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Analysis and Diagnosis of Queue Lines in a Drugstore of the IMSS Clinic-Hospital in The City of Cuernavaca

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Abstract

We supply an example of the application of operations research tools particularly Waiting Lines or Queuing Theory to the service employees in a drugstore of the Mexican public sector in the city of Cuernavaca, state of Morelos, to find a solution to the problems faced by many of their customers. We describe the system's initial conditions, and then apply a model to help decision makers in raising the level of service quality and customer satisfaction. Preliminary results show a high level of dissatisfaction associated with the waiting line at the server station.

Keywords: Queuing Theory, Customer Satisfaction, Drugstore waiting lines management.

1. Introduction

Queuing Theory (QT) or waiting lines is an Operations Research (OR) tool that serves managers for the purpose of supplying models for the efficient handling of queue lines, formed by people, cars, and phone calls among others (Moskowitz & Wright, 1997).

Waiting lines are a common phenomenon that occurs in service businesses that attend customers in their facilities, and where actual demand is higher than the capacity to provide the service (Buffa, 1968). The purpose of the present study is to analyze the arrivals and waiting times that customers have to go through at a pharmacy in the city of Cuernavaca, state of Morelos, just 60 kilometers south of Mexico City, the country's capital. Direct observation of the site shows how waiting customers get anxious, tired and desperate when expecting to receive the medicines they need to acquire in this Medical facility.

The drugstore belongs to the Social Insurance Mexican Institute or "IMSS" a 54 years old public institution in Morelos, attending to the needs of hundreds of customers and more than 617,000 members called right-holders (derecho habientes), who must receive medical services and benefits with quality and on time.

Operation of the IMSS Pharmacy's current system

The IMSS opened up its first Family Medicine Unit in 1956 in the famous old Hotel Hernan Cortes at downtown Cuernavaca (called "the city of eternal spring" due to its agreeable weather all year round). According to the institution archives the first general director of the hospital was Doctor Rodolfo Becerril de la Paz. In the same place today they have the offices of the federal delegation of the institute and the Family Medical Unit # 20 (IMSS, 2012).

The actual medical supply system in this pharmacy works in a schedule from Monday to Friday from 8:00 a.m. till 8:00 p.m., divided in two shifts, a first shift from 8:00 a.m. to a 2:00 p.m. And the second from 2:00 p.m. till 8:00 p.m. Attention to the public is performed by four window servers each shift, supplying approximately from 700 to 750 prescriptions. Ninety percent of the customers stand on line waiting to be served by 3 servers, and the remaining 10% belong to senior citizens who are attended by one server in another and different queue. Both lines will be analyzed and diagnosed in this work, to define their characteristics and behavior. Population being attended at IMSS Cuernavaca is approximately 500 thousand persons. In all the services the institute provides, there is the waiting line phenomena an issue that is a constant problem for management. This justifies our interest or motivation to perform the current study. We consider useful to apply operations research methods and more precisely Queuing Theory or waiting lines to the delivery service in the Pharmacy located on Plan de Ayala Avenue, one of the most important roads in the city of Cuernavaca.

We take this location as a case study or (a sample of one) for convenience purposes. Among the many services (more than 50) the hospital supplies to the community, the drugstore is one where the problems abound and affect citizens. Helping the managers to find scientific or technical solutions is another reason to perform this exercise.

Justification

The main cause that justifies the present study is the constant complaint expressed by customers who need medicines and prescriptions. They explained to researchers that they must spend around two hours to be helped in the hospital pharmacy, and they could even see the long line going all the way out from the building.

"Right holders say they are desperate because the service is so slow in that area that they must stand in line for more than two hours, and sometimes after the long wait, they are told by the attendant that there is no availability of the prescribed medicines they are looking for" (IMSS, 2010).

Document structure

The document is divided into five sections: the first section presents the conceptual development of Queue Theory focused on health sector, which involves the mathematical study of queues or waiting lines. In this section Queuing Theory will describe the situation of a waiting line, using mathematical models with which we can predict some traits of the line. The second section analyzes the queue system structure in the IMSS (Mexican Institute of Social Security) pharmacy, problem at hands is formulated, and variables, objectives and hypothesis are presented.

