Gest. Prod., São Carlos, v. 26, n. 4, e3945, 2019
https://doi.org/10.1590/0104-530X3945-19

Original Article

GESTÃO & PRODUÇÃO
ISSN 0104-530X (Print)
ISSN 1806-9649 (Online)

Application of statistical analysis to improve time management of a process modeling project

Aplicação de análises estatísticas para melhoria do gerenciamento do tempo de um projeto de mapeamento de processos

Mariana Mello Pereira[1]
Luiza Lavocat Galvão de Almeida Coelho[1]
Gladston Luiz da Silva[1]
Yanne Souza Alves Cunha[1]

How to cite: Pereira, M. M., Coelho, L. L. G. A., Silva, G. L., & Cunha, Y. S. A. (2019). Application of statistical analysis to improve time management of a process modeling project. *Gestão & Produção*, 26(4), e3945. https://doi.org/10.1590/0104-530X3945-19

Abstract: This work was the result of a cooperation agreement between the University of Brasilia (UnB) and a security organization. Its goal was to model the logistic processes of the company to assist in the modernization of a control system for the management of materials. The project was managed in a dynamic model, through the monitoring and control of activities executed during its various stages. The development of a control system enabled the detection of discrepancies between what was planned and how it was performed, identifying its causes and which actions to take to ensure that the project got back on track according to the planned schedule and budget. The main objective of this article was to identify which elements controlled by the project affected its execution time. With that knowledge, it was possible to improve the planning of the next phases of the project. To this end, we performed a case study of exploratory aspect and quantitative nature to provide information on the object and guide the formulation of hypotheses. The qualitative analysis of the execution time of the modeling identified two dependent variables - systematic version and team - out of the four evaluated. The quantitative analysis studied two variables - number of modifications and number of elements -, which did not indicate evidence of correlation with the aforementioned time.

Keywords: Project management; Time management; Test of independence; Test of correlation; Process modeling.

Resumo: *Este trabalho decorreu de um termo de cooperação firmado entre a Universidade de Brasília (UnB) e uma organização de segurança, cujo objetivo foi o mapeamento de seus processos logísticos, realizado com o intuito de amparar a modernização de um sistema de controle gerencial de materiais. O projeto foi gerenciado num formato dinâmico, mediante o monitoramento e controle das atividades executadas no decorrer de suas diversas fases. Foi desenvolvido um sistema de controle que permitiu encontrar as discrepâncias entre o planejado e o realizado, identificar as suas causas e agir para que o projeto retornasse ao seu curso no prazo e nos valores planejados. Este artigo teve como principal objetivo identificar quais os elementos controlados pelo projeto impactaram em seu tempo de realização para a melhoria no planejamento das fases seguintes do projeto. Neste sentido, foi realizado um estudo de caso de cunho exploratório e natureza quantitativa com o objetivo de oferecer informações sobre o objeto e orientar a formulação de hipóteses. As análises qualitativas identificaram a dependência de duas variáveis - versão da sistemática e equipe - com o tempo de realização dos mapeamentos entre as quatro variáveis analisadas. Já as análises quantitativas abordaram duas variáveis - número de alterações e número de elementos -, que não indicaram evidência de correlação com o referido tempo.*

Palavras-chave: *Gerenciamento de projetos; Gestão do tempo; Teste de independência; Teste de correlação; Mapeamento de processos.*

[1] Centro Interdisciplinar de Estudos em Transporte, Faculdade de Tecnologia, Universidade de Brasília – UnB, Campus Universitário Darcy Ribeiro Edifício Ceftru, CEP 70919-970, Brasília, DF, Brasil, e-mail: pmello.mariana@gmail.com; luizalavocat@gmail.com; gladston@unb.br; yanne_cunha@hotmail.com

Received Apr. 19, 2017 - Accepted Dec. 24, 2017

Financial support: None.

1 Introduction

In general, organizations are recognized for their flexibility, professionalism, and ability to serve their customers in a satisfactory manner. The competition for this recognition in business increases every day. Organizations must meet the expectations of their customers in regard to delivery, cost, and scope (Vargas, 2005). Additionally, in many cases, they need to be innovative to satisfactorily attend to the wishes of their clients (Candido et al., 2012).

In this scenario, projects - responsible for developing new products and improving processes - become a necessity as they play an important role in the strategic management of organizations (Marques & Plonski, 2011). They are seen as an element of change, of strategy implementation, and of innovation since they provide organizations with competitive advantages (Marques & Plonski, 2011).

In this context, project management is fundamental to employ resources and efforts prioritizing what is needed; execute planning based on objectives; form flexible working teams; and be responsible for paradigm breaks so the manager can ensure the success of the enterprise (Vargas, 2005; Candido et al., 2012). According to Vargas (2005), project management has the ability to identify and supervise time, cost, and scope constraints. If rigorous, it provides the focus to reach efficiency in communication, coordination, and control resulting in the success of the organization.

Despite their importance, most projects do not meet their goals (Marques & Plonski, 2011). Success in project management is only achieved when it gets positive measurement results in indicators of cost, time, quality, and productivity (Giacometti et al., 2007).

According to Kerzner & Saladis (2011), there are two components of success in a project: critical success factors (CSF) and key performance indicators (KPI). CSFs are essential to the success of a particular strategy as they underline the more valuable factors to reach the expected results. Regarding KPIs, they measure the processes used to achieve the goals and quantify the results found, therefore, allowing the evaluation of strategic performance.

There is a problem with the traceability of CSFs, which is usually identified at the end of the project. As for the KPIs, they are tracked throughout the project and constitute measurement instruments that indicate if the CSFs will be obtained and used to assist the organization in evaluating its progress when it comes to goals or declared strategic objectives (Kerzner & Saladis, 2011).

In this context, the object of study of this work was a research project on a large public company. Instead of planning the project in a predictive way, we used a dynamic model in successive waves. Each intermediate stage implemented its own planning during the execution of the project, with deadlines, CSFs, and KPIs well-defined.

