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Article

Analysis of waiting lines at the checkout system in a 24-hour supermarket on weekends in Delicias, Chihuahua

Análisis de líneas de espera en el sistema de cajas en un supermercado 24 horas los fines de semana en Delicias, Chihuahua

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Abstract

The main objective of the project "Waiting and service time at checkout counters in the 24-hour supermarket: Based on queuing theory" is to analyze and improve waiting and service times at the checkout counters of the 24-hour supermarket in Delicias, Chihuahua. To achieve this, the application of the mathematical model of queuing theory M/M/S is proposed, which allows studying the arrival of customers, the time they spend in line and the service at the checkouts, in order to optimize the process and improve the customer experience. The problem identified focuses on the long waiting times that customers face, a situation that generates bottlenecks, leading to dissatisfaction, loss of customers and possible negative impacts on sales. The expected results of the study include the reduction of waiting times. The use of tools such as ProModel in the analysis and simulation of data will allow knowing the number of cash registers that should be available.

Analysis of waiting lines at the checkout system in a 24-hour supermarket on weekends in Delicias, Chihuahua		
Objectives	**Metodology**	**Contribution**
Define the waiting and service time at the checkout counters of the 24-hour supermarket in Delicias, Chihuahua, through the analysis and application of queuing theory, specifically the M/M/S model.	Application of the number of customers to be sampled for the study. MMS model Simulation using ProModel software.	Analyze waiting times in the queue and customer service. Identify if there is stability in the system. Determine the optimal number of cash registers that should be open at each time slot analyzed.

Teoría de colas, Clientes, Supermercado

Resumen

El proyecto "Tiempo de espera y de servicio en las cajas en el supermercado 24 horas: Basado en la teoría de colas", tiene como objetivo principal analizar y mejorar los tiempos de espera y servicio en las cajas del supermercado 24 horas en Delicias, Chihuahua. Para lograrlo, se propone la aplicación del modelo matemático de teoría de colas M/M/S, que permite estudiar la llegada de clientes, el tiempo que pasan en fila y la atención en las cajas, con el fin de optimizar el proceso y mejorar la experiencia del cliente. El problema identificado se centra en los largos tiempos de espera que los clientes enfrentan, situación que genera cuellos de botella, lo que provoca insatisfacción, pérdida de clientes y posibles impactos negativos en las ventas. Los resultados esperados del estudio incluyen la reducción de los tiempos de espera, El uso de herramientas como ProModel en el análisis y simulación de datos permitirá conocer el número de cajas que debe estar disponible.

Análisis de líneas de espera en el sistema de cajas en un supermercado 24 horas los fines de semana en Delicias, Chihuahua		
Objetivos	**Metodología**	**Contribución**
Definir el tiempo de espera y de servicio en las cajas del supermercado 24 horas en Delicias, Chihuahua, a través del análisis y aplicación de la teoría de colas, específicamente el modelo M/M/S.	Aplicación del número de clientes que se requiere muestrear para el estudio. Modelo MMS Simulación mediante el software ProModel.	Analizar los tiempos de espera en la fila y en el servicio de los clientes. Identificar si existe estabilidad en el sistema. Determinar el número de cajas óptimas que deben estar abiertas en cada horario analizado.

Queueing theory, Customers, Supermarket

Area: Dissemination of and universal access to science

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Introduction

Queuing theory began with the studies of Agner Krarup Erlang, a Danish engineer who worked for the Danish telephone company. Erlang developed the first mathematical model of queues to analyze telephone traffic and optimize the capacity of automatic switches. His work "The Theory of Probabilities and Telephone Conversations" [Kingman, 2019] is considered the first formal work on queueing theory.

Queuing theory studies the behavior of service systems subject to different operating conditions, in which customers sometimes have to wait for service.

Its applicability is very broad, as it quantifies the dilemma faced by many companies and institutions between effectiveness [providing good service] and efficiency [keeping costs low] [Singer et al., 2008].

The checkout area of a supermarket is a critical point in the customer experience. Throughout the shopping process, customers may encounter a number of factors that influence their perception of service, but few are as decisive as the time spent waiting in line to pay. This final moment of the shopping experience is crucial, as a long wait can transform a satisfactory shopping experience into a source of frustration and discontent. Furthermore, from an operational point of view, long queues can indicate inefficiencies in customer flow management, which could result in financial losses for the supermarket [Otero, 2010].