Third section, discusses the experiment we conducted, first we present the methodology used to collect data related to customer arrival times (right holders) to the queue line, then we analyze service time employed by the servers and the statistics of that data to prove the assumptions of the model and its reliability. In this section the design of data collection and the analysis of variance using the Kruskal-Wallis technique is discussed with the purpose of checking the samples reliability.

Afterwards, in section fourth, we make a general analysis and present the obtained results. This part of the study includes those results with their calculations, charts, graphs

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and interpretation, as well as the diagnosis of each of the variables treated. Finally, in section fifth we present our conclusions.

1. Recent research on Queuing Theory being applied in the health services sector

Here we discuss some important research pieces of the application of QT to health organizations in public or private sector.

Fomunyam and Herman (2007) show the application of the theory in the health services area, emphasizing the waiting time, application analysis, systems design and the use of systems. The objective is to provide information to analysts interested in the use of QT as a model for the operation of multiple processes in health institutions, and help them in making better decisions. The main issues in their work are waiting lines of patients arriving, waiting times to receive attention, the payment when required and departure from the facilities.

Nosek and Wilson (2001) applied the theory in drugstores to study customer's satisfaction. They discuss waiting time and analyze the efficiency aiming to minimize the time the patients must wait, and maximize the efficiency of servers or the human resources such as doctors, nurses, and materials such as beds and others, all of which are considered complex processes. They indicate that restrictions are embedded in the health process, and present the probability of a patient leaving the waiting line in the system and that this defection becoming immense.

Using the QT, McQuarrie (1983) concluded that the rate of occupancy in a hospital doesn't get to 100% if the service quality is no sufficient. He also thinks that saturation in the occupancy rate of 90% would produce waiting lines for the intensive care unit, economic costs associated with bad quality service, delays in the treatment, long lines, and more intensive care.

Linda V. Green (2011) looks at the delay phenomenon in the area of health care, signaling to the treatments, hospitalization, and lack of resources as the main problems faced by health institutions; these make patients report high levels of dissatisfaction. To define a planning strategy her study highlights first the determination of bed capacity for the hospital and after that define the characteristics of the departments like intensive care where costs are higher.

In Griffiths, et al. (2006) is discussed operations research techniques used by hospitals in the United Kingdom. They demonstrate that a queue model can be described by three main components: the occurrence of arrivals, the attention service, and the number of services (as predicted by Kendall, 1953). Within these components its remarkable the length of patient stay in the intensive care unit (ICU).

Most patients spend little time in the ICU before being authorized to leave. They include the patients in mayor surgery and patients with terminal diseases. There is a small amount of patients that spend weeks or months, and receive intensive care therapy; examples include people with organ insufficiency that need intensive support such as dialysis, due to kidney insufficiency.

Nosek and Wilson (2001) reported the use of mathematical models and the measurement of efficiency to evaluate and develop the flow of customers through a waiting line in pharmacies. The application was to analyze patient waiting periods and time of service supplied.

1.1 Queuing systems

A Queuing system is characterized by four main elements: 1) the time of customer arrival, 2) the line discipline, 3) the service mechanism, and 4) the cost structure. This last factor specifies the payment made by the customer, and the different operating costs of the system.

The Mason Virginia Medical Center in Seattle, Washington, uses the QT to reduce patients waiting times (from 42 days to 13) and in the emergency room from 45 minutes down to 15. Queue theory is related to simulation models that help to define problems and make business decisions.

1.2 Customer behavior and satisfaction

In general, customer satisfaction is a multifactorial construct and the model is related with behavior itself and factors such as customer expectations, attitudes and the attention of the service supplier. In most cases these factors are intangible, which means you get more of an imaginary return than a real one.

The main objective of the waiting line is to maximize the level of customer satisfaction with respect to the service being supplied. The main purpose in the waiting line is the level of satisfaction with the service added to the time the customer has to wait for the service.

Customer satisfaction is defined as the difference between the expectations the customer has and the real experience during the events; when waiting time diminishes, satisfaction rises. This relationship was improved by Maister (1985), who proposed that satisfaction depended on the customer's expectations and remarks.

An important example is a study that evaluated the attitude of customers with regards to waiting times in hotels and restaurants. It was found that more than 70% of those surveyed manifested their worries about waiting times. In fact, the most worried people were in general, willing to pay more so as to evade waiting in line. The survey results showed that queues affect the level of customer satisfaction to the point of generating a predisposition to pay more. This research also discovered that there is a point where a long wait begins to impact the customer as a quality principle and starts to deteriorate the brand's image or the name of the institution.

