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Modeling and Simulation for the Purchasing Process: A Case Study in a Service Provider Company

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Abstract

The strategic management of processes is a key factor in improving organizational efficiency. This study analyzes the purchasing process of a service provider company using Petri nets to simulate the flow of processes. The analysis focused on purchase requests (in Brazilian Reais, BRL) with values above BRL 5,000.00, which are the most significant amounts to the company. The simulation started with a process model analysis called Business Process Model and Notation (BPMN), which was employed for the delimitation of activities and identification of analysis points. Preti nets were then created to evaluate the number of resources and duration of activities. At the end of the simulation process, graphs were generated to identify bottlenecks related to the steps involved in the purchase process. In summary, a modelling and simulation structure capable of representing a complex purchasing process was developed to manage and optimize the purchase process of a service provider company. For instance, several bottlenecks were identified in the strategic parts of the process and their mitigation was key to improving the efficiency of the company.

Keywords: Petri Nets, Purchasing Process, BPMN, Modelling and Simulation

1. Introduction

The purchasing process is an important step in the workflow of a large number of companies, such as suppliers, distributors, resellers, and producers. It guarantees the acquisition of materials and/or services at the correct time and aims at the best possible relationship between price and quality to increase profit margins. These are essential factors for guaranteeing the continuity of collaboration between the parties involved in the process. This process is even more critical in service provider companies as they may incur penalties from indirect public administration bodies, regulators, and their customers in the event of failures, delays, and/or regulatory disagreements. In addition, any issues in the purchasing process can impact the supply of necessary resources to proceed with service delivery, causing delays, harming the image of the company, and negatively affecting profits (Nise, 2017).

The appropriate employment of quality tools and specialized software to evaluate all possible scenarios in a company sector is of key importance to support the strategic management of resources, identify bottlenecks, and optimize the workflow. It is a control system, which consists "of subsystems and processes built with the objective of obtaining a desired output with a desired performance, given a specified input" (NISE, 2017).

Xavier (2022) defined the purchasing process in the industry, which involves five stages: (i) review and analysis; (ii) observation and prediction; (iii) supplier selection; (iv) planning and development; and (v) allocation and delivery. In contrast to the goods production industry, the income source of a service provider company is the service itself, which requires proprietary software for activity control and management.

According to Christopher (2022), quality can be defined based on the perspective of the customer and realization of their needs. It can also be defined from the perspective of a product and its tangible elements. Xavier (2021) explains: "on the one hand, the perspective of production evaluates quality by meeting technical requirements", on the other hand, "the perspective of value creation defines quality by offering a product with the best characteristics to the customer best price, creating value for the customer". Moreover, the author recognizes that such a concept of quality "is not static", which implies that "the emergence of new requirements and new tools leads to the need to continuously improve", which is an element that supports the use of the analysis proposed in this study. Petri nets provide models with high efficiency and analytical effectiveness. By employing such networks, it is possible to evaluate and develop events to optimize the production process, purchase, or even the provision of a service, with significant gains in efficiency, and increased customer satisfaction.

This study focuses on a case study analysis of a company in the field of service provision (Lisboa et al., 2019). The main objective of this research is to analyze the purchasing process

of a large company in the service sector to understand the proces workflow and identify opportunities for improvement. The following points are outlined as specific objectives: to analyze the purchasing process of a large national company in the service sector, assess opportunities for improvement, and simulate scenarios using Petri Nets. This work is an attempt to understand the current reality of the company situated in the state of Minas Gerais (Brazil) and evaluate the different possible scenarios using engineering tools to identify the best possible scenario. Therefore, it is expected that the use of simulation software will allow for savings and efficiency improvement in the workflow of the company, guaranteeing the optimization of bottlenecks identified (Lisboa et al., 2019).

2. Material and Methods

2.1 Services Sector in the Brazilian Scenario

Characterized by markedly diverse activities, heterogeneous in terms of size, average remuneration, use of technology, and services provided, the service sector stands out for its dynamism and presence in Brazilian economic production. Data from 2020 indicate that the activity of providing non-financial services comprised 1.4 million active companies, responsible for employing 12.5 million people, in a gross amount of 373.5 billion Brazilian Reais (BRL) in salaries, withdrawals and other remuneration, with 1.8 trillion BRL in net operating revenue and 1.1 trillion BRL in added value (IBGE, 2021).

