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Application of the Queue theory in the Optimization of systems of attendance in the ice Cream Shop in the city of Manaus-AM-Brazil

Manoel Eurizelio lima Maia Junior, Marden Eufrasio dos Santos, David Barbosa de Alencar

Academic department, University Center FAMETRO, Manaus-AM, Brazil

***Abstract*— *A queues through investigations of probability distributions generated and directed to the flow of customers and services to meet the demand of new customers waiting time in queues through practical ways. This work had as objective, a real reduction in the service queue of an ice cream shop. They were selected according to the specific needs of the optimization of processes, eliminating bottlenecks and processes. Some services have taken into account the peculiarities of the place, and public, having been receiving quality services and financially for the clients.*
***Keywords*— Theory of Queues, Process optimization, probability.**

I. INTRODUCTION

Queues are integrated into our lives, we come across them every day, they are easily found everywhere we go. Whether it's a simple trip to a supermarket, or even the time to pay for the products purchased, we will participate in queues. Queues are also visible in the production process, either awaiting the raw material to forge a particular part, or in the production line waiting for the previous processes to continue production.

Queuing theory and a mathematical subdivision of probability, which studies the creation of queues through mathematical formulations, is possible to calculate the beginning of the queue and even the sizes that will reach in the future, through existing models and mathematical formulas, it is possible to size this information so that an ideal layout can be created to meet the necessary demands of the queues.

Because the ice cream shop is a direct customer service, it has to address the employee to request the service desired, create temporary queues that directly affect the waiting time of the same, adversely affecting the process of the service to be offered; the agility in the queues appeals directly to customers, due to the fact that they expect less, waiting for that and for them time lost since it does not add anything to the process of acquiring your product.

Through data collection at peak times, it is possible to identify the main negative factors that contribute to the formation and development of the queues, with this data at hand and possible to work on effective solutions to solve the problems identified, using the numerical data of times of queuing, customer service, and if it is possible to perceive the temporal deficit that is in the service flow, using the tools of queuing theory makes it possible to identify the data that will be necessary to supply the demand of identifying the total number of queues required and the ideal time to take the activity.

II. LITERATURE REVIEW

Even with all technological advances, companies that provide direct customer service will not be able to get out of the queues, the congestion of customers in queues for the purchase of products or services, be it invoice payments, internet or bank services, or until the use of equipment, for example a printer of papers, and a daily problem that the administration must handle, the waiting time in a queue reflects directly in the quality of the service of a certain establishment being directly connected the quality of the service offered.

The ice cream shop has a model of direct customer service, that is, all the service offered and requested to the responsible official, after the request is made the same, goes to prepare the service that was requested, that time between the request and the the queue is formed during the flow of processes, queues that do not add benefit to the process, and only cause customer dissatisfaction. The ice cream shop has a model of direct customer service, that is, all the service offered and asked the responsible official, after the request is made the same, goes to prepare the service that has been requested, this time between the request and the conclusion of the service, creates if a lead time, due to the attendance system if by

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single queue, and the arrival rate is higher than the attendance rate, form the queue in the course of the flow of processes, queues that do not add benefit to the process, causing dissatisfaction to customers.

2.1 QUEUING THEORY

The queuing theory is a technical and mathematical concept that aims to minimize the queues that form in the process and services lines, through determined theories and formulas, if it is possible to realign them, consequently the correction of lost time in the waiting of the process of attendance.

According to [1], it is noticed that the waiting, in general, sensitize the client in its future behavior. A consumer dissatisfied with his waiting time may be able to give up his purchase at that time, however, he may no longer return to that establishment because of the perceived negative image. This is a difficult loss to be quantified, and if the problem persists for a long time the establishment will drop demand without discovering the reason of it.

When offering a product, it is offering a range of service, the time to complete the service is one of the most important factors, due to affect directly in the customer experience, leaving to positive or negative memory.

However, queuing theory is not only applied to people, in industries this fact often occurs, parts and products can wait for processing. As well ships may be waiting to enter the ports, and airplanes may be awaiting authorization to land [2].

