

Study on the factors of delay in construction works

Estudo sobre os fatores de atraso nas obras

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Abstract

The delay in civil construction works is observed globally and affects the economy of countries. Therefore, identifying the causes of delays is of paramount importance to minimize their consequences. This paper aims at identifying the causes of delay in construction works and their analysis and existing correlations through statistical factor analysis. The research methodology included a Systematic Literature Review (SLR), a Survey Research through questionnaires and interviews was conducted, as well as the identification of the main causes of delay through the Relative Importance Index (RIL) and the ABC Curve. Finally, factor analysis of the causes of delay was performed, not limiting only to their identification. The results showed that the 12 identified causes are correlated to 4 delay factors, which account for 69.18% of the sample variance: supply management (21.41%); workforce management (20,79%); project management (17.64%) and management of climatic conditions (9.34%). It is concluded hereby that the delay factors mentioned herein can be considered management deficiencies in the projects and that the research has expanded the knowledge on construction delays, thus contributing to the frontier of knowledge to mitigate this problem in several countries, especially developing ones.

Keywords: Factors of construction work delay. Factor analysis. Causes of delay. Project management.

Resumo

O atraso em obras é observado globalmente na construção civil e afeta a economia dos países, sendo fundamental a identificação de suas causas para a minimização das consequências. O objetivo deste trabalho é a identificação das causas de atraso de obras em edificações e a análise de suas correlações pela análise fatorial estatística. A metodologia de pesquisa incluiu uma Revisão Sistemática da Literatura (RSL), uma Pesquisa Survey, por meio de questionários e entrevistas; assim como a identificação das principais causas de atraso pelo Índice de Importância Relativa (RII) e a Curva ABC. Por fim, efetuou-se a análise fatorial das causas de atraso; não se limitando apenas a identificação das mesmas. Os resultados demonstraram que as 12 causas identificadas são correlacionadas a 4 fatores de atraso, que explicam 69,18% da variância da amostra: gestão de suprimentos (21,41%); gestão da mão de obra (20,79%); gestão do projeto (17,64%) e gestão das condições climáticas (9,34%). Conclui-se que os fatores de atraso citados podem ser considerados como deficiências de gestão dos empreendimentos e que a pesquisa aprofundou o conhecimento sobre atrasos na construção, contribuindo na fronteira do conhecimento para mitigação deste problema presente em vários países, principalmente os países em desenvolvimento.

Palavras-chave: Fatores de atrasos de obra. Análise fatorial. Causas de atraso. Gestão de projetos.

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Introduction

The delays in the delivery of work contracts still appear as a recurring issue in engineering projects, which often occur from design to completion, whether in public or private works, in developing or developed countries. The consequences are disputes and litigation between the parties, cost escalation, loss of profit, poor service quality, arbitrage, overrun of the deadline defined for executing the works or closing the project (AKOGBE; FENG; ZHOU, 2013; DOLAGE; PATHMARAJAH, 2015; GONZÁLEZ *et al.*, 2014; GUNDUZ; NIELSEN; OZDEMIR, 2015; KHAN; GUL, 2017; MARZOUK; EL-RASAS, 2014; SWEIS, 2008; ULLAH *et al.*, 2018). It is further observed that the delays in construction projects is a fact observed globally or on a large scale, affecting not only the industry itself, but the economy of nations in general; thus negatively impacting the success of the project due to changes in the original execution schedule and the previously established costs, quality criteria and management of safety conditions (CHAUHAN; SHAH; RAO, 2008; DORAISAMY; AKASAH; YUNUS, 2020; FARIDI; EL-SAYEGH, 2006; FLYVBJERG *et al.*, 2002; MYDIN *et al.*, 2014a).

Because this is one of the biggest problems in construction management, the delay in construction works poses a strong financial and social impact on all the stakeholders in the project. However, it is more intense and common in developing countries, which usually overrun project costs and have budget problems and shortage of resources (ABBAS; PAINTING, 2017; KAMING *et al.*, 1997; RACHID; TOUFIK; MOHAMMED, 2018; SHEBOB; DAWOOD; XU, 2011). Venkatesh and Venkatesan (2017) also emphasize there is a variation in occurrence of the causes for delay among countries and that occurrences regarded as critical are very different in developing countries than those in developed ones.

In the Brazilian case, for example, Filippi and Melhado (2015) cite data from the Brazilian Consumer Association (ABC), which found an increase of 65% in delays in works carried out in São Paulo during the years 2005 and 2010. In addition to also reporting the increase in the number of lawsuits between 2008 and 2013, which jumped from 140 new lawsuits against São Paulo construction companies to 3,779, that is, 2,600% more in just 5 years; according to a survey by Tapai Advogados, which works with real estate law. Corroborating the above, Maués *et al.* (2017) emphasize that the performance in the construction industry is much lower in terms of meeting contractual deadlines, especially in developing countries, if compared to other industries, such as the manufacturing industry. These authors researched 142 projects in the Brazilian Amazon region between the years 2005 and 2015, and found that 81.69% of the works suffered delays in their original schedules; which corresponded to 116 projects delivered after the deadline.

Other countries can be cited, such as the case of Iran, which presented a cost of approximately US \$ 21 billion to the government of that country regarding the delays in the works from 2002 to 2012; according to the Iranian statistical center (SAMARGHANDI *et al.*, 2016). In Qatar, Senouci, Ismail and Eldin (2016) detail that the public projects carried out, between 2000 and 2013, presented a percentage of 54% increase in costs and 72% of delays in the completion of the works; as well as an increase of 50% in relation to the cost and delays in the realization time in the case of building maintenance services. Mukuka, Aigbavboa and Thwala (2015) and Prasad *et al.* (2018) report, for instance, the challenge of the construction industry in South Africa and India to deliver works within the contractual deadline and the importance of adopting mitigation measures, and this is the subject of studies of the possible causes for delay in construction works.

