BPMN and Petri Nets: A Case study of Process Optimization in a Project Engineering Company

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Abstract

The present work presents a case study in a project engineering company analysing and proposing improvements to be employed. The research focuses on the application of the BPMN (Business Process Model and Notation) to a company with more than 20 years of experience in the market. Such optimization sought the standardization that would make it possible to reduce the time for preparing proposals. Quality tools were used in the development of the research. As a result, organizational alignment was achieved through artifacts such as: Organogram, Flowchart, PDCA (Plan-Do-Check-Act), 5W2H (What-When-Where-Why-Who-How-How Much) and Ishikawa Matrix were delimited for surveying and analyzing the case. To achieve these outcomes, technical visits and analyses were carried out during the months of September and October 2022 to collect data and requirements for the described process. A modeling and simulation was carried out via Petri nets to find bottlenecks and present possible solutions to problems encountered. The generated models reduced days of analysis in the processes involved in proposals that reach millions of reais.

Keywords: Engineering; BPMN; Modelling and Simulation; Petri nets

1. Introduction

The industrial sector operates on an optimized strategic management basis, weighted with quality tools and simulation modeling. In recent years, engineering design companies have needed to optimize their internal processes due to the market downturn as well as the impact on the sector due to the pandemic; thus, decisions and processes need to be more assertive (Rocha et al., 2019). In this scenario, project engineering figures as a set of strategic professional activities that add value to the viability of the enterprise. The development, planning and implementation of the activities within the project engineering affect the entire decision-making process and aim to reduce the total execution lead time of the tasks with an additional benefit to reduce costs (Srinivas, 2019; Souza et al., 2020).

Currently, the project engineering sector has been recovering from the impacts caused by the Covid-19 pandemic, which caused the Brazilian construction industry sector to have a lower investment retraction than it did four years before the start of the pandemic and consequently fewer engineering projects (CNI, 2022). According to Dohale et al. (2022), to have a strategic production decision, it is necessary for those in charge to understand their responsibility regarding the strategy of the company, having well-defined performance objectives, making decisions regarding production, and considering the functional strategies of the company in the foreground. In addition to management strategies, there are quality tools that help productivity achieve objectives by using methods and analysis tools that guide the intervention process, which results in performance improvements and cost reduction (Rumane, 2013). In this research, the following tools were used: Organogram, Flowchart, Ishikawa, PDCA (Plan-Do-Check-Act), and 5W2H (What-When-Where-Why-Who-How-How Much). Finally, in an evaluation of tools that can contribute to the construction of optimized strategic management, the modeling and simulation process forms a set of possibilities. Among the existing techniques, a graphic technique called Petri nets was chosen, which according to Lisboa et al. (2019), is a form of representation that manages abstract resources, their forms of consumption and distribution, as well as the times in which each event occurs. The company under study is a service provider operating in the Brazilian market, covering multidisciplinary project engineering (civil, mechanical and electrical), construction management, labor allocation, cellulose, chemistry and others.

Therefore, with the scenario and tools evaluated and with the focus of the study on the aforementioned company, the general objective of this research is to propose an optimization process based on quality tools for an engineering company that operates for more than 20 years in the field of multidisciplinary conceptual engineering projects. The optimization process aims at updating the procedures and methods for carrying out technical and commercial proposals. To this end, some specific objectives are outlined: first, to analyze the process of preparing a commercial and technical proposal; then, evaluate the proposed process with analysis based on quality tools to assess possible bottlenecks; to present a simulation modeling proposal based on Petri nets for the analysis of possible scenarios not only of bottlenecks but also of possible improvements; finally, analyze how a proposed use could be employed by modeling through a PDCA cycle with the definition of a 5W2H. This work is justified because the engineering sector in recent years has experienced a considerable drop in demand, requiring an optimization of the production process to make it profitable in such a competitive market.

2. Materials and Methods

Concepts from engineering projects, quality tools, modeling, and simulations were used. PMBOK® (ANSI/PMI 99-001, 2004) defines project engineering as the application of knowledge, techniques and skills to meet a project within its requirements, having the responsibility to strictly follow the conditions and characteristics that were established in the technical proposal. According to Rumane (2013), quality tools are tools used in the interpretation of data through simple methods to discover the cause of problems or even in the search and control of continuous improvements in addition to a technical diagnosis for more assertive decision-making. In this study, the following were used: organogram (to describe the hierarchy of the organization), Flowchart (to describe the processes), Ishikawa (to investigate and survey the root causes of a given problem), PDCA (a cycle that guarantees quality and continuous improvement) and 5W2H. For the modeling and simulation process, the Petri Nets tool was researched. According to Lisboa et al. (2019), it is a graphical model of a real system consisting of a bipartite graph in which it is used to perform simulations and to obtain an optimized flow.

