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DISCRETE EVENT SIMULATION APPLIED TO SINGLE QUEUE MANAGEMENT: A CASE STUDY AT A BANK AGENCY

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ABSTRACT

Capacity and queue management are currently used in financial institutions. With decreasing bank units due to internet services, research in this field has focused on improving to utilize their employees efficiently and achieve service excellence. In developing countries like Brazil, the customer has become more bank-accounted due to government and labor requirements, such as the wage credit became mandatory in the wage account. The paper's aim is motivated by a real-life case study to simulate discrete events to improve queue management at a Brazilian bank branch with the Arena software simulation environment. The simulation model was designed, tested, and applied considering the Discrete Event Simulation (DES) replication for queuing strategies on a real-world banking scenario.

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The arrival and service times were collected from 115 customers in Ferraz de Vasconcelos/SP city. It was performed in version 15.10 (2018) of the Arena software, with processor Intel core i3 CPU dual-core 3.07 GHz and 8GB of RAM. The results indicate that the bank agency should consider providing 9 to 11 operators to attend customers considering the arrival and service rate.

Keywords: Simulation; Arena Software; Queues; Banking Management

1. INTRODUCTION

Government and labor requirements have become customers more bank-accounted as well as the growth of internet-linked services. The number of online services available to Brazilian banks has been increasing since 2015, where people are using smartphones and computers to connect to internet banking. Nonetheless, bank agencies and branches have been decreasing due to country technologic development, which caused an increase in the number of customers and reduced the number of employees.

The government imposed severe fines and sanctions on banks to avoid queues' time overflow when the queue surpasses five minutes. Queuing system monitors were adopted to attempt the solve these issues, but time overflow occur continually. Therefore, the challenge is understanding two points. The first is a waste of time-related to the service category since each category demands its time, and the second it refers to customer perception. This perception consists of customers' experiences with the system adopted (Ullah et al., 2014).

Recently, studies have focused on queuing management using technologies to solve these issues (Mourõo et al., 2017; Kambli, Sinha, & Srinivas, 2020; Entringer, 2020; Campos, Encarnação & Silva, 2019; Da Costa et al., 2017; Clementino et al., 2018; Dos Santos, Cajuí & Da Silva, 2020; Pereira Júnior, Da Silva & Moraes, 2020; Moraes & Silva, 2021). Some models have been proposed to identify the problem.

However, all of them face difficulties identifying many variables on the model for all the services categories and customers' experiences for a single queue. According to Zheng (2011) and Mutingi, Mapfaira, Moakofi, Moeng, and Mbohwa (2015), the importance of customer satisfaction and the time the customers wait before the services taking into account business competition to service quality evaluation. Cowdrey et al. (2018) studied different solutions for queuing methods, such as First in First out (FIFO),

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Shortest Job First (SJF), Last in First out (LIFO), and Longest Job First (LJF). They implemented a mobile solution using a Field Programmable Gate Array (FPGA) to bank queuing simulation. The results showed that LIFO disagree with the customers, and the best outcomes were obtained with the SJF strategy at peak hours.

This investigation presents a study about single queuing management through Discrete Event Simulation (DES) by Arena Software to improve customer attendance service, resulting in options that the bank can consider in designing operators' service.

This paper is organized as follows. Section 2 presents the theoretical references about the queue and discrete simulation subjects, Section 3 details the methodology used, and Section 4 shows the results of simulation using Arena Software. Section 5 discusses the results. Finally, Section 5 summarizes the results.

2. BACKGROUND ON SIMULATION CONCEPTION AND APPLICATION

To apply the simulation process concerning many aspects, but the most important is to identify and minimize process bottlenecks, and some techniques used on system modeling are queuing theory and computer simulation (Prado, 2017). Koyama, Gonçalves, and Chin (2016) clarified that queuing is a part of life routine, due to start when the resources are limited and the attending demand is high. The Queuing Theory concerning to process of attending the customer with agility and improve the company profit.

