A Case Study Through Queue Simulations of a Basic Health Center

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Abstract — *The objective of this paper is to propose improvements in the emergency care of a basic health center, in a small country town in the state of Minas Gerais (Brazil), based on the application of a discrete event simulation tool, in order to solve the queue saturation problems. The study is based on collected data, such as: service time, patient arrival time in the queue, patient departure time, interval between patient arrivals, priority percentages based on the type of service, number of employees. From the data collected, emergency care was simulated in order to visualize various ways to solve the problem. The proposed solution uses the licensed practical nurse to assist the head nurse in the screening process, thus increasing by one the number of patients seen per day, which proves to be relevant since an average of twenty-one patients are seen per day.*

Keywords — *Emergency service, Simulation of Discrete Events, Queue.*

I. INTRODUCTION

The training of each basic health center (UBS) is adapted to the requirements of each region, which is responsible for ensuring the health of the residents of a specific region, named the coverage area. The entire health schedule and actions of a UBS health are directed at this group of people.

The service is free and is intended for prevention only. In more complex and/or emergency and urgency cases, they are referred to an emergency room, in which there are appropriate equipments and tools for such services.

The simulation of discrete events has its importance due to its wide range of segments, and it can be an operational research technique due to its originality in the Theory of Queues, making it possible to analyze the systematic process behavior based on its time and characteristics. In recent years there has been an increase in interest in this area due to the precision of predicting how the system behaves very close to reality. However, not yet all the features of such a tool are known. Few institutions provide services aimed at teaching the tool's approach [1].

Improvement is a process of seeking different set of resources for conditions that can be controlled by looking for a combination of resources that offers the most expected means of a simulation model. Today there are several software that make it possible to practice improvement through simulations, among them, we can mention: OptQuest, OPTIMIZ, AutoStat, WITNESS Optimizier and SimRunner, which have the function of commercial packages in that the simulation module is also incorporated [2].

The queues start due to the growth in customer demand and the disqualification of the system. Therefore, through simulation methods, the aim is to reach a level of balance that serves the users and is viable to the service provider [3].

Given the above, this paper aims to improve, by means of simulation methods, organization and design of experiments, the operational dynamics in the emergency department of a UBS located in the Zona da Mata region of the state of Minas Gerais (Brazil).

II. THEORY BACKGROUND

A. Operational Research

Operational research is essentially based on the concept of the scientific method of solving an obstacle or task. The analysis of the processes and the definition of the problem are the most fundamental points to reach the solution [4].

Operational research is an extension of Manufacturing Engineering that provides managers with admission to a structured and solid procedure that facilitates them in the difficult function of human resource management, transportation, finance, materials, among others. Indeed, this important area promotes scientifically based tools for managers to make decisions, making planning more efficient and consequently avoiding losses [5].

Simulation and queuing theory are devices of operational research, however they are not as objective in relation to the methods mentioned, as they require simulations with changes, tests and observation of system performance in order to understand which arrangement of resources will yield the best system return or productivity [4].

As such, the use of this tool contributes to the solution of problems both in the quantitative and in the qualitative part, providing its users with important data to predict future results.

B. Queue Theory

Another technique is the simulation of discrete events that have queue theory as a principle. Although not as straightforward as other techniques, it is of great importance for the improvement of practical situations.

Due to the large number of new individuals that has been increasing daily, it is common to observe the discontentment of consumers because of the waiting lines, due to the lack of a good customer service policy, lack of trained attendants, system deficiency, among others [6].

The period of simulation and discrete events is discontinuous, that is, the simulation is performed in discrete time intervals. It is highly complex to produce a simulation only for discrete events and exclusive to constant events, from the moment that two problems arise in each other, even if in small intensity [7].

The simulation of discrete events has the function of complementing the theory of queues, given that it is a device that examines problems of similar queues; however, with the emergence of computers, it made possible to create software that facilitates the performance and analysis of calculations and simulations.

C. Simulation of discrete events

In general, queue theory is the analysis of pauses that occur in many possible ways. It uses queuing processes to show the different types of queue (systems that include queues of the same model) that they display in real situations. The equations for each type of queue show how the queuing process suits the job, including the average waiting time that will happen, in a set of circumstances [1].