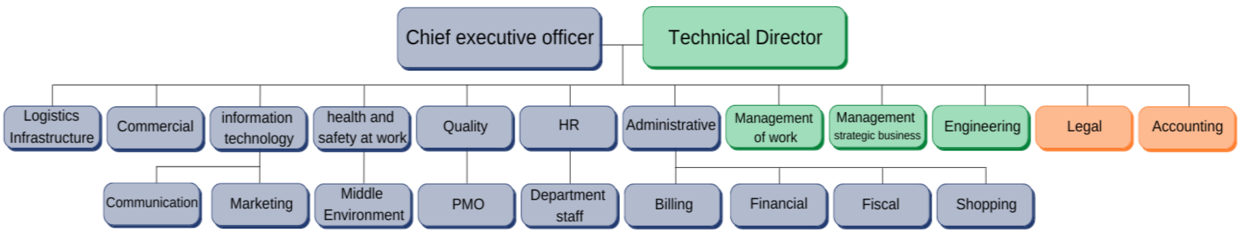
Following the research process, in the first stage, using quality tools in the development of the research, an Organization Chart, Flowchart and Ishikawa Matrix were delimited for surveying and analyzing the case. The organization chart focused on how the sectors of the company are structurally arranged. The flowchart focused on the flow of commercial processes, delimiting from the beginning of contact with the client until the closing of a contract. The Ishikawa matrix was carried out considering the process of issuing a technical and commercial proposal for delimitating the investigation process of the root cause of the problem. Technical visits and analyses were carried out during September and October 2022 to collect data and requirements for the described process. In the second stage, an analysis based on Petri Nets was performed, where the flowchart served as a reference for the resource allocation process and process flow. In the third stage, a PDCA with 5W2H was performed for planning and mapping improvements to be implemented based on the process and flow designed by the simulation via Petri nets.

3. Results

3.1 Analysis via Quality Tools

During the research, an evaluation was first carried out based on the organizational structure, through the organizational chart tool, and an evaluation of processes, via a flowchart. The organizational chart of the company shown in Figure 1 is one of the initial steps for analyzing the company under study. It presents how the sectors of the organization are arranged and how they are hierarchically interconnected. It was mapped how the work was done and which sectors acted directly and indirectly in the elaboration of the proposals. The organization is made up of two partners: the technical director and the executive director, who are the legal representatives of the company. Under their command, there are other sectors within the company. The commercial sector is of key importance because it is responsible for generating the contracts, and this sector is also responsible for carrying out the proposals. The commercial team requires support from other areas to compose the service demand and define the contract costs to be sent to the customer.

Figure 1: Organogram

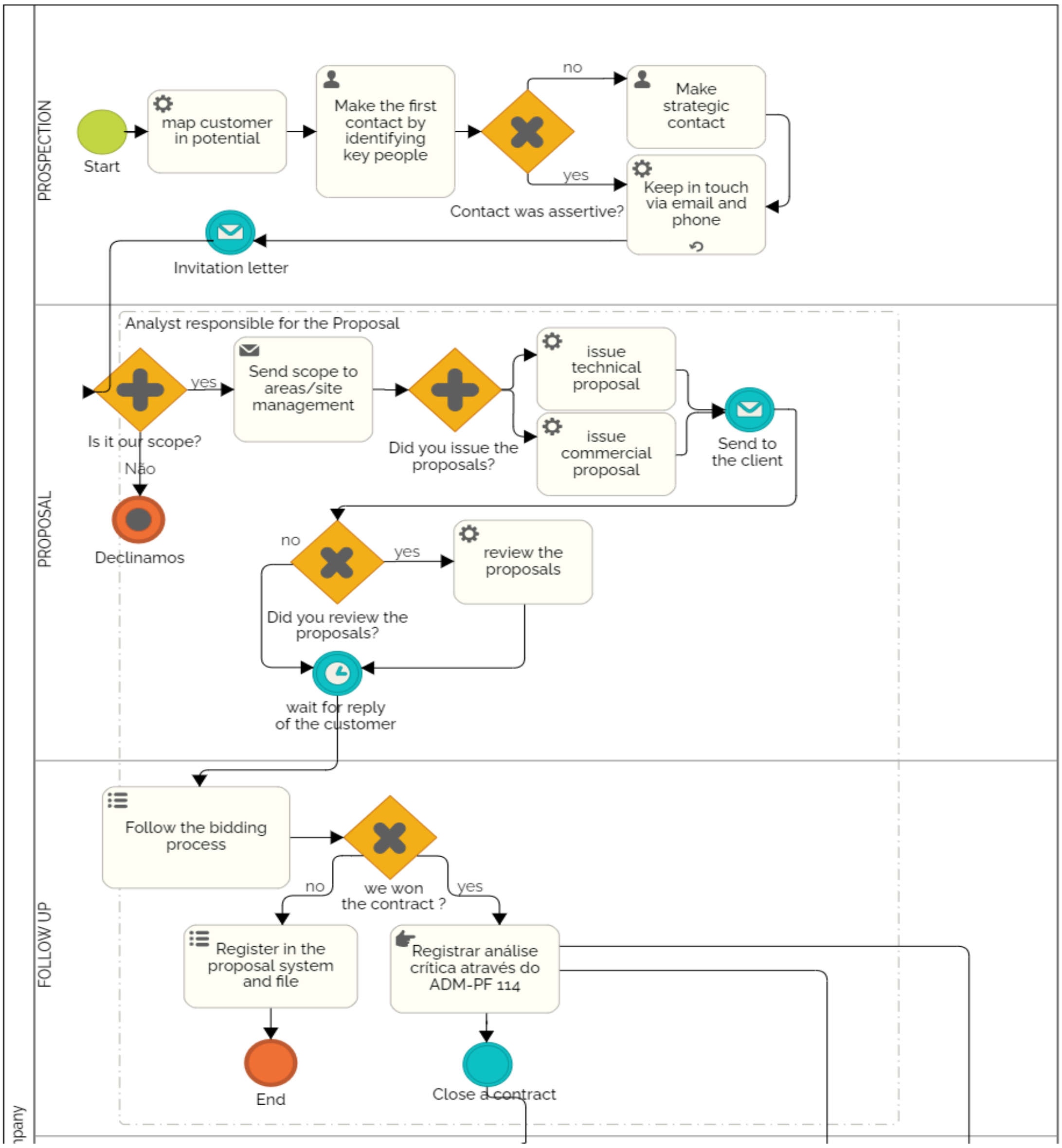


Source: (Authors, 2023)

