Enhancing Customer Service Efficiency in Telecommunications via Queueing Model Simulation: A Quantitative Case Study

Mejorando la Eficiencia del Servicio al Cliente en Telecomunicaciones a través de la Simulación de Modelos de Colas: Un Estudio de Caso Cuantitativo

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ABSTRACT: *The **objective** of this study was to improve and control the customer service process in a service center through queuing model analysis, with the goal of reducing waiting times, improving service levels, and increasing productivity. To achieve this, a detailed waiting line analysis was conducted, evaluating waiting and service times, as well as the service level of the system. Subsequently, a process simulation was implemented using JAAMSIM® software to represent the system and evaluate various improvement strategies. The **results** showed that the service system had significant deficiencies, with waiting times ranging from 5 to 56 minutes and a service level below 40%. After applying improvement strategies, such as correcting process instability and improving human resource management, waiting times were reduced by 55%, and queue length decreased by 72%. Additionally, productivity increased by 7.76%. The **conclusions** indicate that process standardization and proper human resource management lead to significant improvements in service efficiency, reducing waiting times, increasing productivity, and optimizing operational costs.*

Palabras clave: *process optimization, queue management, improvement cycle, DMAIC, operational performance.*

RESUMEN: *El **objetivo** de este estudio fue mejorar y controlar el proceso de atención al cliente en un centro de servicio, mediante un análisis de modelos de colas, con el fin de reducir los tiempos de espera, mejorar el nivel de servicio y aumentar la productividad. Para ello, se empleó un análisis detallado de las líneas de espera, evaluando los tiempos de espera y atención, así como el nivel de servicio del sistema. Posteriormente, se implementó una simulación de procesos utilizando el software JAAMSIM® para representar el sistema y evaluar diversas estrategias de mejora. Los **resultados** mostraron que el sistema de atención presentaba deficiencias significativas, con tiempos de espera que variaban entre 5 y 56 minutos y un nivel de servicio inferior al 40%. Tras aplicar las estrategias de mejora, como la corrección de inestabilidad en los procesos y la mejora en la gestión de los recursos humanos, se logró reducir el tiempo de espera en un 55% y la longitud de las colas en un 72%. Además, la productividad aumentó en un 7,76%. Las **conclusiones** indican que la estandarización de los procesos y una adecuada gestión de los recursos humanos permiten mejorar significativamente la eficiencia del servicio, reduciendo los tiempos de espera, incrementando la productividad y optimizando los costos operativos.*

Palabras claves: *optimización de procesos, gestión de colas, ciclo de mejora, DMAIC, rendimiento operativo. 4*

1. INTRODUCTION

The economy of a country is made up of companies, one of them the services, which according to recent studies generates most of the GDP of nations, approximately 76%, being the fastest growing sector in the global economy of the last decade. Therefore, it is vitally important to analyze the capacity they have when it comes to meeting customer requirements. At present, companies recognize that giving good customer service generates a level of satisfaction in it, in this way they cause it to reacquire a good or service at a later time, make the company known to other potential customers [1].

In the last decade, several quality management strategies have been implemented, especially in the service sector. Among them, continuous improvement prevails as the most popular due to its unique ability to provide a competitive advantage to companies [2].

Modern economies are under constant pressure and those that ensure correct negotiation in all their processes remain in the market. Corporations that can minimize waste and errors, and that possess a management philosophy that can turn mistakes into learnings for later success will be the ones that survive in the market making profits and maintaining an efficient business. The six sigma method is a project-driven management approach to improving the organization's products and services and processes. It is a business strategy that focuses on improving customer requirements, understanding, business systems, productivity and financial performance [3].

Six sigma tools discover the causes of potential problems and through this methodology eliminate possible defects, this means that this methodology takes action in the early stages of product or process development before the problem arises [4].

Within the modalities of customer service, there are customer service systems, which consist of an arrangement of people willing to solve the questions or needs that this maintains, therefore, it is appropriate that companies worry about giving a good service through a convenient waiting time to receive attention and a timely service time to meet the expectations that the client has with the service [5].

One of the companies that uses this type of service is the National Telecommunications Corporation EP, by its nature of providing services, uses these customer service systems. The company has identified that the value offer is not met in terms of waiting time and customer service time in one of its centers, the level of service is less than 40% and the wait fluctuates between 5 to 56 min, therefore, it is essential to identify the causes to be attacked [6].

The objective of this work it was to propose a plan for improvement and control of the customer service system through the application of the methodology of waiting line analysis and scheduling of operations with emphasis on reducing waiting times, improving the level of service and increasing productivity.

To achieve this objective, the following route was proposed: to carry out an analysis of the current situation of the waiting line of the customer service system according to waiting times, times and level of service, to apply the waiting line simulation to develop a model of study of the current state of the service system, Through the simulated process, evaluate the different strategies for improvement and increase in productivity, and propose a plan for improvement and control of the care system according to the results of the improvement strategies [7].

2. METHODOLOGY

Before referring to customer service systems, it is essential to understand what it truly means to serve the customer. According to [8], customer service is a set of procedures coordinated by the company in which the relationship between the company and the customer is managed, promoting customer satisfaction. In this sense, customer service focuses on meeting the needs that the customer has, and for this, the company provides various resources, whether physical, human, infrastructure, and so on. These resources allow the company to provide appropriate and efficient service, ensuring that the customer receives the attention they expect.

This focus gives rise to what is known as customer service systems. A customer service system, therefore, is understood as the set of physical facilities, human resources, and technologies organized to respond quickly and effectively to customer needs. Its primary goal is to generate satisfaction, loyalty, and a positive experience for the customer, which in turn fosters loyalty to the company [9].