According to [3], a queuing system is composed of many elements that are waiting to be serviced at a service station and that should wait until the station is available. According to [4], in the characterization of a queuing system, it is possible to highlight five basic components, the model of arrivals of the users, the service model, the number of available channels, the capacity for user service and the discipline of queue.

All queues follow parameters that can be measured which are them: clients, quantity of clients in the process; Average number of clients in queue (Lf) and arrival rate (λ); execution of care; limit of resources, be they equipment, helpers, among others; frequency of the queue; Number of service channels, average number of customers in queue (Lf); Average number of customers in the system (L); Average time the client waits in queue (Wf), average time that the client waits on the system (W).

The form of customer arrivals in a system occurs, most often at random, ie the number of customers arriving per unit time varies according to the behavior of the arrivals flow. For this, it is important to make a statistical survey in order to verify the arrival process of the clients [3], [5].

2.2 MODEL OF SERVICE

Queue systems have varying structures, and each case requires a different analytical study. The structures can be classified as a single-queue and one-channel system, a single-queue system and multiple channels, and a complex system of queues and channels in series and in parallel [6].

The system of a queue is the simplest case of service queue, consisting of only one channel and a single queue, figure 1.

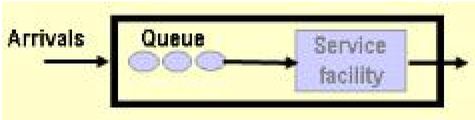

Fig.1: System single-queue and one-channel.
Source: [6].

The multi-channel system consists of multiple attendants for a single queue, thus facilitating service flow, Figure 2.

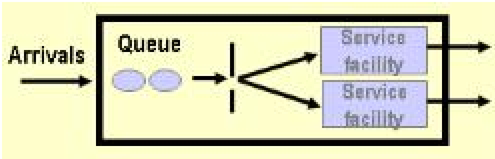

Fig.2: One queue and more than one channel.
Source:[7].

Single queues with 1 channel are the simplest and the most common ones, due to being the simplest and easiest applicable principle, however, depending on the demand in which the queue is fed, this concept must be rethought and reanalyzed in order to suppress the and provided in the queue by changing the channel quantity if it was possible to suppress the demand due to the increase in system finishing capacity.

2.3 LAYOUT

The layout also referred to as physical arrangement [8], is a graphical demonstration of the production system, although it seems to be only a system design, layout is more than that, it is a technique used to identify the locations to distribute properly the physical components of the production area, in order to organize the components in their proper places, in order to obtain the maximum possible efficiency in the production.

In order to establish exactly the layout of the production process, it is necessary to consider the location of the equipment and the employees, always aiming to be as close as possible to the process, without ignoring the process flow and the safety areas [9] .

According to [8], the 3 main types of layout are: Layout by product or linear in which the product moves between the machines and the workstations, which remain

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fixed. It is applicable on assembly lines. Process or functional layout is applied, for example, when products with different production flows are manufactured involving them. Fixed or positional layout in which the product remains fixed in place while machines and personnel move by performing the production tasks. This is the case of the manufacture of a ship.

An irregular layout with failures leads to a longer lead time [10], which can be improved with the alignment of the activity flow, shorter distance between equipment, less time in the process flow, which directly influences the service offered, due to the agility to carry out the process, directly influencing the reduction of queues, and customer satisfaction.

2.4 Ishikawa diagram

Known as a cause and effect diagram because it demonstrates the relationship between the possible and effects and their causes, facilitating the understanding of the problem, also known popularly as a fishbone due to its shape, the more detailed the diagram is more like a fishbone

To build the Ishikawa you must follow some steps:

• Describe the problem to be analyzed.

• Do a research on the causes to be able to elaborate the diagram, using methods like check sheet, or any other.

• Construct the diagram by specifying the problem on the right, and choose the categories of causes that will be used, such as measurement, method, people, machines, environment, materials. Or whatever you think is necessary.

Carry out the analysis of the diagram by observing the frequent causes, analyzing those that have a greater influence in the problem's appearance, thus being able to look for a plausible solution.