The problem identified in this study focuses on the observation that customers at the 24 Horas supermarket are experiencing excessive waiting times at the checkout, suggesting the existence of bottlenecks in the service process. This problem not only generates consumer dissatisfaction, but can also have broader repercussions, such as a decrease in customer retention rates, a negative impact on the reputation of the 24-hour supermarket, and a reduction in overall sales as customers may choose to shop at other establishments where the checkout process is faster and more efficient.

Identifying and analyzing the underlying causes of these long wait times is the first step in addressing the problem.

Factors that could be contributing to this situation include: an insufficient number of open checkouts during peak hours, a lack of adequate staff training in checkout operation, problems with the layout of the checkout area that hinder the efficient flow of customers, the ineffective implementation of payment technologies, and variability in service times due to the complexity of transactions or the lack of homogeneity in cashiers' skills.

To address these issues, the study proposes the application of queueing theory models, which allow different operating scenarios, such as arrivals and customer service, to be simulated and analyzed. Through mathematical modeling of the checkout system, it is possible to obtain an accurate representation of the customer arrival process, the time spent in line, and the service time at the checkout counters. This approach allows for the identification of congestion points and the evaluation of how different variables, such as the number of cashiers, the customer arrival rate, and the service time per customer, affect the total waiting time.

Justification

The 24-hour supermarket faces one main problem: long wait times at the checkout, which affects customer satisfaction. Implementing a project based on queueing theory can bring benefits to both customers and the business. This model will allow analysis of when customers arrive and how long they wait to be served, helping to identify problems that cause long waits. Increasing the number of cashiers during peak times will significantly reduce queues and speed up the checkout process.

More efficient service will improve the shopping experience, increasing customer loyalty and the likelihood of their return. Resources can also be optimized and costs reduced through better staff management. In addition, improving the payment system and the design of the checkout area will facilitate a more efficient flow of customers.

General Objective

Define the waiting and service times at the checkouts of the 24-hour supermarket located at Av. Fernando Baeza Meléndez 200, Delicias, Chihuahua, through the analysis and application of queueing theory, specifically the M/M/S model.

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Problem Statement

There are four supermarkets in the city of Delicias, Chihuahua. These are: Supermercado Plus, at Privada Av. Ferrocarril Ote. 401; Supermercado Centro, at Ave. Primera Pte. and Tercera Poniente; Supermercado 24 horas, at Av. Fernando Baeza Meléndez 200; and Supermercado Sur, at Av. Fernando Baeza Meléndez 1223. The study focuses on customers of the 24-hour supermarket. The city of Delicias has a population of approximately 146,033 inhabitants and combines agriculture and industry, which affects the purchasing habits of residents.

Box 1

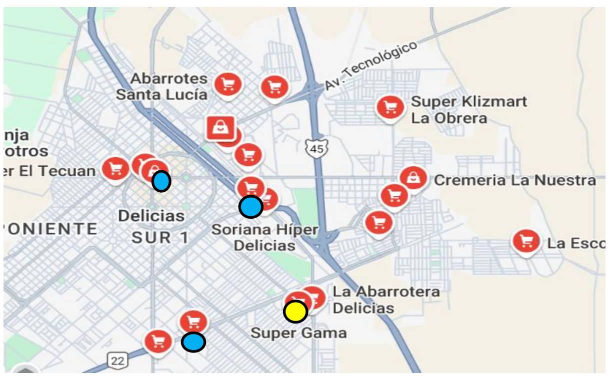

Figure 1
Location of Supermarkets
Source: Google Maps

Materials and Methods

Customer shopping behaviour in the 24-hour Supermarket varies significantly by day of the week and time of day, which are key factors in analysing the study population. Behavioural patterns have a direct impact on waiting time and checkout service, as they influence the number of customers in the queues at certain times, and the amount of products they buy.

Box 2

Figure 2
Traditional Supermarket Boxes
Source: El Heraldo de Saltillo

The 24-hour supermarket has 37 multifunctional employees, all of whom are trained to perform the role of cashiers in the 3 shifts for 10 checkouts and 2 express checkouts.

Queuing Theory

Queuing theory seeks to find the best level of service that organisations should offer [Moya, 1999]. The aim is to satisfy customer demand and keep costs low, without compromising service quality [Abad, 2002] [Présiga et. al., 2023]. Certain terms are used to measure the performance of the system under analysis [Hillier & Liebenmen, 2010].