It is relevant to highlight that customer service systems do not only aim to resolve issues or attend to requests, but also to anticipate the customer's expectations. This involves clear, accessible, and efficient communication at all points of contact with the company, from phone service to digital channels. In this regard, a good customer service system does not just respond to needs but also improves the overall perception of the brand, creating an emotional connection with the customer that strengthens the long-term relationship [10].

Additionally, in the current context, customer service systems must constantly evolve, adapting to technological changes such as process automation, the use of artificial intelligence, and the integration of omnichannel platforms. This enhances the customer experience and reduces waiting times [11].

2.1. Waiting line analysis

In everyday life, waiting lines are a constant presence, whether it's cars waiting for a traffic light to turn green, or customers forming lines at financial institutions eager to make a transaction. However, just because waiting lines are common doesn't mean they don't present challenges for organizations. These lines can lead to time and financial losses, and even human costs if, for example, the waiting time in a hospital becomes too long [12].

The analysis of waiting lines involves studying key factors such as the patterns and distribution of customer arrivals, as well as ensuring the adequate provision of resources to deliver the service efficiently. These elements are essential for understanding how to optimize processes and reduce the negative impacts that long waiting times can have on both organizations and customers [13].

2.1.1. Disposition and distribution of arrival of customers

In the study of customer arrival, it is necessary to specify the origin of customers: a finite population (for example in doctors' offices, the demand for patients is fixed and there is no possibility of serving more) or infinite (for example in financial institutions, the successive arrival of customers), this will define the law of probability to be used in the distribution of the arrival and estimation of customer demand.

The arrival distribution refers to the speed or rate at which customers approach the system requiring a service, however, to conduct a study of the arrival of customers, it is necessary to differentiate the arrival times of customers and the time between arrivals Figure 1.

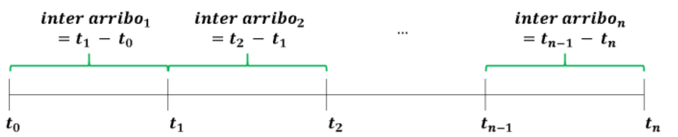

Figure 1. Time of arrival and time between arrivals. Source: own elaboration.

The time of arrival corresponds to the moment of arrival), on the other hand, the inter arrival times correspond to the width of the interval. $(t_0, t_1, \dots, t_n(t_1 - t_0)$.

For the estimation of customer demand, it is necessary to apply the Poisson Process or counting, which represents the number of events (customer arrivals) that can be generated in a time interval [14]. For the application of this probabilistic model it is necessary to meet the following conditions:

- The arrival of customers is independent of each other.
- The arrival of customers has to be one at a time, and the probability of 2 or more arriving is zero.

- The number of customers arriving in one-time interval is independent of the number of customers arriving in another time interval.

With the fulfillment of these conditions, the time between customer arrivals follows an exponential distribution (with parameter) λ[7].

$$P(t) = \lambda \cdot e^{-\lambda \cdot t}$$

And the arrival rate of customers follows a Poisson distribution (with parameter). λ[15].

$$P(n) = \frac{\lambda^n \cdot e^{-\lambda}}{n!}$$

2.1.2. Provision of resources to provide the service

Within the analysis of the waiting line, the speed of customer service must be taken into account, this can be constant or variable. Waiting lines are configured in such a way that they can include multiple servers, in a phased and channel flow design [16].

The most commonly used configuration is multiple channels with multiple phases; This arrangement includes consecutive servers, and multiple wait lines Figure 2.

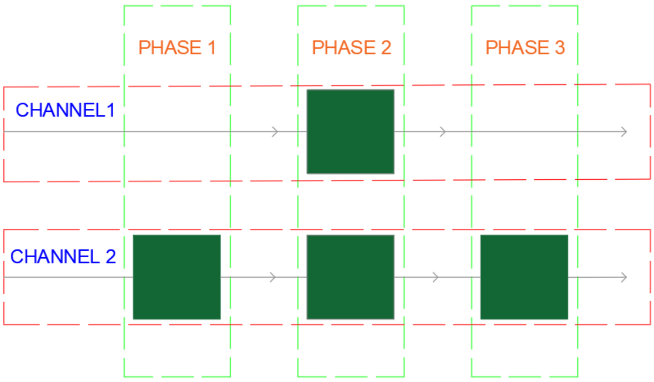

Figure 2. Configuration multiple channels and multiple phases. Source: own elaboration.

To solve these types of problems, there are equations developed for some configurations. [17] However, for more complex systems, where different processes are involved, therefore different times, different customer demands, a variable number of servers, etc, the waiting line simulation is used.

2.2. Waiting line simulation

Wait-line simulation combines probabilistic models (e.g., exponential distribution), and statistical functions (e.g., minimum, maximum, medians) to represent the randomness and characteristics under which the system works. This tool monitors the occurrence of events of interest and the flow resulting from the system's own interactions through the analysis of random variables [15].

Given the complexity of these models due to the interactions they imply, in the present work it uses the JAAMSIM® software which is programmed to carry out this type of studies and offers certain advantages over other types of software [18].

2.3. Statistical process control

The statistical control of processes is a tool for the management of quality in the company, through control graphics the representation of the limits is made (either specification, or control), and which serve as a guide to control the evolution of the performance of a system ([19].

