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Stochastic Timed Petri Nets Applied to The Purchasing Process: A Case Study in A Large Cosmetics Retailer

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Abstract

The purchase process of a large cosmetic and perfumery company is one of the pillars of its existence. When this process is time consuming or has a high concentration of responsibilities on a single manager, the productivity curve of the process can be affected. This fact is aggravated by the new perspectives of work and production due to COVID-19, where a high rate of unemployment and concentration of activities has permeated companies. This work demonstrates the application of the concepts of modelling and simulation, with the application of Stochastic Timed Petri Nets (STPN) as a proposal for efficient management. The first stage of the research consisted of an evaluation of the process in two aspects: the sequence of activities and time and money resources involved. The purchasing processes of the company were evaluated for four months at this stage. The second stage demonstrates the application of STPNs to manage the evaluated process. As a result, it was found that the financial values that guide service orders are between R$ 5.00 to R$ 80,000.00 Brazilian reais (totalling approximately R$ 800,000.00 during the analysis period), with service orders that accumulated approximately 120 days of delay for their resolution. In addition, a complete flowchart of the purchase process was developed, which enabled the use of STPNs. A simulator was created with the ability to identify bottlenecks (demonstrating the sectors and managers that need readjustments) and demonstrated proposals with 20% increase in the operational efficiency.

Keywords: Purchasing Process, Stochastic Timed Petri Nets, Retail, Modelling and Simulation, Large Companies.

1. Introduction

The retail market has an intense flow of customers with infinite varieties of merchandise with a limited quantity. In retail trade, the product segment can vary according to the target audience, ranging from food to electronic materials (Deepak & Jeyakumar, 2019).

The retail segment is the person, store or business that sells goods in a fractional way and in small quantities (Rasch, 2019). The retail sector tends to grow each year, regardless of economic cycles or capital costs. According to the National Confederation of Trade in Goods, Services and Tourism in expanded retail (involving all segments) sales are expected to grow by 5.3%, while in retail (except the automobile and building materials segments), the number should reach 3.5% in 2020. However, the retail sector started the year of 2020 in decline, showing the worst performance in a year, foreshadowing more intense losses ahead as a result of the closing of stores and shops due to the measures to combat COVID-19 (IBGE, 2020).

According to the Brazilian Institute of Geography and Statistics (IBGE) the volume of retail sales dropped 1% in January, when the sector was not yet affected by the coronavirus epidemic. Compared to the same period of the previous year, sales increased by 1.3%, against a projected gain of 2.5%. In 2020, the stoppages due to COVID-19 cause concerns about job losses and wage cuts, which should control consumption with force besides the closure of numerous factories and businesses (IBGE, 2020).

The inventory management process in this type of market is essential. Thus, the relevance of this research is precisely based on the statement that it is possible, through the combined use of organizational tools and modeling and simulation structures, to provide intelligent inventory management. This premise focuses on a critical analysis of the strategic organization of a company in the cosmetics and perfumery retail business.

Based on this, the article has the general objective of proposing the modeling of a tool oriented to discrete events, through the structure based on Petri net, for assistance and management in the optimization of the budget approvals process, in a large company of the cosmetic and perfumery sector. For this, the specific objectives are: to outline the current situation of the company through the organizational tools, organization chart and flow chart; assess the main bottlenecks in the supply sector process; model, through the Petri net, the purchasing process, in order to implement a management aid tool. Such exemptions aim to provide a capacity to optimize the time for approving budgets and to guide the definition of priority and expansion of branches.

This research aims to model and analyse mathematically the financial losses due to process delays. Such problems are due to the lack of standardization of the purchase process. Thus, the aim of this research is to highlight the financial values involved and through Petri net modeling to assist in the redistribution of authority and time analysis.

The aforementioned tools can operate as a reference for a discrete event modeling and simulation (SED) process used to model systems that change their state at discrete moments in time, starting from an event episode (Chwif, 2015).

Among the SED structures, there are Petri nets, which according to Lisboa et al. (2019) this methodology is an effective tool when it comes to simulate the process of the activities performed, to quantify the period of execution, to develop the simulation process and to work out the possible risks that may appear in the process, modeling the simulation and optimizing period scenarios, in addition to observing flaws and effects.

Organizations with their different strategic models of markets, from small enterprises to multinationals, must maintain their model of process in harmony and standardized and can increase competitiveness and intensify the chances of success and survival of the enterprise. When there is not a very well-defined structure, this model can lead to delays in the execution time and conflicts, be it hierarchy or activities to be performed. Even with this tooling set, it is not possible to measure how much this integration can optimize a company's process.

