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Analysis and optimization of the waiting line system of a vehicle verification center

Análisis y optimización del sistema de línea de espera de un centro de verificación vehicular

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Abstract

The present research work studied the behavior of the waiting lines of a verification center in the state of Veracruz due to the fact that it presented constant complaints from customers when receiving the service of long waiting times, that is why the analysis was carried out Using the waiting lines method obtained information on the arrival rate and the service rate to quantitatively determine values that help to visualize the current state of the system and based on that information to be able to propose the optimization of the service by adding a new server that helps reduce time by reducing customer waiting times.

Waiting lines, Optimization, Verification center

Resumen

En el presente trabajo de investigación se estudió el comportamiento de las líneas de espera de un centro de verificación en el estado de Veracruz debido a que presentaba constantes quejas por parte de los clientes al recibir el servicio de largos tiempos de espera, es por ello que se realizó el análisis Utilizando el método de líneas de espera se obtuvo información sobre la tasa de llegada y la tasa de servicio para determinar cuantitativamente valores que ayuden a visualizar el estado actual del sistema y con base en esa información poder proponer la optimización del servicio agregando un nuevo servidor que ayude a reducir el tiempo disminuyendo los tiempos de espera de los clientes.

Líneas de espera, Optimización, Centro de verificación

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Introduction

The following research work was carried out in a Vehicle Verification Center in the state of Veracruz, where the behavior of its queuing system was studied for the attention of customers who needed to comply with their obligations in accordance with the State Law of environmental protection issued by the Secretary of the Environment of the Government of the State of Veracruz to grant proof of compliance or rejection of the units that do not comply with the established parameters of the allowed emissions of Nitrogen Oxides (NOx), Hydrocarbons (HC), Carbon Monoxide (CO), Carbon Dioxide (CO2) and Oxygen (O2); as well as the lambda factor. The technique used was the analysis of waiting lines, which is a mathematical model that helps to analyze and make decisions based on quantitative information and that gives a real forecast of the behavior of a waiting line or queue. The problem with this verification center is the constant complaints from clients in receiving the service where the wait when receiving the service is very great, causing disagreement and the possibility that potential clients look for another verification center to carry out the emissions test. thereby reducing customers and closing the business, which is why the incorporation of a new server is proposed to provide the service to reduce the time of customers receiving the service. In this research work, chapter two explains what the waiting line analysis method consists of as well as the mathematical formulas for its application, chapter three shows the results of the study, chapter four the acknowledgments, chapter five the conclusions and at the end of chapter six the bibliographic references.

Method description

The analysis of the waiting lines is a mathematical model that helps decision-making because it studies the behavior of the queues or waiting lines. This factor is a temporary imbalance that occurs to all businesses when the demand for a service is higher than that of the system.

This mathematical model studies the behavior of the rows based on the time factor, for this the following actors participating in such an event must be distinguished, such as: the client that the element that arrives at the facility to request the service, servers are the element that offers the service is usually an operator or a machine, the queue or queue is made up of customers or people who are waiting to be served and the facility is the infrastructure, that is, the area.

The system analysis process evaluates six main aspects that are the analysis of customer arrivals, which in most cases are stochastic, that is, they are of non-deterministic intrinsic behavior where it is necessary to specify the random variables for each instant of time. and for a basic model of analysis a Poisson distribution is considered, which means a discrete distribution, however it is important to emphasize that there are different types of distributions. The second aspect to consider is the server service pattern, which is the way in which the system serves clients, which can be in groups or batches or individually, and is the service time provided to each client, varying over the course of the weather. The third aspect is the discipline in the queue, which is basically the order in which customers are served within the system, currently waiting to be served, there are several rules such as Processor Sharting, here customers experience the same delay since they are all served by Likewise, Random selection of service (RSS) this rule consists of randomly selecting with some priority or pre-classification procedure the clients to be served, Last in first out (LIFO) this rule consists of serving the last person who is in the row and last and the most used rule in most of the companies or activities where there is a row is the First in first out (FIFO) here customers are served in the order they reach the queue, the first to arrive it will be the first to be attended to and in the analysis of this mathematical model this rule is the one that is considered unless otherwise stated. The fourth aspect to consider is the capacity of the system, which basically consists of the maximum number of clients queuing within the system to be served. Here they can see two panoramas, a source of arrivals that can be finite or infinite.

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The fifth aspect to consider is the number of service channels is the number of operators that will be serving customers and the last aspect is the number of stages that the service has, that is, it can be a single stage or several stages, which is the number of stages a customer must go through to receive the service.

