CUSTOMER SERVICES MULTICHANNEL MODEL A DISCRETE SIMULATION CASE STUDY

Área de investigación: Operaciones

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Customer Services Multichannel Model
A Discrete Simulation Case Study

Abstract

This paper develops a model to determine the actual system capacity of customer service in a Health Service Institution - HSI, in which users request service on a system of multi-channel expected M/M/n, with arrivals Poisson and exponential Times. The current care system works with customers waiting for service at several stations and therefore is required to queue in several rows to complete the requested services. In the first station, the customer makes a queue sampling for diagnostic aids; a second station in line for medical consultation and finally, they are in line to receive the results. The institution considers an "estimated" time of about two hours for a full service; but the reality, frequently, shows that for some users a full service process takes up to 4 hours; causing strong and frequent discomfort and the costs raised, also the perception of service quality used to decrease and the constant discomfort of direct and indirect users who use the HIS´s services. Analyzing the waiting phenomena using discrete simulation which occur in customer service area, to define improvement strategies for attention´s perception and to increase the HSI´s competitiveness.

It is an analytical research using work measurement techniques to calculate time process, a queuing study to design the system capacity and discrete simulation for finding the probability distributions of service´s time and demand. Historical data is used from a database with 384,237 records and as a result the customer service module is designed and model runs for one year of operation. On average user stays in the system waiting for 145.51 minutes, regardless of service times in different processes

Key words: Discrete simulation, Operations Research, Customer Service, Optimization Techniques, Empirical Analysis.

JEL: C15, C61, C44, D22

Resumen

Este proyecto desarrolla un modelo para determinar la capacidad real del sistema de atención al cliente en una Institución Prestadora de Servicios de Salud - IPS, en la cual los usuarios solicitan servicio en un sistema de espera de canales múltiples M/M/n, con llegadas Poisson y tiempos exponenciales. El sistema de atención actual funciona con los usuarios esperando servicio en varias estaciones y por tanto sometidos a hacer cola en varias filas para completar los servicios requeridos. En la primera estación, cola en la toma de muestras para las ayudas diagnosticas; en una segunda estación cola para la consulta médica y por último, cola para recibir los resultados. La institución considera un tiempo "estimado" de dos horas para un servicio completo; pero la realidad, con alta frecuencia, muestra que el proceso completo demanda hasta 4 horas a un usuario; ocasionando fuertes y repetidos malestares y los subyacentes incrementos en costos, disminución de la percepción de calidad del servicio y la constante incomodidad y reclamos de los usuarios directos e indirectos que utilizan los servicios de la IPS.

Es una investigación analítica que utiliza técnicas de medida del trabajo para determinar los tiempos de procesos, un estudio de colas para diseñar la capacidad del sistema y la simulación discreta para hallar las distribuciones de probabilidad del tiempo de servicio y la demanda. Se utiliza información histórica registrada en una base de datos con 384.237 registros y como resultado se diseña el módulo de servicio al Client y se corre el modelo durante un año de operación. En promedio un usuario permanece esperando en el sistema 145.51 minutos, sin contar los tiempos de atención en los diferentes procesos.

Palabras Claves: Análisis Empírico, Simulación Discreta, Investigación de Operaciones, Servicio al Cliente, Estudios de Tiempos.

JEL: C15, C61, C44, D22

Introduction

This project belongs to the research in business management, applied to the health services field, where there is an infinite range opportunities for the application of modeling techniques: such as simulation, queuing theory, methods and times, linear programming, among others.

In the current turbulence conditions of environment, health Institutions, like Institutions devoted to services, requires not only offer a wide range services for different target audiences, but also develop strategies to deliver the service properly; therefore, in the customer service process they are critical success factors aspects as customers comfort, closely related to the time it takes the system from the time of service request to completion (Jiménez, 2011). The simulation techniques application, is not very common in medical systems, there is a work (Gardner and Berry, 1995) which develops a simulated experiments for three groups patients' treatment.

The added value in this project lies in simultaneously applying industrial engineering techniques, which often they applied separately, namely: taking time, the demand study, the study of waiting phenomena and the event simulation discrete in a health services institution, to find an optimal solution to the installed capacity problem, understood this solution as the implement the recommendations as the best answer to problem (Eppen, 2000); in this case the permanent queues formation in the customer service area.