III. MATERIALS AND METHODS

The study was carried out in an ice cream parlor that serves the public from Monday to Sunday, from 11:00 am to 11:00 pm, with a daily workday of 8 hours per employee, which is between service preparation of the service and delivery of the service together with the payment of the customers. The ice cream shop has 1 queue and 1 service channel.

The methodology applied was as follows, a survey of the arrival and attendance times was performed, and after the queue calculations were performed, the results were used the Ishikawa diagram, whereby the main problems were identified and finally proposed new layout for optimization of the process.

3.1 USED QUEUE MODEL

In order to accurately measure the process times, searching for the solution of the queues required the collection of the queue arrival data, queue times, and total service time.

Arrival in the queue is the number of customers arriving in a certain time interval, which can generate a probabilistic behavior, which justifies the same arrival of clients at a certain time, for example, the probability of arriving 2 clients every 30 minutes, is visually analyzed in the actual queue, by collecting the time of arrival of the clients and the interval between them, it is possible to calculate probability of arrivals of clients at a given time.

Queuing time is the time that the customer takes when arriving in the queue until being served, which takes time in the process that is very unsatisfactory for the client, and interferes directly in the customer experience, and directly influences the service time. Total time of service is the time of arrival in the queue until the exit of the system, time that appears in the actual experience of the client, sum the previous times with that of the service, and determines the actual time of the service flow, and with it is possible to analyze temporal bottlenecks, and where to improve. In order to better target the collected data and analyzed parameters it is important to map the activity flow, the current layout of the system, being able to propose new layout, and correcting the unnecessary lost times and bottlenecks presented.

The single-queue attendant system used in the system, shown in figure 3, by the design of the current layout, as it is possible to be observed, has an excess of queue causing dissatisfaction in the customers waiting on it.

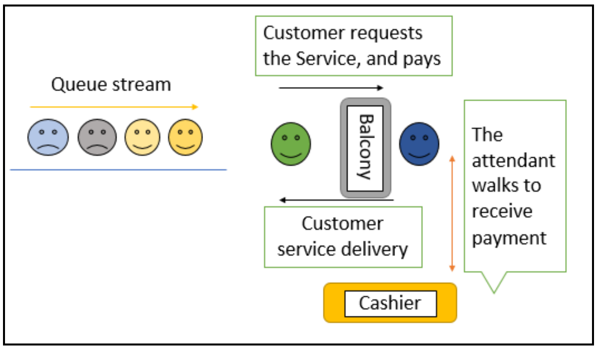

Fig.3: Current Layout

Source: author

3.2 IMPORTANCE OF THE LAYOUT

As the layout becomes old, defects begin to be visible, due to several factors, which can be an increase in productive demand, change in process, among others. These defects create bottlenecks in the layout process, creating unnecessary activities, which cause delays in the process, thus making the layout expensive, because of this it is important to modify the layout so that the current process needs can be met, because the layouts are assembled to meet a specific process, they are subject to

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the process, if there is modification in the process should modify the layout, because they are in a connection and depend on each other.

By proposing a new layout in a way that harmoniously assimilates with the variation of the service channels, eliminating unnecessary activities, the system becomes leaner and more practical, being able to complete the service cycle within the necessary walls, improving the customer's final satisfaction.

IV. IMPLEMENTATION

In order to eliminate the system's needs, it was analyzed the important factors for the implementation of the suggested process through the Ishikawa diagram that made visible the main causes that directly influenced the cause of the problem, later the analysis of the current layout where unnecessary activities are observed that influence the growth of the system, generating activities more than necessary, is due to the collection of data at peak service times that demonstrates the reality of the problem, thus proving the need for change, so a new layout, which in sync with the new service process will solve the problems encountered supplying the needs of the demand, made so the practical system is lean towards customer satisfaction at the end of the process.

4.1 LAYOUTANALYSIS

By analyzing the Ishikawa diagram, we identified the factors that were negatively influencing the queue flow, problems that were in the actual layout that was in the installed system, the factors that were hindering the process flow in the layout, was the position that was the service desk, the cashier that was located a considerable distance from the service desk, since the service and payment was done in the same operation, the employee took considerable time to go to the cashier to make the payment of the customer, unnecessary time that directly affects system time, making prolonged directly affecting the waiting customer, another observation was the lack of visible information about the variety of flavors and containers of different sizes, thus creating an increase in time due to the employee to have a dialogue with the client explaining the formats of services offered s and flavors available, an explanation that could be of a visual form and the client would only have some doubt if it were necessary, since the customer would already know the service he wants, thus developing the flow of time.