For the continuation of this project, the team monitored and controlled the activities done in each phase to assist in the planning of the next one. The control system was a vital element in the project management since it could detect discrepancies between what was planned and how it was performed. With the knowledge of these discrepancies, the project manager, with the aid of the team, was able to identify what caused these differences and take action to ensure that the project got back on track according to the planned schedule and budget (Giacometti et al., 2007).

A critical success factor for the viability of a project is its execution time, which can ensure higher competitiveness among rival organizations (Padilha et al., 2004). That said, this article aims to identify which elements controlled by the project affected key performance indicators related to execution time, in order to improve the planning of the next phases of the project.

The article was structured into six sections, with this one as the first. The second section brings the theoretical framework, followed by the methodology, the characterization of the case study, data analysis, conclusion, and references.

2 Project management

To understand what is project management, first, we need to know what is a project. Project is a temporary endeavor undertaken to create a unique product, service or result with a well-defined objective, scope, and resources under cost, time, and quality constraints (Kerzner, 2006; PMI, 2016). According to Slack et al. (2009), project is the process of setting resources and/or activities to meet the functional requirements of customers through a product, service or the transformation process that produces it.

Projects can be implemented in virtually all areas of human knowledge and reach all levels of an organization. Often, they will extrapolate the boundaries of the organization and reach its stakeholders, becoming part of its business strategy in most cases (Vargas, 2005).

Regardless of the type of project, they all go through the same life cycle, which consists of four distinct phases: planning, execution, implementation, and completion. Each phase has its own set of objectives, activities, tools, and skills. As a result, the project manager will have to act taking what each of them needs into account (Duffy, 2008).

As stated by Alencar et al. (2007), the phases of a life cycle can vary according to the nature of the project, but overall, they include viability (initial phase), planning, execution, control, and completion. Different people can manage each of these phases, and not everyone on the team will be involved from start to finish. It is in this scenario that project management comes into existence.

Project management means applying skills, knowledge, and techniques for the effective and efficient execution of the project to meet the desired results (Heldman, 2005; PMI, 2016). It can also be defined as the planning, scheduling, and control of connected activities with the purpose of achieving goals (Kerzner, 2006).

According to Vargas (2005), project management is a set of managerial tools that control single, non-repetitive and complex events, within a predetermined context in relation to time, cost, and quality. For this control to exist, the managerial tools allow the organization to develop a set of skills, knowledge, and individual capabilities.

Project management is a way of meeting project goals through planning, execution, monitoring, and control of activities (Lewis, 2000). It is considered a complex and challenging activity that has unlimited potential, but with predictable patterns, despite these characteristics (Duffy, 2006). It can detect and control costs and deadlines while maintaining competitiveness to exceed the expectations of customers (Bomfin et al., 2012).

The objective of project management is to trace, disseminate, monitor, and fix the path the projects will take, considering the risks, uncertainties, contingencies, failures, and changes that may occur in this period. It covers the identification of needs; the establishment of goals; the balance between quality, time, scope, and cost; the adaptation to changes; and the expectations of stakeholders (Jordão et al., 2015).

Project management is performed through the appropriate application and integration of some processes belonging to five groups defined by the PMBOK Guide: Initiating; Planning; Executing; Controlling; and Closing (PMI, 2013). These process groups are phases that comprise the life cycle of the project. Each process produces results that will become inputs for the next process group by means of successive interactions as shown in Figure 1 (Heldman, 2005).

The objective of the initiating process group is to define a new project or a new project phase, confirming their start after the identification and survey of physical, financial, staff, and stakeholders needs, and giving the necessary permissions after a thorough feasibility study (Candido et al., 2012; PMI, 2013).

The initiating process group will become an input to the planning process group. The goal of this second group is to consolidate a project plan that includes customer requirements, the scope of the project, schedule, budgets, and communication plan among other items (PMI, 2013). Planning is not static and can undergo modifications throughout the life cycle of the project. Therefore the project manager, with the help of the team, must be attentive to the documentation and its updates (Candido et al., 2012).

The planning process group will provide input for the executing process group, which will have the purpose of implementing what was defined to meet the established specifications. It must constantly be updated with the input from the controlling process group. This last group is characterized by processes of monitoring, analysis, and control of the progress and performance of the project. It establishes the necessary changes by comparing what was executed to how it was planned (PMI, 2013). Controlling is fundamental to the success of the project as they allow the identification of problems in enough time to be solved (Candido et al., 2012).

Lastly, the closing process group aims to conclude all activities of all process groups for a formal closure of the project or phase using records that will contribute to increase the know-how of the organization (Candido et al., 2012; PMI, 2013).

The PMBOK Guide mentions a total of forty-seven (47) processes grouped into ten (10) areas of knowledge. Twenty-four (24) of these groups belong to the planning process group, making it the main operational guideline of project management (Jugend et al., 2014).

In a study conducted by Terribili (2013), the five main problems raised by Brazilian organizations are directly related to four disciplines included in the PMBOK Guide: time management, scope management, communication management, and cost management.

Of the participating organizations, 60.2% report that they are "not meeting deadlines", i.e., in every five organizations surveyed, three have problems

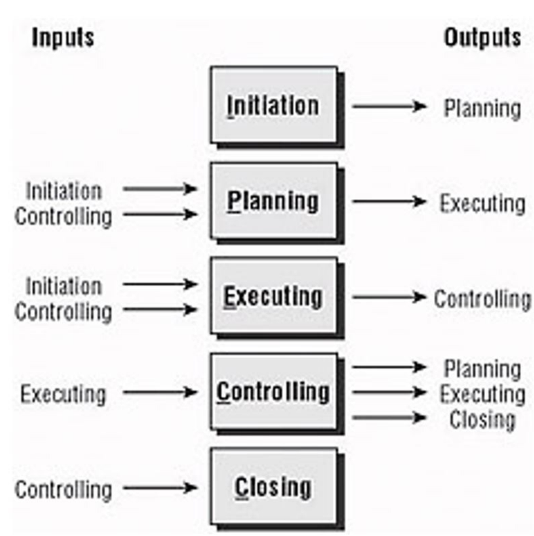

Figure 1. Project Management Process Groups. Source: Heldman (2005).

with time management (Terribili, 2013). The delays in a project may be unavoidable, but, at the same time, they can be mitigated by a good control of the progress of the project, which will readjust the schedule to accommodate the delays and bottlenecks that happen during execution (Duffy, 2008).