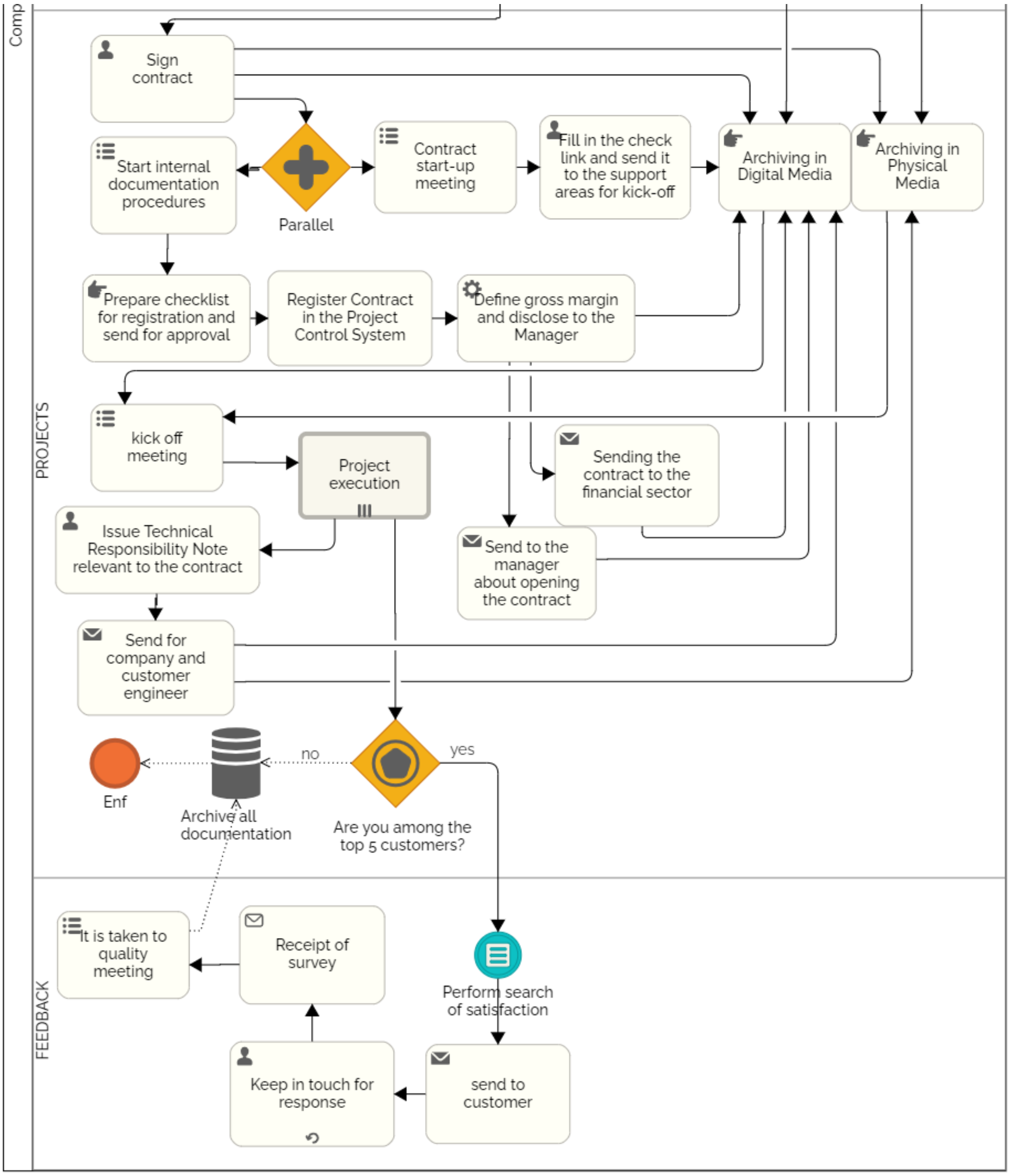
The process flow is demonstrated by the flowchart in Figure 2, which is a graphic representation of a workflow carried out in the commercial sector of the study company. It can be seen that the sector is subdivided into areas (prospection, proposal, follow-up, projects and feedback). In this flowchart, the commercial operation was analyzed in detail, from the beginning of the prospection with the mapping of client companies until the closing and archiving of the contract. The range of the proposal in which the process of issuing a technical proposal is allocated is of key importance, and its operation and process flow will be detailed in this study. An Ishikawa analysis was conducted, as shown in Figure 4, in which it was possible to identify the potential causes of the problem and thereby analyze their impacts, considering different perspectives, to find suitable alternatives to solve the problem. Regarding workforce, there are two problems with respect to time.