This document is organized as follows: in the introduction the problem is defined and justified. Then, theoretical basis of modeling systems and their application in business cases was developed. The third part is a theoretical approach to the methodology used and probability distributions feasible to use; for the simulation process the Promodel software was used and for statistical data analysis is used Statgraphics and Excel will be used to program macros with information on times and model the probability distributions of times customer service used. The fourth part displays the proposed methodology and the data and information to be used and presents the fieldwork, the information analysis and the modeling application. Finally, the main findings, limitations and future work are presented.

1. Theorical Framework.

1.1. Work Measurement

Work measurement is the application of techniques to calculate the time spent by a qualified worker to carry out a defined task by following a preset standard execution (De la Fuente, 2006). Is the different techniques application such as the work's measurement and the study's methods to analyze the man work in all its contexts and systematically investigate the efficiency's and productivity key factors, in order to design improvement plans (De Mena, et al, 2002). Besides work standards support management in making smart decisions about hiring staff, purchasing equipment, division of labor and especially to determine the cost of the product or service (Meyers, 2000); (Organización Internacional del Trabajo, 2005).

The study methods are classified as the main technique to reduce the workload and eliminate unnecessary materials movements or operators and substitute inadequate methods by other efficient; after determining the downtime existence and their causes it feasible take action to reduce them, for example by simplifying tasks, eliminating those that do not add value and combining those permitted (Meyers, 2000); (Castanyer, 1988); (Prieto, 2007). The time and motion studies help entrepreneurs and employees to understand the nature and the true work's cost in order to develop strategies to reduce unnecessary costs (Alfaro, 1999).

The general procedure for the work measurement comprises six stages: task selection, record relevant information, critical data analysis, work amount measurement, the compilation of standard times and finally, the operation method definition. It should be noted strict adherence to the earlier stages when it comes to setting the standard times (Neira, 2006).

1.2. Queue Theory and Work Measurement

Waiting lines are very common phenomena observed in several industrial and trade activities: banks users, consumers in stores, production orders, gas stations, among others (Calderón, 1979). For there to be a queue only it requires that arrivals and / or services occur at irregular intervals. The basic process is assumed to formulate a model queue is: requiring service units coming into the system; these units entering the system and attach to the "queue". On certain points in time, a queue element is selected to be serviced by a rule known as "queue discipline", then the "service mechanism" system makes the unit chosen the required service (Thierauf, 1995).

1.3. Basic Structure of Queue Models

The queue phenomenon comprises six main elements: the source population, the customer's mechanism arrival to the service facility, the queue characteristics, the customer selection mode in the queue, the service facility's characteristics, and the system output condition by a customer (or back to the source population) (De la Fuente & Díez, 2000). The population is the set of potential system users and its size can be finite or infinite; when it is finite, but large enough so that the client arrival does not affect the likelihood's value of another arrival it will be considered infinite (Miranda, 2003).

The queue is where customers wait before being served and is characterized by the maximum permissible number of supported clients and can be finite or infinite, as the customer number is finite or infinite. The assumption of an infinite line is the standard for most models, even in situations where in fact there is a (relatively large) higher fee of the allowed number of customers as they manage a fee as well, can be a factor complicated for analysis. Queue systems where higher fee is so small that it is filled with some frequency, need to assume a finite queue (Calderón, 1979). The queue discipline refers to the rule by which customers are waiting in line will receive the service (Render, 2006).

1.4. The servicing mechanism

The servicing mechanism is the procedure by which service is given to customers who request it. To fully determine the service procedure is necessary to know numbers of servers in the mechanism and the time's probability distribution it takes to complete each server in service (Abad, 2002). The time from the service beginning until terminated in an installation is called service time (or service's length). To model a particular queue's system, you must specify the time's probability distribution of the service for each server (and perhaps for different customer's types), although it is common assume the same distribution for all servers (Roscoe, Davis & Patrick, 1986). The service's time distribution more recurrent use in practice (being more manageable than any other) is the exponential distribution. (Hiller & Lieberman, 2002).