After conducting a root cause analysis, we can conclude that the reason for delays in projects stems from several variables, many of which transcend the behavioral characteristics of the project manager and materialize in aspects of administration, managerial skills, and non-technical expertise (Terribili, 2013).

Terribili (2011) identifies eight groups of potential causes of delays in projects: poorly defined scope, badly estimated deadlines, insufficient human resources, delays in the execution of activities, delays in deliveries from suppliers, tested quality below expectations, excessive bureaucracy in the organization, and risks that become a reality.

Kerzner (2010) emphasizes that the successful implementation of processes and methodologies is necessary to achieve excellence in project management. The managerial level of the company cannot ignore how the organization uses information. It is this information that will help the manager make decisions, find solutions, and deal with customer satisfaction (Bomfin et al., 2012). According to Fonseca (2006, p. 35), "[…] well managed projects reduce uncertainties and achieve customer satisfaction."

Numerous problems arise during management. If treated in a static manner, they result in the incidence of delays in the schedule and unwanted costs, regardless of the advances in technology and management techniques. It takes a huge effort in planning and control of project management to mitigate these chronic symptoms (Lee et al., 2005).

3 Methodology

This research can be classified as a case study of exploratory and quantitative nature. We used some working documents containing sensitive data as support to find a conclusive result and reach the objectives of the article.

The research is exploratory since its goal is to provide information about the object and guide the formulation of hypotheses (Cervo et al., 2007). Furthermore, according to Gonçalves (2014), exploratory research aims to discover, to find, to elucidate phenomena or to explain those that were not accepted despite being evident. That way, it reiterates the objective of this study to investigate a phenomenon that will directly affect the work routine.

Regarding technical procedures, the research is a case study as it is applied directly to the reality of one project. Yin (1984) posits that a case study consists of an intensive analysis of a particular situation investigated, without significant interference from the researcher.

In this case, the site of analysis was a research project that started with a cooperation agreement between federal institutions - the University of Brasilia (UnB) - and a security organization. The required result was the modeling of logistic processes, in order to assist in the modernization of a control system for the management of materials.

Several supporting documents served as management control and were used as input for the development of this article, such as general spreadsheet of processes, update control tool, team data spreadsheet among others. In this regard, the case study had the aid of documentary research and statistical analysis to achieve its goal.

The study has a quantitative nature, which, according to George & Bennett (2005), is based on statistical techniques to describe the reality being investigated. The statistical analysis used demonstrates the relationship between the delays at work and six selected variables (Duration of the Project, Stage of Material, Systematic Version, Team, Number of Modifications, and Number of Elements). In this respect, one of the ways to evaluate the effectiveness and efficiency of the monitoring process is through the application of statistical methods.

3.1 Statistical analyses

We conducted statistical analyses to verify the similarity between the selected variables and the execution time of activities, thus determining the effectiveness of the project management process. To this end, we used the test of independence and the test of correlation, explained, respectively, on topics 3.1.1 and 3.1.2.

3.1.1 Test of Independence

The Test of Independence between two qualitative variables is performed using data available in a contingency table (double entry). The cells of this table contain the respective frequencies observed, as presented in Table 1.

In this test, we consider the independence between the variables A and B as a null hypothesis, that is, the marginal proportion of variable A in the i-th class $(n_{i.}/n_{..})$ can be found in any class of variable B, $\left(n_{ij}/n_{.j}\right)$. Similarly, the marginal proportion of variable B in the i-th class $\left(n_{.j}/n_{..}\right)$ can be found in any class of variable A $\left(n_{ij}/n_{i.}\right)$.

Formally, we could consider p_{ij} as the probability of an element being classified in categories i and j at the same time, with $p_{i.}$ and $p_{.j}$ as marginal probabilities. Consequently, we could write the hypothesis of independence as follows:

Table 1. Contingency table of categorical variables *A* and *B*.

Variable *A*	**Variable *B***						**Total**
	B_1	B_2	...	B_j	...	B_s	
A_1	n_{11}	n_{12}	...	n_{1j}	...	n_{1s}	$n_{1.}$
...	...	...	...	...	...	...	...
A_i	n_{i1}	n_{i2}	...	n_{ij}	...	n_{is}	$n_{i.}$
...	...	...	...	...	...	...	...
A_r	n_{r1}	n_{r2}	...	n_{rj}	...	n_{rs}	$n_{r.}$
Total	$n_{.1}$	$n_{.2}$	...	$n_{.j}$	...	$n_{.s}$	$n_{..}$

H_0: $p_{ij} = p_{i.} \cdot p_{.j}$, for each pair (i, j);
H_1: $p_{ij} \neq p_{i.} \cdot p_{.j}$, for any pair (i, j).

We could describe such hypotheses literally as:

H_0: The variables (A, B) are independent;
H_1: The variables (A, B) are not independent.

The test statistic used is based on Pearson's chi-square statistic following Formula 1 (Casella & Berger, 2010):

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{s}\frac{\left(n_{ij}-n_{ij}^{*}\right)^2}{n_{ij}^{*}} \sim \chi^2_{(r-1)(s-1)}, \quad (1)$$

in which n_{ij}^{*} brings the expected value under the hypothesis that the two variables are independent.