Services provided in the field of information technology, including software for the management of the purchase process, registered a growth rate of 3.1% in 2020. The information and communication services segment corresponds to approximately 36% of the service provision market in Brazil (IBGE, 2021). Between 2011 and 2020, despite growth, the information and communication services segment presented a significant decay in terms of participation in gross revenue from services in all regions (IBGE, 2021).

Considering that the southeast region is the most relevant in the composition of the country's gross revenue, with 65.4% in 2020, and the state of Minas Gerais generating 11.8% of the total amount of the services sector, it is possible to verify the relevance of the development of specialized software in the process of purchase. These tools allow the optimization of processes based on the analysis of a complex set of elements in the company, as proposed in this study.

2.2 Flowcharts in Processes

In this study, the purchasing process of the company under study is analyzed so that an optimization process can be implemented. A thorough analysis is conducted to monitor, map, and organize the end-to-end flow of the purchasing process, covering the origin (producer, supplier, distribution, etc.) to the destination (intermediary reseller or even final consumer).

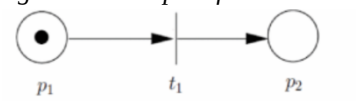
The design of the purchasing process involves the construction of a flowchart that clearly demonstrates the processes involved through a graphic representation that allows better visualization of bottlenecks and critical points. After careful analysis, it is possible to verify the issues and suggest corrective actions improve and optimize the system (Nise, 2017).

Identifying the details of the purchase flow process provides an overview of how it occurs within the company. By visualizing the present process flow, it is possible to suggest changes to establish an improved process that is more adequate to the needs of the service provider and its customers, acting directly on quality and satisfaction, and positively benefiting the service itself and the reputation of the company on the market (Nise, 2017).

2.3 Petri nets

Simulations with Petri nets were used for the tests in this research. According to Lisboa et al. (2019), it constitutes an appropriate technique for modeling discrete event systems, which can be timed and/or stochastic. Figure 1 shows a representation of a directed and bipartite graph that expresses a point of departure, a transition, and a point of arrival, which are characteristic of such a model.

Figure 1: Example of a Petri net.



Source: (Lisboa et al., 2019)

Its composition is based on places (white circles – p_1 and p_2), transitions (bars – t_1), directed arcs (arcs p_1t_1 and t_1p_2), tokens (black tokens) and marking vector x (in the case of Figure 1, x= [1 0]). The operation of the purchasing process in a given service provider company, which is under study, can be represented by a Petri net that ensures a clearer view of the workflow and allows for improvement to guarantee efficiency and optimize the operation (Cassandras & Lafortune, 2008 ; Murata, 1989).

2.4 Related Works

To support this research, studies with similarities and contributions that could serve as inspiration were analyzed. Table 1 presents an objective analysis of references that met this perspective. The expository table considers recent references on how the subject has been approached by other researchers, with methodologies, objectives, and conclusions similar to those possible in the present study.

Table 1: Comparative list of literature works

Reference	Description	Difference
Almeida et al (2022)	This study analyzes the processes of a small beverage distributor to identify bottlenecks and propose improvement solutions. The concepts and theories are based on organizational tools and the stages of the planning phase of the PDCA cycle (Plan-Do-Check-Act): problem identification, observation, analysis, and finally, the action plan of technical visits.	A service provider company was used, and the purchasing process using Petri nets was analyzed on the beverage resale sector.
Batista et al (2020)	The article presents a case study of inventory management in an orthopedic medical clinic, developing a system based on Stochastic Petri Nets (SPN) to simulate material availability scenarios.	For the current study, a service provider company was used, and the Petri net simulation aims to analyze the purchasing process and not the inventory process.
Ribeiro et al (2021)	This study is based on a tool that can model and simulate each type of product, with its time and resources spent during the manufacturing process, with a production hierarchy according to the production priority that the manufacturer requests.	The current study deals with the analysis of the purchasing process, not the manufacturing one.
Tocafundo et al (2021)	This article is about the purchase process of a large cosmetics and perfumery company, carried out during COVID-19, where a high unemployment rate and concentration of activities has permeated companies. This work demonstrates the application of modeling and simulation concepts, with the application of Stochastic Timed Petri Nets (STPN).	The current study with the analysis of the purchasing process in a service provider and does not consider extraordinary situations, such as COVID-19.