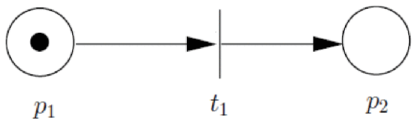
Thus, some questions guide this work: What sectors are involved in the organization? How does the procurement process in the Supplies sector work? How can it be distributed to the demands in this sector? Can the procedural flow be optimized? Would it be possible for a simulation structure, based on Petri nets, to assimilate supply management? These questions were answered during this research.

2. Material and Methods

2.1 Stochastic Timed Petri Nets

The elements of a Petri Net are composed of places (P), transitions (T) and arcs (A). Places or positions are passive elements represented by a circle, interpreted as a condition, resources, information or procedures. A transition is an active element in the Petri Net, represented by a bar or rectangle. They are associated with events that occur in the system. The nodes of a Petri Net are connected by arcs, labelled with weights (positive integers). Stochastic Timed Petri Nets (STPN), on the other hand, associate a stochastic distribution for firing times (Cassandras & Lafortune, 2009; Lisboa et al., 2019). Figure 1 shows an example of an STPN.

Figure 1 – Petri net example



Source: Lisboa et. Al, 2019.

2.2 Research Method

The methodology adopted for the execution of this work was the exploratory research model, where technical visits were made for better visualization and understanding of the scenario, in a company in the perfumery and beauty market located in the city of Belo Horizonte – MG, Brazil. Based on the information acquired over a period of five months, through data collection performed and analysis of the entire functional process of the supply sector, the following were identified:

I - Procedural evaluation: a flowchart is presented graphically, which illustrates the entire process of requesting, purchasing and meeting the steps that encompass the purchasing process in the supply sector. Being able to switch the long periods of delays in the current model of approval of purchase budgets and failures to execute the "Service Level Agreement" (SLA).

II - Simulation: a diagnosis of the company was carried out so that it is possible to propose an optimization in the purchase process. A simulation structure was developed using the Petri Nets tool, in order to simulate the purchasing scenarios of the company, based on the real data collected and propose alternatives, in order to evaluate the effects of purchases and direct authorities among buyers in order to improve the flow of budget execution and approval.

III - Application of the results: After defining the structure of the simulation tool, the needs were simulated, such as: hiring, firing, readjusting or training employees, and analysing the feasibility for the company.

3. Results

3.1 Process Flow Assessment

The procedural line for the supply sector is represented by the graph in Appendix I, which illustrates the timeline executed in approving a budget for purchases. For the purchase process to be completed, one must go through 6 procedural steps and 4 different sectors, in order to carry out the solution of the problem effectively and with less financial value to be paid by the company. In order to start the purchase process, there must be a demand and, in order for this demand to become an order, it is imperative to register it on a request platform, in order to facilitate the monitoring of this registration. The process is initiated through a specific demand.

With the request opened by the applicant, the demand becomes the responsibility of the supply sector and is directed to the waiting queue, where the responsible analyst begins the analysis process for each request. Due to the fact that those responsible for the request do not know the organizational structure, they end up opening undue requests and or, that do not belong to the supply sector and even without the real need for the requested demand, being possible the evaluation of the analysts, in order to, sequence only to the demands of purchase need.

After validating the request, the search for a supplier corresponding to the requested demand begins. At the request of management, it is recommended that the budget process has at least three suppliers, in search of the best negotiation value. A table is created with the budgeted suppliers and after analysis of values, the negotiation of discounts and payment terms begins, always looking for the best purchase condition for the company.

After the negotiation is concluded and the supplier is defined, the process is passed on to the sector manager, with the aim of evaluating the negotiation or even intensifying the negotiation and other appropriate situations of his performance. This process is taken to the superintendent, where together with the manager, they define, in fact, the first approval, if there is any way to

meet that demand without generating cost for the company, exhausting the alternatives, it is taken to the direction for final approval.

After the budget approved by the board, the budget process is returned to the analysts, a purchase order is generated and sent to the supplier, as approved by the board. Upon completion of the product delivery, the availability of the withdrawal referring to the registered order is passed on to the requester. Upon receipt of the purchase order, it is scheduled by the supplier on the date of the invoice and delivery of the order.