The most critical issue is the delay in the response of the support areas that are necessary for price composition. The second problem is the short time window to analyze the scope of the project, in which it is necessary to focus on understanding the demands of the customer. An in-depth analysis of the proposal lane was carried out, which focused on where possible causes of the problem were found, as shown in Figure 2. The flowchart presented in Figure 3 shows how the technical and commercial proposal is prepared, which is carried out by the commercial sector. This flowchart shows each step and the areas that indirectly participate in the proposal composition. Analyzing the processes, the main problem is related to the availability of data from the support areas, which is necessary both for price composition and for the quantities needed to meet demand. The delay in this data compromises the time required to prepare proposals. There is another issue related to the computer machines provided to analysts, who are responsible for issuing proposals. These computer issues directly affect the time of the proposal issuance. Regarding the environment, no problems that burdened the realization of the proposals were observed.

Figure 2: Commercial flowchart



A – Flowchart (Part 1)

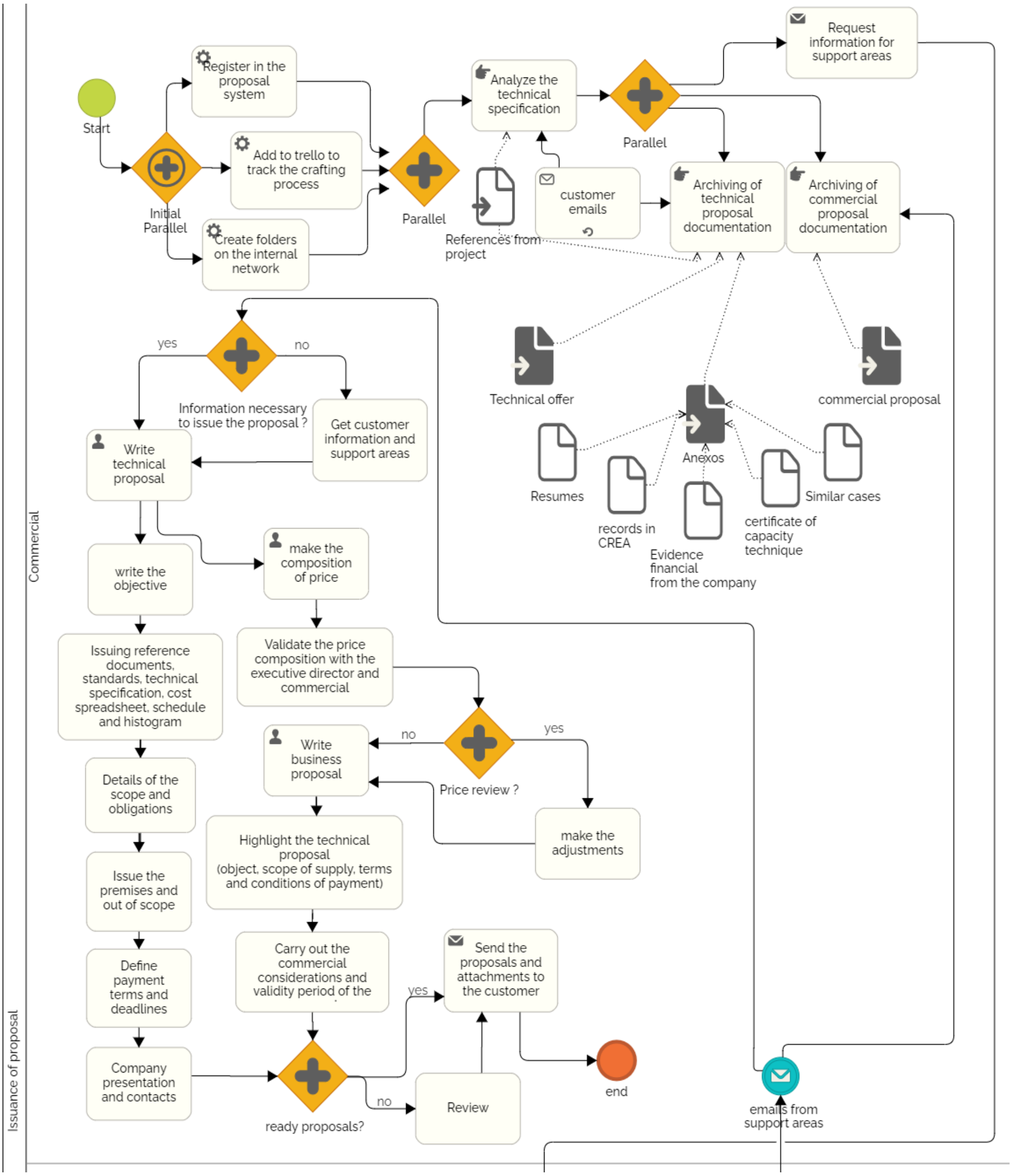


B – Flowchart (Part 2)