The control limits correspond to the following: $\underline{X} - R$

For the :$\underline{X}$

$$LC_{\underline{X}} = \underline{\underline{X}} \pm A_2 \cdot \underline{R}$$

Where:

$\underline{\underline{X}}$: is the average of the averages of the samples taken

A_2: replacement factor

$\underline{R}$: is the average of the ranges of the samples taken

For the :$\underline{R}$

$$LCS_R = D_4 \cdot \underline{R}$$

$$LCI_R = D_3 \cdot \underline{R}$$

D_4: factor for the upper control limit

D_3: factor for the lower control limit

To finish with the diagnosis, monitoring and control of the operation of the system, it is essential to use the process capacity indexes, which allow to conclude on the ability of a process to meet a specific quality level and identify possible improvements [13].

$$C_p = \frac{LES - LEI}{6 \cdot \sigma}$$

$$C_{p_i} = \frac{\mu - LEI}{3 \cdot \sigma}$$

$$C_{p_s} = \frac{LES - \mu}{3 \cdot \sigma}$$

$$C_{p_k} = [C_{p_i}, C_{p_s}]$$

$$K = \frac{\mu - N}{\frac{LES - LEI}{2}} \times 100$$

$$C_{p_m} = \frac{LES - LEI}{6 \cdot \sqrt{\sigma^2 + (\mu - N)^2}}$$

$$N = \frac{LES - LEI}{2}$$

Where:

C_p: potential capacity index

C_{p_i}: lower capacity index

C_{p_s}: Superior capacity index

K: Process centering index

C_{p_m}: Taguchi index

LES: upper specification limit

LEI: lower specification limit

μ: average or average

σ:standard deviation

2.4. Improvement plan

The quality of a service, is not a matter of a short-term goal, much less of establishing a plan and not implementing it, quality is done day by day, with a comprehensive commitment that links from the management to the advisors and people involved in giving a service that satisfies the client.

For the realization of an improvement plan, you can choose several methodologies, among them is the methodology or also known as a clear and easy to implement DMAIC roadmap to improve the processes extracted from the six sigma tools Figure 3 [6].

This methodology establishes a path forward, and the application of the stages of the cycle will allow the realization of benefits as long as the problem or root cause is correctly defined [9].

Figure 3. Six sigma continuous improvement cycle (DMAMC or DMAIC). Source: own elaboration.

3. RESULTS AND DISCUSSION

3.1. Description of the customer service system

The customer service system of a telecommunications company was the subject of this analysis. The service center under study exhibited significant deficiencies, including failure to fulfill its value proposition, insufficient service levels, and extensive waiting times (Figure 4).

The center operates five days a week, from Monday to Friday, opening at 08:00 and closing at 18:30. This results in a daily operating time of 10.5 hours with no interruption during lunch hours.

Figure 4. Customer Service Center Layout. Source: own elabotation.

The service layout includes 17 customer service modules (highlighted in yellow), a seating area with 40 chairs (in green) for clients waiting for their turn, and a reception and shift allocation desk (in purple) that classifies clients according to their service needs.

The process applied is:

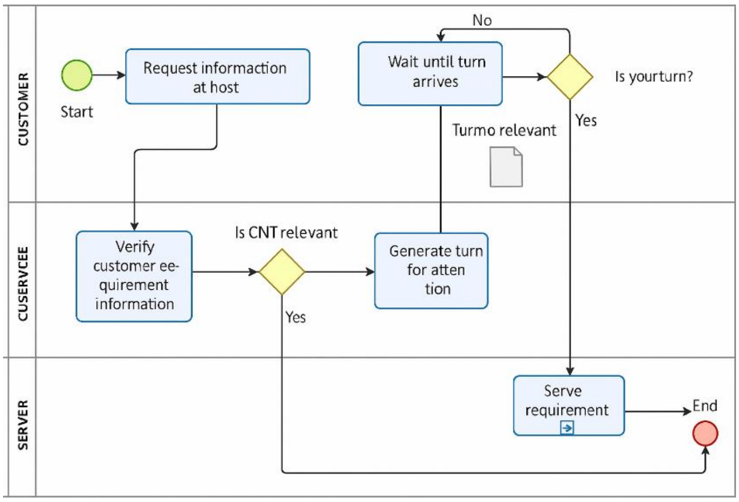

Figure 5. Customer Service Process. Source: own elaboration.

3.2. Waiting line analysis

For the present analysis, the records from the years 2022, 2023 and 2024 were considered, because it can be assumed that the behavior of customers in search of the service is maintained in recent years. Giving a total of 395 962 cases analyzed.

3.2.1. Study of customer arrival

Outlier data, which deviated significantly from expected arrival patterns, were identified and excluded. These anomalies, often caused by uncontrollable external factors, could distort simulation results if included. Visual inspection through box-and-whisker plots confirmed their presence and led to their removal for statistical validity.

It is common for this atypical data to be presented, this system works in real life and is subject to uncontrollable variables. In Figure 6, the black dots correspond to the atypical data, which were not taken into account in the analysis of descriptive statistics Table 1.

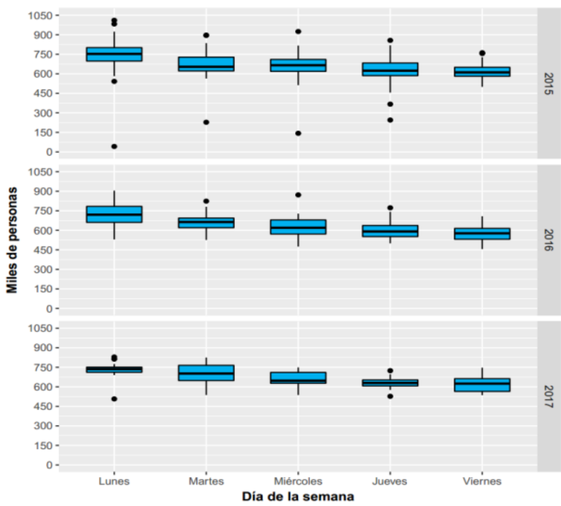

Figure 6. Box and whisker diagrams for the analysis period by years. Source: own elaboration.