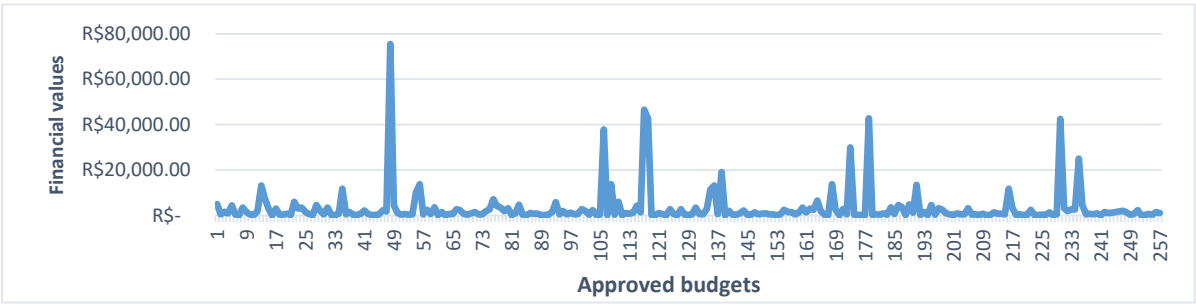
Finishing the requested process, only the withdrawal of the order is expected. After the delivery of the order completed by the supplier, the purchase process is finalized and the invoice with the approval is sent to the financial sector in order to make the payment.

In the financial sector, the invoice is checked, verifying if the budget with approval was signed by the board and if there is any divergence in the approval process. In the event of any divergence, the sector refuses the decision, leaving it to the analyst to resolve, otherwise the financial officer receives and follows the payment schedule.

3.2 Statistical analysis of the process

Data collection was carried out through the monitoring of demands in the purchasing budget (PB) process, where 257 samples of proposals were analysed in the period from January to April of 2019. The analysis began with the degree of relevance of the financial values, mentioned in the Brazilian Real (BRL) currency (R$) that permeates the negotiation of budget proposals, values ranging from R$ 35.00 (thirty-five BRL) to R$ 80,000.00 (eighty thousand BRL), with an average of R$ 3,108, 49 (three thousand one hundred and eight BRL and forty-nine cents) as shown in Figure 2 of financial values by approved budgets.

Figure 2: Financial values versus purchasing budget

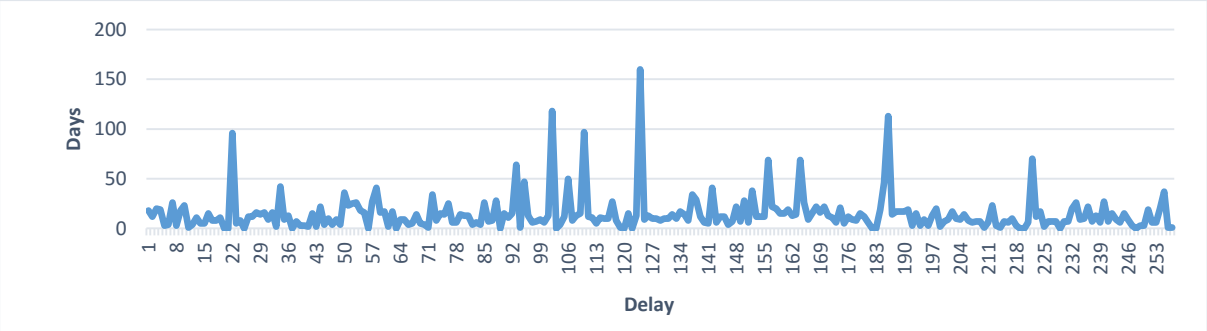


Source: Authors, 2020

In order to validate budgets, authorization is required from the operation managers, which is imperative to complete the process and respond to requests. Based on the data collected for this approval stage, long days of delays are perceived, causing bottlenecks, from simpler problems such as lack of supply of indirect materials to the branches, to suspension of the project under construction because it is not possible to purchase raw material for supply. In the

analysis of the data collected and exemplified in Figure 3, delays ranging from 1 day to 160 days were identified, with an average of 15 days of delay per budget.