λ is the average arrival rate of units in the system.

$1/\lambda$ is the average time between arrivals.

μ is the average speed of the service.

$1/\mu$ is the average time required to service each unit.

p indicates the length of time the provider works with customers.

Pn is the probability that n units are in the system.

Lq is the average number of units in queue.

Ls is the average number in the system.

Wq is the waiting time in the queue.

Ws is the total time in the system.

s represents the number of servers.

M/M/S model.

Features.

- Multiple servers [c], all in parallel.
- Arrivals and service times also follow a Poisson distribution.
- The queue has infinite capacity and is handled in First Come First Serve PEPS order.
- Application: It is ideal for situations such as a supermarket, where there are several checkouts serving customers at the same time. It allows to analyse the influence of the number of cashiers on the waiting time and on the probability that customers have to queue.[Pérez, 2020].

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Box 3

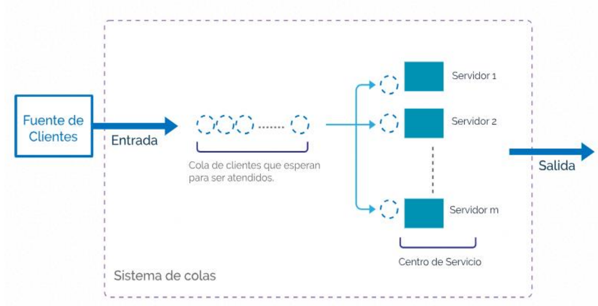

Figure 3

Graphical representation of the MMS model

Source: New Granada Military University

Results

Determination of the universe and obtaining the sample

The study population focuses on the city of Delicias, Chihuahua, obtaining a sample of 660 people over 15 years of age. Given the finite population sampling [Hernandez et al., 2014], where:

$$n = \frac{N*Z^2*p*q}{(N-1)*e^2+Z^2P[1-q]} \qquad [1]$$

Where:

Z = confidence level = 2.576, corresponding to the z-value at a 99% confidence level.
N = universe or population = 146,033 inhabitants in Delicias city.
p = probability in favour = 0.5
q = probability against = 0.5
e = estimation error [precision of results] = 0.05
n = number of items [sample size]

Substituting, the result gives: n=660 persons to be included in the study.

Time Collection

The data collection was carried out on weekends [Saturdays and Sundays], 3 times a day: from 9 to 10 am, from 3 to 4 pm and from 9 to 10 pm; the time collection was carried out during one month in the 24 hour Supermarket, taking each customer when being served in the checkout area, the data were as follows as follows