Table 1. Descriptive statistics of daily care.

Day	Min	Max	Stocking	Standard deviation
Monday	570	924	737	70
Tuesday	526	836	674	69
Wednesday	475	817	645	69
Thursday	456	783	617	63
Friday	456	762	601	66

Source: own elaboration.

Descriptive statistics by weekday showed that Mondays had the highest average volume of clients (737), decreasing progressively toward Fridays (601). Standard deviations remained stable across days, with slightly more fluctuation on midweek days. To standardize the arrival rate between days, it is calculated by:

$$\text{arrival rate} = \frac{operating\ time}{demand}$$

The collected data corresponds to the following records: the system began operations at 08:00:00, and the final client arrived at 18:02:37. This results in a total operating duration of 10 hours, 2 minutes, and 37 seconds, equivalent to 602.62 minutes. Given that 684 individuals were served during that period, the calculated arrival rate is 0.88 minutes per person. Subsequently, the distribution function of customer arrival was identified, which was applied to represent this phenomenon Table 2.

Table 2. Arrival fees.

Day	Stocking	Standard deviation
Monday	0,857	0,100
Tuesday	0,946	0,192
Wednesday	1,001	0,335
Thursday	1,005	0,109
Friday	1,048	0,116

Source: own elaboration.

Figure 7 shows that the distributions that most closely approximate the real data generated by the arrival of customers are the gamma distribution and the normal, the exponential is totally deviated. To avoid subjectivity in choosing the distribution, the goodness-of-fit test was applied [20] (by means of the tests of Kolmogorov Smirnov the following results were obtained Table 3:

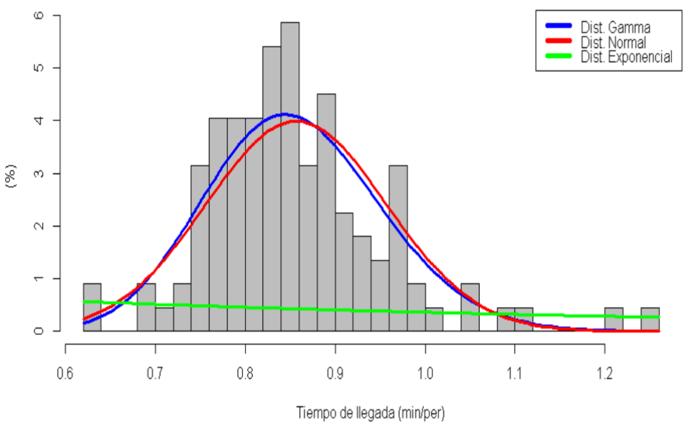

Figure 7. Distribution of arrival time – Monday. Source: own elaboration.

Table 3. Goodness of fit test – Monday.

Distribution	E(x)	Var(x)	p-value	Conclusion
Exponential	0,857	0,100	0,000	Rejected
Gamma	1,005	0,109	0,486	Accepted
Normal	1,048	0,116	0,386	Accepted

Source: own elaboration.

The arrival rate on Mondays can be modeled using either a gamma or normal distribution, as both are considered acceptable; however, the gamma distribution is preferred in this case. The same approach was used for the other days. The arrival rates recorded at the care center follow a gamma distribution, with the corresponding parameters shown in Table 4.

Table 4. Goodness of fit test – Monday.

Day	E(x)	Var(x)
Monday	0,857	0,010
Tuesday	0,930	0,009
Wednesday	0,972	0,012
Thursday	1,004	0,011
Friday	1,047	0,013

Source: own elaboration.

3.2.2. Study of customer service

To analyze the distribution of customer service time, it was necessary to identify the procedures involved. A total of 395,962 clients were attended following the structure shown in Figure 8.

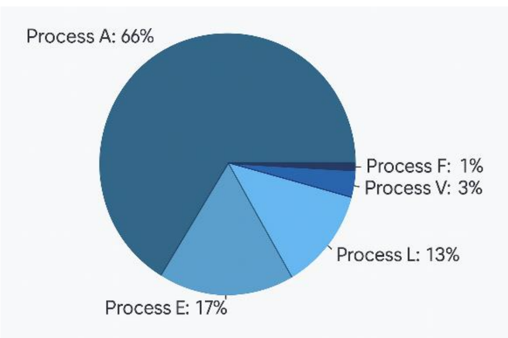

Figure 8. Proportion of care by process Source: own elaboration.

Next, it was necessary to determine the time each procedure takes for the servers. To achieve this, descriptive statistical analysis was applied, resulting in the data presented in Table 5.

Table 5. Descriptive statistics by care process.

Process	Min	Max	Stocking	Standard deviation
To	0,02	26,85	7,46	6,35
And	0,02	26,77	7,90	6,21
F	0,03	12,18	3,60	2,73
L	0,02	32,97	9,18	7,76
V	0,02	32,37	8,33	7,77

Source: own elaboration.

