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Optimization of Service Times in Fast-Food Restaurants in Lima: Application of Continuous Improvement Tools and Process Simulation

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Abstract

The growth of the fast-food sector in Lima, driven by the demand for efficient and high-quality services, has created the need to optimize service times in these establishments. This study arises with the objective of addressing inefficiencies in service processes in a fast-food restaurant, using continuous improvement tools such as queuing theory, aggregate planning, and simulations with Arena software.

The research focused on improving order handling times through the standardization of methods and times, aggregate production planning, and the application of queuing theory. A continuous improvement model was developed in seven stages, which included detailed time and method studies, flow determination and time standards, and validation through simulations.

The most notable results included a significant reduction in average order handling times from 23.14 minutes to 19.18 minutes, which nearly doubled the total number of orders attended from 679 to 1,397. Additionally, the queue size and the number of customers leaving the line drastically decreased from 785 to 75 customers. Furthermore, revenues increased from 17,128 soles to 35,522 soles, demonstrating a remarkable improvement in operational efficiency and customer satisfaction. These indicators highlight the effectiveness of the proposed model in optimizing service times and increasing competitiveness in Lima's fast-food sector.

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Keywords
Continuous Improvement, Queuing Theory, Aggregate Production Planning, Fast-Food Service Optimization

1. Introduction
The global fast-food restaurant sector has experienced significant growth over the past few decades, driven by its ability to offer quick and convenient meals to a large volume of customers. Originating in the United States, fast-food

chains such as McDonald's, Subway, Starbucks, Dunkin' Donuts, and Pizza Hut have expanded globally, transforming into highly efficient and effective franchises. According to Kolmar (2023), the fast-food industry generated revenues of $797 billion in 2021 and is projected to reach $907 billion by 2023, surpassing the GDP of several countries (Sena, 2021). In Latin America, and particularly in Peru, the sector has shown notable growth. The National Institute of Statistics and Informatics (INEI) reported a 9.1% increase in the production index of lodging and restaurants in April 2023 compared to April 2022, with fast-food contributing an 11.1% variation (INEI, 2023). This growth highlights the sector's resilience and adaptability, especially post-pandemic, where there is an increasing demand for healthier menu options, efficient delivery services, and enhanced customer experiences (Casas Reyes & Palomino Martel, 2021).

Despite its growth, the fast-food sector faces several challenges, particularly concerning customer service times. One of the primary issues is the low productivity of processes within these establishments. Inefficient processes can lead to long waiting times, which negatively impact customer satisfaction and loyalty. A study by Intouch Insight (2022) found that the average service time across ten major fast-food brands in the United States was 6 minutes and 12 seconds, with the fastest being KFC at 5 minutes and 20 seconds and the slowest being Chick-fil-A at 8 minutes and 29 seconds. This disparity underscores the need for better process management and optimization in fast-food restaurants to meet customer expectations. Additionally, inadequate supply chain planning and lack of standardization further exacerbate service delays. For instance, the improper scheduling of ingredient deliveries can lead to shortages, while the absence of standardized procedures can cause inconsistencies in food preparation and service (Avalos-Maldonado et al., 2022).

Addressing these challenges is crucial for the sustainability and competitiveness of the fast-food industry. Improving service times not only enhances customer satisfaction but also boosts operational efficiency and profitability. Fast-food restaurants must adopt continuous improvement methodologies, such as Lean Service and queuing theory, to streamline operations and reduce service times. Implementing these strategies can lead to a significant reduction in non-value-added activities, optimize resource allocation, and ensure a consistent customer experience. Moreover, leveraging technology for better inventory management and process standardization can mitigate issues related to supply chain disruptions and process variability (Gumus, Monday, & Humphrey, 2016).

In conclusion, the fast-food restaurant sector plays a vital role in the global and local economies, providing quick and affordable meals to millions of customers daily. However, the sector must overcome challenges related to service times, productivity, and process standardization to maintain its growth trajectory. Future research should focus on exploring advanced technological solutions and innovative process improvement methodologies to further enhance the efficiency and customer satisfaction in fast-food restaurants. By addressing these issues, the fast-food industry can continue to thrive and meet the evolving demands of consumers.