4.2 IMPLEMENTATION PLANNING

Observing the errors that were explicit in the layout, the need to split the queue demand was analyzed, it was also observed that it was not necessary to create 2 queues because the space was limited and also the demand was not so great, with the help of the mathematical calculations of operational research it was possible to verify that the minimum number of service channels to supply the demand will be of 2 channels

4.3 LAYOUT IMPLEMENTATION

The crucial part was to propose and deploy the new layout, figure 4: proposed layout, with the necessary corrections for the problems encountered, that goes from the reallocation of the freezers with the nearby box, facilitating the interactivity between the operations, and the informative signs with the flavors and types of service, facilitating the visibility of the customer, who expects to be served the same is already analyzing what will be your request, thus facilitating the time to make the purchase and entertain during waiting in line.

In order to develop the process more efficiently, unnecessary activities were eliminated, with the introduction of the box next to the service desk, with a specific employee to receive and pass the change, thus eliminating an activity that was performed by other employees.

In order to develop the care flow, it was analyzed and found that the use of a single queue with 2 channels of care was feasible to supply the demand, thus making the service quick and practical, since the related activities were lean, eliminating unnecessary ones , and redirecting the important activities in the correct order to be applied.

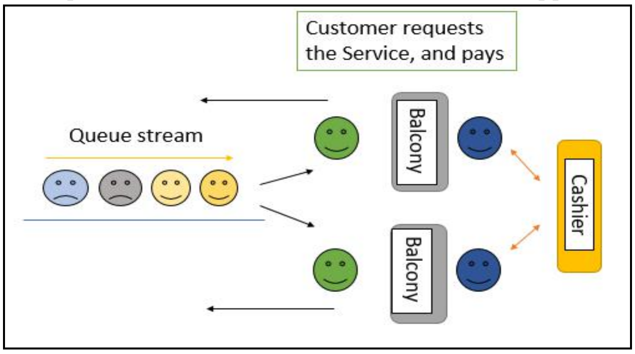

Fig.4: layout proposed

Source: author

The customer upon arrival goes straight to the single queue, while the queue is already analyzing the service you want, and the channels feed and as they are getting free, the time will vary from client to client due to the choice of services that are different and the quantity is also requested, ie a customer choosing a service with greater complexity will take a longer time to be attended, noting that the choice of 1 or more services can occur thus increasing the time in the process, it is worth noting that due to this it is not possible to create a single time parameter for each customer due to these possibility of different quantities and services, the average being used.

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V. DATA ANALYSIS

Observing the queue that was formed in the ice cream shop, the data was collected through a digital timer, shown in table 1, the variation of time between arrival, queue and attendance.

Table 1: Data obtained with only 1 channel.

Customers in Queue	Arrival Time (min)	Holding time (min)	Service Time (min)
1	0	3,03	1,93
2	0,38	1,42	0,62
3	0,65	2,35	1,13
4	1,13	4,35	1,91
5	0,53	3,41	2,18
6	1,57	5,25	3,75
7	0,22	2,25	1,37
8	1,28	3,34	2,60
9	1,23	3,67	1,94
10	2,31	2	0,97

With the data collected it is possible to consolidate some information through calculations, using applicable formulas to accurately demonstrate the real situation, thus facilitating the analysis of the facts.

$$P_o = \text{Prob}\begin{bmatrix}\text{system is}\\ \text{empty (idle)}\end{bmatrix} = 1 - \frac{\lambda}{\mu}$$

$$L_q = \begin{matrix}\text{average number}\\ \text{in the queue}\end{matrix} = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

$$L = \begin{matrix}\text{average number}\\ \text{in the system}\end{matrix} = \frac{\lambda}{\mu - \lambda}$$

$$W_q = \begin{matrix}\text{average time}\\ \text{in the queue}\end{matrix} = \frac{\lambda}{\mu(\mu - \lambda)}$$

$$W = \begin{matrix}\text{average time}\\ \text{in the system}\end{matrix} = \frac{1}{\mu - \lambda}$$

Note:
λ is the arrival rate.
μ is the service rate.