Moreover, Taha (2016), fortify that queuing theory is not a study to system optimization, but more than this is related to service performance indicators of the company. Costa (2003) elucidated that there is different queuing compose for some kind of attending, for instance, applied methods like FIFO – First in, First out or LIFO – Last in, First Out, and random system that not show any standard defined and is related the early attending considering priority criteria, in general, by law.

According to Andrade (2015), the most bottlenecks to be solved in a queuing study is how to minimize the attending of customers congestion and reduce the accumulation of people due to operational limited resource. The Author argued that queuing congestion affect the company profit, so is it important to manage the timing of the operation, as well as two fundamental variables that directly impact system performance: 1) the numbers of customers arrivals per period; and 2) the capacity to attending the quantity of customer in the system per period.

Exploring the queuing theory, Arenales, Armentano, Morabito and Yanasse (2015)

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highlight four queuing systems considering if has a unique attending stage or multiple stages of completing customers attending. For the three first models, there is the unique attending stage, and the four models are the multiple stages.

2.1. Simulation process and development of the concept

The simulation process was built over the years, and it was improved by computers during the II World War, as cited by Baladez (2009), Oliveira, Loshi and Pires (2018), EDVAC, MARK I, and ENIAC, the last one was used for ballistic artillery calculations in H Bomb Manhattan project design. Up to 70 decades, the simulation building was too expensive, due to the necessity to contract the specialized group with higher acknowledgment.

The simulation system model is a construction of graphics to present the interaction among systems part, in other words, is an abstraction to reality, as closer to real system behavior as possible (Chwif & Medina, 2014). As Prado (2017), concerning using the word simulation, explained that there is much interpretation in this context to system modeling, but there is a consensus that when applying simulation, a system or ideal process is being imitated.

Therefore, Chwif and Medina (2014), presented concepts as a system is a group of elements of a unique function, that are linked considering some interaction and interdependence, to run some process. The entity is an important object in the system, and an attribute is the characteristic of the entity. Moreover, activity is described as some action consumption time to be processed. The system state is a variable group important to describe the system in a period. Besides, the event is defined as actions that could change the status of the system.

The simulation process is present in the household environment due to a personal computer became a household appliance and it is used daily, so the simulation process could be applying in many cases (Prado, 2017). However, considering a complex world and the creation of big data, becoming easier to applying simulation, the technology aggregated value in this process.

Therefore, a simulator is software capable to produce and operate simulations of some system behavior. Among software more common, it is possible to highlight spacial, agricultural, textile, flying, medical, shipping, wars, mechanical, transportation simulators, and so on (Baladez, 2009). Nowadays, is common to use the PROMODEL, HEXAGON,

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FLEXSIM, CAD, and ARENA software to construction small and big simulation process to optimize time and profit. For instance, simulation applied to optimize logistic operation especially transportation system as such railroad, road, shipping, and airway.

De Freitas Filho (2008) mentioned that the system computer simulation translates the application of mathematics techniques based on computer performance, to imitate process function, system, and actual operation. Many authors present the simulation concepts, however, is important to highlight what is not consider simulation, in this aspect, Chwif and Medina (2014) clarified that simulation is not a psychic process neither future predict model, is not a mathematic model closed, as well as is not any descriptive tools and not overlap an intelligent perception in process of decision making. The authors continue to recommend that simulation should be not used after detection of fails from other techniques that have been applied in the same way, simulation should be avoid applied to solve specific problems.

To clarity, Leal (2016), mentioned that simulation into the computer system in the first step creates an ideal model, so data were obtained based on queuing theory study. After this, it is possible to calculate the statistics and identify the variables that represent a random behavior, and procedure with the distribution of probability and building the sample to use in adhesion tests. To demonstrate this, Freitas (2008) reinforced that the simulation process must follow some standard to its construction, Figure 1.

