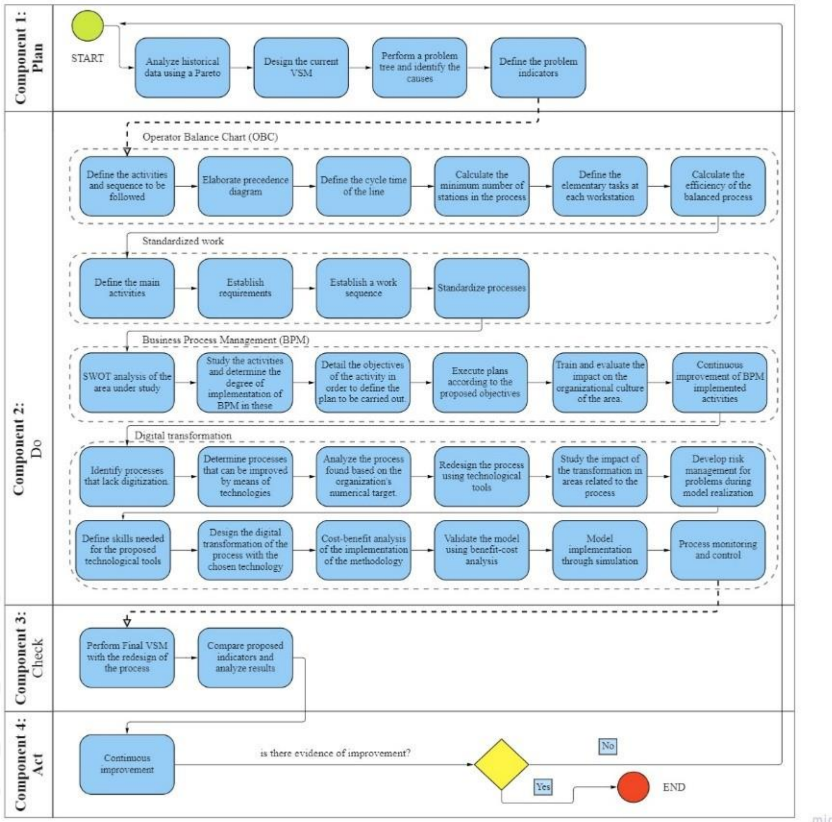

Figure 3: Model Implementation method

Table 1: Model Indicators

Indicator		Expected	Reference
Productivity(%)	$\left(\frac{Real\ time}{Available\ time}\right) x \left(\frac{Solicitudes\ atendidas}{Solicitudes\ esperadas\ a\ atender}\right) x\ 100\%$	>80%	[10]
Care rate(%)	$\left(\frac{Requests\ attended}{Total\ requests}\right) x\ 100\%$	88 %	[23]
Rejection rate (%)	$\left(\frac{Rejected\ requests}{Total\ requests}\right) x\ 100\%$	<2 %	[5]
Registration efficiency (%)	$\left(\frac{Real\ production}{Expected\ production}\right) x\ 100\%$	95 %	[12]
Average cycle time (min)	$\left(\frac{Total\ process\ time}{Total\ number\ of\ requests\ attended}\right) x\ 100\%$	<500 min	[23]

3.3.3 Phase 3: Check. In the third phase, the validation of the model and the fulfillment of the proposed objectives were carried out using Arena simulation software. Likewise, the final VSM was developed to analyze the processes benefited by the proposed improvement, and a comparison of indicators for monitoring was made [19].

3.3.4 Phase 4: Act. As a final phase, it is necessary to determine opportunities for improvement in each process and analyze the impacts and risks of the improvement through the results obtained. Likewise, the best performance of the system and the most efficient way to carry out the processes must be constantly sought.

3.4 Model Implementation method

Figure 3 shows the implementation of the proposed method based on the components mentioned in our proposed model.

3.5 Model Indicators

According to the literature review, we propose indicators to validate the proposed model, which are presented in Table 1.

