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COMPARATIVE STUDY IN THE PROBLEM-SOLVING USING SERVICE LINE QUEUING THEORY AND SIMUL8

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ABSTRACT: *This paper shows the results obtained by performing a comparative study using the queuing theory model and the Software Simul8 to a problem that arises in the registration process, Faculty needs to improve this and reduce the waiting time for students, which took over five hours to complete it. The first part presents the form and planning of how the procedure was being done, identifies the parameters and variables and its consequences in affecting quality of service. In the second how it addresses the problem and its approach to the mathematical model and simulation. Finally we analyze the results obtained from both models.*
KEYWORDS: Simulation, optimization, Quality of Service Timeouts

INTRODUCTION

One of the main activities of the directors of the company's services is the ability to determine which service provides the appropriate balance of resources used to address a number of customers whose arrival time and service time are not predictable. There are many situations where people or objects must be sorted or grouped in a structure imposed by a system, awaiting a service to meet a need. The branch of Operations Research commissioned the study of systems with these characteristics is what is called the Theory of Queues or waiting lines. Providing a service usually involves having lines of customers that comprise a line-out which is probabilistic or random behavior [1].

When analyzing queues can be done through the study of queuing theory, this methodology is a collection of mathematical models that describe the linear systems that must wait to be served, the information generated is used to determine the ability appropriate service, although in reality this is not given in this way by how difficult it is, in most cases, collect accurate information necessary for its implementation [2].

This comes from the fact that the variables involved in formulating the mathematical model behave in a completely random so that the rigorous mathematical treatment that is designed to make this phenomenon is meaningless in many cases, because the results obtained may be far removed from reality.

To remedy this situation then uses techniques such as simulation for analysis and sizing of systems with these characteristics thereby gaining not only reduced costs but also the accuracy in some cases, but the results are more consistent with reality.

Why is it considered important to study waiting lines? Because being a set of items waiting to be served are in a state of idle time is considered lost and could be on using these resources more efficiently elsewhere.

It is difficult to determine the cost that is generated by being in a waiting line, but there are ways to do that is considered for this case study will be the maximum waiting time takes an average customer to be served with this can also determine the serviceability of the system. As the service is provided efficiently reduces the cost of waiting, the goal is to find the point where the system provides a better service at minimal cost.

A working structure of a waiting line has to be entering a person or object, some call it customer, who expects to receive a service and on the other hand, there is someone who will give the requested service, which is called server.

Gallagher presents four typical structures expected lines in figure 1 [1]:

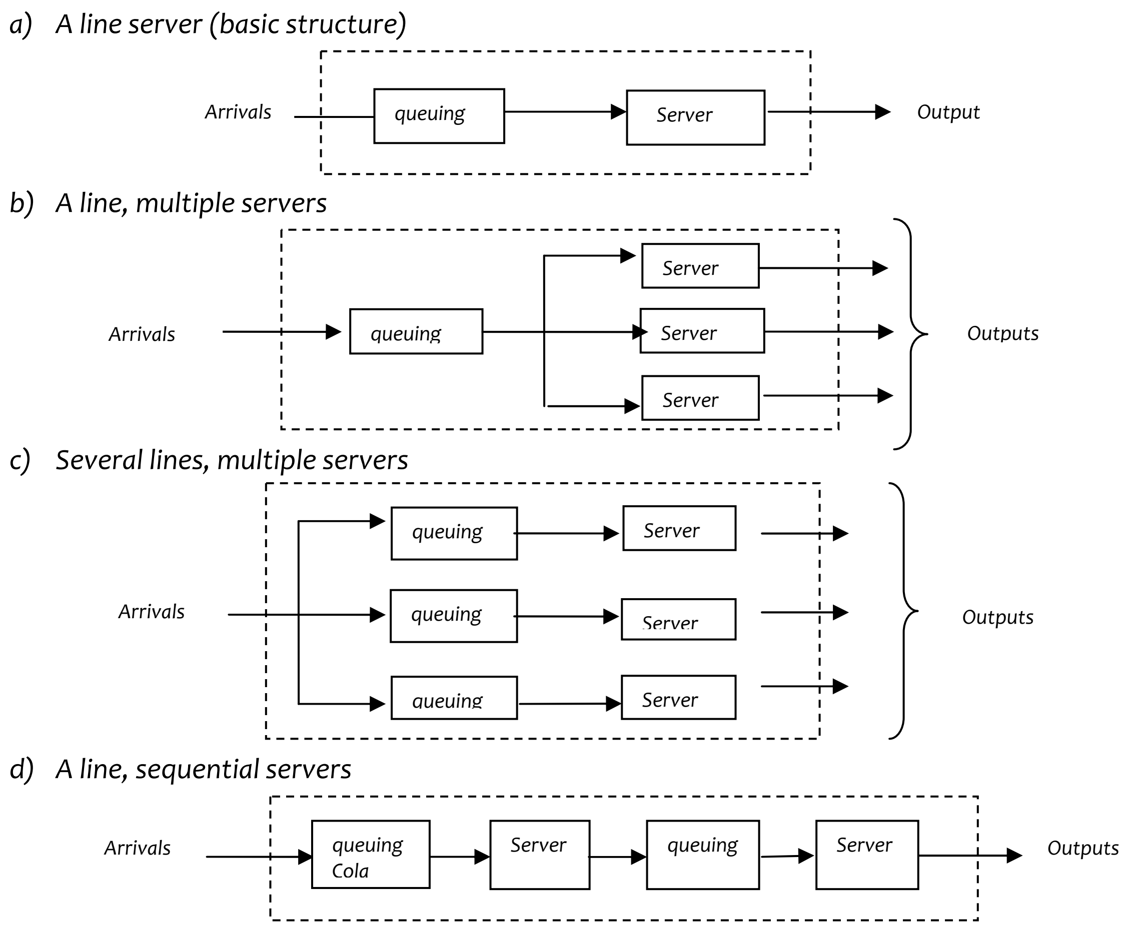

Figure 1. Four structures typical of queuing line [1]

In this scheme, customers are individuals who are requesting a service, the system randomly come and join the queue waiting to be seen. If the server is idle, the client receives the service and immediately leaves the system. The randomness of the flow of demands and service times causes in certain periods of time at the entrance of the system (in queue), to accumulate too many demands. In these situations, customers join the queue or leave the system without receiving service. In other cases, the system will operate with incomplete use of the service or remain free, or standing for long periods of time consuming resources.

Queuing theory allows using mathematical models to find solutions to problems like those mentioned above, but these models only consider variables and / or features of the system when in fact other situations involved in the service as they are external factors that alter their conditions of the problem because they include random events, variables that have complex relationships and dynamic phenomena (which change over time), then that makes use of experimentation through simulation [3].

Discrete event simulation is an analysis tool that spreads rapidly in the business environment, proving its usefulness to support decision-making related to planning [4].

In order to formulate an accurate representation of the computer-assisted real-world system described above, it was decided to use simulation, visualization and analysis tool provided in discrete event simulation environment "SIMUL8 [5].

The main advantage of the proposed methodology is that it allows computer consistently reproduce the complex process in an abstract form and integrated display the dynamic behavior of its elements in time. A basic model is generated to discern the main weaknesses and bottlenecks in the process, but is also useful for making decisions to improve the current process performance [6].

It was through the development of the simulation model, which identified all the restrictions and performance standards to be considered for the optimal solution to the problem of making materials.

The paper is structured as follows, section 2 describes the system under analysis, in Part 3 the system is modeled mathematically using the simulator Simul 8, point 4 is a discussion of the results by both methods and finally in 5 concludes the proceeds from the realization of this application both mathematical and simulation.

BACKGROUND

The system being tested has the following characteristics:

The study site is the Faculty of Chemical Sciences and Engineering, a top-level public school that belongs to the Autonomous University of Morelos State in Mexico evaluated the student population is 450 students studying industrial engineering degree, same as are distributed in 13 semesters (first semester not included). The system being evaluated is the administrative process known as Registration Matters Making (RMM) which made the students to register for subjects who wish to pursue a semester.