Box 4

Table 1

Recording of times taken from customers in minutes

Day	Timetable	Arrival	Remarks	Promedio	Boxes
Sunday 1	09:00-10:00	133	105.0, 98.3, 102.1, 99.5, 100.9, 99.8, 104.2, 97.4, 103.0, 99.0, 101.2, 98.4, 102.0, 100.3, 99.6, 102.7, 98.0, 101.0, 103.8, 98.6	100.74	4
	15:00-16:00	162	187.02, 99.71, 96. 46, 88.83, 92.43, 91. 74, 94.77, 126.83, 86.41, 85.43, 197.54, 131.49, 96.43, 85.83, 93.68, 115.82, 88.43, 90.18, 98.52, 165.05	110.63	5
	21:00-22:00	131	187.07, 48.50, 58.41, 78.44, 72.33, 155.02, 64.28, 100.45, 85.67, 58.90, 175.11, 130.22, 54.71, 160.09, 91.38, 66.50, 115.77, 182.06, 71.12, 121.34	103.8685	3
Saturday 1	09:00-10:00	106	59.88, 108.46, 143.29, 81.05, 137.63, 52.94, 90.21, 103.48, 128.80, 77.12, 60.07, 169.39, 147.88, 62.43, 120.18, 151.67, 93.55, 56.10, 70.01, 101.13	100.7635	3
	15:00-16:00	171	134.2, 89.7, 124.5, 95.8, 110.6, 85.4, 115.2, 100.9, 124.7, 80.1, 139.2, 70.2, 104.8, 134.6, 74.9, 95.5, 110.3, 85.6, 119.8, 96.4	104.62	5
	21:00-22:00	113	120.5, 75.3, 95.8, 85.6, 90.2, 80.1, 92.7, 88.3, 96.5, 79.9, 125.0, 70.0, 89.4, 119.8, 74.5, 85.7, 91.3, 82.1, 97.2, 115.9	92.79	3
Sunday 2	09:00-10:00	141	115.3, 90.4, 118.0, 95.1, 110.6, 85.2, 105.9, 116.0, 123.0, 80.5, 112.7, 75.8, 100.2, 118.9, 88.6, 92.4, 107.3, 84.7, 117.0, 100.8	101.92	4
	15:00-16:00	179	160.5, 75.8, 220.1, 103.4, 150.7, 130.2, 280.3, 180.6, 93.2, 165.9, 120.4, 155.1, 135.0, 200.7, 90.5, 80.3, 145.9, 125.0, 230.8, 112.0	147.82	6
	21:00-22:00	111	101.5, 95.0, 98.2, 93.8, 100.4, 90.7, 97.9, 102.1, 96.5, 90.6, 95.8, 89.4, 99.5, 103.7, 92.2, 93.0, 96.0, 101.3, 101.4, 94.4	96.67	3
Saturday 2	09:00-10:00	129	50.36, 67.34, 128.11, 141.87, 96.04, 111.79, 67.85, 135.26, 100.53, 146.04, 85.77, 107.26, 116.91, 74.48, 123.56, 93.22, 139.61, 90.32, 106.88, 97.40	104.03	4
	15:00-16:00	158	215.67, 129.88, 86.73, 162.94, 196.45, 83.57, 174.32, 119.48, 90.62, 124.37, 148.26, 125.58, 69.72, 161.09, 183.45, 152.74, 94.13, 110.87, 147.33, 173.4	137.53	6
	21:00-22:00	105	54.04, 29.25, 56.02, 61.45, 111.20, 69.37, 119.3, 84.72, 170.11, 57.98, 101.87, 138.06, 76.10, 46.99, 118.66, 88.59, 162.47, 70.99, 134.22, 59.01	90.52	2
Sunday 3	09:00-10:00	146	156.34, 88.57, 146. 21, 64.39, 84.22, 90.23, 41.78, 97.45, 96.22, 136.52, 61.56, 83.17, 80.32, 171.45, 93.26, 89.44, 144.55, 67.98, 105.12, 91.33	99.51	4
	15:00-16:00	183	78.65, 112.39, 139.82, 67.41, 146.7, 151.83, 95.28, 160.24, 118.53, 171.4, 184.77, 89.66, 162.85, 173.29, 84.16, 121.92, 143.6, 75.48, 163.31, 113.51	127.74	6
	21:00-22:00	106	90.68, 94.23, 147.89, 69.54, 92.34, 141.76, 78.56, 100.12, 183.8, 109.43, 61.87, 87.23, 153.45, 75.34, 96.78, 104.67, 42.89, 67.54, 91.23, 167.45	102.84	3
Saturday 3	09:00-10:00	129	98.45, 189.78, 79.21, 96.33, 93.14, 83.56, 105.12, 113.45, 64.78, 95.34, 151.46, 79.39, 100.67, 108.99, 144.56, 71.23, 95.92, 128.36, 87.74, 161.12	107.43	4
	15:00-16:00	135	198.53, 174.86, 243.75, 182.34, 196.41, 161.27, 209.68, 227.39, 189.53, 206.13, 176.48, 215.24, 186.29, 233.86, 194.95, 106.74, 204.32, 165.81,	192.25	6

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			222.08, 149.34		
	21:00-22:00	95	99.67, 107.89, 144.98, 70.12, 94.56, 110.45, 86.01, 160.45, 97.23, 149.56, 72.34, 195.87, 43.78, 82.45, 104.12, 112.34, 63.79, 92.56, 156.78, 78.45	106.17	3
Sunday 4	09:00-10:00	112	80.6, 118.7, 97.4, 96.5, 110.8, 74.2, 91.6, 104.1, 68.9, 98.2, 85.3, 106.7, 77.4, 93.5, 89.1, 108.6, 64.9, 97.8, 72.1, 111.0	92.37	3
	15:00-16:00	167	141.4, 189.6, 175.3, 162.7, 198.9, 147.8, 184.2, 165.1, 192.5, 170.3, 180.6, 159.4, 200.8, 144.7, 193.1, 176.9, 186.3, 155.2, 167.5, 202.9	174.76	7
	21:00-22:00	129	85.4, 100.2, 77.1, 120.7, 93.6, 115.1, 78.9, 125.4, 105.8, 88.3, 132.1, 99.7, 107.6, 114.5, 84.2, 123.9, 90.4, 118.3, 94.8, 97.2	102.66	3
Saturday 4	09:00-10:00	99	60.3, 112.8, 75.5, 98.7, 121.4, 110.9, 130.1, 85.6, 118.3, 103.7, 95.2, 125.6, 80.4, 134.7, 99.8, 115.5, 107.3, 137.2, 91.9, 102.1	105.35	3
	15:00-16:00	145	44.3, 81.6, 102.2, 120.1, 70.5, 120.3, 95.7, 85.9, 130.4, 102.2, 88.6, 140.1, 65.8, 118.7, 78.9, 100.5, 90.3, 125.4, 105.7, 89.4	97.83	4
	21:00-22:00	108	80.5, 140.2, 155.4, 97.3, 140.3, 165.1, 95.6, 180.4, 120.8, 155.7, 130.9, 145.3, 170.6, 115.4, 135.8, 160.2, 100.1, 185.5, 125.0, 140.5	133.43	3