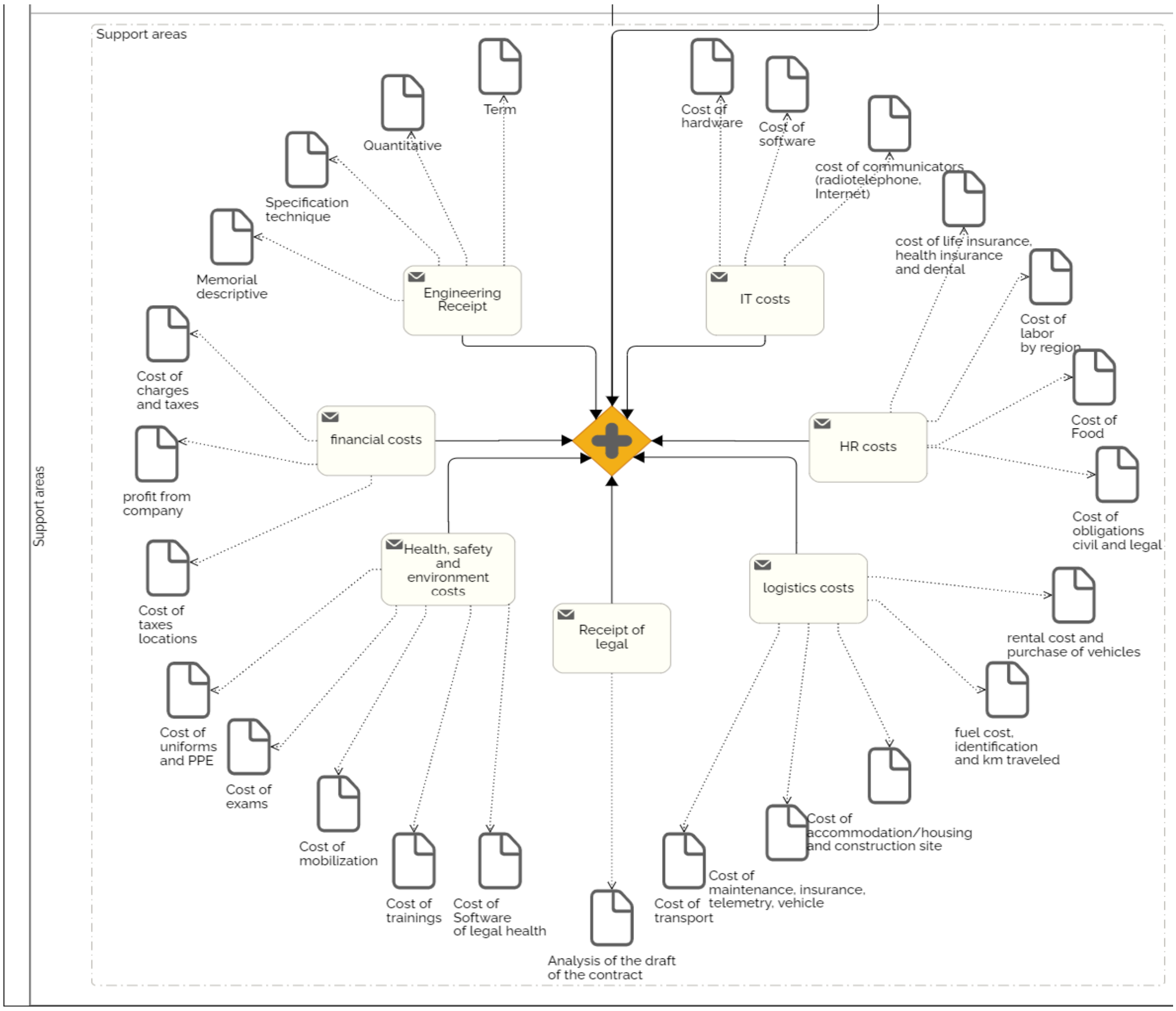
Source: (Authors, 2023)

The method lacks a previous document called "ADM PF 126", which is a document in the company under study that governs the kick-off meeting. This document summarizes all the details presented in the proposals, and it contains a draft of the details discussed with the client. In addition, this document guides who is issuing the proposal so that no details go unnoticed and helps save time by being more assertive in points that will be scored together with the customer later. It also benefits the commercial coordinator who is responsible for filling it. By filling this in a previous step, the coordinator saves time, and it is only necessary to validate the information contained therein. Such problems contributed to the slowness in the elaboration of the proposals and scrutinizing them brought to light problems that in the past were not seen as an issue that could delay their delivery.

Figure 3: Proposal flowchart



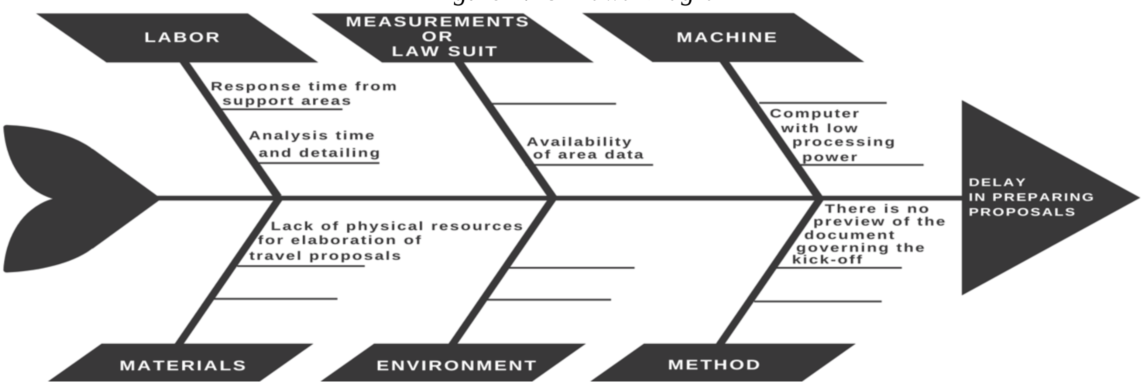
A - Commercial Flowchart



B - Flowchart Support Areas

Source: (Authors, 2023)