Source: (Authors, 2023)

The main contribution of this work is to demonstrate the importance of analyzing and simulating possibilities represented by software and a Petri net for optimizing the purchasing processes in the studied company. The computational model makes it possible to view existing relationships from end to end and to solve any problems encountered in the process. This capability is of key importance to ensuring the success of the enterprise, both quantitatively and qualitatively point of view. Furthermore, this work presents a case study of a service provider company, contributing to the literature on a particular process of a company operating in the market.

2.5 Methods

The present work is based on a case study to demonstrate the impact of the use of digital tools on the purchase process and the qualitative relationship between the service provided and the consumer. The tools used contributed to identifying the hierarchy and existing processes, which were analyzed using an organizational chart and a flowchart. The analysis contributed to identify bottlenecks and resulted in an action plan to solve the identified problems. This process allowed for the standardization of the information obtained, with an eventual gain in the quality of service provision.

Thus, this research was conducted in the following stages. The first stage covers the qualitative phase of understanding the purchasing process, with quality tools, in order to describe the production process of the company and to identify possibilities of contributions, bottlenecks, and the person responsible for each area. The second stage is Petri net modeling and simulation to identify the possibilities for optimization. The work ends with a critical analysis of the optimization possibilities with the guidance offered by the tool proposed by the modeling and simulation structure.

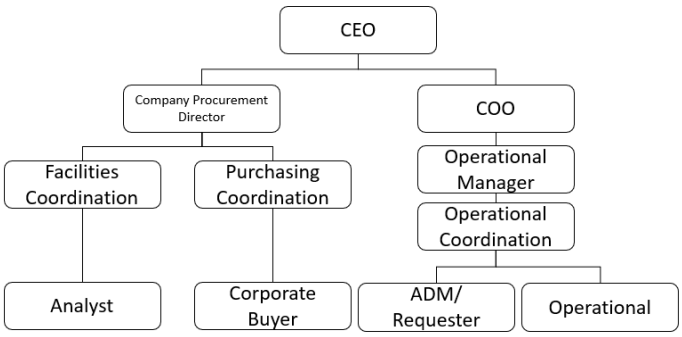
3. Results

3.1 Company Analysis

During the development of this study, a detailed analysis was carried out on the operation of the company, its sectors, and positions involved in the purchasing process so that an evaluation based on the organizational structure would be feasible. Thus, it would be possible to reach the objective end of bottleneck mapping and data collection, which would result in an action plan to solve the identified problems and allow standardization of the information obtained with eventual gains in the quality of service provision.

The structural base of the company was identified by mapping the positions involved in the purchasing process according to the organization chart in Figure 2, which shows the layout of the sectors, their communications, and hierarchies. The analyzed company, as can be seen, is composed of a CEO (Chief Executive Officer), a supply board and an operational board. The personal responsible for the control of the supply board are the coordination of facilities and their analysts, the coordination of purchases, and the corporate buyer. The operational board commands the operational manager and operational coordination and is composed of administrators, requesters, and the operations sector. The organization chart is one of the initial stages of the analysis of the processes of the company, and it is essential to explain the hierarchy of the company studied to facilitate the understanding of its structure.