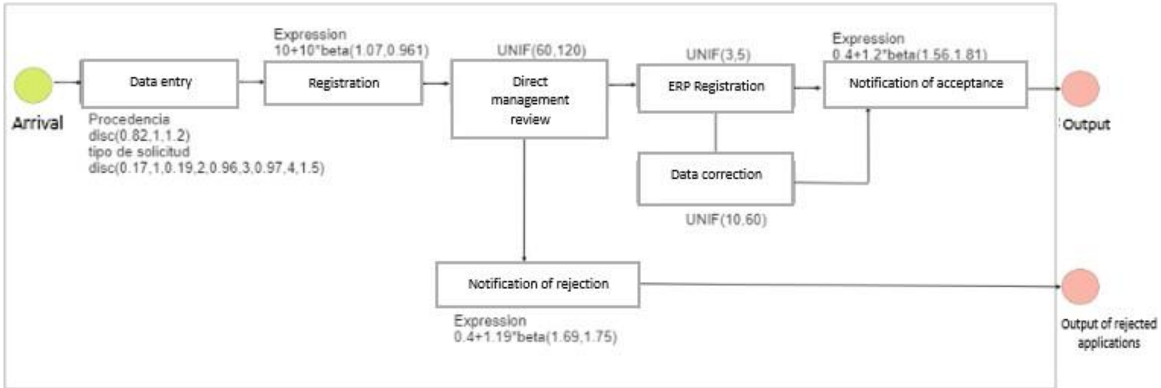

Figure 4: Improved system representation

4 VALIDATION

4.1 Initial diagnosis of the company under study

The administrative maintenance area presents a low productivity index of 62% in 2019 due to the high delay in attending to requests from technical personnel, causing an economic loss of PEN 284,216, equivalent to 21% of the maintenance area's expenses. Likewise, it is essential to mention that the administrative area currently has an average care rate of 67.95%, a rejection rate of 5%, a registration efficiency of 80%, and an average cycle time of 1119 minutes/Request attended.

4.2 Validation design and results

The simulation design of the initial system for attending to requests was carried out to validate the indicators of the proposed model. The process starts with the arrival of the requests from the aeronautical technicians; then, the numbering process is performed, where a ticket number is assigned, and the person in charge performs a general review of the technician's data to check if important data was entered into the system.

Subsequently, the request is identified, which can be: shift change, medical rest, attendance control, vacations, and overtime; in addition, it can belong to the productive or support area. After the communication, each chief communicates with the direct boss of each technician, and when they have the final answer, this is communicated to the administrative area of maintenance; if the request was not observed, the process continues with the verification where it is verified if there are duplicities in the personnel code, request number, and type of queries in the internal database. Then, the requests that have been approved are registered on the corporate platform; subsequently, an email is generated informing the registration, and the approval of the request is communicated.

Once the current system has been described, the improved simulation model is carried out, through which, firstly, the implementation of standardized work and BPM managed to unify some processes, and define the best sequence, also through the application of digitalization, it was possible to increase the care rate by 25.4%,the rejection rate was reduced by 2.09%, for which BPM and digital transformation were implemented; it was possible to increase the efficiency of registration by 30.45%. The cycle time was drastically reduced by 87% of the initial cycle time. Finally, the structured application of the solution model using the three tools increased productivity from 62% to 80.62%, thus fulfilling the primary objective outlined in this research. Figure 4 shows the representation of the improved system and Figure 5 shows the representation of the process in the final VSM:

In order to perform a comprehensive analysis, a simulation model was applied in Arena software. [20]. This model was represented from the arrival to the system until the generation of a notification indicating whether the request was accepted or rejected. For calculating the optimal number of replications of the system, a total number of 30 runs was started, and the cycle time of attention of 1 request was evaluated. In the first 30 runs performed, an average cycle time of 886.62 minutes was obtained with an error time of 17.99, thus determining an initial confidence interval of [868.63; 904.61] minutes.

Due to the high error time, the following formula was implemented:

$$N = 30 \times \frac{17.99^2}{8^2} \div 152 \ optimal \ runs$$

With this result, we proceeded to simulate the system and obtained a cycle time of attention of 1 request of 880.06 minutes with an error time of fewer than 8.61 minutes, resulting in a more accurate system with a confidence interval of [871.45; 888.67] minutes, with an approximate time difference of 17 minutes of accuracy. The required distributions were established in each process, and we proceeded with the simulation, the system modeled in the Arena software of the current situation is shown in Figure 6, and Figure 7 shows the simulation of the improved model.