Queue theory is a tool that works on problems through mathematical formulas and with values that can be measured, with the collection of real information, to be executed in a context, in which the purpose is to optimize the system or the middle procedure in order to have a queue that is convenient for the client, monitoring costs and bringing the most efficient process possible [8].

D. Software Arena

Arena is a graphic software composed of simulations that involve abundant resources for statistical analysis, modeling, animation and analysis of results. The Arena simulation software has the following features: Input data analyser, Results analyzer (Output Analyzer), Process analyser, Optimizer (Optquest) [9].

The Arena software is the conjunction of the SIMAN package and programming language that incorporated into one of the most advanced simulation and graphic tools available, providing a process flowchart and with no code base to be placed. Through this, Arena facilitates the formation of information as much as possible. It has the function of statistical analysis, simple and 3D animations, result analysis. The software is produced by the company Rockwell Software [1].

The Arena software is a great tool for simulations and analysis of various processes. According to the increase in complexity, randomness becomes an essential component to understand the behavior of the system. Through dynamic analysis, and the relationship between the components of the system, it is permissible to define bottlenecks, adjust operations requirements, visualize queue dimensions, resource charges and examine the system performance [10].

Flowcharts are produced from simulations carried out by boxes and blocks, that is, in an intuitive way, since it constitutes the information of the company and the flow of processes.

E. Hospital Management

Due to the diversity of human resources, the complexity of the physical-functional structure and specialized materials that are essential to its activities, a clinic or small hospital requires a high and continuous financial investment, in which, in the great majority, exceeds profits and causes challenges to its development [11].

Some management strategies seek to maintain or guarantee corrective actions and/or continuous improvement in which they ensure both the management the hospital and its services [12].

The hospital management processes consists of investing in practices that enable the quality of services provided, financial sustainability and patient safety [13].

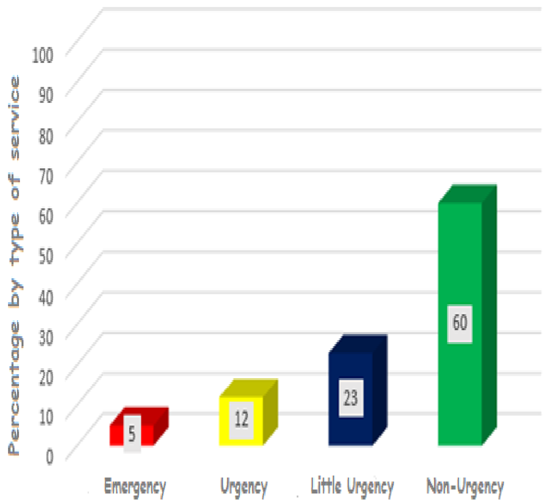
In view of the authors' statements, it is observed that hospital management is necessary, and management tools facilitate the study of processes, not only clinical, but also in association with patient satisfaction.

III. SIZING THE CASE STUDY

A case study method of a UBS is used to present the relevance of the technique, not only for processes in general, but also for simple and highly valuable systems for the community, in addition to help understand the discrete event simulation functionality. The research area was determined due to its high importance to the community. Initially, data collection was performed at the UBS itself on a typical day of care, then modeling the analysis and study of information in the Arena software.

IV. CASE STUDY

The objective of the study was carried out in a UBS in a small municipality, located in the state of Minas Gerais. According to a medical care system, in view of its many stages, it is quite complex, as it requires a set of elements with the order of priority of patients who need exams, treatments, among other factors. The first step of the study was to establish all these service procedures, which are performed by the UBS in the company of medical professionals, and then data collection was carried out. Thus, it was identified that approximately 20 % of patients who arrive at the basic health unit are patients returning and the remaining are new patients. Upon arriving at the UBS, patients need to complete a service record, in which it is done by two receptionists in a process that is called triage (TRIA), in other words, a triangular distribution, due to the fact that it takes an average of 3 min, at least 2 and at most 5, to be elaborated. It was observed that all UBS processes are treated as TRIA, excluding only the patient arrival process, which has an average interval of 6 min. After filling in the data, patients are sent for a screening with the nurse, which lasts an average of 8 min, a maximum of 10 and a minimum of 5 min. Figure 1 shows the four types of priorities and their frequency of occurrences of patients in the UBS, which is defined by screening, since in the cases treated as urgency and emergency, the patient is referred to a hospital.