With the data obtained, we proceed to apply the MMS model of queuing theory by day and hour.

Application of the MMS model formulas

The results obtained and the application of the formulas for Sunday 1 between 09:00 and 10:00 hours are explained. The same procedure will be followed for the following days included in the study.

Sunday 1
λ= 133 customers/hour
μ = [3600 seg/Hour]/[100.74 seg/ client] = 35.73 = 36 customers/hour
S = 4 OPEN BOXES

$$\rho = \frac{133}{36*4} = .923 = 92.3\% \quad [2]$$

$$\rho_0 = \left[[\Sigma_{n=0}^{4-1}[\frac{\frac{133}{36}^{n=0,1,2,3}}{n=0,1,2,3}]] + \left\{ \frac{\left(\frac{133}{36}\right)^4}{4!} * \left(\frac{1}{1-0.923}\right) \right\} \right]^{-1} = 0.008 \quad [3]$$

$$Ls = 133 * \ 0.099 \ = 13.167 = 14 \, clientes \quad [4]$$

$$Ws = 0.072 + \frac{1}{36} = \ 0.099 \, hrs * 60 \, min = 5.94 \, minutes \ in \ the \ system \quad [5]$$

$$Lq = \frac{0.008\left(\frac{133}{36}\right)^4 *0.923}{4!(1-0.923)^2} = 9.67 = 10 \, customers \ in \ the \ queue \quad [6]$$

$$Wq = \frac{9.667}{133} = 0.0726 \, hrs * 60 \, min = 4.35 \, minutes \ in \ line \quad [7]$$

Between 9:00 and 10:00 a.m., it was found that customers spend an average of 5.94 minutes in the system, which includes the time it takes for customers to enter the checkout area and leave as served customers.

Of that time, customers spend 4.35 minutes waiting to be served. At the same time, it was found that there are an average of 10 customers in line and 14 in the system, which means that there are four people in the process of scanning and paying for products at the four checkouts that the supermarket has available for service. As can be seen, four checkouts are sufficient to serve customers in a reasonable waiting time of almost six minutes.

System Status

The data obtained on each day that information was collected is shown, specifying the number of checkouts that were open as well as the service offered in the various analyses that were carried out.

Box 5

Table 2

Status of the supermarket checkout system

Day	Horario	Average	Boxes	Stable	Maximum	Inestable
Sunday 1	09:00-10:00	100.74	4	✓		
	15:00-16:00	110.63	5		✓	
	21:00-22:00	103.8685	3			✓
Saturday 1	09:00-10:00	100.74	4		✓	
	15:00-16:00	110.63	5		✓	
	21:00-22:00	103.8685	3		✓	
Sunday 2	09:00-10:00	100.74	4		✓	
	15:00-16:00	110.63	5			✓
	21:00-22:00	103.8685	3		✓	
Saturday 2	09:00-10:00	100.74	4	✓		
	15:00-16:00	110.63	5		✓	
	21:00-22:00	103.8685	3			✓
Sunday 3	09:00-10:00	100.74	4		✓	
	15:00-16:00	110.63	5			✓
	21:00-22:00	103.8685	3		✓	
Saturday 3	09:00-10:00	100.74	4	✓		
	15:00-16:00	110.63	5			✓
	21:00-22:00	103.8685	3	✓		
Sunday 4	09:00-10:00	100.74	4		✓	
	15:00-16:00	110.63	5			✓
	21:00-22:00	103.8685	3			✓
Saturday 4	09:00-10:00	100.74	4	✓		
	15:00-16:00	110.63	5		✓	
	21:00-22:00	103.8685	3			✓