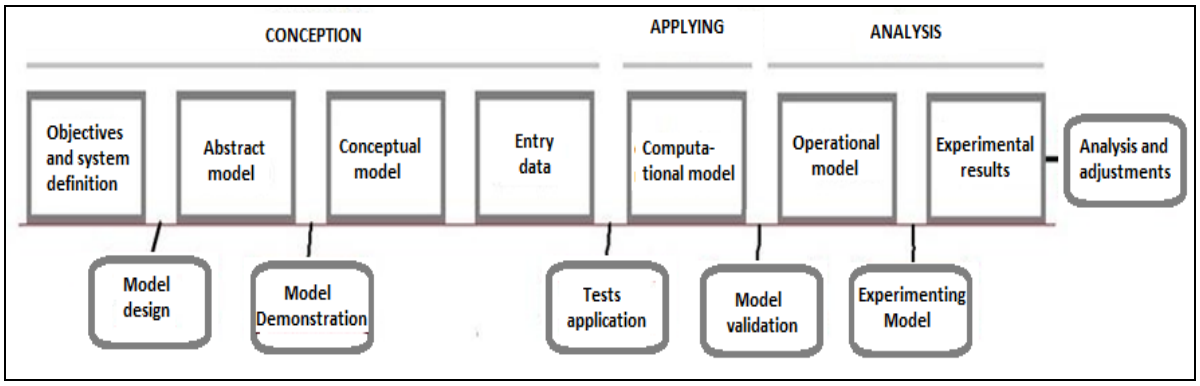

Figure 1: Simulation process in blocks
Source: Adapted from De Freitas Filho (2008)

On the other hands, Law, Kelton and Kelton, (2000), listed some common criteria on simulation model programming, as such:

- To create random numbers, in other words, observation from the distribution of probability.

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- To create random variables based on specific probability (for instance, Poisson or exponential).
- Advance in simulated time should be applied on event discrete.
- Inputting data into the software.
- Collect data statistics from the block and report results to the direction.
- Detection of the error condition to a new adjustment

Taha (2016) explained that queuing studies are probabilities into a stochastic standard and because to be random it presents an indeterminate state due to discrete event. So, this data into a simulation is translated as a behavior measure that reproduces the real system and how it reacts. Moreover, every method shows some advantages and disadvantages, in this way, Andrade (2015), argued that there are many advantages in applying simulation for business, such as predict results, reduction of decision errors, measure system performance, properly resources apply. Moreover, Corrêa, Gianesi and Caon (2001) cited that there are also some disadvantages in using simulation associated with simulation model size, due to demand time and complex technical process, as well as the utilization of specialized hardware and expensive to data process.

3. METHODS

Marconi and Lakatos (2017) explained that scientific research has the objective to guide and support decisions adopted by researchers, following an action group and norms that trying to reach the scope of the study considering reduce time, money, and applying security to validate the finding. Based on Silva and Menezes (2005) explanation, we consider this study as research applied due to it has the objective to contribute to the solve real problem of the company used as a case study.

According to Guedes and Araújo (2013), contextualized that in the banking sector, queuing management is highlighted as an important method because it explores the limits of the system to offer a great solution without extrapolating company resources. Therefore, it is necessary to consider simulation models procedure in three steps, first the conception of the system (clear objective and modeling conception), second conducting the computer simulation model using specific software, and the last one is to obtaining results after many simulation rotations (Chwif & Medina, 2006). The simulation models were performed in version 15.10 (2018) of the Arena software, with processor Intel core i3 CPU dual-core