After applying the procedure to estimate the service time distributions, it was determined that none of the tested distributions accurately fit the behavior of service times across the different processes. A total of 32 distributions were evaluated using EasyFit® software, but none proved suitable. As a result, control charts were used to identify the behavior of service times for each process. Since the analyzed processes are of a mass-service type, control charts are the appropriate tools. Consequently, the following X-R control charts were obtained. $\underline{X} - R$, The control charts (Figures 9 and 10) revealed that the service processes (regardless of which one) are not in statistical control.

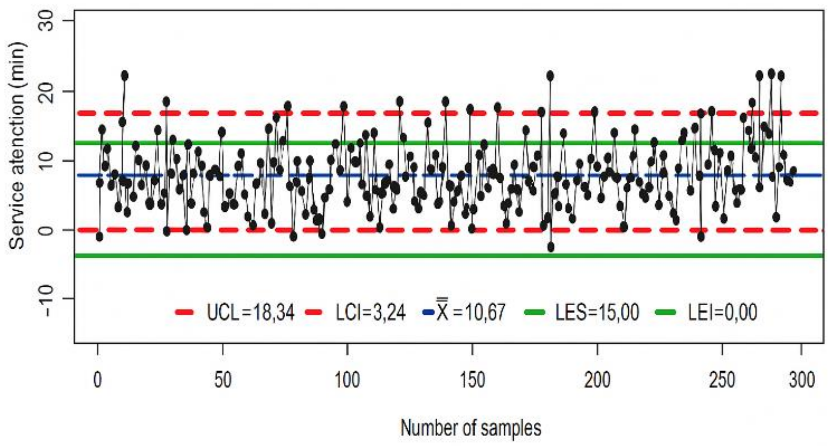

Figure 9. Control chart for process A $\underline{X}$. Source: own elaboration.

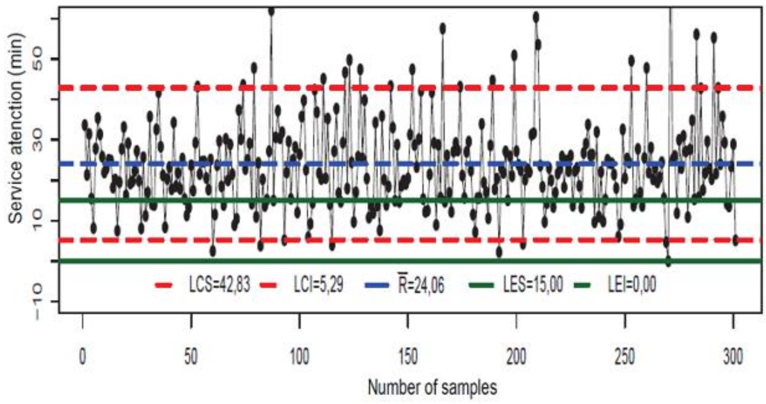

Figure 10. Control chart for process A R. Source: own elaboration.

The control limits defined by the processes exceed the specification limits, and it is common to find data points falling outside these specification bounds. Regarding the range charts, a significant deviation was identified: rather than a reduction in the dispersion of service times, the ranges have widened, indicating an increase in process variability.

For process F, no observations were obtained during the last year, because, as of 2024, the shifts that were attended with process F, are now attended in process A. To finalize the diagnosis, the process capability indices were applied. With which the following results were obtained Table 6:

Table 6. Capacity indices.

Process	C_p	C_{p_i}	C_{p_s}	C_{p_k}	K	C_{p_m}
To	0,26	0,36	0,15	0,15	40,69	0,15
And	0,26	0,39	0,13	0,13	49,28	0,14
L	0,22	0,35	0,08	0,08	62,10	0,10
V	0,23	0,35	0,11	0,11	51,68	0,11

Source: own elaboration.

Based on the capability indices, it is evident that the process variation is excessively high relative to the specification limits. With an average Cp of approximately 0.24, the processes are unable to comply with the required specifications. Regarding the actual capability index Cpk, which accounts for process centering, a higher capability was observed in relation to the lower specification limit, whereas for the upper limit, the process capability is significantly lower. This indicates that, in most cases, the data points exceed the upper specification limit. These results suggest not only that the processes lack capability but also that they are off-centered, with a clear tendency toward exceeding the upper bound. Additionally, the K index, which assesses how centered the process is within the specification range, showed values greater than 20%, confirming the misalignment. Unlike these indices, which rely on intervals for their calculation, the Taguchi index provides a stricter assessment of process performance. The values obtained through this index revealed extremely poor performance, highlighting that the existing variability is too great to align with the company's value proposition.

3.3. Simulation of the customer service system

Through a simulation model built in JAAMSIM, the behavior of the demand that the care system perceives daily was incorporated, the attention time according to the applied process,® and the disposition of both physical and human resources and the disposition of the waiting line Figure 11.

Figure 11. Simulated workstation. Source: own elaboration.

1. Represents the human resource assigned to provide service at a specific workstation.
2. Acts as an indicator of service availability; when displayed in green, it signifies that both the station and a server are ready to attend a client.
3. These linked elements jointly execute the task of assigning a client to a station and a server; this triad must be complete for the service process to initiate.
4. This component is where the actual customer service operation takes place.
5. These elements handle the release of the previously formed service set once the client has been attended, they exit the system, and both the station and server become available for the next client.
6. Although clients do not physically queue at the workstation, these objects simulate internal queues, which are essential for the proper functioning of the simulation model.