2. Literature Review

2.1 Methods Engineering in the Production Process of the Fast-Food Restaurant Sector

Methods engineering has been widely applied in the fast-food restaurant sector to improve operational efficiency and reduce costs. A study conducted by García et al. (2019) evaluated the implementation of methods engineering techniques in a fast-food restaurant chain in Spain, where preparation times and service times were reduced by optimizing work processes. Additionally, an analysis by López and Ramírez (2020) highlighted the use of flowcharts and time and motion studies to identify bottlenecks and areas for improvement in the production chain of a fast-food restaurant in Mexico. This study showed that reorganizing the workflow and training staff contributed to a significant improvement in operational efficiency. Furthermore, research by Kim and Lee (2021) in South Korea demonstrated that applying methods engineering techniques, such as line balancing and process standardization, not only improved operational efficiency but also increased customer satisfaction by reducing wait times and ensuring greater consistency in product quality.

2.2 Aggregate Planning in the Production Process of the Fast-Food Restaurant Sector

Aggregate planning is a crucial tool for efficiently managing capacity and demand in the fast-food restaurant sector. According to a study by Martínez et al. (2018), implementing an aggregate plan in a restaurant chain in Argentina allowed for better alignment between supply and demand, thus reducing inventory costs and improving service levels. This approach facilitated medium-term planning, enabling managers to make informed decisions about hiring staff and procuring supplies. Similarly, Gómez and Torres (2019) in their research in Colombia, showed that using aggregate planning models allowed fast food restaurants to adjust their production and staffing levels according to seasonal demand fluctuations, thereby improving efficiency and reducing food waste. Finally, a study conducted by Nguyen and Pham (2020) in Vietnam highlighted the importance of aggregate planning for anticipating demand peaks and preparing contingency strategies, resulting in increased responsiveness and adaptability of the business.

2.3 Queueing Theory in the Production Process of the Fast-Food Restaurant Sector

The application of queueing theory in the fast-food restaurant sector has been fundamental for effectively managing queues and improving customer experience. A study by Rodríguez et al. (2017) in Brazil used queueing theory models to analyze and optimize wait times in the service line of a fast-food restaurant, reducing average wait times and increasing customer satisfaction. Similarly, Chen and Zhang (2018) investigated the application of queueing systems in fast food restaurants in China, finding that adding extra servers during peak hours and redistributing tasks significantly decreased wait times and increased operational efficiency. On the other hand, research by Smith and Johnson (2019) in the United States applied queueing models to supply chain management in fast food restaurants, which improved synchronization between food preparation and delivery to the customer, thus reducing the total time from order to delivery.

2.4 Continuous Improvement Tools in the Production Process of the Fast-Food Restaurant Sector

Continuous improvement tools, such as Kaizen and Six Sigma, have been successfully implemented in the fast-food restaurant sector to foster quality and operational efficiency. A study by Hernández et al. (2020) in Mexico demonstrated that applying the Kaizen methodology in a fast-food restaurant chain resulted in continuous improvements in service quality and a reduction in food waste. Additionally, an analysis by Silva and Costa (2021) in Portugal showed how implementing Six Sigma allowed fast food restaurants to identify and eliminate process variability, improving product consistency and reducing cycle times. Furthermore, research by Patel and Desai (2022) in India highlighted the combined use of continuous improvement tools and digital technology, which facilitated the rapid identification of problems and the implementation of efficient solutions, resulting in a significant increase in operational efficiency and customer satisfaction.

3. Methods

3.1 Proposed basis and model

The model of continuous improvement shown in **Figure 1** was based on a systematic methodology to optimize the production processes of a fast-food restaurant. Its objective was to improve the time of orders through the improvement of restaurant processes, reduction of waiting for diners and proper management of inventories of required inputs. Initially, time studies and methods were conducted to understand the existing workflow. Subsequently, time standards were determined, and queue theories were applied, followed by the identification and allocation of the necessary resources. An aggregate production plan was developed to manage demand. The improvements implemented were monitored using economic performance indicators, recording results and validating the effectiveness of the model. This approach sought to increase operational efficiency and customer satisfaction through iterative and sustainable improvements.