The implemented model achieved the primary purpose of increasing productivity by increasing the rate of attention to requests. It is worth mentioning that the digital transformation combining BPM and LM allowed the result of our indicators to be efficient. Likewise, the self-service model proposed for the attention of requests can be used in other areas that manage administrative processes involving requests, complaints or claims from personnel. The results obtained from the application of the model are shown in Table 2 comparing scenarios according to the proposed objectives of the case study:

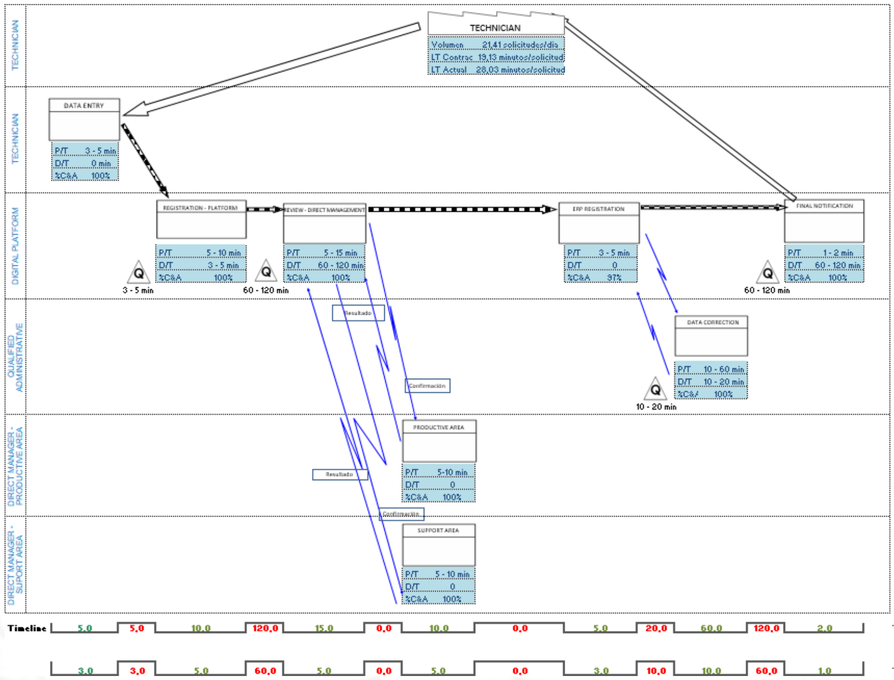

Figure 5: VSM with proposals for improvement

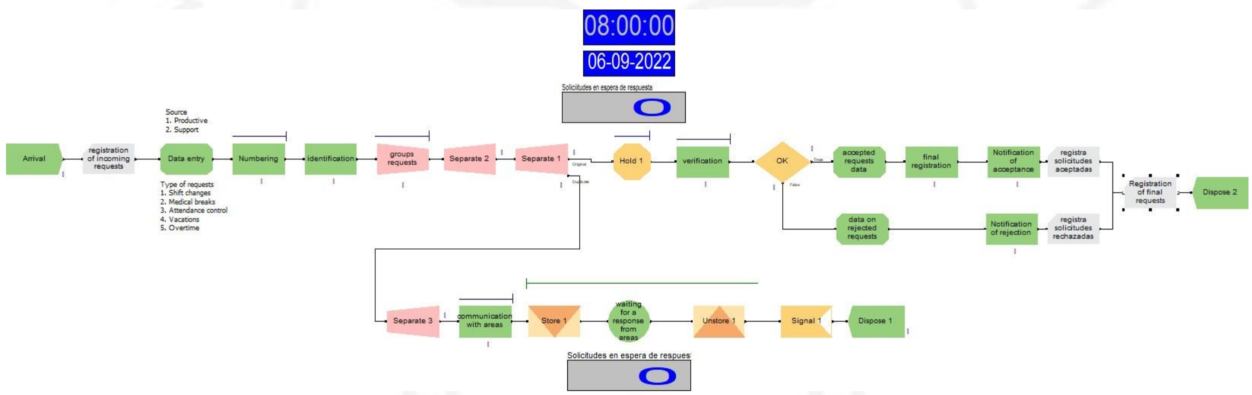

Figure 6: Simulation model in Arena without improvements

Table 2: Results

Scenarios	Objectives				
	O1	O2	O3	O4	O5
E1	62.00%	68.10%	5.00%	64.58%	880.13 min
E2	80.62%	94.50%	2.91%	97.17%	111.15 min
Variation	+18.62%	+26.40%	-2.09%	+32.59%	-768.98 min