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The results show that on weekends, whether Saturday or Sunday, most of the results of the MMS study indicate that the 24-hour supermarket is operating normally in the mornings. In the afternoons and evenings, the system is operating at maximum capacity in the checkout area most of the time, but is clearly unstable at night due to a limited number of open checkouts [between 3 and 4]. On the other hand, the highest customer traffic is concentrated in the afternoons on weekends, resulting in a breakdown of the MMS model due to the lack of capacity in the checkout area, making it necessary to consider opening more checkouts during the specified periods.

PROMODEL simulation

Data analysis is applied in the ProModel simulator to identify how many checkouts should be open according to customer traffic records when the MMS model is not met, i.e., when the condition p>1 arises, as it is identified that the process is exceeding its capacity. The evaluation is carried out in percentages, where 0% is when the checkout is not being used and 100% is when it is being used to full capacity; when 100% is exceeded, bottlenecks would quickly arise because the system does not have the capacity to cope, and each simulation and the adjustment made is explained in detail.

The average operating time at the cash registers is efficient, varying between 2.4 and 2.5 minutes. In turn, the simulation run indicates a problem with waiting times in line and system times for customers, with times ranging from 34 to 40 minutes, respectively. This is because there are only three open cash registers, which means that only three customers can be served simultaneously.

Box 6

Table 3

Simulation under current conditions at ProModel on Sunday 1 from 21:00 to 22:00 hrs..

Setting	Number	Total Outputs	Average Time in System [min]	Average Time in Queue [min]	Average operating time [min]	Average blocking time [min]
Baseline 1	Cliente 1	43	38.787	34.66026	2.436	1.6907
Baseline 2	Cliente 2	44	39.6875	35.52484	2.471	1.6916
Baseline 3	Cliente 3	43	38.85	34.66026	2.499	1.6907

Source ProModel Simulator

Box 7

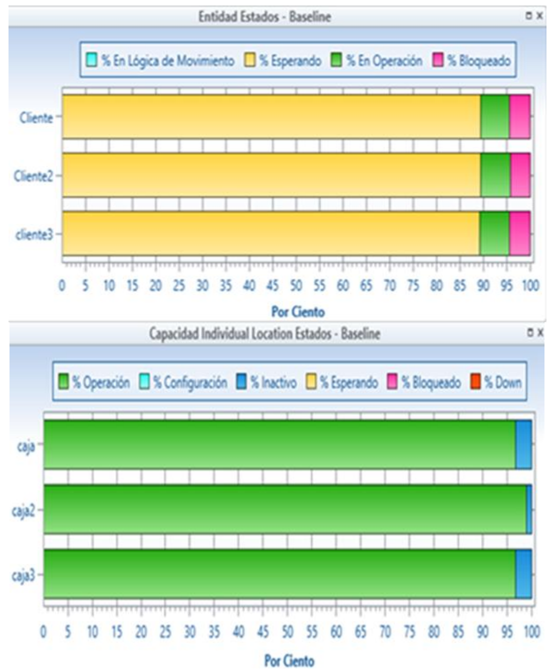

Figure 3

Percentage of waiting times, system and current operation

Source: ProModel

ProModel shows that of the total time spent by customers in the checkout process, 90% of the time is spent waiting in line, where only 5% is spent scanning goods, collecting and packing products. At the same time, it is identified that the 3 cash registers that are open for customer service are 96-99% utilised, which means that there is no possibility of idle time.

The simulation was carried out again, now considering the arrivals and the service to determine the optimal number of checkouts, considering to reduce the waiting time percentages.

Box 8

Table 4

ProModel simulation proposal on Sunday 1 from 21:00 to 22:00 hours.