The length of medical care has different waiting times depending on the type of patient, whether returning or new. In the case of a returning patient, an average of 7 min is spent, a minimum of 4 and a maximum of 10 min. When it comes to new patients, an average of 11 min is spent, a minimum of 5 and a maximum of 16 min. It is considered that the UBS has 2 working doctors.

Three types of treatment are employed in the UBS in special cases, the intravenous treatment, which has 10 available treatment spots and takes an average of 70 min, a maximum of 120 and a minimum of 40 min, the intramuscular treatment that is applied by one of the nurses, who spend an average of 4 and a half minutes to be taught, at most 5 and at least 3 min, lastly the third type of treatment is inhalation, in which the duration of the procedure takes an average of 10 minutes, maximum 13 and minimum 8 min. Inhalation and intravenous treatment are performed by the same nurse who performs the intramuscular treatment, which takes an average of 1 and a half minutes, a maximum of 2 and a half and a minimum of half a minute.

It was found that 60 % of patients are return patients, in which they make constant use of medications and go to the BHU to check in and renew the prescription, the rest of these patients are for consultation of common diseases, such as cold, and 10 % these are special cases in which you need medication intravenously, intramuscularly or inhalation. However, it was observed that after exams, 60 % of patients need to return to medical care and the other 40 % are discharged, among those who return, 53 % return to the medical care queue on the same day, the other 47 % return to another day. Most of the return patients, around 90 % are classified as non-urgent, 9 % are classified as semi-urgent and only 1 % as urgent and after being seen, 78 % are discharged, 2% need specific exams and 20 % need medication. It has been reported that an average of 20 patients are seen per day.

After modeling the UBS processes under study in the Arena software, it was possible to diagnose the entire UBS service process, making it possible to carry out a critical analysis of the process. The appendix shows the whole process that the patient goes through the service, such as: Entrance, Screening, Treatments, Queue, Medical Care and Exit, generating a flowchart of all the steps that the patient goes through until the end of the medical care.

A. System simulation of the UBS

From the data collected, the simulation of an 8 h working day was performed in the Arena software. The data obtained was compared with the reality of the UBS to validate whether the simulation was reliable with the reality of the UBS.

Scheduled Utilization	Value
atendente 1	0.6117
enfermeira	0.3112
fila de espera	0.9882
medico 1	0.01708697
técnico de enfermagem	0.06616857

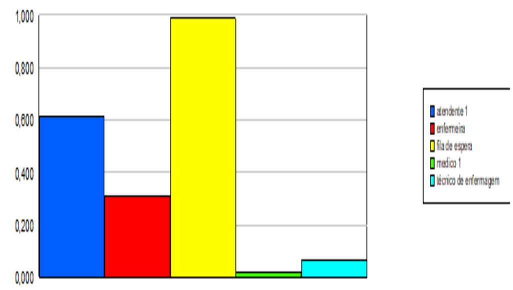


Figure 2 shows the report of the Arena software in which it is possible to observe the number of patients who are treated each day, in which the employees with the highest level of burden are: attendant with 61.17 % and nurse with 31.12 % of load. Within the report obtained is the average number of patients seen, in which the practical number is currently 20 patients per day. The simulation obtained an average of 21, which is in line with the reality of the UBS. Another parameter analyzed is the occupation time, which is consistent with that analyzed in the basic health unit.

The size of the queues was also analyzed, in the study it was found that the queue with the waiting time for the doctor's office is the longest at the UBS, which causes inconvenience to patients waiting to be seen.

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
atendimento médico paciente de retorno.Queue	0.00	(Insufficient)	0.00	0.00
atendimento médico paciente novo.Queue	0.00	(Insufficient)	0.00	0.00
Fila de espera para atendimento medico.Queue	32.7323	(Insufficient)	0.00	65.0000
inalação.Queue	0.00	(Insufficient)	0.00	0.00
tratamento de via intramuscular.Queue	0.01148758	(Insufficient)	0.00	1.0000
tratamento de via intravenosa.Queue	0.00	(Insufficient)	0.00	0.00
TRIA Atendente.Queue	0.4505	(Insufficient)	0.00	4.0000
TRIA Enfermeira.Queue	0.2031	(Insufficient)	0.00	2.0000

The report shown in figure 3 is in line with reality, in which the waiting lines for medical care are the longest. The report also provides information on patients' waiting times.