Where:
O1: Productivity
O2: Care rate
O3: The rejection rate
O4: Registration efficiency
O5: Cycle time

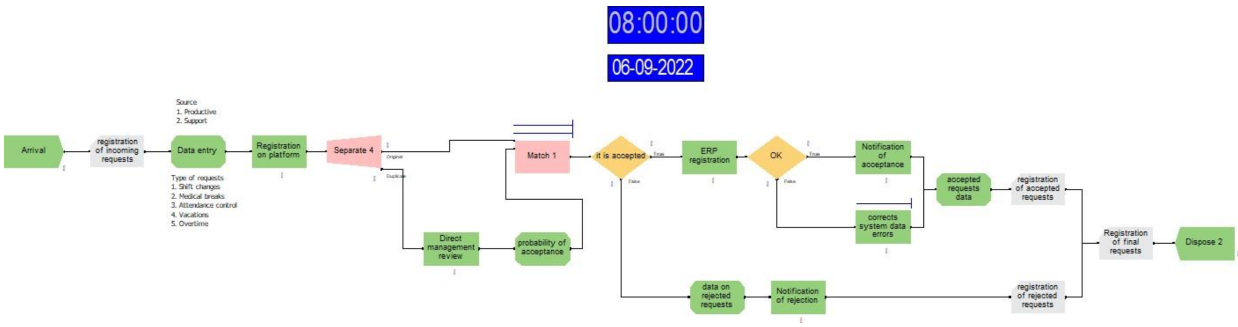

Figure 7: Improved simulation model in Arena

E1: Initial situation
E2: Situation after improvement

The results from Table 2 show that the indicator with the best positive variation was the registration efficiency; this indicator was related to the management controlling staff shifts and the long registration delay in the database. This improvement is due to the proposed data registration based on the Operator Balance Chart (OBC) that identified bottlenecks and downtime, thus joining processes to streamline data registration.

Also, the reduction in the number of rejected requests reduced reprocessing costs and improved the registration service for the technicians in the area. Likewise, there was a significant reduction in the cycle time of the process due to the decrease in the waiting time of the requests that were to be confirmed by the managers, the tools used for this were the Standardized Work and the Bussines Process Management (BPM); the former determined the process requirements establish a flow of actions and the latter served to reduce the delay in data input and output through the implementation of systematic processes that were performed automatically with the proposed transformation tool.

This research could be used as a preliminary basis to redefine and manage administrative areas with an excess of attention time; this case study would serve companies seeking automatic planning in their manual registration processes for any data management process that wants to raise its level of service. Accordingly, the impacts of this research are focused on digitally transforming companies using BPM and Lean methodology, in addition to achieving the identification of processes that urgently need digital transformation [9]. Another impact of the research within administrative systems with an extensive database and where traditional manual management activities are performed is the automation of processes and time reduction [10]. In addition, the BPM tool helps to improve business strategies through the implementation of systematic proceduresthat are performed automatically and then can be evaluated based on indicators that reflect the increase in productivity and efficiencyof the entire production cycle [8].

5 CONCLUSION

Implementing this digital transformation model using BPM and Lean in a company in the aeronautical sector obtained beneficial results that were within the initial expected range; through the simulation, it was possible to increase by 18.62% the productivity of the administrative maintenance area. In addition, the proposed objectives were achieved for each of the indicators mentioned in this article, especially the cycle time of attention, which had a decrease of 768.98 minutes; this was achieved thanks to the implementation of BPM, Lean, and the digitization of manual input and output of data, as well as the determination of a working method to reduce bottlenecks and identify downtime in the process.

Finally, this research conducted in an air transport company demonstrated the advantage of implementing digital transformation based on BPM and Lean, showing that digital transformation helps to benefit from a more efficient data recording, BPM helps to organize information, have greater control of the operation and reduce delays in the data recording process. The Lean tool is responsible for lowering identified bottlenecks and establishing work methods. Likewise, the advantage of using these tools is demonstrated in the improvement simulation presented, in which the number of rejected requests from maintenance technicians was reduced and the increased rate of attention to requests.

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