Based on the results calculated through the test statistic χ^2, we can reject the null hypothesis (H_0) if the result is higher than a critical value (χ^2_c), with a specified significance level value, or if the descriptive level (*p-value*) is lower than 5%.

3.1.2 Test of correlation

To verify the correlation between two variables, we used the Pearson Correlation Coefficient, which is usually calculated to determine the coefficient of correlation for a sample (r), since this value is unknown to the population. In this case, we have Formula 2:

$$r = \frac{\sum_{i=1}^{n}\left(X_i-\bar{X}\right)\times\left(Y_i-\bar{Y}\right)}{\sqrt{\sum_{i=1}^{n}\left(X_i-\bar{X}\right)^2}\times\sqrt{\sum_{i=1}^{n}\left(Y_i-\bar{Y}\right)^2}}. \quad (2)$$

We formulated the hypotheses bellow to verify if the hypothesis of correlation between two variables (X, Y) has a certain value ρ_0:

H_0: $\rho(X, Y) = \rho_0$ versus H_1: $\rho(X, Y) \neq \rho_0$.

Ronald Fisher suggested the following transformation for the statistic r (Bussab & Morettin, 2013) as a measure to be used as the test statistic following Formula 3:

$$\xi = \frac{1}{2}\ln\frac{1+r}{1-r}, \quad (3)$$

which has a distribution very close to Normal distribution, i.e., $r \sim N\left(\mu_\xi, \sigma^2_\xi\right)$, in which following Formula 4:

$$\mu_\xi = \frac{1}{2}\ln\frac{1+\rho_0}{1-\rho_0} \text{ and } \sigma^2_\xi = \frac{1}{n-3}. \quad (4)$$

with n as the sample size $(X_1, Y_1), \ldots, (X_n, Y_n)$ and ρ_0 as the value of the population parameter. The approach proposed by Fisher does not apply to $\rho = -1$ or $\rho = 1$.

With a specified significance level α, the critical region for a unilateral test (right side) is following Formula 5:

$$RC = \left\{\xi : \xi > \mu_\xi + 1{,}645\sqrt{\sigma^2_\xi}\right\}. \quad (5)$$

We should reject H_0 if $\xi_0 \in RC$, in which $\xi_0 = \frac{1}{2}\ln\frac{1+r}{1-r}$.

We formulated the hypotheses below to verify the hypothesis of non-correlation between two variables (X, Y):

H_0: $\rho(X, Y) = 0$ versus H_1: $\rho(X, Y) \neq 0$.

In this case, we can use a precise test based on the following statistics following Formula 6:

$$T = r\sqrt{\frac{n-2}{1-r^2}}, \quad (6)$$

which has a t-Student distribution with n - 2 degrees of freedom.

As in the previous case, we must specify the significance level α to determine the critical region. If the value is $T \in RC$, we reject H_0. If the decision is based on the descriptive level, the rejection of H_0 should happen when the *p-value* is lower than 5%.

4 Presentation of the project context

The project - object of study of this work - started with a cooperation agreement between federal institutions - UnB - and a security organization. The required result was the modeling of two hundred and twenty (220) logistic processes, with the goal of assisting in the modernization of a control system for the management of materials during nineteen (19) months.

We divided the total duration of the project into quarterly partial deliveries, each of them with clear goals of process modeling. In the first quarter, the project was organized, and team members were trained in the technical content of business process management. Modeling activities started properly as of the second quarter.

We grouped the processes into distinct stages. They reflect part of the life cycle of the material within the security organization: acquisition and control of material. Acquisition of material covers the planning involved in the acquisition, starting with the survey of needs, followed by budget planning, and ending with the contract for the acquisition of material. Control of material encompasses the management and procedures done on the material after its delivery by the supplier.

We modelled the processes in stages so that each of them could be understood before being integrated into other processes. In addition, the processes varied according to the different materials the organization had.

In regard to human resources, the project counted with eight teams with the following structure: a professor advisor; a leader, called research assistant; two undergraduate students; and a requirements analyst. Except for the latter, from the Software Engineering area, the other team members were Production Engineering graduates or undergraduates.

In addition to the modeling teams, there were two other teams. The first one worked in the processes office and consisted of a chief research assistant and two specialists in Business Process Modeling Notation (BPMN). Primarily, this team was responsible for unifying the understanding of processes within the group through the Systematic of Process Modeling.

Systematic of Process Modeling was an important document as it standardized and guided necessary and specific procedures for the interview, modeling, validation, documentation, and analysis of requirements. It was upgraded and improved throughout the project, resulting in different versions of the document.

The second team oversaw project management and was composed of a project manager, a professor coordinator, and a chief research assistant. They worked in the management of the project as a whole, including control of scope indicators, costs, quality, and, most importantly, time. We will highlight some of them in this article.

The main quality check happened when different actors (research assistant, processes office, and professor advisor) verified and validated the compliance with the standards established. Those responsible for this task developed a control tool for the proposed changes to monitor these validations. It recorded the suggestions made, how many they were, and why they had been submitted for later analysis and proposal of corrective measures. It also registered the number of elements in the process at that point so its size could be known.

Every day, a number of control tools administered the time. The first was the modeling meeting report, which had information on its date and time, participants, transcription, and decisions made. This tool provided input to fill out the process monitoring board put in the workplace for visual control. The board informed the execution dates of each activity and, in case of delay, the reason it occurred. Figure 2 illustrates this tool.