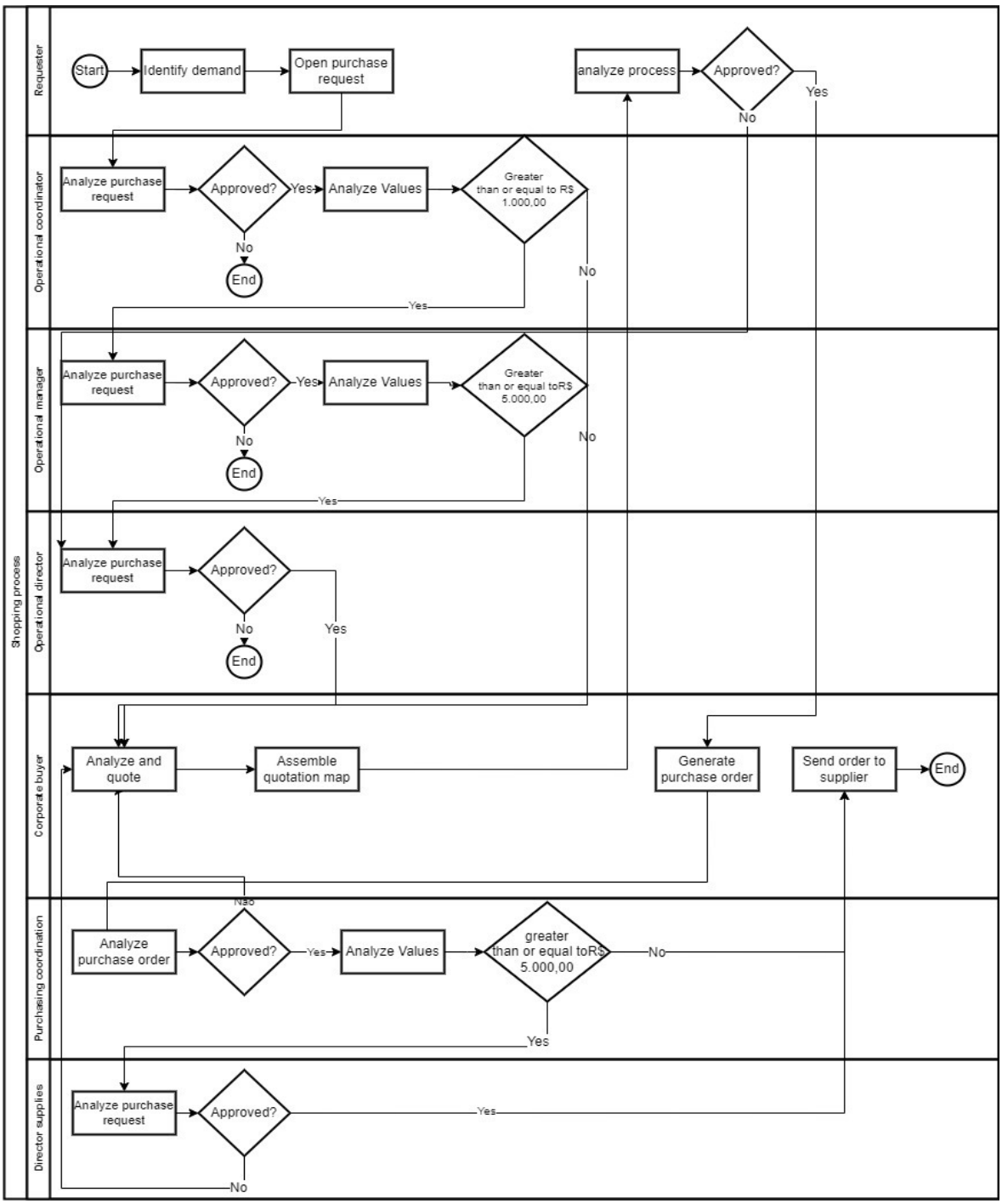
Figure 2: Organizational chart of the purchasing process of the company under study.



Source: (Authors, 2023)

This chart presents the CEO as the main manager of the organization, followed by its directors, managers, and coordinators, each in their respective positions in the hierarchy. Both areas (operational and supply) rely on each other to carry out the procedures, as illustrated in the flowchart in Figure 3. The flowchart aims to analyze all the procedures and tasks involved in the purchasing process of the analyzed company. This represents the workflow carried out in the purchasing sector, subdivided according to the functions mentioned in the organization chart (Figure 2). Each department is described as follows: supply department, responsible for analyzing purchase orders; purchasing coordination, responsible for analyzing the values of purchase orders; corporate buyer, whose function is to analyze the purchase orders, quote them, map them, and send the gathered data for operational approval; director and operational manager, who also analyze purchase orders; operational coordinator, who also analyzes purchase orders; and the requester, who is responsible for identifying the demand, opening the purchase request, and analyzing budgets.

Figure 3: Flowchart of the purchasing process of the company under study.