Setting	Number	Total Outputs	Average Time in System [min]	Average Time in Queue [min]	Average operating time [min]	Average blocking time [min]
Baseline 1	Cliente 1	17	16.284	12.2188	2.436	1.6291
Baseline 2	Cliente 2	19	18.041	13.9391	2.462	1.6398
Baseline 3	Cliente 3	19	18.115	13.9391	2.536	1.6398
Baseline 4	Cliente 4	19	18.101	13.9391	2.522	1.6398
Baseline 5	Cliente 5	19	18.087	13.9391	2.508	1.6398
Baseline 6	Cliente 6	19	17.995	13.9391	2.416	1.6398
Baseline 7	Cliente 7	19	18.101	13.9391	2.522	1.6398

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Box 9

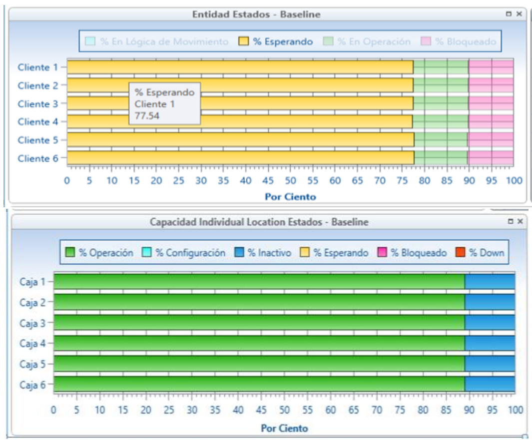

Figure 4

Percentage of waiting times, system and proposed operation

Source: ProModel

The results show that for an operation of the checkout system for Sunday 1 from 21:00 to 22:00 hours, 7 open checkouts should be attended [the same behaviour from 6 cash registers as shown in figure 4], which decreases the queue times to 14 minutes from the current 35 minutes, and the waiting percentage is reduced to 75% and the checkout operation percentages are at 96%.

Simulation in ProModel for Unstable Days

Once the unstable days were identified and the excess of demand over system capacity was observed, a simulation run was made to identify the optimal number of checkouts to operate the supermarket 24 hours a day.

Box 10

Table 5

Simulation of unstable days in ProModel.

Day	timetable	Unstable System			Stable System		
		Boxes	Average Time in System [min]	Average or Queue Time [min]	boxes	Average Time in System [min]	Average Time in Queue [min]
Sunday 2	15:00-16:00	6	26.544	22.722	8	16.422	14.52
Saturday 2	21:00-22:00	2	41.103	37.753	4	20.651	17.411
Sunday 3	15:00-16:00	6	34.604	29.874	8	24.96	20.32
Saturday 3	15:00-16:00	6	38.808	32.179	8	27.654	21.06
Sunday 4	15:00-16:00	8	32.443	26.355	10	19.8	21.05
Sunday 4	21:00-22:00	3	38.182	34.259	6	18.1	14.62
Saturday 4	21:00-22:00	3	37.808	34.259	6	21.2	16.803

After the simulation carried out in ProModel, it is proposed that on most days when instability occurs, at least two additional boxes should be opened in addition to the service offered by the supermarket.

Conclusion

As shown in the simulations in ProModel and in the analysis in the MMS mathematical model, carried out on each of the days included in the study, the days on which the model was unstable, i.e., exceeded 100% of the system's operating capacity, were of greater relevance and required immediate attention. Of the 24 schedules analysed in the study, 8 showed instability, indicating a decrease in the capacity offered [servers] to meet the required demand for the service. From this, it can be identified that the optimal number of checkouts to function properly in the three shifts analysed is 4 checkouts in the morning, 9 checkouts in the afternoon and 6 checkouts in the evening. Although the 24-hour supermarket has 10 conventional checkouts and 2 express checkouts, the problem of unopened checkouts is not due to a lack of them, but rather to the scheduling of openings at different times according to the monitoring of customer demand, queue times and service times, in order to determine the number of servers required at the right time, bearing in mind that a solution is not to open the maximum number of available checkouts, as this would present a problem for the supermarket with idle servers.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have influenced the publication of the article disclosed in this research.

Contribution of the authors

Morales-Aguilar, José Socorro: Lead author of the article, recognised as Desirable Profile

Morales-Chávez, Emmanuel: Co-author

García-Molina, Michelle Esperanza: Co-author

Rojas-Hernández, Ulises: Co-author

Availability of data and materials

The study of queues was carried out at the 24-hour supermarket, where we were given the facilities to take times and record the number of customers who came to the store to shop during the three shifts that were established. ProModel software was also used to perform the simulation and determine the optimal number of open checkouts to provide the required service to customers and be convenient for the supermarket.

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Abbreviations

Min: Minutes

MMS: Queueing model where arrivals and service times are exponentially distributed [M], and there are ‘s’ servers available [s].

ProModel: Simulation and optimisation software.

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