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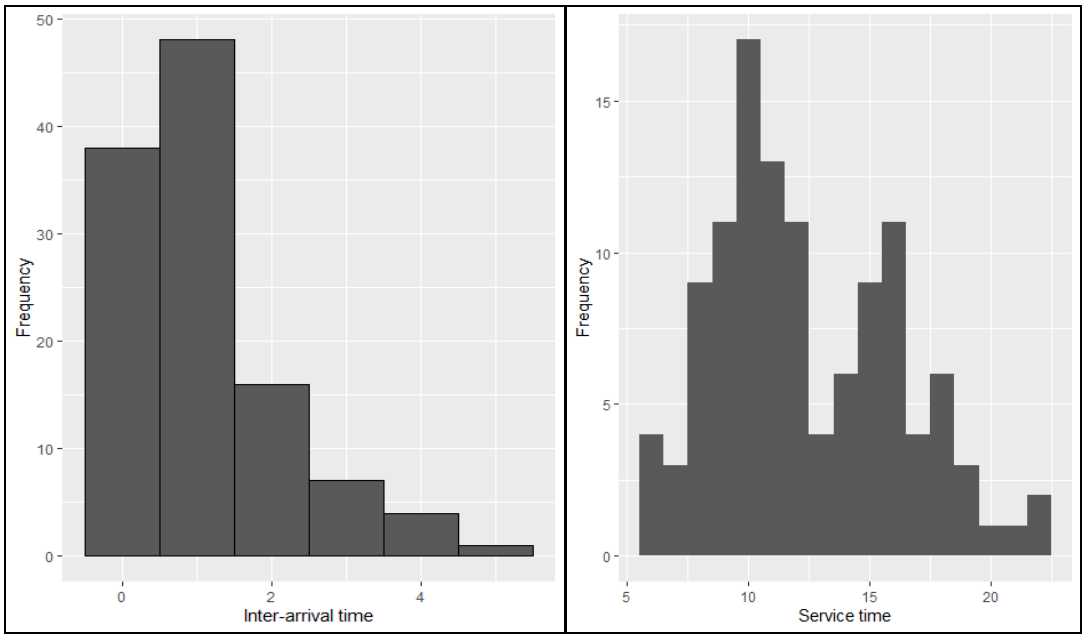
3.07 GHz using 8GB of RAM. The data were collected in a bank agency in the city of Ferraz de Vasconcelos/SP. The agency is open from 10h to 16h. The data is a sample of arrivals of 115 customers collected during 1h10 from 13h14 to 14h20, and the service time of operators from the same period.

4. RESULTS

The arrival times and service times were collected from 115 customers. The histogram of the data is presented in Figure 2. The inter-arrival times were tested to identify which distribution would best fit the data. We used the Input Analyzer of Arena to perform this analysis. The best distribution fitted was Gama. The results of the tests can be seen in Table 1.

Table 1: Results of the test of inter-arrival times and service time

	Inter-arrival times	*Service time*
Distribution	Gama	Triangular
Expression	-0.5+Gama (0.699, 2.23)	TRIA (5.5, 9.2, 22.5)
Squared error	0.003264	0.007831
Chi-Square test	1.58	8.01
p-value	0.22	0.22



[a] Inter-arrival times [b] Service time

Figure 2: Histogram of the inter-arrival times and service time

After the tests, the model was built on Arena as shown in Figure 3.

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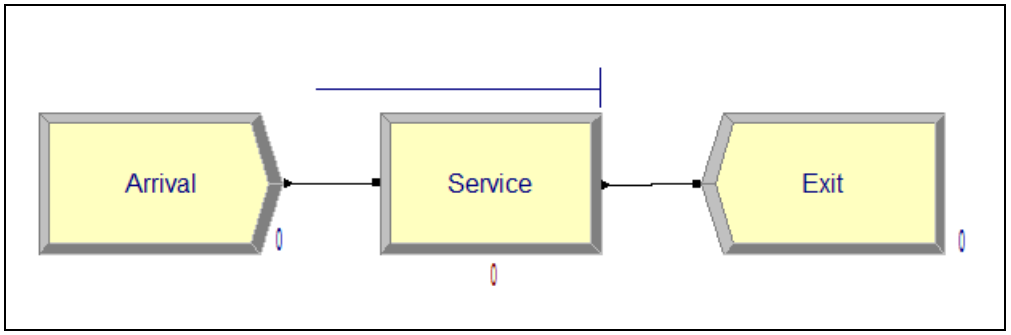

Figure 3: Model in Arena

We performed 100 replications by changing the number of operators to verify the change in the number of customers out of the system, waiting time in the queue, queue length, and utilization. The results are shown in Table 2.