Based on the above information there are different types of queuing systems that are used by companies to provide services to their customers, the first of them is the simplest where there is a single queue and a single server, the following system is where There is a single queue and there are multiple servers, the following system is where there are several queues and multiple servers and finally where there is a single queue and there are sequential servers to be able to receive attention or receive the service.

In the following figure 1 the process of a basic waiting line system is presented since a single queue and a single server are shown, this figure represents the procedure that is carried out in a general way. Customers who want to be served are generated over time in an input source, then enter the system and accumulate in a row or queue if the service is not idle and are coupled to the discipline of the queue to later be called to be attended by the server or operator and then exit the system when it has been attended.

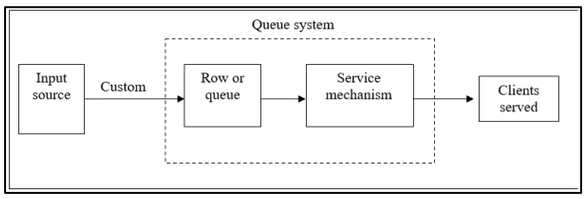

Figure 1 Process of a basic waiting line system
Source: operations research book (Frederick S. Hillier - Gerald J. Lieberman p. 665)

Waiting line systems use special labeling to quickly identify the characteristics to be studied, basically it is divided into 3 parts, the first is the probability distribution that follows the times between arrivals to the system, the second is the distribution of times of service and at the end of the number of servers. The nomenclature used for identification is the one shown in the following table 1.

Characteristic	Symbology	Meaning
Distribution of times between arrivals.	M	Exponential (Markovian) distribution
Distribution of service times.	D	Degenerate distribution (constant times)
	E_k	Erlang distribution
	G	General distribution (allows any arbitrary distribution)

Table 1 Nomenclature used regarding arrival and service patterns
Source: operations research book (Frederick S. Hillier - Gerald J. Lieberman p. 667)

In most of the analyzes of a queuing system, the exponential distribution is used as previously mentioned, where arrivals occur randomly and randomly. The random times between arrivals and obtaining the service are described by the following formula:

$$f(x) = \lambda e^{-\lambda t}, t > 0 \quad (1)$$

The terminology and notation used to analyze a system by means of the mathematical model of waiting lines is the following:

1. $E =$ System status = number of clients in the system.
2. Queue length = number of clients waiting for service / system status minus number of clients served.
3. N (t) = Number of customers in the queuing system at time t (t≥0).
4. P_O = Probability that the system is empty.
5. s = number of servers.
6. ρ = System utilization factor or probability that the system is busy.
7. λ = average arrival rate (expected number of arrivals per unit of time).
8. μ = average rate of service throughout the system (expected number of clients completing their service per unit of time).
9. L = expected number of clients in the system.
10. L_q = expected length of the queue.

11. W = Waiting time in the system for each client.

12. W_q = Waiting time in the queue for each client.

13. s = servers.

The formulas to be used to analyze a waiting line system whose calls follow a Poisson probability distribution, with a single server, infinite system capacity and FIFO-type discipline are the following.

$$\rho = {\lambda}/{\mu} \quad (2)$$

$$P_O = 1 - \rho \quad (3)$$

$$L = {\rho}/{1 - \rho} \quad (4)$$

$$L_q = L - \rho \quad (5)$$

$$w = {L}/{\lambda} \quad (6)$$

$$w_q = {L_q}/{\lambda} \quad (7)$$

The formulas to be used to analyze a waiting line system whose calls follow a Poisson probability distribution, with more than one server, infinite system capacity and FIFO-type discipline are the following.

$$\rho = {\lambda}/{s\mu} \quad (8)$$

$$P_o = \frac{1}{\sum_{n=0}^{s} \frac{(s\rho)^n}{n!} + \frac{(\rho s)^s \rho}{s!(1-\rho)}} \quad (9)$$

$$P_{SO} = \frac{(\rho s)^s}{s!} \frac{1}{1-\rho} P_O \quad (10)$$

$$L_q = \frac{1}{1-\rho} P_{so} \quad (11)$$

$$L = L_q + \rho s \quad (12)$$

$$w_q = {L_q}/{\lambda} \quad (13)$$

$$w = {L}/{\lambda} \quad (14)$$

Results

The analysis of the methodology of the waiting lines was carried out and applied to a vehicle verification center in the state of Veracruz where the information was obtained to measure the times of the arrival rate and the service times to perform the corresponding calculations and thus Get an overview of the service that is being offered to customers.