Another study analyzed patients' satisfaction with ambulatory services from the drugstore at a large University hospital. This report describes that among those patients who received prescriptions from the university doctors, 21% of them deserted the queue to get their medicines somewhere else, due to the length of the line, even though prices were cheaper.

1.3 Drugstores and queue lines

Queuing Theory has been applied very little in drugstores; nevertheless this practice can benefit a lot by using the available techniques, and models.

An issue of a pharmaceutical operations journal analyzes Queuing Theory from the perspective of customers' waiting time and based on renowned authors who use actualized mathematical models. The only recommendation from the authors is that customers should use the waiting time with entertainment, refreshments or favorable conditions like watching television or drinking coffee.

From many published works the single most repeated recommendation is to reduce waiting times and elevate the service personnel efficiency. Afolabi and Erhun (2003) used workflow analysis, and waiting time analysis to define those factors that generate an excess waiting time in an ambulatory pharmacy.

Vemuri (1984) used simulation models to analyze the patients waiting time at the pharmacy of the school of medicine in the University of Virginia, concluding that the most important factor that explains waiting time was the interaction with the supply service at the drugstore.

It is important to mention that the traditional method employed by drugstores in general is to distract customers with comfortable waiting rooms, coffee and television, and it has proved effective in pharmacies which attend more than a thousand prescriptions a day, and whose patient waiting time is between one and two hours.

1.4 Technology in waiting lines at pharmacies

The automated queue technology (AQT) is being used in the public federal sector that includes numerous pharmacies in the Department of Defense. Other non-federal organizations that also use it are for example the University of North Carolina, and the School of Medicine of Virginia.

The AQT is a system based on personal computers, where a great amount of useful information is utilized by the managers to ease the handling of variables such as customer arrivals and exit times, arrival indexes, waiting times and personnel efficiency. Without a doubt there are several physical, psychological and emotional factors that affect a customer while it waits to receive his or her medicines, and that is why there exist several tools like simulation models, and automated technologies to aid in the waiting process at any establishment.

Queuing theory involves the mathematical analysis of queues or waiting lines. These lines arise in many business and other institutions, when actual demand is higher than the installed capacity to de dispatch or attend customers.

For example, in a health center decisions must be made around the level of capacity to deploy. It is impossible to accurately predict how many units will arrive in search of service, or how much time will be required to supply such service, this is why these types of decisions are hard to make.

Offer too much service would imply excessively high costs, but on the other hand, not providing an adequate amount of service would cause that in certain times the queues become excessively long. In some sense the excessive wait is also expensive; (in hospitals) it is a social cost, the cost of idle workers or another important cost. The final goal will be to achieve an economic balance between the service cost and the cost associated with the waiting time previous to the service. Queuing theory by itself does not solve this problem directly, nevertheless, it contributes with vital information required to make decisions of this kind, predicting different characteristics of the waiting lines such as average waiting time.

2. Analysis of Queue system structure in the IMSS (Mexican Institute of Social Security) pharmacy: One line with several servers.

In figure 1, we see the arrival of customers that need their prescriptions to be filled up in the pharmacy department of the IMSS, therefore they stand in line and after some time, they are attended and receive the attention by the server in turn and after wards they leave the line and depart from the facility (Hillier and Lieberman, 2009).