Daily, the process monitoring board populated the General Spreadsheet of Processes - a complex, automated, and relevant tool for the control of process performance. This spreadsheet was divided into two

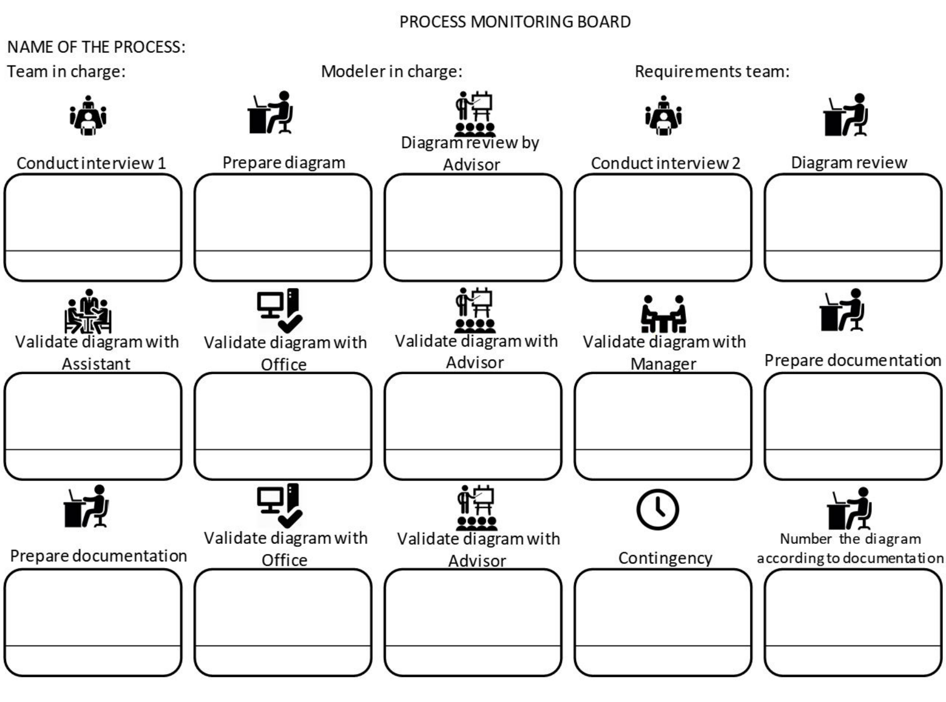

Figure 2. Process monitoring board.

main areas of the data file. The first identified the process through status, code, name, change control, and the team responsible for the modeling, as shown in Figure 3.

The second recorded the scheduled and execution dates for each activity planned, as well as the number of days of delay, its category, and the reason it occurred, as illustrated in Figure 4.

Using the registered data, the spreadsheet performed automatic operations and worked as a management tool for project indicators with an emphasis on time control, as presented in Table 2.

A dashboard displayed these indicators in an illustrative way to simplify and guide the analyses that led to decision-making on a daily basis, as shown in Figure 5.

It is clear that time control of the project was a major concern as it is a paramount factor in achieving the objectives set in the defined scope.

Understanding which elements related to time - delays in specific - helped us improve the planning and management of the project. Section 5 will present these relationships.

5 Data analysis

We could only define the data analysis after choosing which variables to study - result of an assessment of the root cause by experienced members of the project. They were selected for their direct influence on the flow of working time and, consequently, for their potential involvement in the delay of activities. The variables were: Duration of the Project, Stage of Material, Systematic Version, Team, Number of Modifications, and Number of Elements.

In addition, we created the following classes to represent the number of days of delay observed in the modeling of processes (the key activity of the project studied): no delay, $1 < X < 10$, $X > 10$. All statistical analyses used these classes. Next, we will present the results of the qualitative analysis on topic 5.1, and of the quantitative analysis on topic 5.2.

5.1 Qualitative analysis

We performed statistical tests of independence to check if the delays were related to the variables of qualitative nature - Duration of the Project, Stage of Material, Systematic Version, and Team.

5.1.1 Analysis between delay and duration of the project

The total duration of the project was divided into six quarters of work analyzed. We disregarded the first quarter of this analysis since it does not have enough processes for the application of the chi-square test.

Table 3 presents data on the frequency of processes on the other quarters per delay interval: no delay, from

Status	Code	Name of the Process	Change Control	Team

Figure 3. Process identification in the general spreadsheet of processes.

2. Prepare Diagram				
Scheduled date	Execution date	Delay	Category	Reason

Figure 4. Record of the process progress in the general spreadsheet of processes.

Table 2. Time indicators of the project.

Name of Indicator	Description
Number of concluded processes	Processes with all planned activities executed
Total percentage of the project	Number of concluded processes in relation to the total number of processes
Duration control per process	Bar graph indicating the duration of processes with goal identification in red
Average duration of processes	Average duration of all concluded processes
Average delay of processes	Average delay of all concluded processes in comparison to the schedule
Control of processes per team	Number of ongoing processes on time, ongoing delayed processes, and concluded processes for the modeling teams subdivided by shifts
Control of delay per activity	Percentage of processes delayed in each scheduled activity
Burndown graph	Relationship between actual and planned modeling progress