Figure 4: Ishikawa Diagram

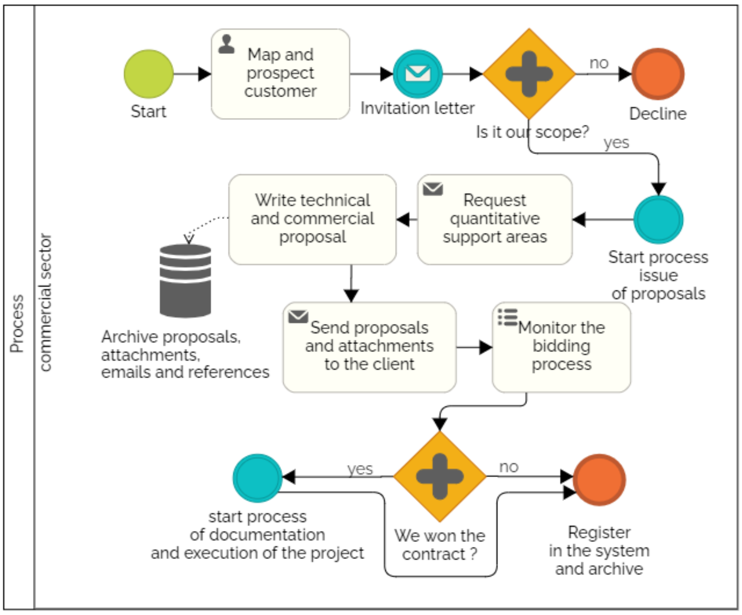


Source: (Authors, 2023)

3.2 Modeling and Simulation

To proceed the modeling and simulation, it was necessary to delimit the process, which, as shown in Figures 2 and 3, is complex with several specificities and involves many variables. To create the model, it was necessary to bring strategic points (Figure 5) that involved the entire process, from mapping the client to closing the contract. This subprocess generally shows the functioning of the commercial process of the company. The process begins by prospecting the client through prior mapping and, therefore, a survey with the client to prospect them. After the prospection phase the company receives an invitation letter from the client to participate in the bidding process. Upon receiving it, an analysis is carried out, and verification is performed to check whether the object of the project is part of the scope of the work. Otherwise, the client invitation is rejected.

Figure 5: Commercial sub-flow

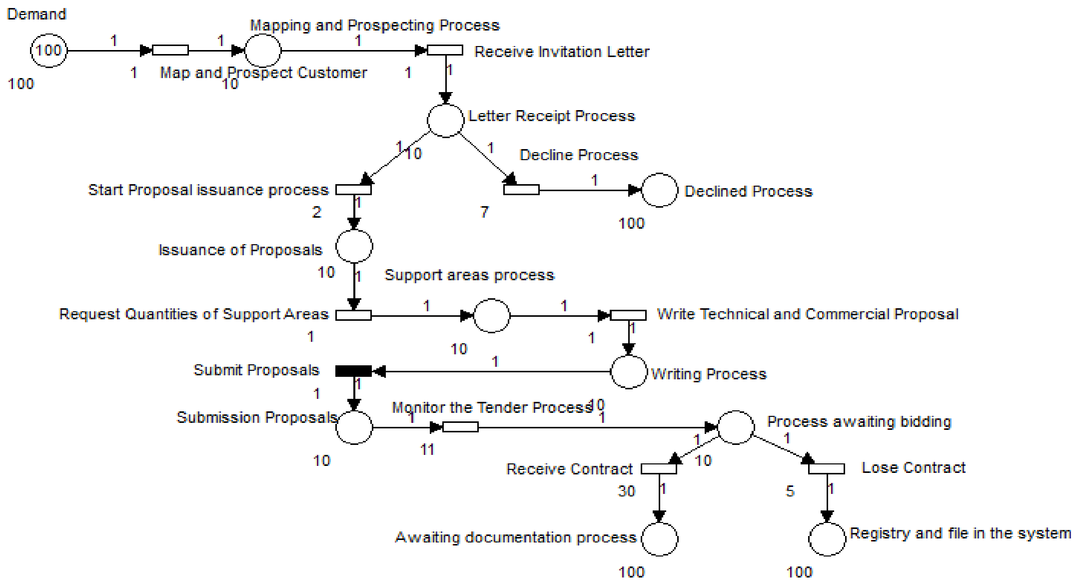


Source: (Authors, 2023)

Once the invitation is accepted, a query is sent to the support areas requesting the quantities necessary to carry out the project, which will be used to compose the technical and commercial proposals drawn up by the commercial sector. Finally, the proposal is sent to the customer together with attachments that contain important information. These documents are archived, and a follow-up is carried out by the commercial sector to obtain feedback from the customer to check if the company was the winner of the contract. Otherwise, the reason for losing the contract is registered and archived in the system. If the company wins the contract, the documentation process, relevant meetings, and the execution of the project begin. At the end of the project, all the information is registered and archived in the system.