The mathematical formulation to determine the service's mechanism is presented in Table 1, which correspond to formulas

Table 1. The mathematical formulation to determine the service's system's queuing M/M/s

Source: Based on data of (Thierauf, 1995)

$$Po = \frac{1}{\sum_{n=0}^{k-1}\left[\frac{\delta}{n!}\right]^{n} + \left[\frac{\delta}{\mu}\right]^{k}\left[\frac{k\mu}{k\mu - \delta}\right]^{n}\frac{1}{k!}}$$	$$Po = (n < k) = Po\sum_{n=0}^{K-1}\frac{1}{n!}\left[\frac{\delta}{\mu}\right]^{n}$$ $$Po = (n \geq k) = Po\frac{k^{k}}{k!}\sum_{n=k}^{\infty}\left[\frac{\gamma}{k}\right]^{n}$$ $$Po = (n \geq k) = Po\left[\frac{1}{k!}\right]\left[\frac{\delta}{\mu}\right]^{k}\left[\frac{k\mu}{k\mu - \delta}\right]$$
$$Lq = Po\,\frac{\left[\frac{\delta}{\mu}\right]^{k}}{[k-1]!}\left[\frac{\delta\mu}{(k\mu - \delta)^{2}}\right]$$ *Average number of unoccupied stations* $$E = \left[k - \delta/\mu\right]$$	$$L = Po\,\frac{\left[\frac{\delta}{\mu}\right]^{k}}{[k-1]!}\left[\frac{\delta\mu}{(k\mu - \delta)^{2}}\right] + \frac{\delta}{\mu}$$ $$L = Lq + \frac{\delta}{\mu}$$
$N = Limited\ system\ size$ $S = k = Number\ of\ service\ channels$	$n = Number\ of\ customer's\ system$ $\sigma = service\ standard\ deviation\ time$
$\delta = average\ arrival\ rate\ system$ $Po = Empty\ system's\ probability$	$\mu = verage\ service\ rate\ per\ unit$ $Lq = Average\ number\ of\ queue\ units$
$Ls = L = Average\ number\ of\ system\ units$ $Pw = Busy\ system's\ probability$	$Pn = probability\ n\ system's\ units$

1.5. Simulation

The econometric models, although they exhibit clear advantages, they have some limitations; The first concerns the estimation technique as such, ie once estimated parameters, the exogenous variables and the dependent variables, it is possible estimate causal relationships with endogenous variables; but once established these values, the link remains the same; for example, if a relationship between consumption and income is established, until another estimate is not executed, the coefficient will be the same and similarly, ever the same independent variables intervene. Secondly, econometric models are highly aggregated and essentially contain linear equations, which constitutes an exception to incorporate nonlinear relationships in some of them (Pindyck, 2001). This is due to the difficulty, or in some cases inability to solution of nonlinear systems. Finally, econometric models can not include additional economic factors. In the light of the above disadvantages, it is possible to use procedures that try of experiencing in finding particular solutions. As the case with the methods used in engineering, which do not care about general type's mathematical solutions, but rather applying numerical solution forms, graphical or other type as is the case of the simulation models.

The use of simulation tools to solve business problems has taken lot of popularity in the past decade (Funke & Frensch, 1995; Sternberg & Frensch, 2014). This innovative and dynamic approach generates attraction because of *the contrast with static models, once it simulates scenarios offering an unbeatable opportunity to decision-making support and study the human and organizational behavior in the workplace where both the subjects and their actions are in simultaneous and constant change (Funke, 1991).*

Simulation means the process of designing and developing a computer model of a system or process and conduct experiments with it in order to understand the system behavior and evaluate various strategies which can operate the system (Banks, Jerry & Carson, 2005); (Coss Bu, 1993). Further definition, argues such as simulation is the set of logical relationships, which integrating maths and probabilistic behavior of a system under study when a certain event occurs (Dunna, et al. 2006). It is also defined as the process of building computer models that describe the essential part of the interest's system behavior as well as in designing and conducting experiments with such models in order to draw conclusions from their results to support decision-making (Blanco, 2003). Typically, it is used in the complex systems analysis that is not possible by analytical treatment or numerical analysis.

Simulation is now a fundamental methodology experimentation in fields as diverse as economics, statistics, computer science, chemical engineering, ecology and physics, with huge industrial and commercial applications, ranging from manufacturing systems, simulators flight to computer games, stock market prediction and weather forecasting. (Ríos & Jiménez, 2009).

2. Methodology

The decision making on the underlying problem include a sequence of interdependent decisions, carried out in a process that changes depending on decisions's sequences or in both directions (Edwards, 1962), as the process is dynamic the decisions must be made with real-time information collected (Brehmer, 1992). So, this is an analytical research with a quantitative orientation, where queuing theory and discrete simulation is applied to find the probability distributions both time service as demand, in order to design the customer service module. Information from a database with 384,237 historical data records is used. The starting point are three hypotheses derived from preliminary problem analysis which suggests among other several reasons: the first is unknowing of the system's real capacity, because they have not determined the processes times, both new and old; the second, underlies in the variability of the number and distribution of physicians and work shifts in the company, and finally, do not have any demand studies that allow their modeling. For its comparison, the proposed methodology consists of the following activities:

2.1. Current situation's diagnosis

At this stage the recognition of all institution's processes is done and data from past studies for analysis is collected and generate a comparative basis before and after the project.