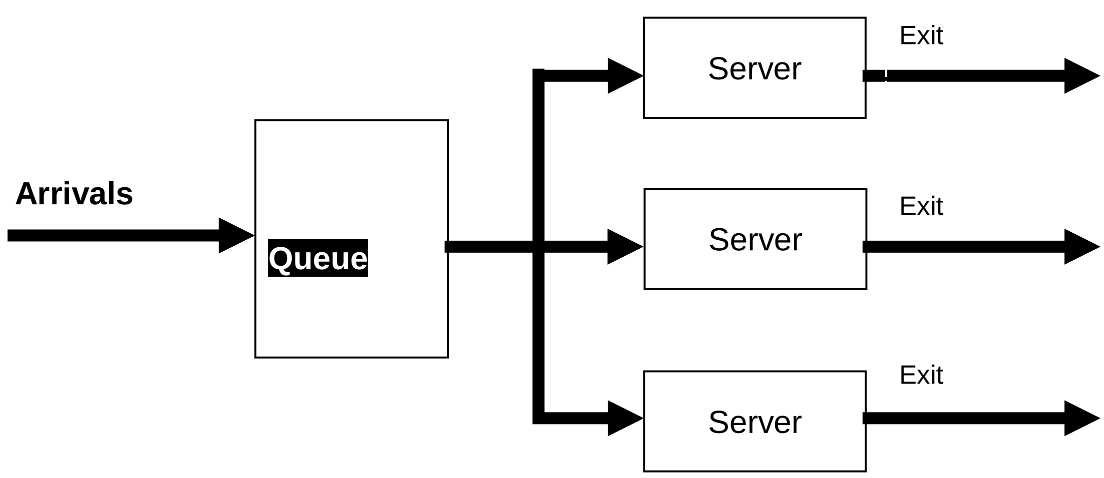

Fig. 1 The Queue System source (Hillier and Lieberman, 2009).

The queuing model followed for this study is the following: “customers” that require service are generated through a “source of entrants”. These customers enter the queue system and join a line. Then one of the customers standing in the line is selected for being attended through the rule known as the queue discipline of service discipline. The above diagram shows this process.

A characteristic of the source of entry or potential population is its size that is the total number of customers that could require or demand service from time to time.

In the current study the queue is infinite because the source of entry is unlimited. The number of generated customers up to any specific instant has a Poisson distribution. This is the case when arrivals to the queue system happen randomly but with a given average rate; an equivalent hypothesis is that the probability distribution of time between consecutive arrivals generates an exponential distribution. The time between consecutive arrivals is known as “time between arrivals”.

The service mechanism consists in one or more service media, each one containing one or more parallel service channels called “servers”. As shown in the figure there is more than one medium through which the customer can receive the service like service channel in a series.

The time that passes for a customer from the beginning of the service until he or she is served in one of the media is known as “service time” (or duration of the service). The model we present here specifies the time of service probability distribution for all the servers. The service time distribution reflects an exponential distribution.

From the Hospital perspective, the customers are called “right owners” because by Mexican laws, workers and employees who work for any institution should be registered with the Social Security Institute pay their fees, and get their number. This number gives them the right (access) to receive free medical insurance, including hospitalization, consultation, surgery, and medicines for them and their close family (husband, wife and children, sometimes even the parents). It is an old institution that covers the whole country, providing medical coverage to several million people.

The right holders complaint that they are desperate because the service takes too long and many times they have to stand in line for up to 2 hours to be assisted and sometimes when they finally approach the server’s window they are told “sorry we don’t have the medicine to fill that prescription”. This is a very different story when compared to what the institution advertises about its services and benefits, asserting that every day they are getting better and have more quality. One of the reasons why we performed the study was the quantity of medical prescriptions that are filled up daily and are around 3000 or 3200. This volume represents an institutional and social problem when for obvious reasons the patient is not willing to wait a long time to be taken care of; on the other hand the institute must execute an analysis for determining how to improve its administrative system, and be ready for future governmental and public pressures or claims.

2. Objectives

2.1 Problem at hands

With the idea of examining the distribution of waiting times and service times in the pharmacy department of Clinic Hospital no. 1 of the Mexican Institute of Social Insurance (IMSS) in the city of Cuernavaca, south of Mexico city, we state the problem as "How to achieve an economic balance between the service cost and the cost associated with the wait for the service in this pharmacy?".

2.2 Objectives

General Objective

The main objective of this project is to perform a quantitative/qualitative analysis and diagnosis in the pharmacy department of the IMSS focusing on both waiting times and service time to fulfill prescriptions. This was done with the goal of recommending actions to eliminate as much as possible, the discomfort being experienced by the patients or customers that demand the service.

Specific objectives

At the next level the objectives are focused on two main aspects:

- The first is oriented to the quantitative analysis of the two variables (waiting cost and service cost) to find how they behave and relate to each other.
- The second specific objective shows the degree of satisfaction experienced by right holders with the attention received, plus the efficiency analysis of the servers that supply the medicines.

2.3 Waiting cost and service cost

As one of the main variables under investigation the waiting cost represents the variable dependent on waiting time from the customer. It is defined as the sum of unitary cost by the time the person waits on average to receive attention, plus the risk cost of the customer deciding either to wait on line (the queue) or not. Such risk is based on the average percent in function to the degree of desperation shown by the study.