Figure 3: Days of delay



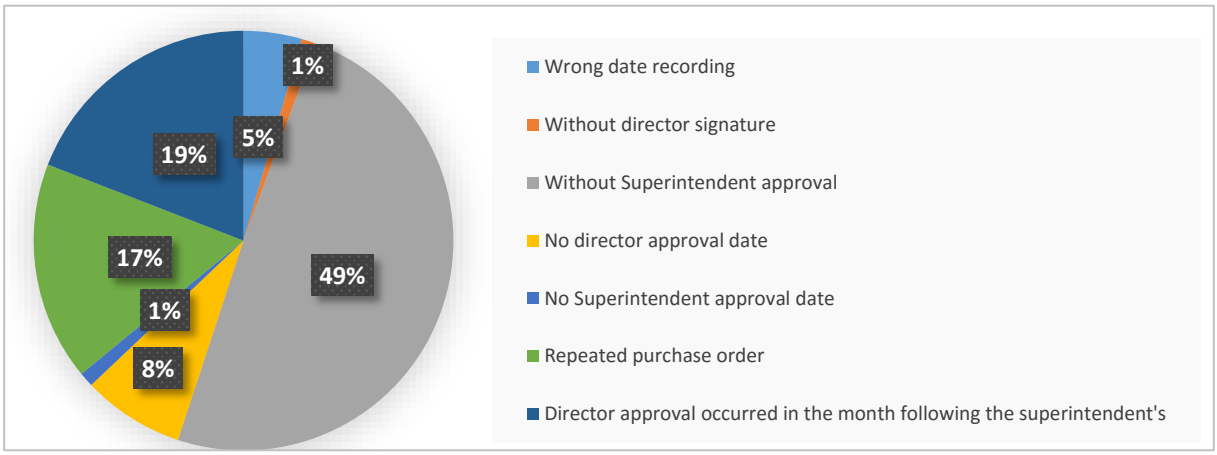
Source: Authors, 2020

Delays in approvals occur due to the absence of directors for final approval, superintendent and/or manager for budget validation. There are situations in which for the validation of budgets it is up to sectors other than supplies, which can cause large-scale delays in which the process depends on another sector for validation. In the operational part, delays can occur mainly, due to the analysts, who are directly responsible for executing the purchase process, are overloaded or do not contain the necessary information to start the quotation with suppliers.

Because it is a manually executed process, tasks tend to be more susceptible to errors that interfere on the results of the organization. Among 257 approvals, 90 budgets focused on errors related to the delays that guide the purchase process.

The data shown in the graph in Figure 4, indicate that the highest incidence is 49% of errors, which correspond to the absence of signature of the superintendent's approval and 1% without his authorization date, that is, the superintendent is the first position of management responsible for validating or invalidating the budget process, when there is no signature from this manager, it represents two situations, the first is that he was not in person at the company to authenticate the operation, whether on vacation or monitoring works at the branches, or not being responsible for approval, allowing the board to be directly responsible. Situation that makes the process at risk, as it does not contain interest among the pillars of those involved in understanding the real reason why that budget was executed.

Figure 4: Error distribution



Source: Authors, 2020

Every end of the month, due to the fiscal closing between financial and accounting, all budgets previously authorized by the operations superintendent who have an invoice and have not yet been authorized by the board, may be forwarded to the financial sector attached with a copy of the process until get the signature of the direction. Among the identified errors, 19% required the approval of the financial sector before the board authorized the process.

The remaining errors identified are due to manual failure, 17% of which were caused by an irregularly generated purchase order number, repeating the number already launched. Similarly, with 5% of the budgets, the execution dates were mistakenly launched.

Finally, the board's task is to validate the approvals, signing and dating the budgets, and the data collected indicates that 1% of the tasks remained unsigned and 8% do not have any dates for approval.

Even using the process in an archaic way, the requests were answered, but in an extremely inoperative manner, as it contained major bottlenecks in service time and request analysis. Most of the time, the board is absent, preventing the fluency of tasks. The negotiations could be executed in an optimized way, making the search for the best price become more effective, expanding the range of suppliers buying the best with the lowest. As shown above regarding the values that guide the purchase process, it is possible to identify great relevance in the supply sector, since a high monetary value was circulated, around R$ 800,000.00 in 4 months of analysis. It is well known that the concept of modeling and simulation can effectively guide decision making, contributing to the process management for the sector with the potential for purchases with values added up to over R$ 1,000,000.00 BRL.

3.3 Simulation structure modeling

For the simulation structure, the Petri net tool was used as a technique for the purpose of validating the flowchart of the supply process, preserving the fluidity and the steps

chronologically using the time of occurrence of the purchase process as shown Table 1, in which the network is timed and the value of the arcs corresponds to the displacement of the procedural steps.