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
atendimento médico paciente de retorno.Queue	0.00	(Insufficient)	0.00	0.00
Fila de espera para atendimento medico.Queue	0.00	(Insufficient)	0.00	0.00
inalação.Queue	0.00	(Insufficient)	0.00	0.00
tratamento de via intramuscular.Queue	1.1028	(Insufficient)	0.00	5.5140
tratamento de via intravenosa.Queue	0.00	(Insufficient)	0.00	0.00
TRIA Atendente.Queue	2.4371	(Insufficient)	0.00	13.2937
TRIA Enfermeira.Queue	13.9235	(Insufficient)	0.00	49.9606

Figure 4 shows the waiting times for the processes carried out by UBS, in which it was analyzed and consistent with reality. After defining the three parameters, it was obtained that one of the processes that causes the greatest impact of time spent is the triage performed by the nurse, even with a low load time, the process demands a long time to be performed, that is, the reports indicate that the TRIA nurse process is a bottleneck for other subsequent processes.

B. Improvement Proposal

Observing the reality of the UBS, after analyzing and investigating whether it is possible for a licensed practical nurse to assist the head nurse without compromising their routine service, as their work involve subsequent processes, therefore, it would not cause a delay in their official service. This change was made in the Arena software in which there was a small increase in the occupation time of the nursing technician from 6.61 % to 22.41 % in which the occupation is kept low and without compromising their work and as a consequence there is an increase of 1 patient attended per day.

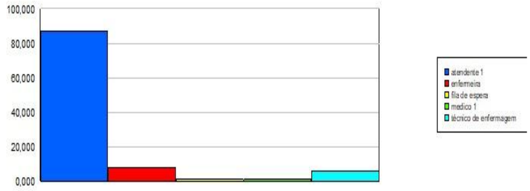
Replications: 1 Time Units: Minutes

Resource

Usage

Total Number Seized

	Value
atendente 1	87.0000
enfermeira	8.0000
fila de espera	1.0000
medico 1	1.0000
técnico de enfermagem	6.0000



User Specified

Tally

Interval	Average	Half Width	Minimum Value	Maximum Value
quanto tempo o paciente gasta	221.81	(Insufficient)	3.0394	470.39

Figure 5 shows the time spent by the patient from the entrance to the exit. The shortest time being 3.03 min for patients whose treatment was certainly treated as very urgent or emergency and for this reason left the UBS and was referred to a hospital, the longest time spent was 470.39 min representing patients in a special case who underwent the intravenous treatment process, such as patients who need venous serum and the average time spent by patients being 221.81 min.

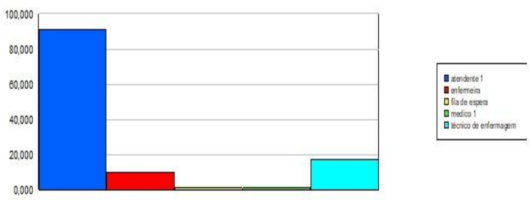
Replications: 1 Time Units: Minutes

Resource

Usage

Total Number Seized

	Value
atendente 1	91.0000
enfermeira	10.0000
fila de espera	1.0000
medico 1	1.0000
técnico de enfermagem	17.0000



User Specified

Tally

Interval	Average	Half Width	Minimum Value	Maximum Value
quanto tempo o paciente gasta	232.04	(Insufficient)	3.0394	471.41

Figure 6 shows the time that the patients spend to carry out the treatment at the UBS, but even though they visually appeared to have spent more time in the care, with this change the number of patients seen per day is increased by one.

V. CONCLUSIONS

The objective of the present study is to demonstrate the improvements in the waiting time of the queue in a UBS using simulation of discrete events, which made it possible to visualize and analyze the emergency care process.

This paper expands the knowledge in relation to the study of operations in view of the application of the simulation tool of a UBS that enables improvements in other UBS.

There are other wards that have not been presented, however they can be inserted for further research obtaining a broader dimensioning of all the services in which they are performed in the system under study at the health unit. It is essential to remember that operational research provides a list of tools and techniques, some of which are presented in the theoretical basis which can be used as a basis for future research in order to assist in management, decision-making, avoiding rework or loss resulting from unfounded scientific decisions.

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Apendix 1: Service Flowchart