2.2. Field work

The input data's analysis is made, from the HSI's historical database, totaling **384,237** rows with customer information and examinations.

2.3. Customers Types

With the above information, ten customers types were defined and their possible tests combinations, it covering 80.25% of customers's database and 69.78% of examinations for one year

3.3.1 Conduct a study of methods and times.

Traceability of the customer service area and its process is developed, the protocol used is governed by ILO standards. Flowcharts are built for both operations and processes. The work supplements for each task to run are valued. Then normal times and standard times for each of the operations described are taken.

3.3.2 Data Collected

The activities time for each customer type are taken. These are: Call the patient, perform pre blood sample, perform bleeding, take weight, perform pre visiometry sample, make visiometry, take action, make questionnaire of spirometry, perform spirometry, perform audiometry, perform medical assessment and print the results

3.3.3 Times

Because of times variability, the adjustment of data's probability distributions for a faithful representation of data collected was performed. The adjustment procedure was: first, a descriptive data analysis using histograms and central tendency measures to analyze their behavior. Table 2 shows as an example descriptive statistics and frequency histogram for analyzing the activity named "call for patient".

Table 3 shows the service times variability, suggesting first adjusting the data to probability distributions and later develop an independence analysis (both service demands and process times) of each customer type through the scatterplot diagram and "runs tests" in order to verify the data non-correlation.

Table 2. Descriptive statistics and frequency histogram for analyzing the activity named "call for patient"

Source: Authors. This table shows a descriptive statistics and frequency histogram for analyzing the activity named "call for patient".

descriptive statistics

data points	30
minimum	3.16
maximum	17.84
mean	8.486
median	7.82
mode	7.675
standard deviation	3.22265
variance	10.3855
coefficient of variation	37.9761
skewness	0.912205
kurtosis	0.881213

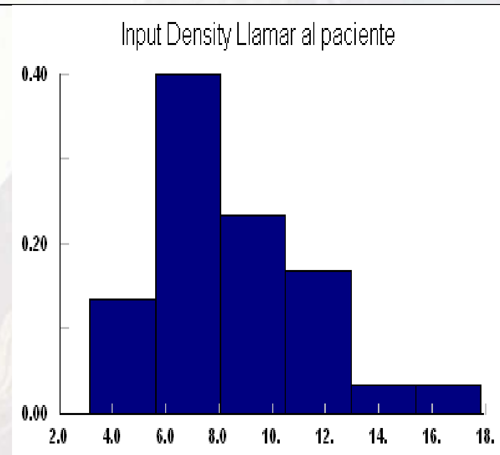
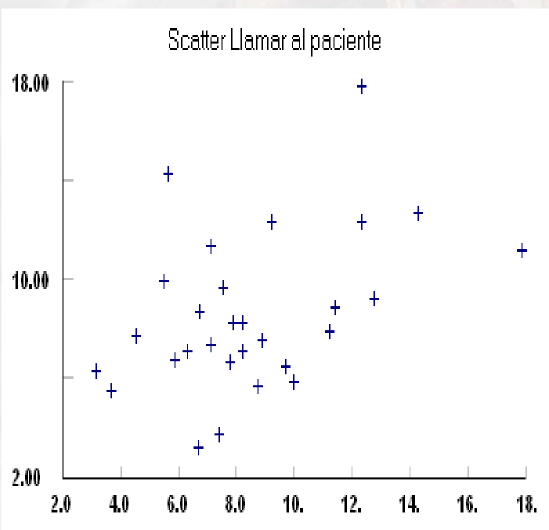


Ilustración 1. Analysis of independence for the activity named "patient called".



runs test on input

runs test (above/below median)

data points	30
points above median	15
points below median	15
total runs	11
mean runs	16.
standard deviation runs	2.69098
runs statistic	1.85806
level of significance	5.e-002
runs statistic(2.5e-002)	1.95996
p-value	6.31607e-002
result	DO NOT REJECT

runs test (turning points)

data points	30
turning points	17
mean turnings	19.6667
standard deviation turnings	2.23855
turnings statistic	1.19125
level of significance	5.e-002
turnings statistic(2.5e-002)	1.95996
p-value	0.233557
result	DO NOT REJECT

Source: Authors.