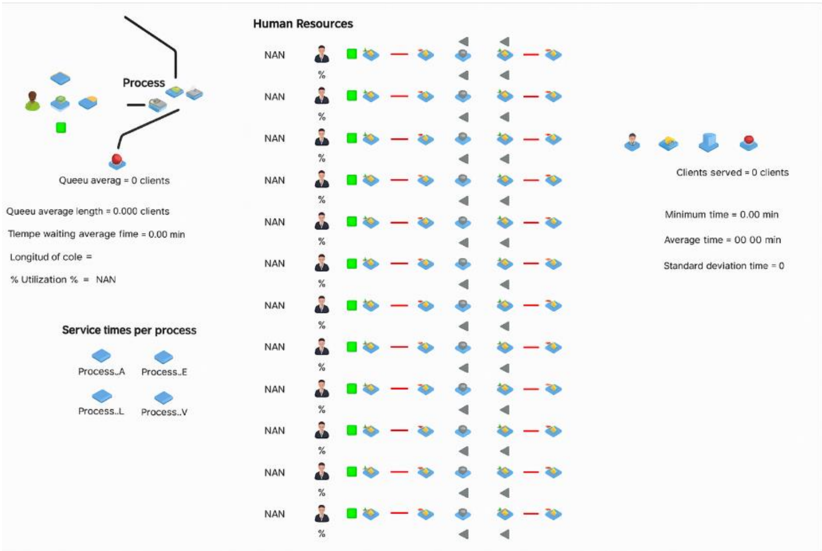

Figure 12. Representation of the system using a simulation model. Source: own elaboration.

To validate the operation, the absolute error rates were verified Figure 13.

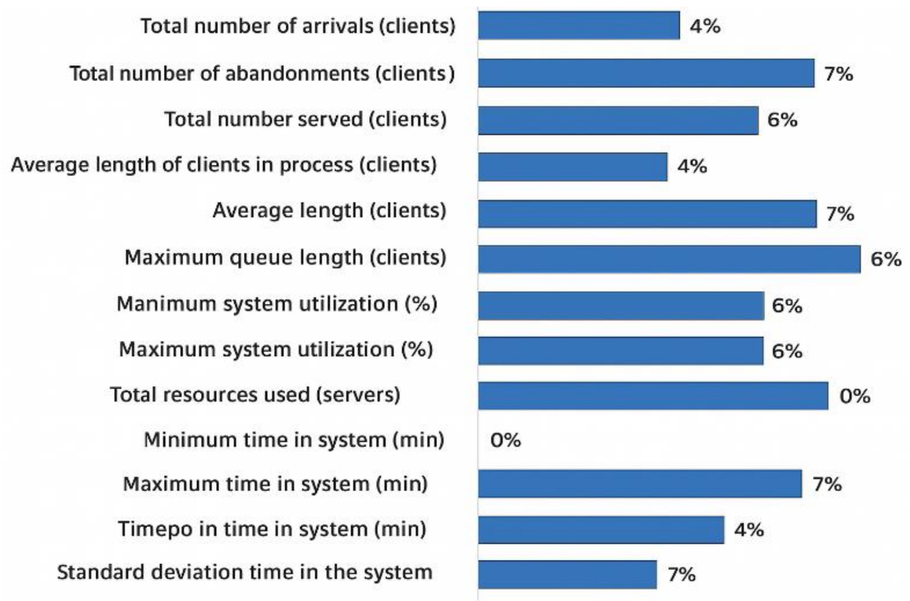

Figure 13. Absolute error rates between observed and simulated. Source: own elaboration.

The average error rate in demand (Total number of arrivals) Figure 11, I show an absolute error equal to 4%, that is, the simulated demand is similar to the observed demand. This same reasoning is made for the others, indicators, the maximum queue length, is the one with the highest error rate, reaching 8%, however, it is still valid. The simulated model represents the real system.

3.4. Evaluation of productivity improvement and increase

For the identification of root causes and strategies we applied the Ishikawa diagram or heavy spine Figure 14 [4].

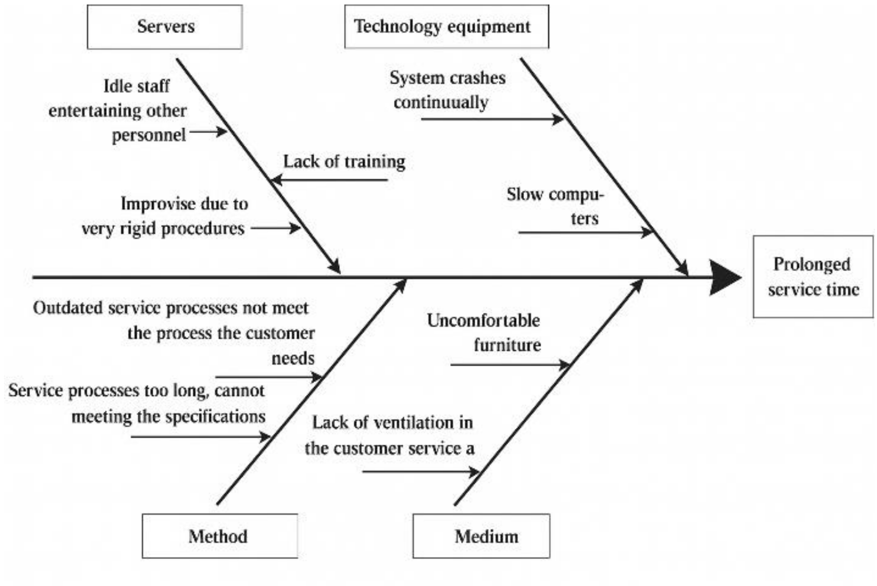

Figure 14. Ishikawa diagram. Source: own elaboration.