Source: (Authors, 2023)

As can be seen, the flowchart in Figure 3 presents, in a simplified way, how the purchasing process of the analyzed company takes place. The first step is carried out by the requester, and consists of identifying the demand and opening the purchase process request. Once

opened, it is forwarded to the operational coordinator. The second stage comprises an analysis of the request and its respective approval. If the value of the purchase request is equal to or greater than 1,000.00 Brazilian Reais (BRL), the analysis and its approval will be the responsibility of the operational manager, but if the value is equal to or greater than 5,000.00 BRL the responsibility will be with the Chief Operating Officer (COO). When a purchase request is approved, it is forwarded to the corporate buyer, whose role is to analyze and quote the purchase as well as produce the quote map. If it is approved, an order is sent to the supplier. Finally, Table 2 presents the standard time used for each task developed by the purchasing sector of the company under analysis.

Table 2: Analysis of Process Tasks and Resources.

Task	Approximate Average Time (Hours)	Resources Involved
Open Purchase Request	1	Requester
Approval 1	48	Operational coordinator
Approval 2	24	Operational Manager
Approval 3	24	Operational director
Quote and Analyze	200	Corporate Buyer
Assemble Quotation Map	48	Corporate Buyer
Approval of Applicant	24	Requester
Send request	24	Corporate Buyer
Approval 4	48	Buying coordinator
Approval 5	24	Supply Director

Source: (Authors, 2023)

3.2 Modeling Via Petri Net

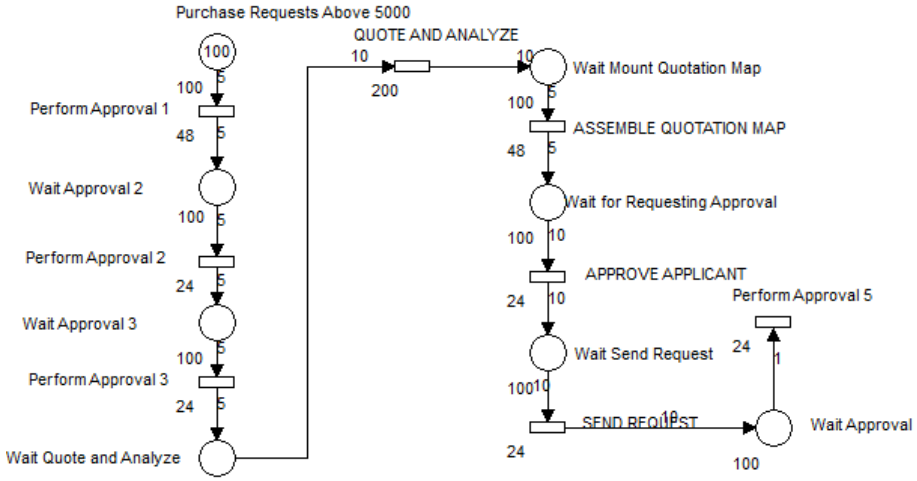
After finalizing the first stage, in which the organization of the company was placed, the next step consisted of a deeper analysis of the way in which the purchasing process took place. In the present case, in view of the need for an epistemological cut, it was decided to carry out a study only of the purchase processes for amounts greater than or equal to 5,000.00 BRL, which requires the approval of the director of supplies, therefore the approval 5 indicated in the Table 2. Considering this scenario, a simulation model was created using Petri nets.

A simulation of 100 purchase requests was chosen for the model with an input capacity of 100 requests. In the Petri net, each rectangle (transition) represents an approval process for the purchase requests required by operational managers. Next, a quotation and analysis of the approved demands are carried out, which are also represented by the transitions in the modeling shown in Figure 4. The circles (places) represent the moment at which each stage of the purchasing process waits for its respective dispatch, so that the next stage can be continued. This is where the resources are maintained.

In the present simulation and modeling, an exponential distribution function was used because each timed value was based on the average μ. The values used in this study constitute a sample of 100 requests over a period of one month. Empirical data were collected

through an analysis of interviews with company employees. From the data collected, it was determined that the request approval processes (approvals 1,2,3 and 5) are carried out in blocks of five by five, and the company takes approximately μ=48 h to carry out approval 1 and μ=24 h for the others. Next, the request analysis and quotation process are performed in blocks of 10, with an average time of μ=24 h. Subsequently, the mapping of quotations is performed in blocks of 5 and takes an average μ=48 h to complete. The applicant's approval is carried out in an average time of μ=24 h in blocks of 10 requests. The last step analyzed consists of sending the requests, also done in blocks of 10, with a period of μ=24 h.