After statistical analysis and independence tests, it proceeded to adjust distributions using chi-square tests, Anderson Darling and Kolmogorov Smirnov, these tests were performed using the maximum likelihood estimate. It is emphasized as in the time probability distribution cases, which are continuous, all of them were adjusted to known distributions. It presents again the activity named "call the patient" by way of example.

Table 3. Descriptive Analisys and Times Variability

Promedio	Tiempo Normal (Segundos)	Tiempo Normal (centiminuto)	Desviación	Muestra requerida a 95% de confianza	Muestra requerida 90% de confianza	Suple-mentos	Frec.	Tiempo estándar (Segundos)	Tiempo estándar (centiminuto)	Tiempo estándar (horas)	Tiempo estándar (Segundos unitario)	Tiempo estándar (centiminuto unitario)
8,486	8,49	0,141	3,223	222	39	11%	1	9,42	0,16	0,003	9,42	0,16
28,13767	28,14	0,469	7,558	111	20	11%	1	31,23	0,52	0,009	31,23	0,52
97,906	97,91	1,632	48,212	373	66	11%	1	108,68	1,81	0,030	108,68	1,81
13,818	13,82	0,230	3,324	89	16	11%	1	15,34	0,26	0,004	15,34	0,26
31,219	31,22	0,520	13,665	294	52	11%	1	34,65	0,58	0,010	34,65	0,58
154,3357	154,34	2,572	72,523	339	60	11%	1	171,31	2,86	0,048	171,31	2,86
8,895333	8,90	0,148	2,331	105	19	11%	1	9,87	0,16	0,003	9,87	0,16
113,1463	113,15	1,886	26,977	87	15	11%	1	125,59	2,09	0,035	125,59	2,09
354,9333	354,93	5,916	171,716	360	63	11%	1	393,98	6,57	0,109	393,98	6,57
238,9923	238,99	3,983	67,269	122	21	11%	1	265,28	4,42	0,074	265,28	4,42
730,0853	730,09	12,168	131,669	50	9	11%	1	810,39	13,51	0,225	810,39	13,51
577,318	577,32	9,622	427,647	843	148	11%	1	640,82	10,68	0,178	640,82	10,68

Source: Authors. This table shows the service times variability, suggesting first adjusting the data to probability distributions and later develop an independence analysis

Table 4. Adjustment of time's probability distributions

goodness of fit

data points	30
estimates	maximum likelihood estimates
accuracy of fit	3.e-004
level of significance	5.e-002

summary

distribution	Chi Squared	Kolmogorov Smirnov	Anderson Darling
Beta	0.4 [5]	8.97e-002	0.213
Chi Squared	2.8 [5]	9.34e-002	0.295
Erlang	1.6 [5]	7.82e-002	0.2
Exponential	12.4 [5]	0.256	3.05
Gamma	2. [5]	7.42e-002	0.192
Lognormal	1.6 [5]	7.29e-002	0.173
Normal	4.4 [5]	0.131	0.512
Pearson 5	1.6 [5]	7.23e-002	0.168
Pearson 6	0.4 [5]	7.59e-002	0.206
Power Function	15.2 [5]	0.244	2.73
Rayleigh	2. [5]	8.83e-002	0.256
Triangular	2.8 [5]	0.15	0.865
Uniform	17.2 [5]	0.301	5.01
Weibull	2. [5]	8.42e-002	0.26

Auto::Fit of Distributions

distribution	rank	acceptance
Pearson 5[-5.2, 20.5, 267]	100	do not reject
Lognormal[-1.98, 2.3, 0.297]	99.9	do not reject
Gamma[1.07, 5.47, 1.36]	99.4	do not reject
Pearson 6[3.16, 231, 3.06, 129]	98.8	do not reject
Erlang[1.07, 6., 1.24]	98.5	do not reject
Beta[3.16, 44., 2.65, 17.]	94.7	do not reject
Weibull[2.66, 1.9, 6.56]	94.6	do not reject
Rayleigh[2.52, 4.77]	93.4	do not reject
Chi Squared[2.26, 6.34]	88.8	do not reject
Normal[8.49, 3.17]	47.1	do not reject
Triangular[2.3, 18.7, 6.46]	20.6	do not reject
Power Function[3.14, 19.5, 0.696]	0.175	reject
Exponential[3.16, 5.33]	8.49e-002	reject
Uniform[3.16, 17.8]	1.86e-003	reject

Source: Authors.