Table 1: Description of arcs, places and transitions

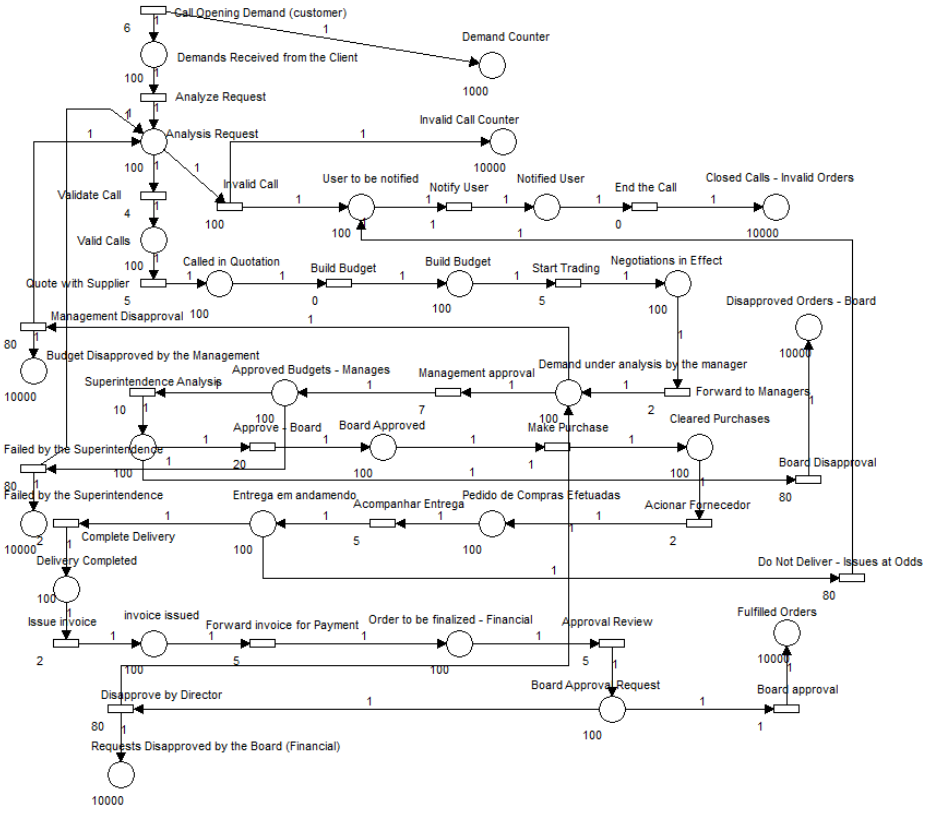
Places	Capacity	Transitions	Timing of transitions (exponential distribution)
Demand counter	1000	Demand opening of ticket (customer)	μ = 6
Demands received from the client	100	Analyse request	μ = 1
Request under review	100	Validate ticket	μ = 4
Valid calls	100	Quote with suppliers	μ = 5
Called in quotation	100	Set up budget	μ = 1
Assembled budgets	100	Start trading	μ = 5
Negotiations in force	100	Forward to management	μ = 2
Demand under analysis by the manager	100	Management approval	μ = 7
Approved budgets - management	100	Superintendence analysis	μ = 10
Approved demands - superintendence	100	Approve board	μ = 20
Board approved	100	Make purchase	μ = 1
Purchases released	100	Trigger supplier	μ = 2
Purchase orders made	100	Track delivery	μ = 5
Delivery in progress	100	Complete delivery	μ = 2
Delivery complete	100	Issue invoice	μ = 2
Issued invoices	100	Forward payment invoices	μ = 5
Order to be placed - financial	100	Approval analysis	μ = 5
Board approval request	100	Board approval	μ = 1
Orders fulfilled	10000	-	-
-	-	Disapprove by the board	μ = 80
Requests disapproved by the board (financial)	10000	-	-
Invalid call counter	10000	Invalid call	μ = 100
User to be notified	100	Notify user	μ = 1
Notified user	1	End the call	μ = 1
Closed calls - invalid orders	10000	-	-
-	-	Management disapproval	μ = 80
Budget disapproved by management	10000	-	-
-	-	Failed by the superintendence	μ = 80
Failed by the superintendence	10000	-	-
Disapproved Orders - Board	10000	Board disapproval	μ = 80
-	-	Do not deliver - issues at odds	μ = 80

Source: Authors, 2020

It is possible to verify the application of the tasks identified in the process developed by the flowchart to develop the modeling and simulation of the Petri net represented in Figure 5, where it illustrates the developed structure. After running the modelled simulation, it is possible to identify several bottlenecks that impact the entire approval process. In most of the problems identified, they occur in a cascade, as the board is not available to carry out budget approvals, this part of the process becomes the bottleneck delaying the other processes, similarly for the superintendence segment and / or management, making it impossible for the purchase to be made and, consequently, the service of the requester.