The curriculum follows the credit system in which each student determines his school career according to their academic and personal needs, we have a syllabus which proposes how to place their materials over 9 semesters but has 14 semesters to finish his career, the regulation allows students with more than 8.5 average carry 16 extra credit, which allows them to advance matters were not of his term. They also have the opportunity to advance through inter courses and quality exams.

It has an enrollment management system (software) that is controlled by a general manager and five limited access that are controlled by the chief race of each educational program. The director and deputy director of the school have the same access to general manager. It also participates in the management process by identifying school subjects offered in the semester schedule and the quota for each subject. In the template matters of the race, there are some that are shared with the other careers offered on campus and quotas should not exceed 40 students. This is where problems arise because there are several situations that complicate this RMM.

Before talking about these situations, we will describe how to make a RMM:

Through a notice to students notifying them of the date, requirements and service hours to make their RMM, students are spread over 5 days, beginning the first day with the last semester, then will attend two semesters per day, and ends with the third and second. Students will have the date and time set for processing with the required documentation and are attended by the academic program manager who will review your documentation, part of the group you requested and extends them proof of registration with the name, password and group of subjects to which he was enrolled. This process can be seen clearly in Figure 2.

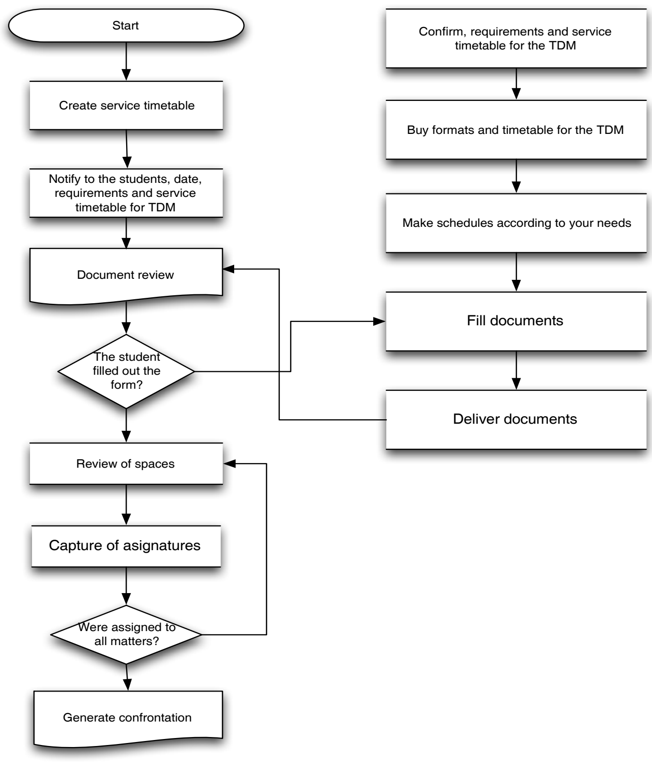

Figure 2. "Registration Matters Making". Source: Administrative Procedures RMM procedure, Chief of Race

Apparently this process is quick and easy, but with the amount of students who are in the program, the process is complicated because it presents the following situations:

1. *In matters of the program, at certain times, or groups that are the most popular and sometimes covers the quota ahead of schedule, leaving out students to them for their half because of early, delayed or disapproved, in addition that some subjects are distinct groups.*
2. *There are matters which the quota is shared with at least one other race and sometimes just a group. The proportion was higher quota for students of the industrial race but it was not enough.There are also matters that are shared and workshops whose quota was reduced to 25 people by limiting the enrollment and the spaces allocated to the race.*
3. *Until the third semester there are five groups of subjects in the basic cycle to which we must add resources to students most of which exceed the limit of 2 per stroke register quickly becoming saturated. Also, groups of demand are generated, but its approval is dependent on other departments and sometimes these groups are not approved because there aren´t enough students.*

Therefore the students concerned to achieve desired space groups came from 4 in the morning and had to wait until the service started at least 4 hours. Those who arrived after 7 o´clock, just had to wait 4 hours at least you run the risk of not finding matters or spaces available. This created problems in the minimum number of credits. Why should wait so long for treatment? There are several reasons:

- *a) The server was constantly out to get places with the manager of school services for students who required it, but this increased attention span, causing anger among the row because he took at least 20 minutes away.*
- *b) Must be added that few students fail to meet their full requirements (formats, copies, records) and delay time of attention, because it must wait until they return with full documentation and could not meet someone else came after it could take the last spaces of some group.*
- *c) Among the students there are special cases such as working students, single mothers, students, irregular, low for adjustment, changes of groups, high half that being seen require extra time to analyze their cases and obtain the signatures of management approval.*

All this generated a considerable waste of time and discomfort among students waiting their turn. Also affecting the activities of the administration of the college, this should meet the demands of the students on all concerned to seek quota in any group.

The problem to be solved is summarized in the following objectives: identify the mathematical model to determine the optimal level of resources or the proper values of the system's ability to minimize the waiting time of service. Also simulate the model and contrast it with the real model and obtained mathematically. In addition, to establish working conditions that allows the efficient use of resources for the customer.

ANALYSIS SYSTEM

This section presents the working procedures under which conducted the analysis. At first glance, there were several considerations:

1. *The number of customers waiting in line. This may be finite or infinite. In reality only the first addition is presented that facilitates the calculations.*
2. *The queues are organized into one.*
3. *Assume a Poisson distribution for arrivals to the system is guessing at random (the time between two consecutive arrivals is a random variable independent), despite having a timetable there is no way of knowing the time or time requirement attention.*
4. *The service time follows an exponential distribution*
5. *Service times are assumed constant. Preprocessing is carried out procedures to eliminate long service times. The service rule is first come, is the first served, you can not go unaddressed customers because there is a schedule of service.*
6. *The model of a row a server will not be considered because it has not worked.*
7. *Models will be assessed a single line and multiple servers in a line sequential servers, looking for the optimal service. The service rates can vary with equipment or additional personnel. No estimated cost of waiting, is to determine a minimum average waiting time*

SYSTEM MODELING - SYSTEM ORGANIZATION

A waiting line can be modeled as a stochastic process in which the random variable is defined as the number of transactions in the system at any given time, the set of values that can take this variable is {O, 1, 2,. . . , N \ and each has an associated probability of occurrence {P_0, P_1, P_2,..., P_N} [7].

The waiting line is represented by the arrival of students to a system in order to receive a service (RMM) for a server or server group. If the server(s) is (are) occupied the student must wait in line and wait to be seen. And important part of the system, are the servants who are doing the required service. These servers can be placed according to Gallagher [1] in series or parallel. The servers serve a certain number of students from the waiting line (which will have a period) whit a probability distribution of time attention to transactions or speed of service, in most common distributions are the exponential, the Erlang, the hyper-exponential, the degenerate [7]. The main variables that influence the behavior of the row are: average rate of arrival of guests, hours of operation, documentation, quotas, service average, subjects offered and the number of servers. Through an analysis, we determined the variables most related to the behavior of the waiting time of the service, which were average rate of arrivals, average service rate and number of servers.

EQUATIONS USED

Gallagher [1] proposes to model a queue server, Moskowitz and Wright [3] proposed to model a queue with multiple servers the following equations, for purposes of this study, we used the value of k = 3:

a) Queuing (for one server)

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} \tag{1}$$

$$W_q = \frac{L_q}{\lambda} = \frac{\lambda}{\mu(\mu - \lambda)} \tag{2}$$

b) System

$$L_s = L_q + \frac{\lambda}{\mu} = \frac{\lambda}{(\mu - \lambda)} \tag{3}$$

$$W_s = \frac{L_s}{\lambda} = \frac{1}{(\mu - \lambda)} \tag{4}$$

$$U = \frac{\lambda}{\mu} \tag{5}$$

a) Queuing (for multiple servers

$$L_q = \frac{\lambda \mu U^k}{(k-1)!\,[k\mu - \lambda]^2} P_o \qquad k = \text{number of servers} \tag{6}$$