3.4 Demand

Data is collected through direct observation, the time between users arrivals to the system for analysis and modeling is recorded. Company's historical information is used to adjust demand and propose theoretical probability distributions with best fit.

3.4.1 Statistical analysis of demand

After getting information from the database, the setting of demand function for each client type is performed. To model the demands by customer type, It was fractionated by hours and hourly adjusted to a probability distribution. In the demand functions's case (patients' arrivals), it was found that did not fit in discrete probability distributions known as the theory says, especially for the Poisson distribution. According with the previous finding, it proceeded to create an empirical discrete distribution for each type of customer in each of the defined time windows (Harrell, C. Ghosh, BK, & Bowden, R. (2000). The following It presents the setting for customer Type 1 in time 1. Summarizing, there were in total 123 different probability distributions to model demand and 12 to model the operation times.

Table 5. Empirical discrete distribution for each type of customer.

Client	Hour 1		Density	E(X)	Client	Hour 1		Density	E(X)
0	0,606	60,6	0,606	0	8	0,983	98,3	0,007	0,056
1	0,822	82,2	0,216	0,216	9	0,986	98,6	0,003	0,027
2	0,887	88,7	0,065	0,13	10	0,986	98,6	0	0
3	0,921	92,1	0,034	0,102	11	0,99	99	0,004	0,044
4	0,949	94,9	0,028	0,112	12	0,993	99,3	0,003	0,036
5	0,959	95,9	0,01	0,05	13	0,997	99,7	0,004	0,052
6	0,962	96,2	0,003	0,018	14	1	100	0,003	0,042
7	0,976	97,6	0,014	0,098	***Valor esperado***				0,983

Source: Authors

3.5 Queues Analisys

With demand function data, the current queues system is analyzed and modeled according to its nature, a M/M/n is suggested, which should be contrasted with the study

3.6 Developing the simulation model

With the above information of the processes and the queuing systems analysis, the simulation is executed. Promodel software is used, running a simulation that describes more accurately the current real system.

3.7 Validating the simulation

With the first model the random features are validated using hypothesis testing and confidence intervals. To define the model's consistency it is compared with the actual data, and in discrepancy case it is proceeded with the variables adjustment which make noise in the initial model.

3.8 Experimenting with the simulation model

After verifying the model's consistency, it will be experimented with the system through different improvement's scenarios and its behavior will be analyzed looking for the best adjustment with real system.

3.9 Analyzing the results

With the improvement scenarios result, the effectiveness of improvements proposed is contrasted. Then, strategies that contribute to the problem solution of waiting in long lines for service delivery are suggested.

4. Results and Discussion

4.1 Model Presentation

The model design has 48 locations distributed as follows: 1 arrival queue, 3 cubicles for sampling, 6 cubicles visiometry and spirometry, 14 physician offices, three locations for audiometry's 1 weight scale to weigh patients, 1 place to measure patients, 4 lounges, and 15 locations for the auxiliaries.

4.2 Entities

The model has 10 types of entities that represent and match the customers type defined above**.**

4.3 Networks

36 networks to simulate all transport that occur in the customer service area were created. Networks were defined with speed and distance, requiring actual measurements between each work place through which patients, physicians and assistants circulate. Six networks for spirometry and visiometry assistants were defined, 3 networks for speech therapists, 14 networks for physicians, 3 networks for laboratory sampling and 10 networks for transportation of the patients to claim for the results.

4.4 Resources

26 Resources equivalent to the service provider stuff inside the HSI facilities were modeled. These resources were modeled with a speed of 20 meters per minute. Six resources for visiometry and spirometry assistants were equally defined, 3 auxiliaries for laboratory sampling, 14 medical specialists and 3 speech therapists.

4.5 Process

In the process it is described for each customer type the whole route done within the system Figure 1**.** The process varies depending on the customer type. In the process programming 341 code lines were required to model the complete system with 10 customers' types. Some additional codes to those of Promodel were also created to ensure that the model accurately represents the process to be modeled. Arrivals for each of the 10 types of selected customers were created, they arrive to a queue of arrival and additionally it contains arrival cycles which will be explained later. The frequency of arrivals is 24 hours. 8 types of shifts that are currently occurring in the HSI were defined.

Figure 1. Process Diagram and Layout of customer service area

This figure describes the process for each client throughout the route made within the system. Source: Compiled by the authors.

4.6 Global Variables

A total of 12 global variables as counters were created to record the arrival of each customer and accumulate the total of customers per day.

4.7 Arrival cycles

10 cycles of arrival were created, one for each type of customer to represent the customers demand by time and day. Each time is represented by a discrete empirical probability distribution.