Cost of waiting. To wait means to waste some active resource that could very well be used in some productive way, and is expressed as:

Total cost of waiting = Cw times L = Cw * L (1)

Where:

Cw = waiting cost per hour per arrival by unit of time

L= average length of the line (Gorunesu, McCelan and Millard, 2002).

Specifically, one queue line has the following risks:

- In general, nobody likes to wait
- When patience gets to a limit, people will go somewhere else
- Nevertheless, a very fast service would have a very high cost
- Is necessary to find an adequate balance

Costs of a queue system

- Waiting cost: Is the cost to the customer for having to wait
- Represents the cost of opportunity of lost time
- A system with a low waiting cost is an important source of competitive advantage

Service cost: It is the operation cost of the service offered

- It is easier to calculate

-The goal of a queue system, is to find its minimal total cost

The cost of service is defined as the unitary average cost by hour, an amount given to us by the manager at the IMSS and that represents approximately $40 Mexican pesos (approximately 3 USD) per server per hour.

2.4 The degree of satisfaction as qualitative variable

The qualitative variable handled in this study derives from surveying customers at the time of departure from the queue and the service. We asked them if they were satisfied or not after waiting certain time in line before receiving their medicines. With the data gathered we summarize the level or degree of customer satisfaction, organizing the data and applying to it the binomial distribution statistical technique, where we calculate the level of satisfaction. The interpretation is summarized graphically.

2.5 Hypothesis

Null hypothesis. Ho. Waiting costs are high with respect to service costs.

Alternative hypothesis. Ha. Waiting costs are equal or less than the service costs.

3. Methodology

For this study, we examined the customer's arrival behavior taking into account the condition where we observe the behavior of the flow of customers during weekdays from Monday until Friday and for the different hours of the day from 8:00 a.m. until 8:00 p.m. The sampling for data collection did not considered weekends (Saturdays and Sundays) or festive days.

Table 1 Data collection schedule May, 2011.

WEEK DAYS	**INTERVAL I** 8:00 am - 11:00 am	**INTERVAL II** 11:00 am 2:00pm	**INTERVAL III** 2:00 pm-5:00 pm	**INTERVAL IV** 5:00 pm – 8:00 pm
MONDAY	20	20	20	20
TUESDAY	20	20	20	20
WEDNESDAY	20	20	20	20
THURSDAY	20	20	20	20
FRIDAY	20	20	20	20

As shown above, we collected 20x5x4 samples equivalent to n=400 data.

3.1 Data collection

For our purposes we want to understand the following quantitative variables:

- Arrival time measured after the previous arrival
- Time of service
- Customers' genre and age.

Besides these variables, we obtained data of the qualitative variables:

- Customer satisfaction, indicating if it is a satisfied or unsatisfied customer according to the waiting time to be served.

In relation with the previous variable, data were collected from the patients making the queue, to find out if they need medicines for a chronic disease or not.

Data are no randomly captured because the project includes arrival times and service time, very foreign to the customers characteristics and for that reason are data taken sequentially according to the time of arrival and the service supplied.

The variables were captured in the following format:

QUEUE STUDY FOR IMSS PHARMACY

Clinic-Hospital 1. P. Ayala Cuernavaca

Date: __________	Interval: _________	Horary: __________
Initial number in queue: __________	Average time of customer service:	__________

Arrival	Arrival time measure against previous arrival	Male	Female	Age	Cronic Ilness	Non cronic illness	Service time	Satisfied customer	Non satisfied customer

Average arrival time: _____________ Average service time: ______________

Fig. 2 Queue study format

The point of departure to classify the behavior of the pharmacy users during the week days and at office hours, and in order to avoid biased data, the days when the information was collected for the samples, were complied with the following characteristics:

- The samples were taken in working days on the month of May 2011 plus a day in June to substitute for the 10th of May (mother's day festivity).
- The hours considered for the research were those in which the pharmacy is open from Monday to Friday from 8:00 am until 8:00 pm.

To examine customers' arrival time behavior, and the behavior of the service, these two were handled randomly according to Table named Arrival Time in Seconds.