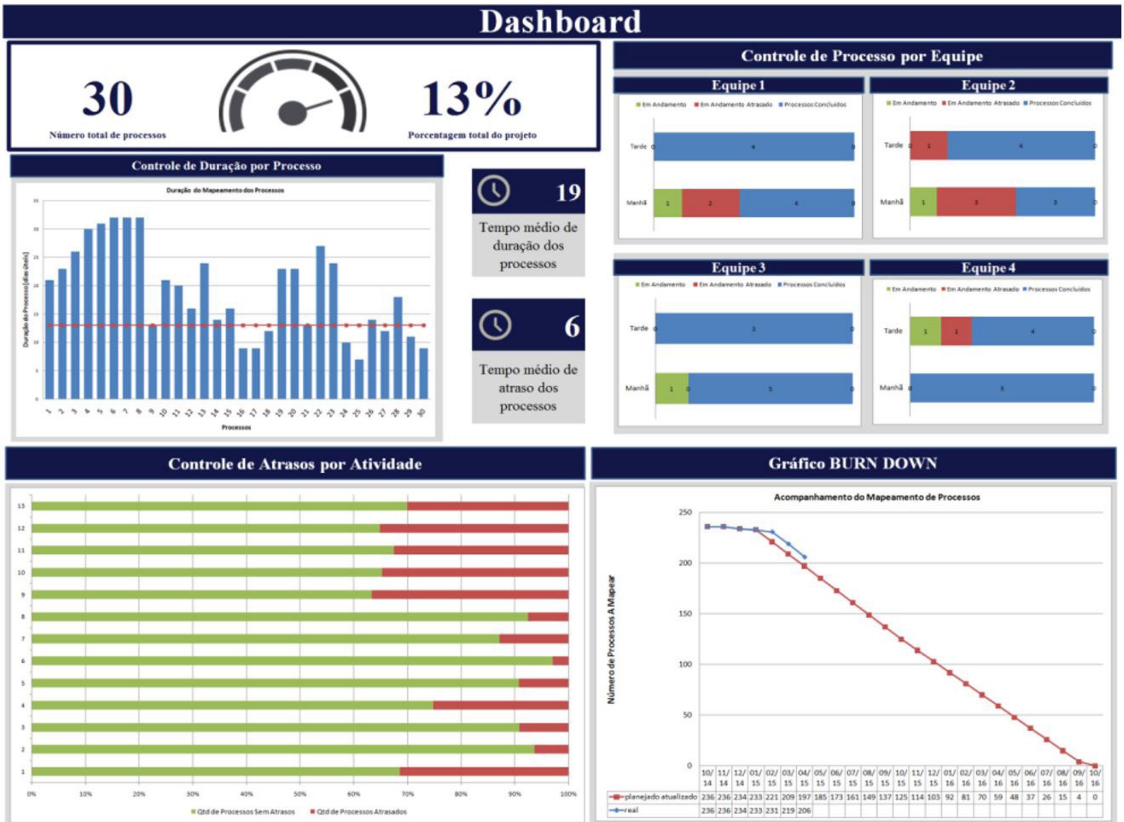

Figure 5. Dashboard of the General Spreadsheet of Processes.

Table 3. Frequency of delay per quarter.

Referent quarter	Frequency of delay per data range (x)			Total per quarter
	No Delay	1<x<10	x>10	
Second Quarter (Feb, Mar, Apr/15)	12	15	6	33
Third Quarter (May, Jun, Jul/15)	14	25	6	45
Fourth Quarter (Aug, Sep, Oct/15)	9	22	10	41
Fifth Quarter (Nov, Dec/15 Jan/16)	8	6	5	19
Sixth Quarter (Feb, Mar, Apr/16)	13	5	6	24
Total per range	56	73	33	162

1 to 10 working days of delay, more than 10 working days of delay.

The observed data demonstrated that the delays do not depend on the duration of the project (χ^2 (8) = 14.276; *p-value* = 0.075).

5.1.2 Analysis between delay and stage of material

Stage of material was divided into "Acquisition of Material" and "Control of Material". The first one covers the planning involved in the acquisition, starting with the survey of needs, followed by budget planning, and ending with the contract for the acquisition of material. The second one encompasses all the management and procedures done on the material after its delivery by the supplier. The material can be preserved, transported, stored, used until total consumption, or become unfit for use.

Table 4 presents data on the frequency of processes on each stage per delay interval: no delay, from 1 to 10 working days of delay, more than 10 working days of delay.

After the chi-square test, the observed data demonstrated that the delays do not depend on the process classification of the stage of material (χ^2 (2) = 0.537; *p-value* = 0.764).

5.1.3 Analysis between delay and systematic version

The systematic adopted by the project was divided into four versions representing major changes that occurred over time. Table 5 presents data on the frequency of processes on each version per delay interval: no delay, from 1 to 10 working days of delay, more than 10 working days of delay.

After the chi-square test, the observed data demonstrated that the delays depend on the systematic version adopted (χ^2 (6) = 13.544; *p-value* = 0.035). This dependency will be investigated on item 6.

5.1.4 Analysis between delay and team

The project has eight teams to model the processes. Each professor is responsible for two teams, one on each shift. The teams were grouped two by two, according to the professor in charge, in a total of four teams.

Table 6 presents data on the frequency of processes on each team per delay interval: no delay, from 1 to 10 working days of delay, more than 10 working days of delay.

After the chi-square test, the observed data demonstrated that the delays depend on the team (χ^2 (6) = 14.650; *p-value* = 0.023). That is to say, the team responsible influences the number of days of delay.

5.2 Quantitative analysis

We used the Test of Correlation to verify if the delays were related to quantitative variables - Number of Modifications and Number of Elements. In this case, the most appropriate test to verify the correlation between two variables is based on the Pearson Correlation Coefficient.

5.2.1 Analysis between delay and number of modifications

Since both variables are numerical, we conducted a correlation analysis between the number of days of delay and the number of modifications. Two spreadsheets stored the data: one for the dates of activities performed in the process, and another one for the changes made on each validation submitted.

After the Pearson correlation test (r = -0.11), there was no statistical evidence to reject the null hypothesis (*p-value* = 0.428), i.e., the correlation between the delay and the number of errors was zero. Figure 6 illustrates the data.

The data did not show any tendency that could connect the variables. In conclusion, the number of changes made in the process and the number of days of delay are two non-correlated variables.

5.2.2 Analysis between delay and number of elements

Since both variables are numerical, we conducted a correlation analysis between the number of days of delay and the number of elements in the process.

Table 4. Frequency of delay per stage of material.

Stage of material	Frequency of delay per data range (x)			Total per stage of material
	No Delay	1<x<10	x>10	
Acquisition of material	25	40	16	81
Control of material	31	39	19	89
Total per range	56	79	35	170

Table 5. Frequency of delay per systematic version.

Systematic	Frequency of delay per data range (x)			Total per systematic
	No Delay	1<x<10	x>10	
Version 1	13	20	9	42
Version 2	14	26	7	47
Version 3	9	24	9	42
Version 4	20	9	10	39
Total per range	56	79	35	170

Table 6. Frequency of delay per team.