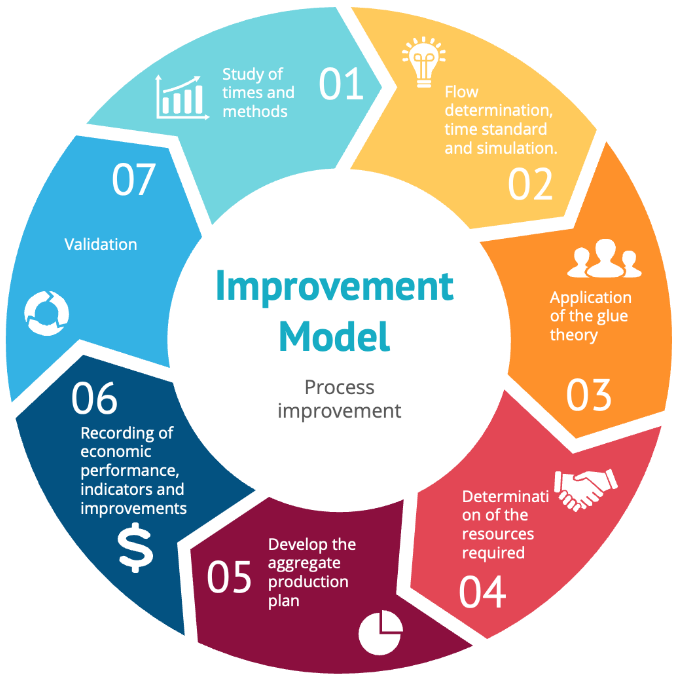

Figure 1. Proposed Model

3.2 Description of the model components

The improvement model depicted in the image was designed to enhance the efficiency and effectiveness of the production process in a fast-food restaurant setting. This model follows a systematic, seven-step approach aimed at optimizing various operational aspects, ultimately improving order fulfillment times, reducing customer wait times, and effectively managing inventory. Each stage of the model plays a crucial role in achieving these objectives.

Stage 1: Study of Times and Methods

The first stage involved conducting detailed time and method studies to understand the existing workflow within the restaurant. This analysis included measuring the time taken for each task and identifying any inefficiencies or bottlenecks in the process. The use of time and motion studies has been extensively validated in industrial engineering to enhance productivity (Barnes, 1980; Niebel & Freivalds, 2003). By meticulously documenting each step, the researchers were able to gather critical data necessary for subsequent stages.

Stage 2: Flow Determination, Time Standard, and Simulation

In the second stage, the flow of operations was determined, and time standards were established based on the data collected in the first stage. This involved setting benchmark times for each task to ensure consistency and efficiency. Additionally, simulation techniques were employed to model the workflow and predict the impact of changes before actual implementation. This approach is supported by various studies that highlight the effectiveness of simulation in operational planning (Banks et al., 2005; Law, 2015).

Stage 3: Application of the Glue Theory

The third stage focused on applying the glue theory, which integrates various elements of the production process to work seamlessly together. This theory emphasizes the importance of coordination and synchronization among different tasks and processes. By ensuring that all elements are aligned, the overall efficiency of the system can be significantly improved. This approach is aligned with the principles of lean manufacturing, which aim to minimize waste and maximize value (Womack & Jones, 2003).

Stage 4: Determination of the Resources Required

The fourth stage involved determining the necessary resources required to implement the improvements identified in the previous stages. This included assessing the needs for labor, equipment, and materials. Accurate resource planning is essential to ensure that the restaurant can meet demand without overburdening its capacity. Resource determination has been recognized as a critical factor in successful project management and operational planning (Kerzner, 2017).

Stage 5: Develop the Aggregate Production Plan
In the fifth stage, an aggregate production plan was developed to manage the overall production process. This plan aimed to balance supply and demand, ensuring that the restaurant could meet customer orders efficiently without excessive inventory buildup. Aggregate planning is a strategic approach that helps organizations align their production schedules with market demand, thereby optimizing operational efficiency (Chase & Jacobs, 2017).

Stage 6: Recording of Economic Performance, Indicators, and Improvements
The sixth stage involved recording and analyzing economic performance indicators to track the impact of the implemented changes. Key performance indicators (KPIs) such as order fulfillment times, customer wait times, and inventory turnover rates were monitored to assess the effectiveness of the improvements. This stage is crucial for continuous improvement, as it provides data-driven insights into the performance of the production process (Slack et al., 2016).