3.2 Reliability and certainty of data

To achieve reliability and certainty of the data, we used the confidence technique by the Kruskal-Wallis method, by taking a 10% of the total random sample that is equivalent to 40 data distributed into the four intervals. With these, we developed the analysis of variance for the defined ranges for each interval. In statistics, this is a non-parametric method useful in proving if a group of data belongs to the same population. The data used in this analysis is also non-parametric.

The characteristics of the Kruskal-Wallis test are (Kruskal and Wallis, 1952):

1. To test if a group of data belongs to the same population
2. Used when you wish to compare three or more populations
3. It equals a one way analysis of variance
4. Does not require an assumption of normality
5. Does not require assumption of equal variances (variance homogeneity)
6. It essentially compares the average ranges observed for the K samples with those expected under Ho.

When using the Kruskal-Wallis test for the analysis and diagnosis of the waiting lines, we took into consideration the following issues:

1 Hypothesis presentation

Ho: The four populations surveyed from the time intervals, are identical.

Ha: At least one of the populations from the four intervals is not identical with respect to the others.

2 Observations are rank ordered from minor to major and are assigned ranks from 1 up to 10.

Table 2 Arrival time in seconds

Arrival time in seconds			
Interval I	**Interval II**	**Interval III**	**Interval IV**
20	25	15	15
20	150	20	30
15	15	150	60
25	110	45	75
15	70	30	30
75	60	60	15
25	15	50	20
45	30	15	40
105	30	20	20
30	10	75	70

Table 3 Sum of rages order by interval

Interval	Range	Interval	Range	Interval	Range	Interval	Range
I	2	II	1	III	6	IV	8
I	3	II	4	III	7	IV	9
I	10	II	5	III	12	IV	14
I	11	II	18	III	13	IV	15
I	16	II	20	III	22	IV	23
I	17	II	21	III	27	IV	24
I	19	II	29	III	28	IV	25
I	26	II	32	III	30	IV	31
I	34	II	38	III	35	IV	33
I	37	II	39	III	40	IV	36
Sum	175	Sum	207	Sum	220	Sum	218

Calculating the test statistic formula

$$\mathbf{H} = \frac{\mathbf{12}}{n(n+\mathbf{1})}\sum_{\mathbf{j=1}}^{K}\frac{\mathbf{Rj^2}}{\mathbf{nj}} - \mathbf{3(n+1)} \qquad (2)$$

Substituting the values

$$\mathbf{H} = \frac{\mathbf{12}}{\mathbf{40(40+1)}}\sum_{1}^{40}\left[\left(\frac{\mathbf{175^2}}{\mathbf{10}}\right] + \frac{\mathbf{207^2}}{\mathbf{10}} + \frac{\mathbf{220^2}}{\mathbf{10}} + \frac{\mathbf{218^2}}{\mathbf{10}}\right) - \mathbf{3(40+1)}$$

Result

H= 0.94975

Evaluation

The result is verified in the chi-square table, which provides an equivalent value of 0.35.

Given that 0.35 is greater than 0.05, the evaluation indicates that the samples taken from different populations, are equal, therefore the reliability of data is 95% or greater.

Sample data reliability

The statistical result of the test is Ho=0.94975. This was verified in the square-chi table by means of the value of interpolation. This value is equivalent to 0.35 with 2 degrees of freedom, which indicate that Ho = 0.35 is greater than 0.05, and based on the null hypothesis, Ho reveals that all the samples taken on the different intervals are identical.

3.3 Data organization and interpretation

Given the format used for data collection, the organization of this information was made in an ordered way through intervals of 20 seconds with respect to the arrival times, measured against previous arrival.

The time to service customers was measured with intervals of 50 seconds. Next table shows arrival times measured against previous arrival:

Table 4 Customers arrival times

GROUP	INTERVAL	FREQUENCY
1	0-20	75
2	21-40	108
3	41-60	72
4	61-80	55
5	81-100	41
6	101-120	20
7	121-140	13
8	141-160	8
9	161-180	6
10	Greater than 180	2
	N	400

4. Result

Based on above table, we made graphs of the variables, arrival time versus frequency, whose value was given in intervals of 20 seconds, with which we graphed those values. Figure 3 shows a Poisson distribution with a tendency towards an Exponential Distribution whose values are spread from lower arrival times to higher ones with respect to the one before. Later calculations will be based on the theorems supported by these distributions.