4.8 User distributions

The demands of each customer type were adjusted for each hour of service. The resulting empirical distributions of the previous adjustment are entered as user distributions in Promodel. In total 123 user distributions in Promodel were created which are the ones that ultimately represent the demand of entities in the model.

4.9 Stream

A seed for the random number generator of Promodel was provided to change the seed in each of the routes and make the statistical validation of the model. It was used as stream: 1

4.10 Model Validation

To validate the model 30 independent routes a year of duration and 30 different seeds were used. In each route the total arrivals of each of the 10 types of defined customers were counted, to then determine the mean and standard deviation of the total arrivals by customer type. It was worked with a 5% level of significance and for this case the value of N is 30.

Table 6. Result of the 30 runs of the simulation to determine the times of arrival

	Total arrivals Type 1	Total arrivals Type 2	Total arrivals Type 3	Total arrivals Type 4	Total arrivals Type 5	Total arrivals Type 6	Total arrivals Type 7	Total arrivals Type 8	Total arrivals Type 9	Total arrivals Type 10	Total arrivals
Average	1856,13	4889,03	1650,97	590,32	354,19	6576,77	2688,39	267,10	493,55	344,52	19704,52
Deviation	597,18	897,31	682,33	304,01	171,36	1302,31	1376,21	182,54	669,51	212,40	2808,83
LI	1642,43	4567,93	1406,80	481,53	292,87	6110,75	2195,92	201,78	253,97	268,51	18699,39
LS	2069,83	5210,13	1895,14	699,11	415,51	7042,80	3180,86	332,42	733,13	420,52	20709,64
Expected Value	1827,6	4903,2	1769,4	595,2	378,6	6396	2709,6	261,6	330,6	314,4	19485,6

Source: Authors.

In Table 6, data from the simulation is presented with a significance level of 95%, with previous data the confidence interval for each type of customer was prepared. The expected value of each customer type was compared in each interval trusted to verify its location within the limits built. 100% of the cases occurred within the confidence interval's limits suggesting the model's behavior consistent with expectations.

Model Results Discussion

The simulation model for a year of operation, throw the following results: On average customers wait a total of 44.72 minutes to be served, either by visiometry and spirometry auxiliaries or by sampling auxiliaries. In the *location to receive the results, the average time is 36.34 minutes. The highest waiting time is registers in the laboratory process testing with a value of 64.45 minutes, very significant figure, once users remaining there have other tests done (spirometry or visiometry) whose wait time represents 44.72 minutes, which means that a user for laboratory examination and spirometry or visiometry spent in the system around 109.17 minutes, adding the results delivery (36.4 minutes); it can conclude that a user remains a system waiting around 145.51 minutes, excluding the service times in the different processes.*

In the other hand, visiometry and spirometry auxiliaries are the one who achieve higher rates of use averaging 85% occupancy, explaining in part the bottleneck of the waiting room for these processes. The percentage of transport consumes about 2%, which is a "dead" time for the suspension of the ongoing activity to call the next user. Something similar happens with the doctors, who consume a percentage close to this value when they stop to call the next patient. The ***¡Error! No se encuentra el origen de la referencia.****, summarizes the behavior of different types of customers:*

The simulation model for a year of operation, delivery the following results: On average customers wait a total of 44.72 minutes to be served, either by auxiliars of visiometry and spirometry or by sampling auxiliaries. In the location where they receive the results, the average time is 36.34 minutes. The register highest waiting time is in the laboratory testing with a value of 64.45 minutes, very significant figure, once users remaining there have other tests done (spirometry or visiometry) whose wait time represents 44.72 minutes, which means that a user for laboratory examination and spirometry or visiometry spent in the system around 109.17 minutes, adding the results' delivery (36.4 minutes); it can conclude that a user spent in the system waiting around 145.51 minutes, excluding the service times in the different processes.

In the other hand, attendants of visiometry and spirometry, have the highest use percentage that reaches an average 85% occupancy, explaining in part the waiting bottleneck for these processes. The transportation consumes about 2%, which is a "dead" time because it suspends of ongoing activity to call the next user. Something similar happens with the physicians, who consume a percentage close to this value and they stop to call the next patient.

summarizes the different types customers's behavior, and displays the percentage time consumption's spent by user in the system. It is noted as the average wait is at 37.43%; the average operating time is 60.71% and average transportation time 2.94%.