Stage 7: Validation
The final stage, validation, involved verifying that the implemented changes achieved the desired outcomes. This stage included conducting follow-up studies and comparisons against the initial benchmarks set in the first stage. Validation ensures that the improvements are sustainable, and that the restaurant continues to operate efficiently. The importance of validation in process improvement is well-documented in quality management literature (Juran & Godfrey, 1999; Montgomery, 2019).

Overall, this improvement model exemplified a comprehensive approach to process optimization in a fast-food restaurant context. By systematically addressing each aspect of the production process, the model aimed to enhance operational efficiency, reduce customer wait times, and ensure effective inventory management. The integration of various engineering and management principles underlined the model's robustness and applicability in real-world scenarios.

4. Validation

4.1 Study of methods and times

The study of methods and times focused on standardizing the steps necessary to optimize order waiting times. A new workflow was developed, and delivery times for the selected products were standardized. The first stage consisted of recording base information through detailed flowcharts and operation diagrams. The same operation diagram was used for the preparation of salchipapa, parrillero, and chicken fingers, while the preparation of fried wings showed differences. The diagrams detailed the number of operations: two operations, one storage, three inspections, two transports, and two combined activities for fried wings; and three combined activities for salchipapa, parrillero, and chicken fingers (Figure 2).

Subsequently, a detailed analysis of the activity times was carried out, presenting in the appendix the average, maximum, and minimum times of the activities for each product. A value analysis matrix of the performed steps was prepared, identifying activities that could be done in advance through expert judgment of the staff. A process activity diagram was developed, incorporating the value analysis.

The results included the standardization of delivery times, with average order attention times reduced to 19.18 minutes compared to 23.14 minutes in the current scenario, practically doubling the total number of orders attended (1,397 compared to 679) and significantly reducing queue size and customer dropouts (from 785 to 75). Revenues also increased significantly, reaching 35,522 soles compared to 17,128 PEN in the current scenario.

Table 1. Comparison of simulation results

Reporting data	Current scenario	Stage with study of methods and times	Scenario applying tail theory
Average order handling time (minutes)	23.14	19.18	19.50
Total orders	679	1,397	1,386
Customers leaving the queue	785	75	87
Cook 1 (% occupied)	49.92%	82.89%	83.86%
Cook 2 (% occupied)	50.00%	83.55%	N.A.
Queue size	11	2	2
Revenue (PEN)	17,128	35,522	35,016
Costos (PEN)	7,707	15,984	15,757

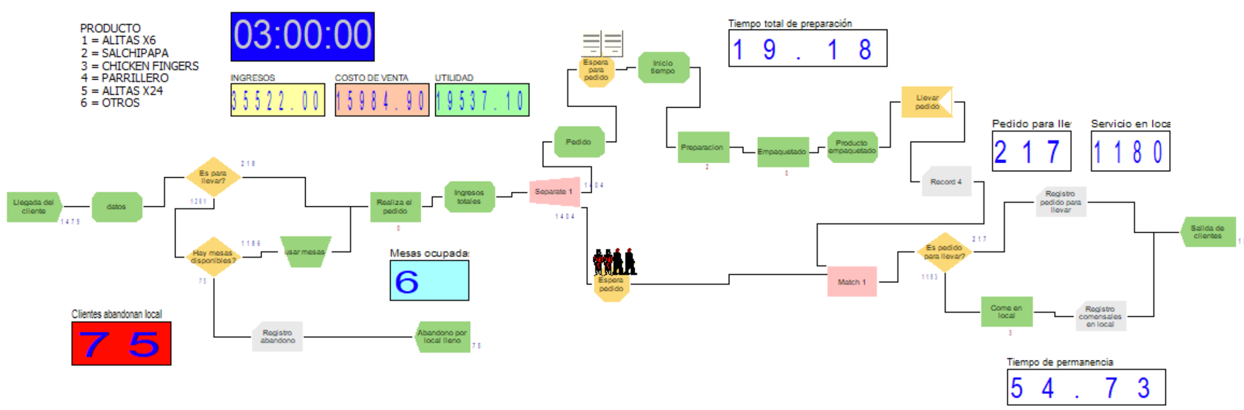

Figure 2. Simulation applying improvements with study of methods and times

4.2 Queue Theory

Queue theory was applied in the analysis of a fast-food restaurant to optimize service time and improve customer service. Real data from 2022 was used to determine the arrival rate of customers by day and hour, obtaining an average arrival rate of 40 customers per hour and an average service rate of 22 customers per hour. The restaurant's system was defined as an infinite population system with a Poisson arrival process and FIFO (first-in, first-out) discipline. The analysis revealed that the probability of servers being busy was 90.9%, indicating a high level of utilization and efficiency in service performance.