Team	Frequency of delay per data range (x)			Total per team
	No Delay	1<x<10	x>10	
Team 1	16	16	6	38
Team 2	22	20	5	47
Team 3	7	19	15	41
Team 4	12	20	9	41
Total per range	57	75	35	167

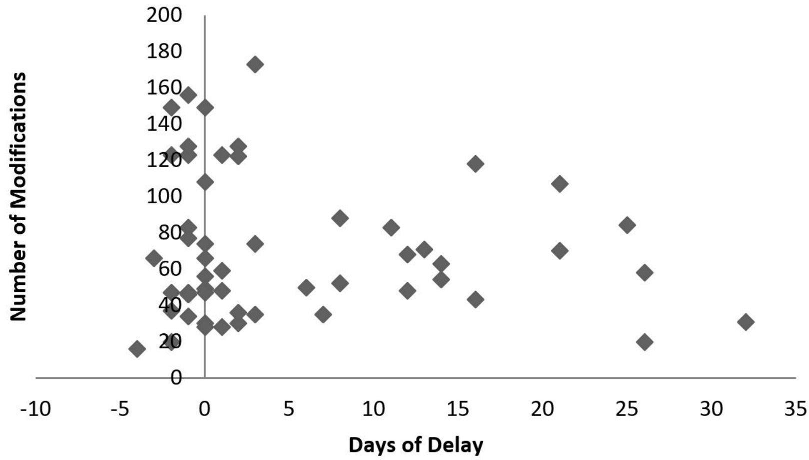

Figure 6. Graph of the correlation between the delays and the number of modifications.

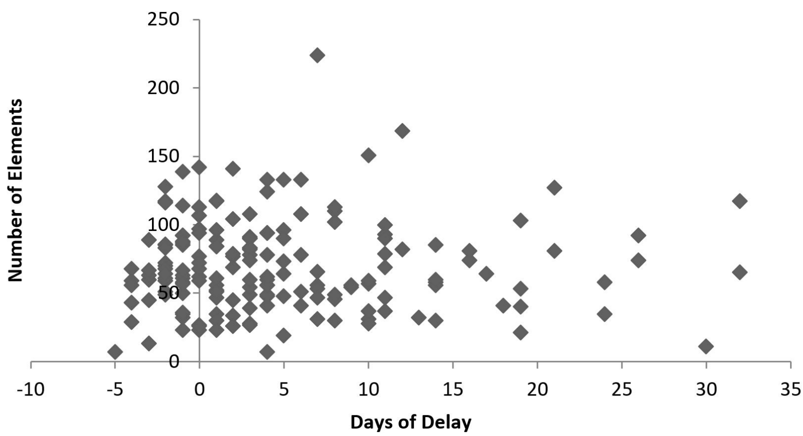

Figure 7. Graph of the correlation between the delays and the number of elements in the process.

The number of elements included tasks, diversions, start events, intermediate events, and end events. Figure 7 represents the correlation between the data.

The sample size was one hundred and seventy (170) processes. There was no statistical evidence to reject the null hypothesis (*p-value* = 0.92), i.e., the correlation between the delay and the number of elements in the process was zero ($r = 0.078$).

6 Conclusion

The research successfully identified which elements affected the execution time of the modeling. To reach that goal, we used statistical analysis techniques - both qualitative and quantitative - to establish the relationships between the elements of process modeling and the delays in the schedule. Qualitative analysis studied four variables: duration of the project, stage of material, systematic version, and team. Of those, two had an effect on delays - systematic version and team. Quantitative analysis assessed two variables - number of modifications and number of elements -, and none of them showed evidence of correlation.

These analyses demonstrated that the delays depend on the systematic version used in the modelings. It is important to emphasize that the changes between systematic versions were made so aspects not defined by the BPMN notation could be better detailed. The need for these changes is a result of customer requirements and/or internal standardization. We believe that the reason for the correlation between this variable and the delays was the clarity in the description of complementary rules, with the use of templates, models, and examples.

Another element that influenced delays was the modeling team. The project counted with four professors advisors and four research assistants for the modeling. The four teams studied had different professors and research assistants in charge. The relationship between the team and the delays suggested that there is variation in behavior and attitude depending on the members involved.

Understanding which elements affected the delays contributed to a better project planning. With that knowledge, the coordination was able to decide which actions to take to reduce the factors that could cause delays in the schedule. For example, we organized training workshops in the processes of control of material; improved the descriptions of the systematic modeling to make them clearer; standardized the postures of teams with less delay as good practices for the other teams; among others.

The improvement in the planning capacity of the project was important as it gave input to the executing processes. These processes had the goal of implementing what was defined to meet the established specifications. Also, the controlling processes constantly provided information on the need for updates based on the observed occurrences along the progress of the project. A survey of new applications of analysis was essential to improve planning to meet deadlines, considering that the recurrence of delays in organizations is very high (60.2%), as previously mentioned by Terribili (2013).

Nonetheless, it is important to mention that the research method used has limitations. For instance, the findings cannot be generalized to other similar projects, as this was a case study conducted according to its specific aspects. However, Eisenhardt (1989) underlines the relevance of this type of research. Even if it cannot be broadly used, it facilitates the construction of new theories and models. Despite the limitations, the results obtained can strongly indicate how to prepare future researches or further this study.

As a future investigation, we propose the replication of this method for similar projects to verify whether the relationship between the elements analyzed and the delays in the schedule is specific to this project, considering its context and peculiarity, or if it is recurrent in projects of the same nature and conditions. In addition, we suggest the continuation of the statistical analysis after the implementation of improvement actions in the planning of the project. The statistical analysis can confirm if the knowledge of which elements cause delays can actually improve the planning and reduce unwanted effects on time.

References

Alencar, L. H., Almeida, A. T., & Mota, C. M. M. (2007). Sistemática proposta para seleção de fornecedores em gestão de projetos. *Gestão & Produção*, 14(3), 477-487. http://dx.doi.org/10.1590/S0104-530X2007000300005.