The graph in Figure 6 shows the main simulated bottlenecks involving the supply sector. In the graph in Figure 6, it is possible to observe the demands that require approval from the board and the superintendence have high bottlenecks, they are tasks that directly impact the process if it is not possible to be performed. Based on the idea of simulated bottlenecks for reality, the managers responsible for this part of the process, whether from management or superintendence, in periods of absence from the organization, it becomes impossible to execute these approvals, being necessary to wait for the return, until there is any date available for these budget release meetings.

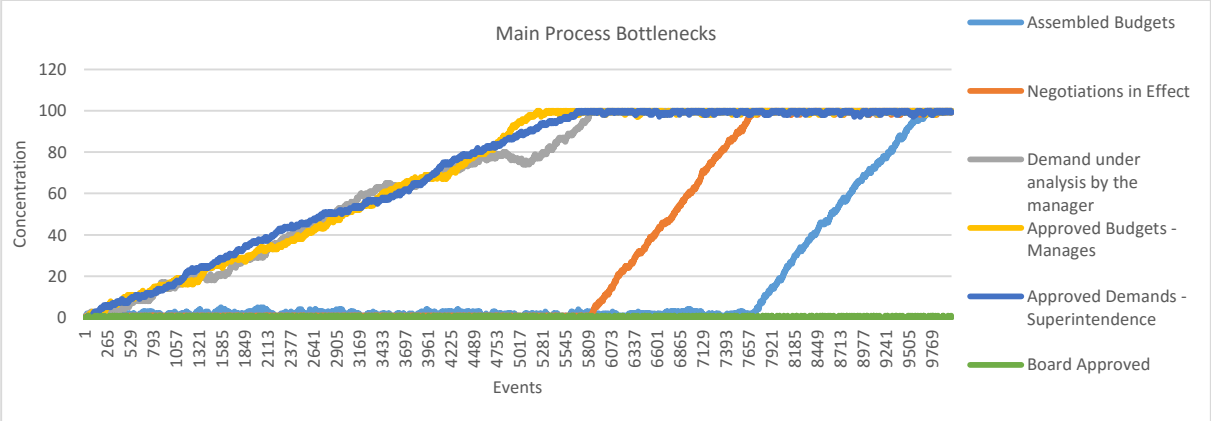
Figure 5: Simulation Structure



Source: Authors, 2020

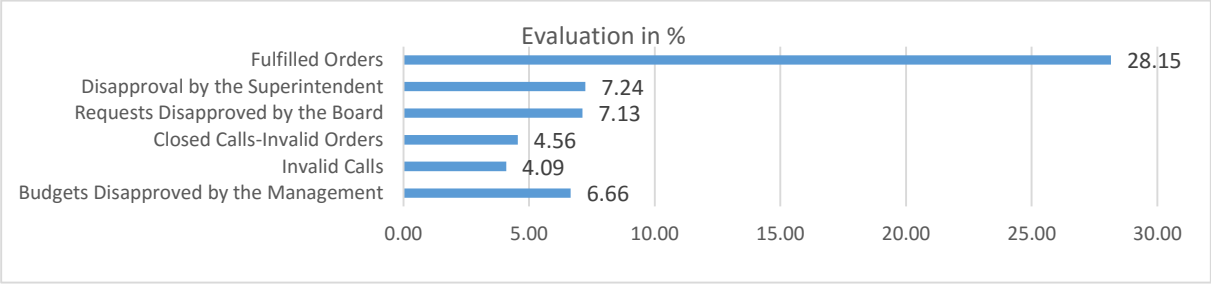
Based on the simulation, 856 budgets simulated by the purchasing process were generated, however, over 57% correspond to the orders that completed the process, whether approved or disapproved. The graph in Figure 7 shows the scenario for the completion of budgets, and it is possible to assess that within the margin of the completed orders, only 27% actually completed the approval process and answered the purchase request, just over 30% signalled how requests disapproved by the board, superintendent, manager or invalid requests, closed by analysts.