Simulations were conducted to determine the optimal number of servers and system capacity under high-demand scenarios. The results showed that the average waiting time in the queue was 0.45 hours, and the total waiting time in the system was 0.49 hours, with an expected number of customers in the system of 19.72. This model allowed the restaurant to better estimate its operational needs and formulate customer retention plans, thereby reducing losses and increasing customer satisfaction.

The application of queue theory also helped identify the impact of service times during peak and off-peak periods. It was determined that a single-server queue structure during high turnover periods could significantly improve operational efficiency. A 30-day simulation showed an improvement in the average order fulfillment time, reducing from 23.14 minutes in the current scenario to 19.50 minutes by applying queue theory. Additionally, the number of customers leaving the queue decreased from 785 to 87, and revenues increased from 17,128 to 35,016 PEN, demonstrating the effectiveness of the implemented improvements.

Figure 3 shows the fundamental parameters used for the description of the queue theory model, including the average arrival rate of customers, the average service rate, the average number of customers waiting in the queue, the average waiting time in the queue, the expected time of a customer in the system and the expected number of customers in the system. These parameters are crucial to understand the behavior and efficiency of the restaurant queue system.

Fórmulas

$$\text{Arrival rate} = \frac{\textit{Nunber of Customers}}{\textit{Duration of data collection}}$$

$$\text{Service rate} = \frac{\textit{Average Service Rate}}{\textit{Number of Customers}}$$

Duration of data collection = 180 minutes

Tasa de llegadas y Servicio (L - V)

Days	Arrival Rate	Service Rate
Monday	47.0	19.0
Tuesday	40.6	21.13
Wednesday	42.0	22.64
Thursday	37.6	22.38
Friday	36.0	22.64

Tasa media

Tasa media llegada=
40 clientes / hora.

Tasa media servicio=
22 clientes / hora.

Parámetros de cola

# clientes promedio que esperan en la cola	Tiempo medio de espera en la cola	Tiempo de espera esperado de un cliente en el sistema	# clientes esperado en el sistema
17.9 clientes	0.45 horas	0.49 horas	19.72 clientes

Figure 3. Parameters for the description of the model based on Queue Theory

Table 2 shows attention time per dish, service rate per server, total service rate, and traffic intensity. This allows visualizing how the queue system behaves with different types of orders and its impact on service efficiency.

Table 2. Total service rate (μ)

	Time of attendance (minutes)	**Service rate per server (clients/hour)**	**Total service rate (μ) (clients/hour)**	**traffic intensity (ρ): λ/μ**
Alitas fritas	18.7	3.2	13	0.94
Salchipapa	11.6	5.2	21	0.58
Parrillero	21.5	2.8	11	1.08
Chicken fingers	13.3	4.5	18	0.67

4.3 Aggregate production plan

The aggregate production plan developed aimed to ensure a constant supply of essential inputs to meet demand. A detailed analysis of demand forecasting was conducted using historical sales data from June 2021 to December 2022. The most suitable forecasting method was selected among several models: seasonal, linear regression, moving average, and Holt's method. The forecasting error metrics, such as CFE, MAD, MSE, and MAPE, were evaluated for each dish. For example, for chicken wings, the seasonal method showed a MAPE of 10%, while the moving average presented 10% and Holt's method 11%. For the salchipapa dish, linear regression proved to be more accurate with a MAPE of 16%, compared to Holt's method which obtained 18%.

The aggregate plan covered the next six months and was adjusted according to the specific demand forecasts for each dish. For the period from July to December 2023, the demand was estimated to be between 459 and 474 units of chicken wings per month, while the demand for salchipapas ranged from 376 to 408 units. For the parrilleros, demand fluctuated between 75 and 127 units, and for chicken fingers, between 80 and 101 units monthly.