Table 2: Results of simulation

	Quantity of operators				
	9	10	11	12	13
Number of customers out	254	279	303	318	323
Waiting time in queue (minutes)	38.46	26.05	12.36	5.22	2.22
Queue length	36	25	12	5	2
Utilization	0.98	0.98	0.96	0.92	0.87

The results varied in a different proportion due to the number of operators. In the first scenario, with 9 operators, 254 customers are served, waiting on average 38 minutes in the queue. The queue length, in this case, is 36 customers long. Also, there is high utilization (0.98) with 9 operators. On the other hand, with 13 operators, 323 customers are served, the waiting time in queue is reduced to an average of 2 minutes, the queue length is 2, and utilization drops to 87%. Table 3 presents the relative variation in the parameters.

Table 3: Relative variation

Quantity of operators	9	10	11	12	13	Average change
Number of customers out	-	+9.84%	+8.6%	+5%	+1.5%	+6.23%
Waiting time in queue (minutes)	-	-32%	-53%	-58%	-57%	-50%
Queue length	-	-31%	-52%	-58%	-60%	-50.25%
Utilization	-	0%	-2%	-4%	-5%	-2.75%

As can be seen in Table 3, the parameters that suffered the larger change were the waiting time in the queue and the queue length, with a drop of 50% on average, and the parameters that changed less were the utilization dropping only 2,75% and the number of customers out rising 6,23%.

5. DISCUSSION

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In the present study, the simulation showed that with 9 operators (banking service desk), the waiting time in queue is on average more than 38 minutes. According to the law of the city of Ferraz de Vasconcelos, No. 2,682, from December 20, 2005, the item I, on normal days, except the day before and after holidays, and on paydays, a customer must wait in line for a maximum of 15 minutes.

To comply with the law of the city of Ferraz de Vasconcelos, the bank branch must use 11 operators, increasing the number of operators by 22.22%, reducing the waiting time to an average of 12.36 minutes, having 96% of operator utilization.

According to the simulation, 10 operators would still not be enough to comply with the law of the city, as the waiting time would be 26 minutes, more than what the law determines. With 12 and 13 operators, there is a significant decrease in waiting time, maintaining a good level of utilization grade by operators, but it could be an increase in costs due to the need for more manpower.

The simulation and the Arena software used by Fisher (2018) in his paper, confirm that the bank branch complies with the city legislation. The Author, used the fixed simulation, the same used in this paper, confirmed according to his data that the probability of complying with the city legislation is 98.6%.

Paz, Teixeira & Alberti (2016), focused the simulation using the Arena software went beyond, adapting the bank branch to the local legislation, other alternatives were studied, such as the qualification of employees, seeking a decrease in the normal service time by 20%. In this way, it could be possible to maintain the number of operators, increasing the number of customers out from 212 to 224 and with the potential to improve the utilization of the operators, because there was a reduction of utilization from 95% to 83%.

The simulation proposed by Entringer (2020), increased the utilization of the operators. The Author proposed the reduction of one operator, obtaining an increase in the utilization from 50.07% to 71.10% and increasing from 1.47 minutes to 8.23 minutes on average in the waiting time in the queue, an increase considered small by the Author.

The simulation was also used to minimize queues. Pinto, Silva, Costa, & Macedo Lemos (2018), proposed to increase the number of operators by 50%, from 2 to 3, decreasing the average waiting time in the queue from 17.16 minutes to 1.48 minutes on average, and also decreasing in the utilization from 80.37% to 56.50%.

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6. CONCLUSION

The simulation has proved to be an important tool for managing the queue and decision-making at a bank branch. With the study, the bank branch can verify the need to comply with the city law, increasing the number of operators from 9 to 11 operators, reducing the waiting time to 12 minutes, according to the law.

Increasing two more operators can also increase costs, and to minimize it, financial companies have been working for massive development using internet transactions, and in automatization, their process and improvement programs can be developed according to Paz et al (2016).

As a suggestion for future studies, in addition to the improvement programs, more data will be necessary, distributed over several times and days of the week and in other situations, such as on days before and after holidays and paydays to further study and improve the understanding of customer behavior at this branch.

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