To mitigate the causes that affect attention time, the following strategies were established Table 7:

Table 7. Association of causes and mitigation strategies.

Causes	Strategies
Lack of training Rigid procedures Outdated processes	Correction of process instability and capacity
Very long processes	Set new specification limits
Unemployed staff	Human resource management
System failures Slow computers Uncomfortable furniture Lack of ventilation	Technical and administrative support

Source: own elaboration.

3.4.1. Correction of process instability

By taking into account the capacity indices shown in Table 6 and the control letters, the processes carried out in the customer service center can be characterized as incapable and unstable.

To correct this behavior you must follow these steps:

1. Identify hypotheses of the causes of instability, through the involvement of supervisors and servers.
2. Analyze the hypotheses obtained from the previous point with the administrative records to confirm the causes of the instability presented in each of the processes.
3. Standardize processes through corrections after the evaluation of hypotheses.

4. Train servers on new methods and maintain a consistent customer service attitude campaign.
5. Perform constant measurements through control letters for the processes to identify if the measures implemented have had a positive effect
6.

The standardization of processes generates a 20% decrease in the variation of the process, with which the results were obtained Figure 15.

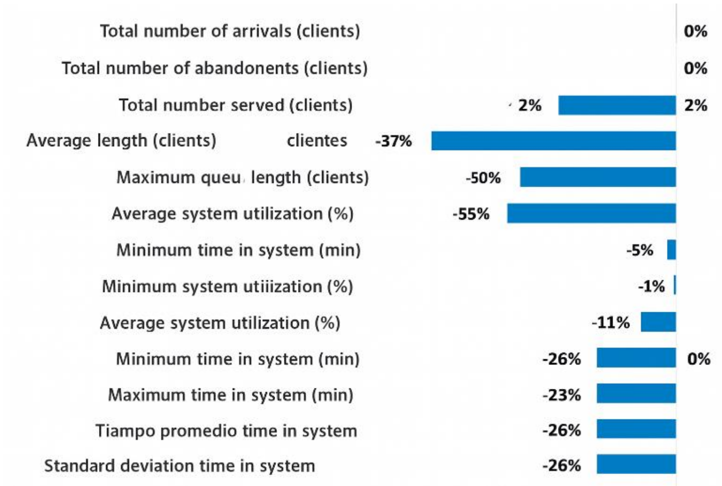

Figure 15. Variation due to process standardization. Source: own elaboration.

The implementation of process standardization led to a positive impact on system productivity. Previously, 17 servers managed to attend 701 clients; after applying this strategy, the number of clients served increased to 712. This reflects a 2% improvement in productivity, achieved without increasing the number of personnel.

3.4.2. Setting new specification limits

The company had previously defined the specification limits for the time individuals spend within the service center, setting an upper specification limit (USL) of 15 minutes and a lower specification limit (LSL) of 0 minutes. However, these limits were not established based on technical criteria; that is, the service policy lacked support from capacity analyses or pilot testing of the customer service system.

To evaluate the sensitivity of the capability indices, a simulation was conducted for process A by adjusting the specification limits. The outcomes of this analysis are presented in Table 8.

Table 8. Simulated capacity ratings for process A.

New limits	C_p	C_{p_i}	C_{p_s}	C_{p_k}	K	C_{p_m}
0 to 15.0	0,26	0,36	0,15	0,15	40,69	0,15
0 to 17.5	0,30	0,36	0,24	0,24	20,59	0,18
0 to 20.0	0,35	0,36	0,33	0,33	5,52	0,22
0 to 22.5	0,39	0,36	0,41	0,36	-6,21	0,24
0 to 25.0	0,43	0,36	0,50	0,36	-15,59	0,26

Source: own elaboration.

Although, the objective is not to establish broad specification limits in order to cover the shortcomings of the system, however, establishing new limits will serve to sincerely the value offer without creating false expectations.

3.4.3. Human resource management

In any project, cost optimization is one of the most closely monitored indicators. In the case of the evaluated system, the proposed improvement involves a reduction in human resources while still maintaining adequate customer service levels.

The simulations showed that simply eliminating extreme values in service times led to a significant enhancement in system performance. The minimum utilization indicator revealed that one operator was engaged 93.04% of the time on Monday, whereas on Friday their utilization dropped to 39.83%, reflecting a 57% decrease. This outcome highlights the presence of underutilized capacity, as shown in Table 9.

Table 9. Impact of human resource management.

Indicator	Friday (before)	Friday (after)	Variation
Average tail length	0,11	0,36	227%
Average timeout (min)	0,07	0,39	457%
Average system utilization (%)	80,50	88,86	10%
Resources used	17	16	-6%

Source: own elaboration.

A slight increase in total average utilization was observed, and this change did not affect the queue length, that is, the waiting time was not affected; Except for Mondays, on this day the strategy would be the increase of one person. In one month, a total saving of 959 USD is achieved, in the first year the cost decrease reaches 11 508 USD, therefore, the implementation of this strategy would allow favorable results for the company in terms of increasing the use of the system, reducing costs.

What represented an increase in productivity of 6.28%, with respect to personnel expenses, therefore, the optimization of system expenses was evidenced.

3.4.4. Technical and administrative support

To address the issues related to the customer service environment and the use of technological tools, a strategy has been designed to offer targeted solutions for each identified cause:

- Frequent system outages: it is essential to evaluate the internet connection methods used by operators and implement a schedule for regular preventive maintenance.
- Computer slowness: technical support staff should perform comprehensive maintenance on computers, including both hardware and software components.
- Inadequate furniture: damaged furniture should be repaired or replaced, and ergonomic accessories should be provided to improve working conditions.
- Poor ventilation: simple desktop fans should be installed at each workstation to enhance air circulation.