Stock levels were determined for each dish, ensuring the availability of the necessary inputs. The main inputs forecasted included potatoes, chicken wings, hot dogs, chorizos, and hamburgers. For example, the usage was estimated to be between 409 and 420 kilograms of potatoes per month and between 1128 and 1224 units of hot dogs. The evaluated aggregate plan strategy showed that the zero-inventory option, for a six-week period, resulted in a cost of S/. 5456, being the most economical. The implementation of this strategy ensured the availability of inputs and minimized costs associated with stockouts and excessive storage.

The **Table 3** shows the quantitative comparison of the different prognostic methods and their error metrics (CFE, MAD, MSE, MAPE), supporting the selection of the most suitable method for each dish.

Table 3. Demand forecast error metrics

	CFE (Sum of forecast errors)	MAD (Mean absolute deviation)	MSE (Average quadratic error)	MAPE (Average absolute percentage error)
Alitas fritas				
Seasonal	-58	11	152	10%
Linear regression	-300	25	729	19%
Moving average	-70	11	140	10%
Holt method	-29	12	210	11%
Salchipapa				
Seasonal	168	16	402	18%
Linear regression	50	13	217	16%
Moving average	170	16	403	24%
Holt method	84	15	371	18%
Parrillero				
Seasonal	-129	11	137	75%
Linear regression	-61	6	39	26%
Moving average	-121	10	116	38%
Holt method	-30	5	39	28%
Chicken fingers				
Seasonal	-135	11	174	44%
Linear regression	-25	5	41	16%
Moving average	-120	10	137	26%
Holt method	-22	8	77	26%

Table 4 below details the monthly demand estimates for each plate for the period July to December 2023.

Table 4. Aggregate Production Plan from July to December 2023

		Jul-23	Ago-23	Set-23	Oct-23	Nov-23	Dic-23
Alitas fritas		459	474	451	459	474	454
Salchipapa		376	383	389	395	402	408
Parrillero		126	99	75	75	127	70
Chicken fingers		96	80	101	98	83	100
Insumos principales	Ratio						
Papa (kg)	0.387	409	401	393	397	420	399
Alitas x 6 und (kg) (90%)	0.290	120	124	118	120	124	118
Alitas x 24 und (kg) (10%)	1.160	53	55	52	53	55	53
Hot dog (unidades)	3	1128	1149	1167	1185	1206	1224
Chorizo (kg)	1	126	99	75	75	127	70
Hamburguesa (kg)	0.120	15	12	9	9	15	8
Pollo (kg)		26	21	22	21	24	21

4.4 Functional Validation of the Improvement Model

The functional validation of the proposal was carried out using Arena software and obtaining real results from delivery applications. The simulation model was developed considering the process variables detailed in Appendix 14, and simulations were conducted for three scenarios: the current one, one with improvements based on methods and time studies, and another applying queuing theory. The simulation was initially conducted for 14 days and then extended to 30 days to compare with real data.

In the current scenario, the average order handling time was 23.14 minutes, with a total of 679 orders, 785 customers leaving the queue, and occupation rates of 49.92% and 50.00% for cooks 1 and 2, respectively. The average queue size was 11 customers, generating revenue of S/.17,128 and costs of S/.7,707.

Applying improvements with methods and time studies, the average handling time was reduced to 19.18 minutes, the total number of orders increased to 1,397, and customers leaving the queue decreased to 75. The occupation rate for the cooks significantly increased to 82.89% and 83.55%, with an average queue size of 2 customers. Revenue almost doubled, reaching S/.35,522, while costs increased to S/.15,984.

The scenario with queuing theory showed a reduction in the average handling time to 19.50 minutes, with a total of 1,386 orders and 87 customers leaving the queue. The occupation rate for cook 1 was 83.86% and cook 2 was not considered in this scenario. The average queue size remained at 2 customers, with revenue of 35,016 PEN and costs of 15,757 PEN.

These results demonstrate significant improvements in operational efficiency and service capacity, leading to increased revenue and better utilization of available resources.

Figure 4 illustrates the simulation applying queuing theory improvements. It shows how order fulfillment times are reduced, and resource utilization is optimized.