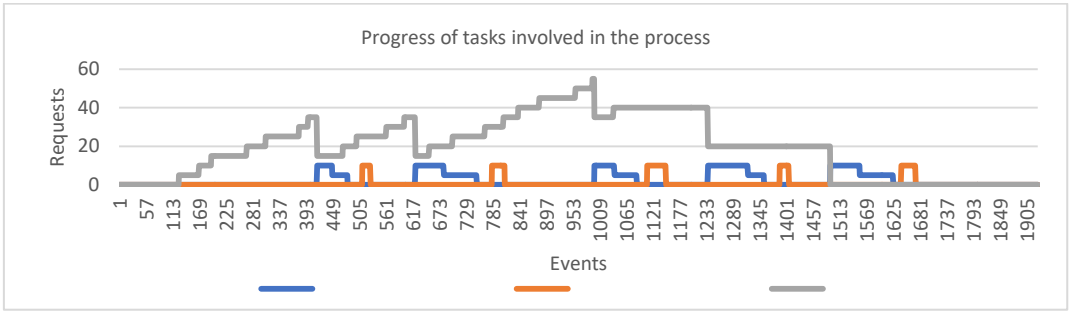
Figure 4: Petri Net Cell Simulating Purchase Processes Over BRL 5,000.00



Source: (Authors, 2023)

As a result of the simulations, graphs with the generated results are presented to facilitate the observation and analysis of each stage of the purchasing process. This analysis allows for the identification and scoring of bottlenecks for the development of suggestions to improve the efficiency of the company. As shown in Figure 5, the stage with the greatest delay in task execution is the analysis of purchase requests, considering the simulated events due to the number of requests.

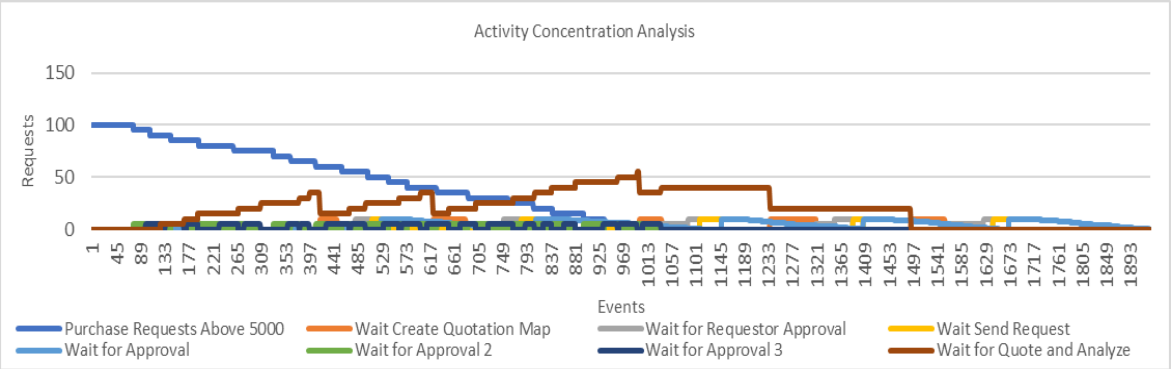
Figure 5: Graph of the progress of the tasks involved in the process.



Source: (Authors, 2023)

From Figure 5, it can be observed that the quoting and analyzing sector is the main bottleneck in terms of execution time. As a result of this delay, other processes end up losing a certain degree of agility, as it depends precisely on the time spent in the preceding step, as shown in Figure 6. This constitutes the two stages that demand a more in-depth analysis in search of solutions, aiming to improve the efficiency of the company's purchasing process. Such a conclusion is possible considering that both processes present the highest degree of concentration of activities to be carried out.

Figure 6: Activity Concentration Analysis Graph.

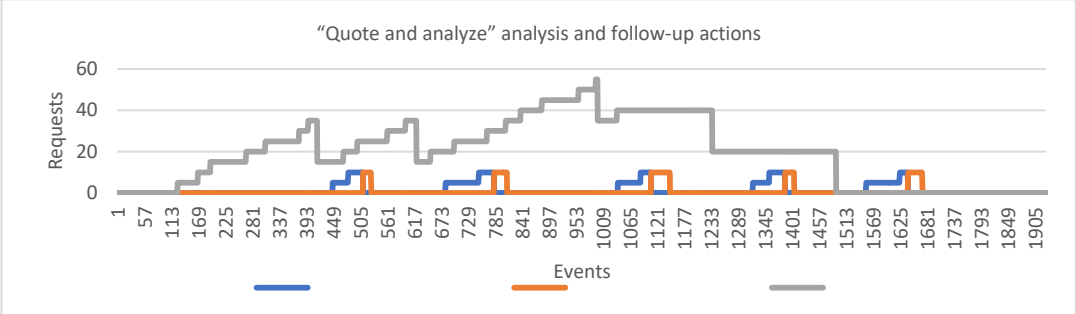


Source: (Authors, 2023)