Tabla **7** *summarizes the different types customers's behavior, and displays the percentage time consumption's spent by user in the system. It is noted as the average wait is at 37.43%; the average operating time is 60.71% and average transportation time 2.94%.*

Tabla 7. Different types customers's behavior, and percentage time consumption's spent by user in the system

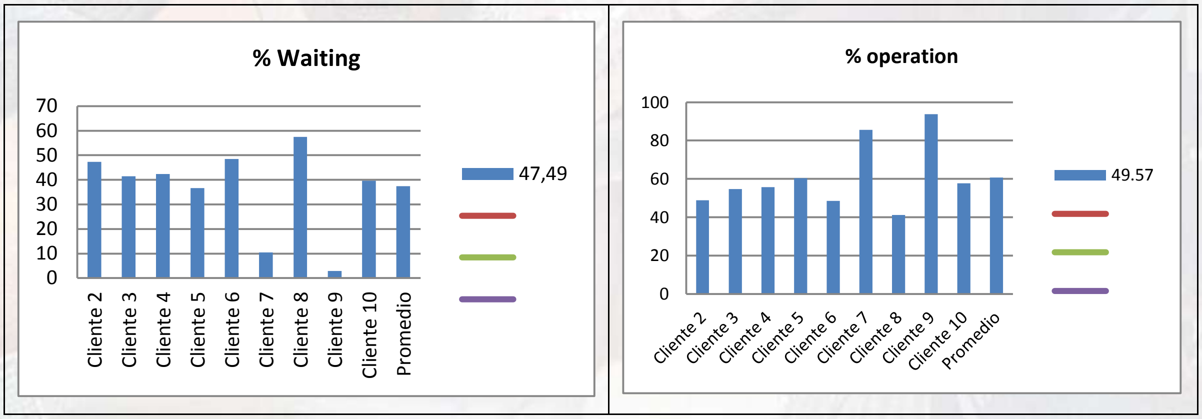
Client Type	**% of movement**	**% of waiting**	**% of operation**	**Client Type**	**% of movement**	**% of waiting**	**% of operation**
Client 1	2,94	47,49	49.57	Client 6	2,68	48,44	48,58
Client 2	3,75	47,35	48,9	Client 7	3,98	10,5	85,52
Client 3	3,89	41,43	54,68	Client 8	1,34	57,52	41,14
Client 4	1,91	42,36	55,73	Client 9	3,37	2,92	93,71
Client 5	2,97	36,68	60,35	Client 10	2,6	39,64	57,76
Average	%Movement	**2,94**	% Waiting	**37,43**		%Operation	**60,71**

Source: Authors

Seen as the clients type 7 and 9 have the least expected percentage in the system, which is consistent with the number of processes performed. Meanwhile Client type 8 has an expected percentage of 57%, as shown in Figure 1.

Where the graph on the left shows how the customer's type 7 and 9 have the least expected percentage in the system, which is consistent with the number of processes performed. Meanwhile Client type 8 has an expected percentage of 57%. The chart at right shows how the average Clients have a percentage of 59.6% operation except Clients 7 and 9 which have the best performance percentage.

Figure 1. Waiting Time and Operation Time in the system by Client type.



Source: Authors.

With the results obtained in the simulation, the following improvement alternatives are proposed, seeking to reduce the waiting percentage of users:

Placing a messenger so the auxiliaries do not have to stop their activities. This scenario was modeled, and the results showed an increase in the resources use, because the downtime is removed, once the auxiliary do not suspend their activities to call a next user.

Overlapping physicians' work shifts. This alternative allows greater physician's availability in higher flow times, according to the different simulation's runs. With this scenario, the model exhibits a reduction in the ranks, and the usage's percentage of resources increases.

Posting efficiency indicators to auxiliaries. This alternative was suggested after a work session with the managers and after explaining the importance of having an instrument to measure, control and regulate the auxiliaries' management.

Assigning random quotes to mitigate the demand effect. Scenario of assigning physician appoints was modeled under the assumption that the commercial area has to meet the minimum goal of 40% service under this system. With this scenario the users system time is notoriously decreased and the need for physicians and auxiliaries is reduced which will not be removed from company but will be assigned to the new business unit to work under appointments.

Placing an electronic equipment - a ticket machine to assign shifts and prevent physicians to move from their work place to call the next patient. This scenario was evaluated against the scenario of using an employee to perform a messenger functions, in economic terms, the equipment's use to assign turns exceeded the use rates that are achieved with the messenger doing the calling labor and placing clients; savings in time generates higher returns.

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