Bomfin, D. F., Nunes, P. C. A., & Hastenreiter, F. (2012). Gerenciamento de projetos segundo o guia PMBOK: desafios para os gestores. *Revista de Gestão e Projetos*, 3(3), 58-87. http://dx.doi.org/10.5585/gep.v3i3.78.

Bussab, W. O., & Morettin, P. A. (2013). *Estatística básica* (8. ed.). São Paulo: Saraiva.

Candido, R., Gnoatto, A., Caldana, C., Setti, D., Spanhol, F., Schutz, F., Carvalho, H., Oliveira, J., & Kachba, Y. (2012). *Gerenciamento de projetos*. Curitiba: Aymará.

Casella, G., & Berger, R. L. (2010). *Inferência estatística*. Boston: Cengage Learning.

Cervo, A. L., Bervian, P. A., & Silva, R. (2007). *Metodologia científica* (6. ed.). São Paulo: Pearson Prentice Hall.

Duffy, M. G. (2006). *Gestão de projetos: soluções práticas para os desafios do trabalho*. Rio de Janeiro: Elsevier.

Duffy, M. G. (2008). *Managing projects: expert solutions to everyday challenges*. Boston: Harvard Business School Publishing.

Eisenhardt, K. (1989). Building theories from case study research. *Academy of Management Review*, 14(14), 532-550. http://dx.doi.org/10.5465/amr.1989.4308385.

Fonseca, S. U. L. (2006). *Benefícios da adoção do modelo PMBOK no desenvolvimento e implantação do projeto de tecnologia da informação de um operador logístico: um estudo de caso da Word Cargo* (Dissertação de mestrado). Universidade Católica de Santos, Santos. Retrieved in 2017, April 19, from http://biblioteca.unisantos.br:8181/handle/tede/502

George, A., & Bennett, G. (2005). *Case studies and theory development in the social sciences*. Cambridge: MIT Press.

Giacometti, R. A., Silva, C. E. S., Souza, H. J. C., Marins, F. A. S., & Silva, E. R. S. (2007). Aplicação do *earned value* em projetos complexos: um estudo de caso na EMBRAER. *Gestão & Produção*, 14(3), 595-607. http://dx.doi.org/10.1590/S0104-530X2007000300013.

Gonçalves, H. A. (2014). *Manual de artigos científicos* (2. ed.). São Paulo: Avercamp.

Heldman, K. (2005). *Gerência de projetos: fundamentos: um guia prático para quem quer certificação em gerência de projetos*. Rio de Janeiro: Elsevier.

Jordão, R. V. D., Pelegrini, F. G., Jordão, A. C. T., & Jeunon, E. E. (2015). Fatores críticos na gestão de projetos: um estudo de caso numa grande empresa latino-americana de classe mundial. *Gestão & Produção*, 22(2), 280-294. http://dx.doi.org/10.1590/0104-530X1091-13.

Jugend, D., Barbalho, S. C. M., & Silva, S. L. (2014). *Gestão de projetos: teoria, prática e tendências* (1. ed.). Rio de Janeiro: Elsevier.

Kerzner, H. (2006). *Gestão de projetos: as melhores práticas* (2. ed.). Porto Alegre: Bookman.

Kerzner, H. (2010). *Gestão de projetos: as melhores práticas* (2. ed.). Porto Alegre: Bookman.

Kerzner, H., & Saladis, F. P. (2011). *Gerenciamento de projetos orientado por valor*. Porto Alegre: Bookman.

Lee, S. H., Peña-Mora, F., & Park, M. (2005). Dynamic planning and control methodology for strategic and operational construction project management. *Automation in Construction*, 15(1), 84-97. http://dx.doi.org/10.1016/j.autcon.2005.02.008.

Lewis, J. P. (2000). *Como gerenciar projetos com eficácia*. Rio de Janeiro: Campus.

Marques, L. J., Jr., & Plonski, G. A. (2011). Gestão de projetos em empresas no Brasil: abordagem "tamanho único"? *Gestão e Produção*, 18(1), 1-12. http://dx.doi.org/10.1590/S0104-530X2011000100001.

Padilha, T. C. C., Costa, A. F. B., Contador, J. L., & Marins, F. A. S. (2004). Tempo de implantação de sistemas ERP: análise da influência de fatores e aplicação de técnicas de gerenciamento de projetos. *Gestão & Produção*, 11(1), 65-74. http://dx.doi.org/10.1590/S0104-530X2004000100006.

Project Management Institute – PMI. (2013). *Um guia do conhecimento em gerenciamento de projetos (Guia PMBOK)* (5. ed.). Atlanta: PMI.

Project Management Institute – PMI. (2016). *What is project management?* Atlanta: PMI. Retrieved in 2016, June 6, from http://www.pmi.org/About-Us/About-Us-What-is-Project-Management.aspx

Slack, N., Johnston, R., & Chambers, S. (2009). *Administração da produção* (3. ed.). São Paulo: Atlas.

Terribili, A., Fo. (2011). *Os 8 porquês dos atrasos nos projetos*. Retrieved in 2012, September 4, from http://www.metaanalise.com.br/inteligenciademercado/index.php?option=com_content&view=article&id=6007:os-8-porques-dos-atrasos-nos-projetos&catid=1:ponto-de-vista&Itemid=353

Terribili, A., Fo. (2013). Os cinco problemas mais frequentes nos projetos das organizações no Brasil: uma análise crítica. *Revista de Gestão e Projetos*, 4(2), 213-237. http://dx.doi.org/10.5585/gep.v4i2.99.

Vargas, R. V. (2005). *Gerenciamento de projetos: estabelecendo diferenciais competitivos*. Rio de Janeiro: Brasport.

Yin, R. (1984). *Case study research: design and methods*. Beverly Hills: Sage Publishing.