In possession of the commercial sub flow, a modeling and simulation proposal designed using Petri nets, as shown in Figure 6, which was limited to simulating an initial demand of 100 proposals. All parameters of the model were defined by the sub flow shown in Figure 5 which permeated the entire process flow. However, bringing with it the transitions (bars) that have as a parameter the time (in each transition *T*), as an exponential function. With the entire process defined, it is possible to perform a simulation to observe how the input behaves one by one for each proposal and in which part of the process there is accumulation. Thus, it is possible to identify where there is a compromise in the process flow and where it is possible to eliminate the bottleneck of the process. The triggering time performed by the transitions is listed in Table 1, which presents the real time required to finalize an event. However, some are events do not have an exact time. To overcome this limitation in the simulation, the timing of some events was established based on the average of the events denoted by μ. This approach was consistent with the reality of the company under study. It is important to highlight that the time taken to map and prospect a client is relative, as it depends on the type of client, the interaction with the strategic sectors and the time between receiving and responding to the invitation letter from the customer.

Figure 6: Petri net Simulation



Source: (Authors, 2023)

Table 1: Trigger time in days

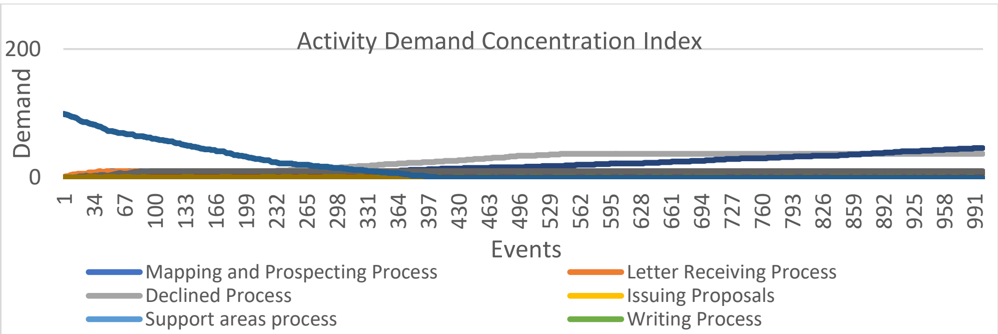
Transition	Time	Transition	Time
Map and prospect customers	$\mu=1$	Write technical and commercial proposal	$\mu=1$
Receive invitation letter	1	Send proposals	1
Decline process	$\mu=7$	Monitor the bidding process	$\mu=11$
Start proposal issuance process	$\mu=2$	Lose contract	$\mu=5$
Request quantitative support areas	$\mu=1$	Receive contract	$\mu=30$

Source: (Authors, 2023)

Although this is not a rule, a decline in a project is carried out at least once per week. A project can be declined for several reasons, and this decline frequency was based on an average observed for the company. The starting of the proposal issuance process takes around two days, as it is the part of the process in which any and all information sent by the client is analyzed, so that the areas can be contacted. Requesting quantities from the support areas usually takes an average of one day, but it can take longer, as this is the average of an exponential distribution. Writing the technical and commercial proposal takes an average of one day, depending on the information requested by the client. Monitoring the bidding process usually takes an average of eleven days, as it depends on how agile the purchasing sector of the customer is to analyze and publicize the company that won the contract. Losing a contract occurs, on average, every five days, as it creates an accumulation of proposals issued but unanswered, therefore occurring within that period. Receiving a contract can take up to 30 days, that is, it is only possible to win one contract in a month because, as stated at the beginning of this article, the project market is very competitive.

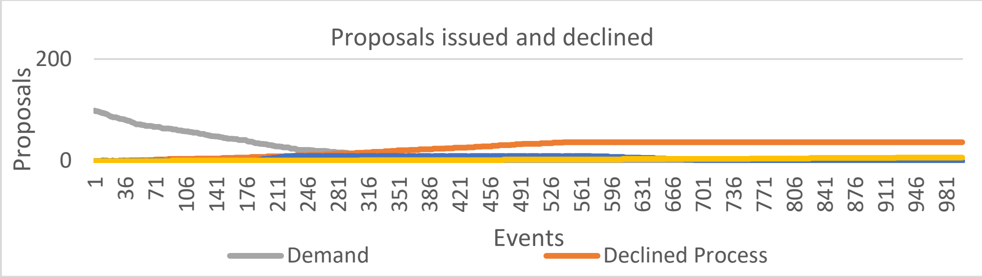
The graph in Figure 7 presents how the activities behave in relation to demand, which shows that there is no homogeneous process and that the demand does not have an abrupt drop. This behavior shows that the process is slow, and a large number of declined proposals may occur because the company is not able to meet the service demand of the customer or deliver the proposal in a timely manner. The graph in Figure 8 clearly shows number of invitation letters (gray line) the company receives and the number of invitations that are declined, which means that the company does not participate in the bidding process for a possible contract (orange line). The blue line shows the extent to which the company participates in and issues a proposal. However, they did not turn into contracts (yellow line). It is noteworthy that the number of declined proposals is three times the number of proposals issued, and the number of proposals that turn into contracts is much less than the number of issued proposals.

Figure 7: Demand for activities



Source: (Authors, 2023)

Figure 8: Rate of issuance and decline of proposals.



Source: *(Authors, 2023)*

3.3 Deployment feasibility study

The process complexity and the numerous amounts of variables present could be visualized by the quality tools and applied simulations. Using the Ishikawa matrix, it was possible to raise some issues in the process, which were confirmed in the simulation using Petri nets. By analyzing the graphs, it was possible to identify the problem and find a process change to mitigate it to obtain an improved execution time. Trought this information, the company under analysis proposed a remodeling of its systems to allocate it to a single structure to store the entire commercial process (eliminating the need for a local network for document archiving because it is based on a cloud storage service). With this new storage system, all prospecting information, customer data, follow-up, proposals, and contracts can be accessed in an organized manner with a higher access speed, optimizing time, and commercial management. The system Trello® was also implemented to monitor and unify both the system project and the proposals. An implementation of an online Excel® file system was also proposed by the company to store monthly updates on the quantities in all areas.