3.3 Process Analysis and Improvement Opportunities

To achieve the objectives of this work, with the flow of the company's purchasing processes as a reference, represented by the flowchart (Figure 3) and by the Petri net with the respective simulation (Figure 4), it was elaborated the analysis of the process. In this analysis, it is possible to identify bottlenecks and observe opportunities for improvements based on points that can be changed to elaborate alternatives that can guarantee greater efficiency for the company. It was found that for the execution of the task of analyzing and quoting purchase requests with amounts greater than 5,000.00 BRL, it takes an average of μ=240 h to complete, a significantly longer period when compared to the other stages of the process. This is illustrated in Figure 7.

Figure 7: "Quote and analyze" analysis and follow-up actions.

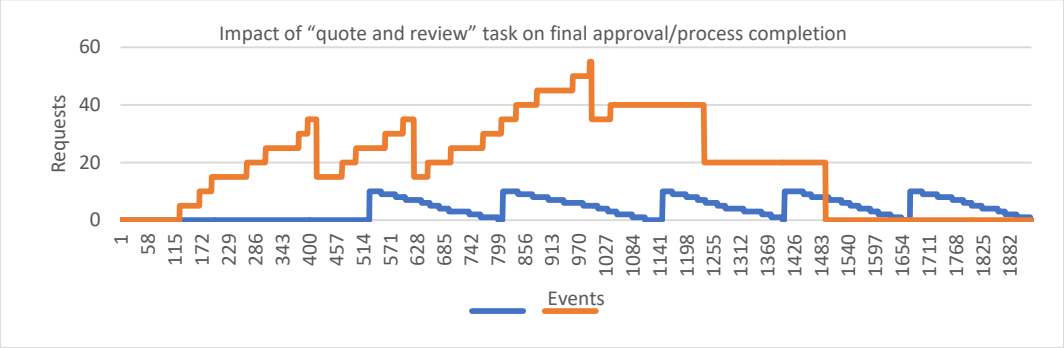


Source: (Authors, 2023)

From Figure 7, it is possible to notice that the process of quoting and analyzing has the longest waiting times, represented by the width of its steps. When analyzing the number of requests in relation to the simulated events, it is possible to notice that this is the process with the lowest progress in the analyzed step.

In a study carried out by the company, it was possible to conclude that the prolonged time of this stage occured because the activity was carried out by the buyer, which consisted of identifying the items to be purchased, followed by the process of locating the purchase, and the search for suppliers that could better meet the demand. For this purpose, the category of material or service requested is considered, as well as the geographic location that can contribute to or hinder the service, together with the best prices, delivery time, and quality that is compatible with the company's needs. Thus, once the request has been sent to the supplier, it is still necessary to wait for the deadline to identify the demand and production of the quotation in view of its capacity to serve. The next stage consists of producing a quotation map in which the responsible buyer selects the budgets and prepares the map upon receiving feedback from the suppliers. This task has the primary function of facilitating the comparison of prices item-by-item. Evidently, the number of items included in the request is directly proportional to the time spent on the activity. Any delay due to the number of items to be mapped and quoted leads to an excessive delay and a consequent delay in the process. The proposed solution is an investment in platforms that can automate the process of mapping quotations. Implementing the aforementioned change in the company can result in a reduction of the total process time and freeing up more time for the employee to work on a greater number of processes or develop other activities. The identified bottlenecks cause delays in the other processes of the company, as shown in Figure 8.