As can be observed in the above figure, the data follow an exponential distribution whose values come from minimum to maximum; values over 150 seconds occurred due to servers attending persons outside the queue or because colleagues interrupted their normal activities as servers; in some way the items representing the end of the curve, are a function of a Poisson Distribution - as shown on the right side of the graph.

This does not affect the objective of our research.

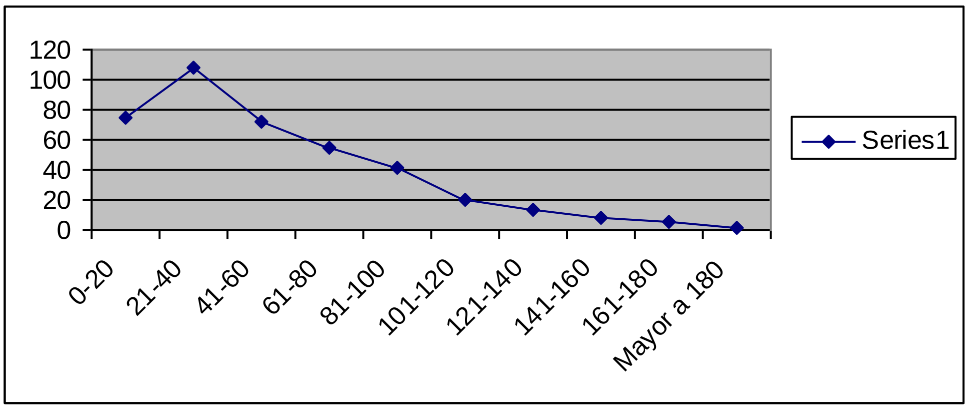

Fig. 3 Customers arrival times

Table 5 Service Times to Customers

Interval in seconds	Frequency
0-30	0
31-60	35
61-90	54
91-120	100
121-150	150
151-180	47
181-210	14
n	400

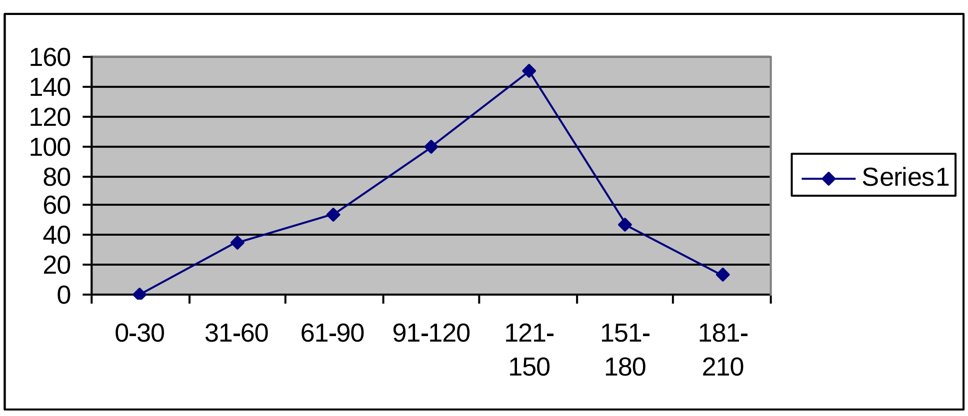

Fig. 4 Service times to customers

5. Discussion

Here we define in a chart, the quantitative variables behavior through the following procedure

a)Queue analysis

Queue average length (Lq)

Theorem $$Lq = \frac{\left(\frac{\lambda}{\mu}\right)^{c+1}}{c*c!\left[1-\frac{\lambda/\mu}{c}\right]^2} Po \quad (3)$$

Where λ = Average ratio of arrivals per unit of time
μ = Average ratio of service arrivals per unit of time

c = Number of persons

Po = Probability that system is empty

Data $\lambda = 64$ arrivals per hour

m $= 30$ Services by hour for each server c $= 3$ Servers

$$P_0 = \frac{1}{\left[\sum_{n=0}^{c-1}\frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^{c}\right]+\frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^{c}\frac{c\mu}{c\mu-\lambda}} \quad (4)$$

Note: Equations whose expressions are P_n will be in function of P_0

Development:

$$P_0 = \frac{1}{1+\frac{32}{15}+\frac{512}{225}+\frac{16768}{263250}} = \frac{263250}{1440658} = 0.183$$

$$\text{Lq} = \text{Lq} = \frac{\left(\frac{32}{15}\right)^4}{3*6\left[1-\frac{\frac{32}{15}}{3}\right]^2} * 0.183 = \frac{\frac{1048576}{50625}}{\frac{18018}{2025}} * 0.183 = 0.43$$

Result: Queue average length equals 26 people.