$$W_q = \frac{\mu U^k}{(k-1)!\,[k\mu - \lambda]^2} P_o \tag{7}$$

b) System

$$L_s = \frac{\lambda \mu U^k}{(k-1)!\,[k\mu - \lambda]^2} P_o + U \tag{8}$$

$$W_s = \frac{\mu U^k}{(k-1)!\,[k\mu - \lambda]^2} P_o + \frac{1}{\mu} \tag{9}$$

$$P_o = \frac{1}{\left[\sum_{n=0}^{k-1} \frac{1}{n!} U^n\right] + \left(\frac{1}{k!} U^k\right)\left(\frac{k\mu}{k\mu - \lambda}\right)} \tag{10}$$

EXPERIMENTAL - APPLICATION OF MODELS

For the application of equations 1-10, used the following data: It has a rate of arrival of 12 students per hour (λ) and given a service charge of 15 students per hour (μ). The models worked M/M/1 were referred to the use of a server and M/M/3 it with three servers. The M/M/1 and M/M/3 nomenclatures mean: A (three) server (s) with Poisson arrivals and exponential service times [8]

Solving the equations presented (1-10) will have the following results shown in table 1:

Table 1. "Results of the application of the mathematical model"

Model	λ	μ	L_q	W_q	L_s	W_s	U
M/M/1	12 per hour	15 per hour	3.2 costumers	16 min	4 costumers	20 min	80%
M/M/3	12 per huor	15 per hour	0.019 costumers	0.0016 min	0.82≈1 costumers	0.069 min	80%

Table 1, shows that the model of a server, the user spends 20 minutes to complete the processing, which means it is a considerable decrease waiting time. In the model of three servers, only have a client waiting in the system and users only have to wait 7 minutes with the primary server for document review and no time with the servers. The total time of service would be less than a minute, which is not very logical.

In both models do not specify the total number of students served at the end of the day, but estimated the amount of 375 (83.7%) persons distributed in five days of eight hours of care. And the equations reported 80% efficiency of the system, which is close to 83.7%.

Using SIMUL8 simulator was obtained the following results, table 2, were achieved on a global basis:

Table 2. "Simulation results with SIMUL8 system. Source: Simul 8".

Model	λ	μ	L_q	W_q	L_s	W_s	U
M/M/1	447	446	9	5	2	11.24	100%
M/M/3	447	446	0	1.69	1	1.13	100%

The model considers the five working days in the RMM, with eight hours of care each day, both of which had an efficiency of 100% and meets almost all the students.

In the table, we observe that the model has a standby server to 9 persons; the user spends 11.24 minutes to complete the processing, less of what they gave the equations.

In the three-server model, one would not have any customers waiting in the system and users only have to wait 7 minutes with the primary server for review of documents and about 1.13 minutes in the system.

DISCUSSION

The first proposal for improvement to be applied according to what the equations suggested was to have three servers and a single row but in this model is kept to the main server who was responsible for the process and who authorized and released to enter spaces the student to subsequently move to any unoccupied for that server conclude the process of RMM. The first three days, the line was only the primary server, but the wait time was no more than 7 minutes with no servers took longer than 5 minutes, but the fourth day they returned to the initial problem because it was at saturation of quotas and other changes were generated because the servers are not respected and not treated properly the order of arrivals generating other problems.

Analyzing the results of the implementation of this model was obtained the following conclusions:

1. *It still had problems, mainly in semesters 4 and 5 °: the status of the student who did not allow income to the requested materials (low for regularization, higher semester, group changes, career changes) and resulted in delayed service and programming of the process or because the system administrator does not perform real-time modifications.*
2. *The student did not comply with the required documentation (copy of re-registration, ballot teaching assessment) by creating other problems with the quality system to not comply.*
3. *Students getting the required spaces in other areas (director, deputy director, administrator) without notice to the chief race, affecting the allocation of space and saturating the groups. If students tried to find offenders to remove them from the groups were lost at least 10 minutes.*
4. *Therefore, demand groups did not achieve the quota required to be accepted, leaving matters to students who had applied. On the other hand were generated groups with more than 50 students, which create a strong demand from the owner of the subject.*
5. *Support servers, who were students of last semester, did not respect the order arrived or lost the light of recent documentation for not keeping good control of the file they were given, with the result that students are not granted a space although the list if you got.*
6. *It was hard to tell who came in groups that did not correspond because it was known to all students and sometimes the waiting list in which scoring was not reliable because they were not admitted as listed for various situations.*
7. *Students were asked for extra credit to print a document showing that his average was requested and should be stapled to the file for subsequent audits and verification that the regulation was violated. Sometimes they did not present the document or assumed that it must meet and see if it was true, but the School Services page of the University had not updated their records and had to check the registration system by increasing time in service.*

MEASUREMENTS MADE

Reviewing the incidents recorded was found necessary to take drastic measures to better plan the activities before, during and after the RMM to improve service. Identify the requirements and execution times before school services of the prerequisites to make the RMM, these were:

- *Registration of the semester, the group changes, the low for regularization, career changes should be made at least two weeks before the re-registration. Thus the day of collection and had their document was approved and the change of status in the system. So two weeks before registration are notified to students via bulletin boards and notices electronically. Those, who do not do their transactions on time and were denied service by sending the last day of the process.*

- *Similarly a week earlier by the same means, they were reminded that they must make their teaching evaluation and get your voucher, it could be printed at the end of the assessment, to present the day of the RMM.*
- *To avoid the problem that most students seeking academic load and had no proof of qualifications, was set to half-listed from highest to lowest average avoiding the paperwork and getting your average print data directly from the registration system is constantly updated by the controller.*

For the slave servers do not commit infractions or errors are found the head of the server race will enter the students to groups, the slave servers would be responsible for follow-up (check in a notebook to make revisions if necessary, review of required documents, registration quotas, delivery receipts and file of documents on file).

In addition to the above, there was general dissatisfaction because students complained that students with academic problems remained with the best locations and schedules due to "less idle time."According to the planning and process requirements are determined to apply the model of multiple servers and a single row. With the above posed a different kind of attention to the following considerations:

1. *To avoid the problem of poor students use to obtain the best times, was set to half-listed from highest to lowest average, thus avoiding the paperwork and getting your average print data directly from the registration system.*
2. *With the above set of arrival rate of 14 persons per hour, but the service rate was 16 people per hour, and there were assigned hours to be respected.*
3. *Work continued with the prerequisites of the foregoing*

This form of work achieves a considerable improvement of service and a drastic reduction in waiting times.

CONCLUSIONS

To simulate a process either in the production of goods or services is a very dynamic and full of observing the behavior of systems, obviously the support we have of mathematical models is also a central point in making decisions.

Then performing the simulation of the RMM with the mathematics, we obtained the reference point allowed us to appreciate the first options for resolving the problem of long wait times suffered by the students. The data focused on the combination of resources that would be used.

In the simulation was able to observe the difficulties and bottlenecks generated when applying the model to many of the features that can not be included or considered in the mathematics.

This research could determine the model that allowed the optimum combination of resources which in both cases (maths through the simulator) was to have 3 servers in sequence, but take it to the real world had other complications that either were part of the model to simulate and there was no way to integrate it.

After analyzing the simulated system and applied in a real environment identified other variables affecting the system and could be considered for the implementation of the model.

This allowed for better planning of previous activities that caused conflict in the application of the model and which were finally resolved.

In conclusion, the shortest waiting time was up it was less than a minute and the largest was five minutes, in general we can say that eliminated the long waiting line for students to expect, 5 hours, for treatment.

NOMENCLATURE

λ = average rate of arrivals per unit time. Is the arrival rate of customers and their units are customers / unit time.
μ = average service rate per server. Is the arrival rate of customers to the server and their units are customers / unit time.
N = number of servers. They are serving customers in row.
L_q = average length of the line in queuing.
W_q= average waiting time.
L_s = average length of the line in the system.
W_s = average waiting time.
U = use of installation.
P_0 = probability that there are zero customers in the system.

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