By implementing the improvement strategies together, and considering that the demand does not change and there is an increase in the number of customers served by the implementation of the process standardization strategy, in addition, personnel expenditure decreases due to the improvement in the administration of human resources, the following productivity is obtained Table 10.

The strategy of establishing new specification limits did not contribute to productivity, this strategy directly affected capacity indexes, however, the administrative support strategy contributed to productivity, however, this must be measured after the implementation of the strategies to be able to quantify what their impact has been.

Table 10. Increased productivity.

Strategy	Before	After	Increased productivity
Correcting process instability	41,23	41,88	1,57%
Human resource management	0,043	0,046	6,28%
Correction of process instability + Human resource management	0,043	0,046	7,76%

Source: own elaboration.

3.5. Improvement Plan Proposal

In order to establish the guidelines of an improvement and control plan for the care system evaluated, the following stages are detailed below.

Define the project: the problem is that the service center is presenting problems with the attention time of the clients, this caused that people must wait and the total time of permanence of a client within the system can easily exceed an hour. In addition, the value offer offered to the customer of maximum permanence of 15 min is not met, because it causes dissatisfaction in customers.

Project Definition:

Project Title: Optimization of the Customer Service System.

Project Leader: Customer Service Management Department.

Problem Statement: Prolonged service times result in increased customer wait times and, consequently, an extended total stay within the service center.

Project Team: Customer service coordinator, branch manager, shift supervisor, and service personnel.

Significance: Clients who experience long wait times tend to perceive the service as low quality and often report dissatisfaction with the attention received.

Objective: To decrease both service duration and customer wait times within the contact center.

Constraints: Expansion of human resources is not feasible due to spatial limitations; demand must be managed by adapting the system accordingly, and operating hours cannot be extended.

Deliverables: Staff training programs, implementation of monitoring tools and statistical process control, and ergonomic improvements at workstations.

Resources Required: Supervisory personnel, customer service staff, and administrative assets (e.g., hardware, software).

Stakeholders Involved: Clients, service personnel, quality and customer service managers.

Assessment of Current State:

To evaluate the existing process performance, the following tools are applied:

Control charts

Process capability indices

Performance indicators derived from simulation models

Root Cause Analysis:

An Ishikawa (cause-and-effect) diagram is utilized to identify the main contributors to extended service times.

Implementation of Solutions:

The identified strategies must be executed to mitigate the root causes affecting the efficiency of customer service.

Control Phase:

All statistical instruments employed throughout the project will be used to maintain and monitor system performance.

Final Consideration:

This continuous improvement plan should remain in effect until the system consistently meets established specifications and delivers service quality aligned with customer expectations and the company's enhanced value proposition.

4. DISCUSIÓN

The results obtained in this study show a significant improvement in customer service efficiency through the application of queueing models and simulation, highlighting the reduction in waiting times and the increase in service levels. When compared with previous research, it is evident that while some studies, such as those by [18],[17] address complex models with multiple servers, random volume customers, or priority schemes, the present work focuses on a simpler yet effective model tailored to the operational reality of a telecommunications service center. Similarly, research applied in hospital settings [5] emphasizes the importance of reducing waiting times to improve user satisfaction, aligning with the findings of this study. Finally, the incorporation of tools such as simulation and the DMAIC approach, also reported in studies like [4] reinforces the validity of the methodology used, demonstrating that even in less technically complex scenarios, substantial improvements can be achieved through the rigorous application of queueing theory.

5. CONCLUSIONES

The analysis carried out facilitated the development of a monitoring and control plan for the system under study, while also establishing a foundation for the implementation of future improvements. The average demand was calculated at 669 users, with Mondays showing peak demand, resulting in longer queues of up to 22 individuals waiting. Additionally, a customer abandonment rate of 5% was observed. The system operates at full capacity (100% utilization), indicating an overload, although this usage drops to 86% on Fridays. The average waiting time was recorded at 7.67 minutes, and the total average time spent by users within the system was 52.11 minutes.

Servers were identified as the primary resource in this system, making it essential to focus efforts on providing them with proper tools, efficient service protocols, a suitable work environment, and ongoing training to ensure the sustainability of improvements over time.

Following the implementation of improvement strategies, the average waiting time decreased by 55%, accompanied by a 72% reduction in queue length. As a result, customers experienced shorter waits and less congestion.

Customer service productivity, measured in terms of the number of clients served per server, improved by 1.57% through process standardization. Furthermore, optimizing the management of human resources led to a 6.28% increase in productivity relative to salary expenditures. When both strategies—serving more clients and reducing staff—were combined, overall productivity relative to human resource costs rose by 7.76%, enabling the company to serve more clients at a lower cost.

Initially, the system's service level was 20%. With the adoption of the process standardization strategy, this indicator doubled to 40%, meaning the number of clients served within the specification limits increased from 147 to 298.

6. ACERCA DEL ARTÍCULO

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Contribuciones de autoría:

José David Barros Enríquez: Conceptualization, methodology, supervision, writing – original draft preparation, and project administration.

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Declaración del investigador principal: Declaro que asumo la responsabilidad total por el contenido, la integridad académica y los resultados presentados en este trabajo, garantizando su rigor científico y cumplimiento ético.

Conflictos de interés: Los autores declaran no tener conflictos de interés.

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