Diagnosis:

As we can see from the results, whose value is 26 people waiting, as compared with what was observed in the study, this is lower, which may mean that it is slightly below the real value, and demonstrates that the queue is too long in regards to what customers expect.

b)System analysis

Average waiting time in the system (W)

Theorem $W = \text{Lq} + \frac{1}{\mu}$ (5)

Data: Lq = 0.43

Development: $W = 0.43 + \frac{1}{30} = 0.46$

Result: Average waiting time in the system equals 28 minutes.

The resulting value of 28 minutes is a function of the number of customers waiting, and compared with what was observed in the study, it is slightly below, and therefore it becomes a very long time for the customer to invest waiting to be attended.

Analysis and diagnosis of the senior citizens queue

Data: $\lambda = \frac{25}{2}$ Arrivals per hour

m $= \frac{9}{2}$ Services per hour

Average length of the queue

Theorem: $Lq = \frac{\lambda^2}{\mu\,(\mu-\lambda)}$ (6)

Development: $Lq = \frac{({}^{25}/_{2})^2}{{}^{9}/_{2}\,({}^{9}/_{2}-{}^{25}/_{2})} = \frac{{}^{625}/_{4}}{{}^{9}/_{2}\,(8)} = \frac{{}^{625}/_{4}}{{}^{144}/_{4}} = 4.3$

Result: Average length of the queue *Lq* = 4.3 persons in the queue

Customer satisfaction

Now we present the average data obtained from the survey, for the measure of degree of customer satisfaction:

Average of satisfied customers 3.35

Average of dissatisfied customers 16.65

Sample size equals 400 people

The probability function for the two variables (satisfied customers and dissatisfied customers) is given by the binomial distribution, and whose theorem is:

$$f(k) = P[X = k] = \binom{n}{k} p^k q^{n-k} \quad (7)$$

Developing the theorem, brings the following result

$$f(k) = P[X = k] = \binom{20}{3}\left[\left(\frac{1}{2}\right)^3 * \left(\frac{1}{2}\right)^{17}\right] = 0.1108$$

According to the result equivalent to 0.1108, this figure indicates a very low level of customer satisfaction with the pharmacy services.

The diagnosis we suggest for increasing the quality of the service in the pharmacy department of the hospital is to install some television screen for entertainment, and a coffee dispenser machine for the customers waiting in line.

We offer these suggestions because the management of this department has a strong dependence on an annual Federal Government budget; this makes very hard wanting to change any numbers.

Given that is seldom impossible to predict with accuracy how many people will arrive to request the service, or how much time will be required to supply such service, it becomes pretty difficult to make decisions. Exceeding service time can generate excessive costs, and on the other hand, not offering enough service capacity will produce in some instants that the waiting line grows excessively long.

In a sense, a long wait is also expensive, be it a social cost, the cost of lost or dissatisfied customers or the cost of idle workers, among others. At the end the final goal is to achieve an economic balance between the cost of the service and the costs associated with the wait. The theory contributes with vital information necessary to make better decisions, predicting different characteristics of the waiting line such as the average waiting time.

5. Conclusions

From the comparative analysis on the Null hypothesis, the study shows that is true and therefore there is no alternative hypothesis. This means that the size of the queue and the time a person lasts in the system is long and should be a worry for the managers and needs to be repaired.

The level of customer satisfaction shown by the results, confirm that they are a function of the time invested by the right holders, and we already gave some suggestions of how to improve that aspect.

When discussing the quantitative and qualitative variables such as if the customer is a male or female, his/her age or if the disease is chronic or not are all very closely related with the important variables of our study and they only give us a relative reference from the results obtained.

It is important to underline that regardless of the type of organization, the government that offers health services through complex institutions like the IMSS hospital and pharmacy must design and redesign the procedures with modern and efficient systems including the training of its personnel to handle their duties and responsibilities with high quality.

Queuing theory is one tool to modernize the systems and procedures for better attention to patients and users of public health services.

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