Figure 6: Main bottlenecks in the process



Source: Authors, 2020

Figure 7: Approval and disapproval percentages



Source: Authors, 2020

It is worth mentioning that in the disapproval stage, the order is not necessarily invalidated immediately, the budget can be sent to the other sectors of the process for correction, negotiation or some type of analysis and resuming the approval process again, following the flow normal.

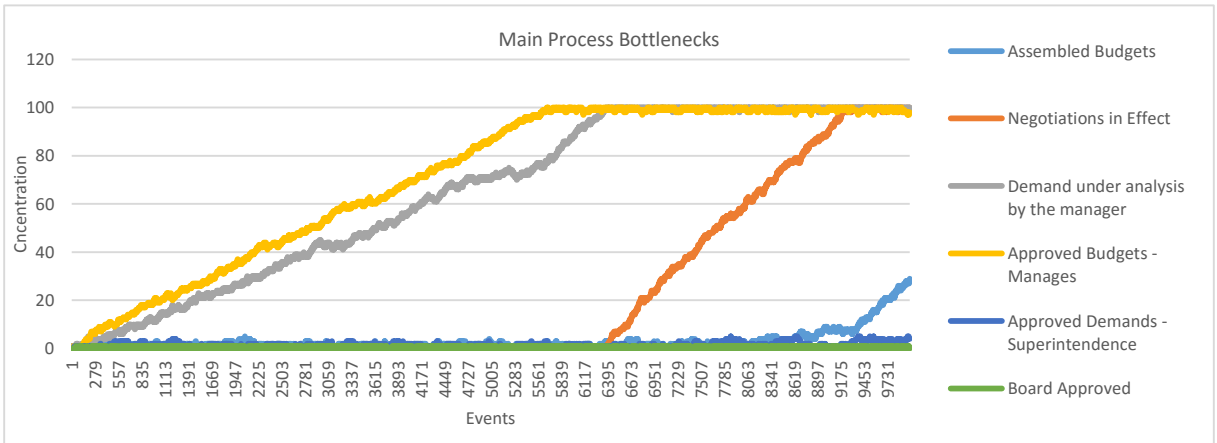
3.4 Simulation of Process Improvement Proposals

Based on the simulation carried out in the current process of the organization, a new scenario was created with the position of director, the main bottleneck of the normal process, in order to delegate the approval stage to someone you trust, in order to minimize your absence and optimize approvals. In this way, the procurement of supplies takes on a new scenario, with the fluidity of approvals by the board, new bottlenecks are beginning to be evident, approvals that require evaluation by management become the main limiter of this process, represented by the graph of figure 8 which demonstrates a new simulated environment.

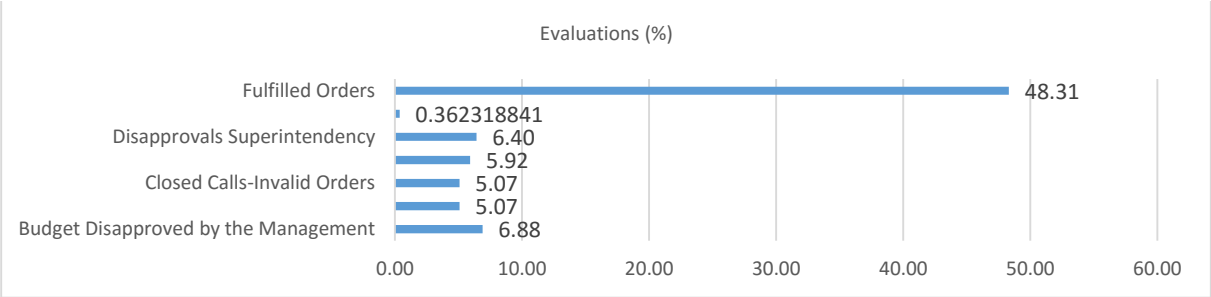
With the simulation of the new scenario, significant improvements in the process are noticeable: the initial 856 simulated budgets remained, it was obtained over 48% of the budgets achieved, 20% more than the normal scenario illustrated in the graph in Figure 9 on the percentages of approval of the optimization proposal.

Due to the numbers obtained in the simulation of the optimization proposal, it is noteworthy that the other managers become more active in the process, due to the fluidity of approved budgets. It is noticeable the most efficient managers, due to the increase in the disapproval percentages of the budgets.

Figure 8: Main process bottlenecks after Optimization



Source: Authors, 2020



Source: Authors, 2020

4. Conclusion

After the simulations and analyses carried out, it was possible to identify possible bottlenecks, concluding that the objectives initially proposed were achieved. A certain complexity was noted in terms of the analysis of the procedural flow, development of the organization chart, in order to analyse who are the responsible managers and participants in the process.