The current system of the verification center has a single row and a single server to be able to carry out the attention of the units, for the investigation the Markovian probabilistic distribution model was used, the arrivals of the clients present a Poisson probability distribution, its service times are presented with a single server, the capacity of the system is infinite, and the discipline of the waiting line is FIFO.

The taking of the times was carried out in a semester in the hours of provision of the services that are six hours a day since there is two hours of food for the worker from Monday to Saturday.

Taking the times, it was determined that the verification center has an average arrival rate of λ = 5 units per hour and an average service rate of μ = 8 units per hour. Considering this information, we proceeded to apply the formulas where the results are shown in the following table

System utilization factor or probability that the system is busy.	$\rho = 0.63$	The system is busy on average 63% of the time.
Probability that the system is empty.	$P_0 = 0.37$	The probability that no unit is in the verification center is 37%
Average number of customers in the system (waiting or being served)	$L = 2$	In the verification center there will be on average two units in the system.

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Average number of customers in the waiting line.	$L_q = 1.37$	In the verification center there will be an average unit in the waiting line
Average time a client lasts in the system.	$w = 24\ min$	It is the average time that a unit lasts in the verification center.
Average customer wait time.	$w_q = 17\ min$	It is the average time of the units waiting for service.
Average service time.	$1/\mu = 7\ min$	

Table 2 Characteristics of the waiting line of the vehicle verification center
Source: Own elaboration

Within the study, tests were carried out in accordance with the Mandatory Vehicle Verification Program (PVVO), where it is stipulated that the vehicle verification centers and the verificentros of the state of Veracruz de Ignacio de la Llave are required to operate in accordance with the State Environmental Protection Law. the applicable Official Mexican Standards, the terms and conditions of the concessions granted, as well as the official provisions, notifications and circulars issued by the Secretary of the Environment of the Government of the State of Veracruz.

Analyzing the above information and complying with the analysis procedure and attending to the clients' suggestions to improve the service, the analysis is carried out considering expanding to one more server for operability, obtaining the following results with two servers from table 3.

System utilization factor or probability that the system is busy.	$\rho = 0.42$	The system is busy on average 42% of the time.
Probability that the system is empty.	$P_0 = 41.18$	The probability that no unit is in the verification center is 41%
Probability that the system is busy.	$P_{so} = 24.5$	The probability that the verification center is occupied 24.5%
Average number of customers in the system (waiting or being served)	$L = 0.35$	In the verification center there will be on average no units in the verification center
Average number of customers in the waiting line.	$L_q = 0.42$	In the verification center there will not be on average any units in the waiting line
Average time a client lasts in the system.	$w = 4\ min$	It is the average time that a unit lasts in the verification center.
Average customer wait time.	$w_q = 5\ min$	It is the average time of the units waiting for service.

Table 3 Characteristics of the waiting line of the vehicle verification center with two servers
Source: Own elaboration

If the comparison of the calculations made is made, we can see if the vehicle verification center implements a new server for customer service, improves the service provided, the following table 4 shows the information:

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	System with 2 servers	System with 1 server
System utilization factor or probability that the system is busy.	ρ= 42%	$\rho = 63\%$
Probability that the system is empty.	$P_0 = 41\%$	$P_0 = 37\%$
Probability that the system is busy.	$P_{so} = 24.5\%$	
Average number of customers in the system (waiting or being served)	$L = 0$	$L = 2$
Average number of customers in the waiting line.	$L_q = 0$	$L_q = 1$
Average time a client lasts in the system.	$w = 4\ min$	$w = 24\ min$
Average customer wait time.	$w_q = 5\ min$	$w_q = 17\ min$

Table 4 Comparison of systems
Source: Own elaboration

The significant change is in the time that customers together with their units would spend in the system in general, reducing 20 minutes and the time of waiting in line for 12 minutes, thereby optimizing customer service, in addition the establishment complies with the Article 58 of the official gazette of the government of the state of Veracruz which specifies the specific elements necessary to ensure the quality of the verification service, complying with said regulations in order to implement a new server.

Acknowledgments

I appreciate the facility that the vehicle verification center gave us for the measurement of times to be able to carry out the analysis of its customer service system.

Conclusions

Carrying out an analysis of the care systems is very important for companies to be able to improve customer service, applying mathematical models that help evaluate current behavior supports making decisions to invest in new strategies to be competitive.

In the case of this vehicle verification center, I helped the company to numerically visualize what its customers complained about the poor service it offered due to the waiting time and thanks to this study it was possible to determine the feasibility of opening a new server to be able to attend to customers and optimize service and waiting times.

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