Using the data shown in table 1, it was possible to verify the following results:

In the sample of n = 10 clients, it was identified that arrival rate (λ) = 1.07, Service time (TA) = (total service time divided by number of clients) = 1.84 clients / minutes, rate (ρ) = 2.14 clients / minute, average number of clients in the queue (Lf) = 4,03 ≅ 4 clients, average number of clients in the system (W) = 3.7 minutes, Average time the customer waits on the system (W) = 5.74 minutes.

Observing the data found in the system with only 1 channel presents an overload due to the arrival rate being higher than the attendance rate with the queue is always with 4 clients on average, and presents an overload in the client system, thus generating the dissatisfaction of the clients. customers that are waiting in line.

After the new layout was implemented with 2 channels, another data collection was made through digital timer, table 2, following the same parameters of the same data collection, considering the peak time and the same amount of sampling (n) = 10 clients , to be able to compare the two models, the old and the new.

Table 2: Data obtained with 2 channels.

Customers in Queue	Arrival Time (min)	Holding time (min)	Service Time (min)
1	0	0	2,93
2	0	0	0,62
3	1,65	1,2	1,25
4	1,60	2,23	1,41
5	0,50	1,73	1,18
6	1,11	2,65	1,75
7	1,22	1,23	1,85
8	1,08	1,72	1,68
9	0,23	1,85	2,01
10	1,31	1,05	0,79

Using the data shown in Table 2, it was possible to verify the following results:

In the sample of n = 10 clients, it was identified that arrival rate (λ) = 1.15, Service time (TA) = (total service time divided by number of clients) = 1.55 clients / minutes, rate (ρ) = 1.79 clients / minute, average number of customers in the queue (Lf) = 4 clients, average number of clients in the system (L) = 0,64 clients / 5.79 ≅ 6 clients, Average time the customer waits in queue (Wf) = 3.5 minutes, Average time the client waits on the system (W) = 5.03 minutes.

It is possible to observe that there was a reduction of the overall time in the system, queuing time was reduced, with the same queue flow and system queues, the queue time was greatly reduced, comparing table 1 with table 2, about 51.28% of the time was reduced by adding a second service channel, leaving the system in equilibrium, the system power is higher and consequently the queue reduces faster, proved by the reduction of 51.28% of the same as previously reported, it is observed that service time was also reduced by around 15.92%, showing that clients are less undecided due to the placement of identification plates, and the service was faster, thus generating a gain end of favorable time, generating a quick and lean flow of time, thus generating customer satisfaction, which is the main goal achieved.

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VI. CONCLUSION

The application of the queuing theory study in a queue of ice cream shows that the use of Operational Research tools is feasible in small processes and also in simple day to day tasks, demonstrating that it is possible to optimize the performance of real processes, through layout organization.

The system studied had only a single queue to serve a channel, serving 1 client at a time, and it was found that it was overloaded, spent an average of 2.8 minutes in the queue and about 1.8 minutes to be served, showing clearly the delay that the old service system suffered. After applying the new layout that started to be a single queue served by 2 channels, it showed a significant improvement, the average queue time was reduced to 1.3 minutes, and the attendance to 1.5 minutes, the customer service has improved, due to the fact that the service involves several factors, customers take some time to decide the purchase, however it is noticeable that the use of signs and the leaner process influenced the reduction of service time.

Due to the availability of space being reduced, there was an initial difficulty in deciding how to modify the layout, so as not to generate unnecessary costs, because the analyzes are at peak times and at normal times the queue flow is less overloaded.

In order to consolidate the information on customer satisfaction, it is suggested to perform a satisfaction survey to determine if the waiting time is satisfactory, for future studies it is proposed to collect new data at different times and different routine days, such as holidays, weekends, beginning of the month, to see if there is a need to deploy a new service channel in the layout.

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