It is perceived great relevance of the work in relation to financial importance, in which circulates more than R$ 800,000.00 of turnover in the analysed process. Finally, identifying that through the modeling of the Petri Network a proposal to increase the efficiency of the board, whether hiring an employee or delegating autonomy, can increase the efficiency of the purchasing process by more than 20%.

Currently, the company operates with little technology and low investment range, which delays the development of the organization. Another point to be highlighted is the organizational culture, since it is a family business, the owners of the organization demand to have control over the entire extension of the enterprise, this situation becomes a bottleneck as to the fact that non-availability becomes routine.

A matrix organization chart was developed, which does not exist in the organization, in order to illustrate the positions and responsibilities, with the intention of representing the global configuration of the occupations and the relationship between the functions and the authorities in the internal environment of the organization, integrating all those involved in the process.

In order to model the simulation process, it was necessary to develop the procedural steps of purchases and identify the autonomies of those involved through the flowchart. Only after identifying these steps, it became possible to carry out the modeling based on the Petri Net tool, to simulate the current scenario and the possible solution optimization proposal, identifying possible bottlenecks in the purchasing process.

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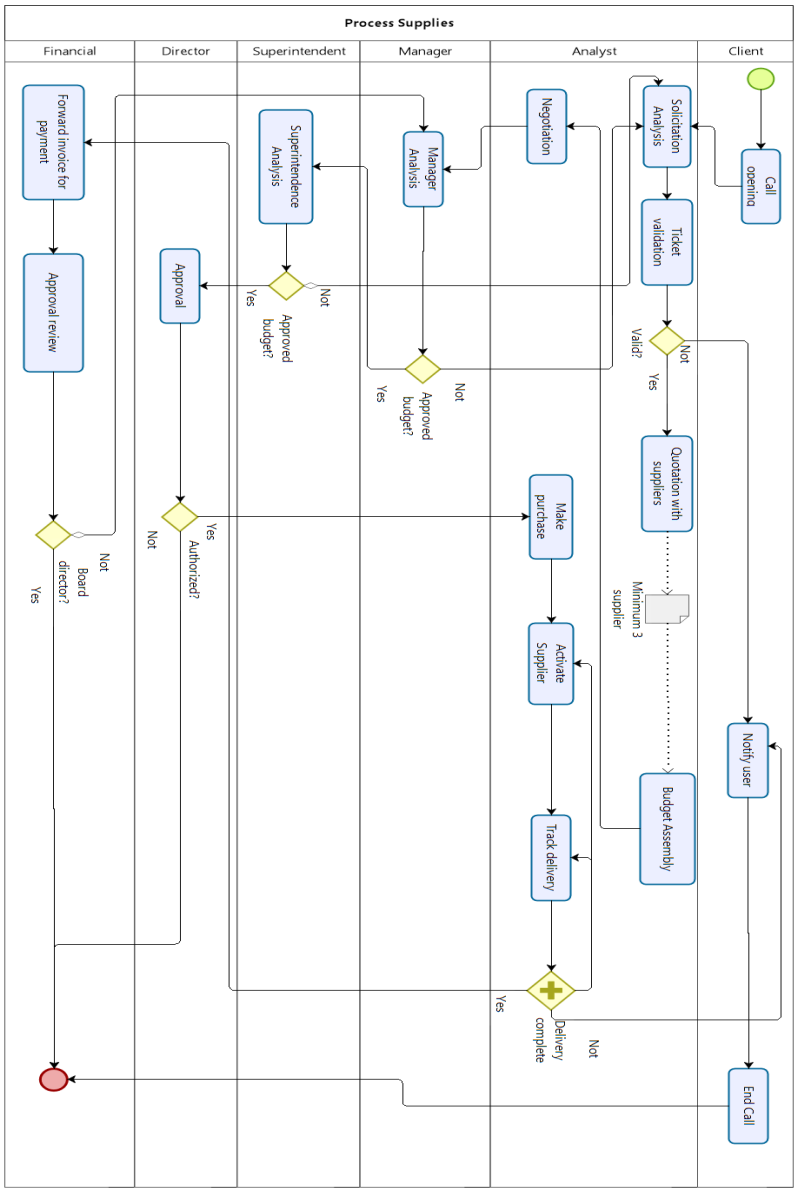
Appendix I – Process Flo



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Source: Authors, 2020