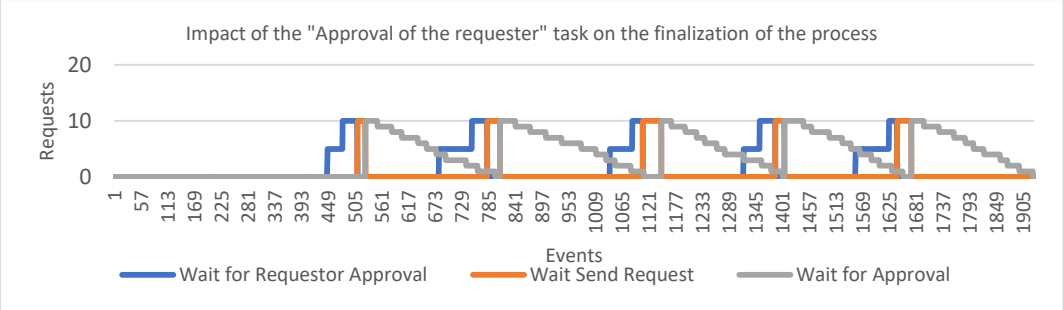
Figure 8: Impact of the "quote and analyze" task on the final approval/completion of the process.



Source: (Authors, 2023)

Given the bottleneck identified in the process of quoting and analyzing purchase requests, it is possible to perceive the impact generated when approving and concluding the purchase process. Thus, the proposed solution to alleviate the perceived problem, the delay in finding the best supplier after a detailed search, is the elaboration of a list of suppliers, registering them, and categorizing them in the internal system of the company. This change aims to speed up the identification of suppliers that can meet the demands according to the needs of the company and take into account the geographic location, aiming at the best, fastest, and most efficient service, thus enabling a more effective purchasing sector to meet the demands of the company. Next, the impact of operational approval on the quote and analysis process is analyzed. The approval stage consists of the analysis carried out by the responsible managers on the items requested by the requester and approved by the managers who are below in the organizational hierarchy according to the organizational chart (Figure 2) when they can check whether the purchases meet their expectations in relation to demand (Figure 9).

Figure 9: Impact of the "Approval of the requester" task on the finalization of the process



Source: (Authors, 2023)

The analysis of the process by the requester described in the organization chart (Figure 2) may be extended too much, thus delaying the entire missing purchasing process. It is suggested to eliminate it and replace it with a step in which the requester responsible would only describe, with a greater degree of detail, the items required by the client, including the

brand and model. Another option is to elaborate on a more detailed material-registration process. By doing so, it is possible to guarantee the quality of the base of data of registered items, avoid mistakes in purchases, and eliminate the task of approval of the requester of responsibility of the requester. Once the process described previously has been overcome, the final phase consists of sending purchase orders to the supplier, which makes the company dependent on the buyer's availability, which can be seen as a bottleneck in the process. It is clear that there are tools in the market that automate the process of sending these orders after completing other steps, requiring only the maintenance of a database with the contacts of suppliers, allowing the system to take care of the process.

4. Conclusion

During the research, it was possible to determine that the purchasing process of the studied company presented bottlenecks that, from the use of the Petri net simulation method, became evident, with simulations that represented the flows already adopted, while allowing solutions for creating new flows or optimizing existing ones. The methodology successfully offers conclusive alternatives to the problems encountered. In this way, there is a considerable gain in the time in which the purchasing process is carried out completely, as well as guaranteeing advantages for the entrepreneur, such as an improvement in the relationship with customers, as the processes can be concluded more quickly without prejudice. There were also improvements in quality and a better relationship with suppliers because, with the use of the described methods, the possibility of errors decreases considerably, and the agility in the processes can influence so that the main suppliers have a more agile cash turnover. Another point of improvement was the management of inventory and the application of inputs/application materials, considering the advantages of automating internal procedures.

Some tasks in the process can be improved and others can be automated. In the Brazilian market, there are complete purchasing platforms (Mercado Eletrônico, Nimbi, and Paradgma) that are viable alternatives for the company. These platforms can help improve the flow of processes by registering and categorizing suppliers in each region of the country and cleaning up the register of materials and services. In this way, it is possible to shorten the activities carried out by the employees involved, and they can improve the process and have more time to direct themselves to other tasks. This gain in time results in a better arrangement of the tasks performed by the company as they contribute to a better allocation of available human resources. In other words, from the moment the employer provides the employee with a work organization previously simulated and tested, it results in an optimized, more dynamic flow, which can consequently improve the company's performance in the market, directly impacting both qualitatively and quantitatively.

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