This structure optimizes the time to carry out the proposal, which was pointed out by the Ishikawa matrix as a bottleneck and was confirmed by the simulation. Another action taken was the hiring of an additional employee to help in the preparation of proposals, which would reduce the scope analysis time. Therefore, each analyst responsible for the proposal will be able to understand, analyze, and detail the scope of the project, and be able to issue proposals with more quality. At the beginning of this study, the company had only three analysts responsible for preparing all proposals. Considering twelve proposals, each analyst would be in charge of preparing four proposals. However, with an additional analyst, each member will have three proposals to prepare, thus reducing the time for making proposals and increasing the production capacity of the company. The 5W2H in Table 2 clearly presents the action plan to be followed by the company. In the PDCA shown in Figure 10, a planning phase was carried out for decision-making by the company under study, which followed the outlined metrics.

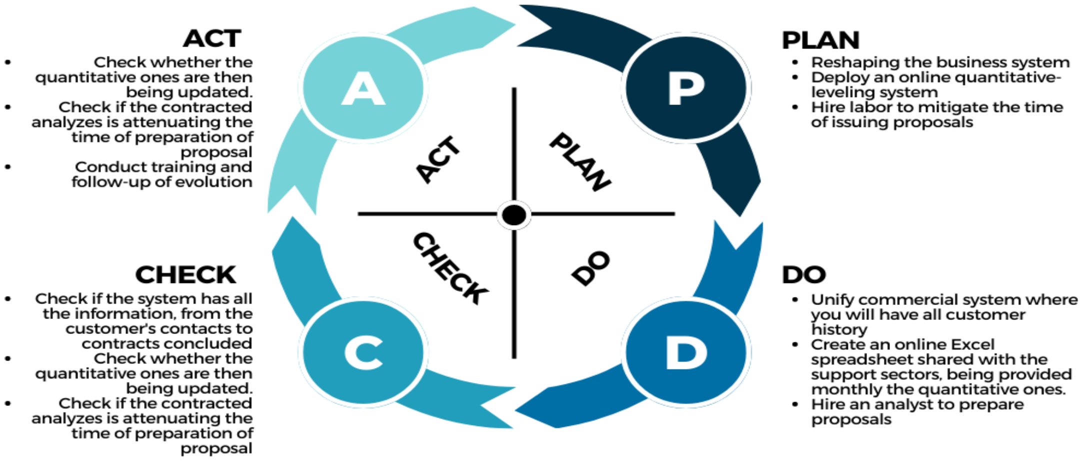
Table 2: 5W2H (Cause: Delay in drafting proposals)

Step	What	Why	Where	Who	When	How	How Much
1	Remodeling of the commercial system	Waste of time with different systems	-	IT and Developers	*2023*	Unifying the proposal system, projects, prospection and internal network folders	-
2	Implementation of quantitative system	Availability of real-time quantitative data	Online	Commercial	01/12/22	Creating a shared spreadsheet with support areas	-
3	Hiring labor	Increased production capacity	Commercial	Commercial analyst	2023	Internal promotion of employees or external contracting	BRL 4,000.00

Source: (Authors, 2023)

This action will bring the desired results to the company in terms of optimizing the process of preparing proposals. In the planning phase, questions such as how and what will be done, why it will be done, where, when it will be done, how much it will cost, and who will do it, are analyzed. After answering all questions, the company is able to strictly follow the proposal. In view of the action plan presented, the company will mitigate the problems that it originally experienced on a daily basis. The action plan will affect the implementation of the quantitative system through a tool that the company already uses, without bringing any extra costs, and being able to be prepared by the sector itself and defined with mandatory areas.

Figure10: PDCA



Source: (Authors, 2023)

4. Conclusion

This study aimed to analyze the proposal issuance process through a case study of a project engineering company operating in the Brazilian market. It was proposed to the company under study to implement a single system for managing documents and projects. In addition, an online Excel® spreadsheet shared with the support areas was implemented so that the company could provide information regarding the quantities needed to carry out the proposals. It was also proposed to hire an additional analyst to prepare the proposals, which would reduce the time for their issuance and increase the productivity of the company.

The actions proposed in this study were implemented by the company because a thorough analysis was performed using quality tools, which resulted in the artefacts: organization chart, flowchart, Ishikawa matrix, PDCA, 5W2H, and through modeling and simulation using Petri nets. The analysis shows that the company had bottlenecks that could be corrected. The application of the aforementioned tools also contributed to the organization, since its process was not delineated or mapped in detail. The change actions presented will contribute to the optimization of the activities of the company, which are based on real problems arising from the reality of the organization. The organizational graphic elements developed were able to organize processes with dozens of steps and other large numbers of people involved, with millions of Brazilian reais involved. Comparing with previous studies, this research demonstrates a very specific case study for this field of activity, with simulations developed to optimize a significantly expensive process. Therefore, it is concluded that the objective of this work was accomplished and will bring significant returns both for the productivity and management of the company.

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