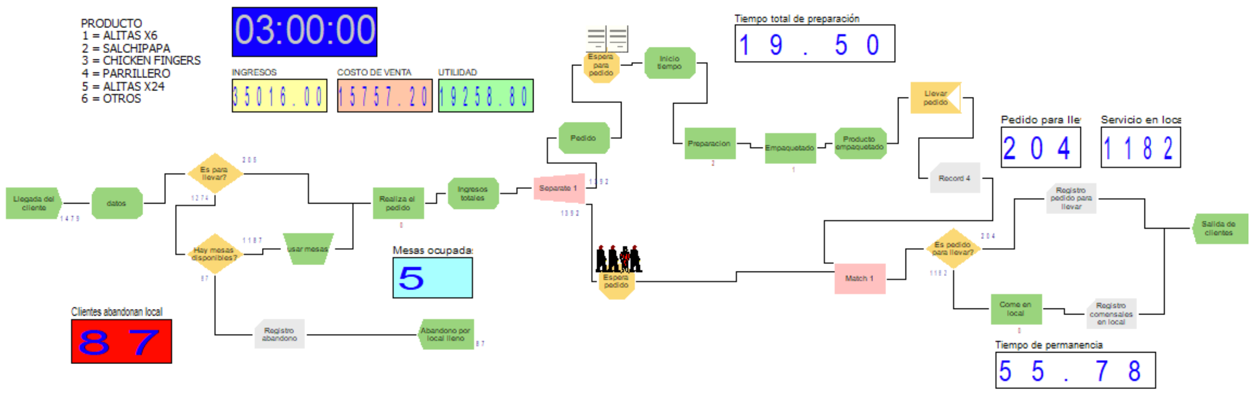

Figure 4. Simulation applying queueing theory improvements

Table 5 shows a comparison of production costs before and after implementing improvements with three strategies: mixed method, leveling, and chase-zero inventory. The results indicate that costs for the mixed method increased from 15,636 to 18,744 PEN and for the leveling method also rose to 8,744 from 9,668 PEN. In contrast, the chase-zero inventory method significantly reduced costs from 6,474 to 3,837 PEN. These data suggest that while some improvements increase costs, optimization through chase-zero inventory significantly reduces total costs, proving to be the most efficient strategy.

Table 5. Comparison of cost production strategies

Strategy	Before improvement	After improvement
Mixed method	15,636	18,744
Levelling method	8,744	9,668
Pursuit method- zero inventory	6,474	3,837

6. Conclusions

The main findings of the study indicate that the application of continuous improvement tools in a fast-food restaurant in Lima significantly optimizes service times and operational efficiency. The implementation of a systematic process improvement model, including time and methods studies, queuing theory, and aggregate production planning, reduced the average order processing times from 23.14 minutes to 19.18 minutes. Additionally, the number of customers leaving the queue drastically decreased from 785 to 75, resulting in a notable increase in revenue from 17,128 to 35,522 PEN. These results demonstrate the effectiveness of the applied methodologies in enhancing service capacity and customer satisfaction.

The research conducted is of great importance as it addresses one of the main challenges in the fast-food sector: efficiency in customer service. In a context where speed and service quality are critical for competitiveness, optimizing internal processes not only improves the customer experience but also increases business profitability. Furthermore, the application of continuous improvement techniques and efficient supply chain management contributes to operational sustainability, especially in such a dynamic and demanding market as fast food.

The contributions to the field of study are significant. This work not only provides a methodology applicable to other fast-food restaurants but also demonstrates the effectiveness of combining various industrial engineering techniques, such as queuing theory, aggregate planning, and continuous improvement tools, to solve complex operational problems. The integration of these techniques allows for more effective resource management, a reduction in non-value-added activities, and greater consistency in service quality, which are crucial aspects for any service operation. Finally, final observations and suggestions for future studies are offered. It is recommended to conduct further research exploring the impact of emerging technologies, such as artificial intelligence and automation, on process optimization in fast-food restaurants. Additionally, it is suggested to evaluate the applicability of this model in different cultural and economic contexts to validate its effectiveness in various regions. The continuous adaptation and refinement of continuous improvement tools will be essential to maintain the relevance and competitiveness of the sector in an ever-evolving global market.

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