Hsu, Aurisicchio and Angeloudis (2017) corroborate this thesis by stating that delays in engineering projects cause innumerable challenges and problems and greatly burden the works. And, therefore, the identification of the causes of non-compliance with the original schedule is essential to avoid the continuity of delays in other stages of construction or in new ventures. Sha *et al.* (2017) also consider for the elaboration of effective strategies to mitigate the consequences of delays in works, especially the extrapolation of costs, goes through the identification of their critical causes. Thus, it becomes paramount to identify the main causes for delays and to adopt preventive measures to minimize the impacts arising from such phenomena (ASNAASHARI *et al.*, 2009; SHAHSAVAND; MAREFAT; PARCHAMIJALAL, 2018; YANG; CHU; HUANG, 2013).

Głuszak and Leśniak (2015), as well as Kowalczyk *et al.* (2018) further clarify that the analysis of construction delays is still relevant for the construction sector, irrespectively of the studies conducted previously of the existing management tools and the expertise of engineers. However, according to Alsehaimi *et al.* (2013), although there are many studies that address the delay of works, most of them do not have objective guidelines on the increase of practical actions for managing the projects; in addition to the suggestions made usually being of a generalist nature and not specifically dealing with the causes of delay.

In view of this context, the main objective of this paper is to identify the causes that contribute to the delay of works in the construction industry and the analysis of the roots and their negative consequences. Therefore, this paper seeks not only to identify the main causes for delays in construction works - a common objective in several research works - but also the study of the correlations among them through the statistical factor analysis technique, applied in the most varied types of constructions; including commercial, residential, public and industrial buildings. Unlike the work published by Maués *et al.* (2017), who used the same statistical technique, only for project variables and some management variables. Furthermore, the broad range of causes of delays in constructions from the original sample were classified hierarchically through the methodology of the ABC Curve and the Relative Importance Index (RII). This way, the authors seek to collaborate to further developing studies on construction delays by contributing to mitigating this problem in several countries, especially in developing ones.

Delay in construction works

It is noteworthy that early research on the topic considered work delays as non-excusable, compensable excusable, non-compensable excusable, and concurrent (ARDITI; ROBINSON, 1995). Keane and Caletka (KEANE; CALETKA, 2008) considered the delays as critical, non-critical or simultaneous, as well as dominant, subcritical or simply non-relevant; in case said delays have been caused by ineffective performance on one party.

In conceptual terms, the delay of a project can be defined as the extrapolation of the contract term for project completion or the period that exceeded the extension of the contract, granted by adding time to the final deadline or even beyond the date of delivery of the works, as agreed upon between the contracting party and the contractor (GÜNDÜZ; NIELSEN; ÖSDEMİR, 2013; TRAUNER *et al.*, 2009). According to Hamzah *et al.* (2011), delays in construction works are inevitable and characterized by slower execution of a project when compared to the planned schedule or even by late completion of the projects. However, according to Agyekum-Mensah and Knight (2017), the delay in construction works is merely defined according to not meeting the original schedule, and it occurs due to several reasons, and can be originated by any of the stakeholders to the project.

Aibinu and Jagboro (2002) further explain that in project delay situations, a typical option is to execute the steps of the works faster or to extend their duration, obviously with subsequent escalation of costs and extension of the originally planned deadlines. In such cases, the standard is to manage this additional cost by including a percentage to the project value in the form of a provision or share in the budget sheet prepared prior to the construction work contract. According to Yang and Wei (2010), the delays in construction works can take place in any step in the construction works, although researchers emphasize that the planning and design phases significantly influence the cost and schedule of the works. Consequently, delays during project planning usually hamper the construction schedule in the ensuing phases, taking into account the completion date for the project.

In relation to the causes of delay, they can be identified as internal and external; whereas those related to customers, designers, service providers and consultants are regarded as internal causes, while the external causes are related to climate issues, suppliers and the government (AHMED; AZHAR; KAPPAGANTULA, 2003; RAFIEIZONOOZ *et al.*, 2015). The following are among the most relevant causes:

- (a) the financial difficulties of customers and/or owners (CHALLAL; TKIOUAT, 2012; FUGAR; AGYAKWAH-BAAH, 2010; LARSEN *et al.*, 2016; MEGHA; RAJIV, 2013);
- (b) the scope changes required (MUHWEZI; ACAI; OTIM, 2014; TAFAZZOLI; AP; SHRESTHA, 2017; TARIGAN; SUBROTO, 2018; VACANAS; DANEZIS, 2018);
- (c) poor management of the construction site (AZIZ, 2013; ILYAS; LI; ULLAH, 2020; SEPASGOZAR; RAZKENARI; BARATI, 2015);
- (d) slow or delayed decision making (ALAGHBARI *et al.*, 2007; KHARASHI *et al.*, 2009);
- (e) poor project planning (DUY; OGUNLANA, 2004; KHOSHGOFTAR *et al.*, 2010);
- (f) inefficient coordination and communication among the parties (HWANG; ZHAO; NG, 2013; TOOR; OGUNLANA, 2008);
- (g) low availability and productivity of labor (ABDUL-RAHMAN *et al.*, 2006; KUMARASWAMY; CHAN, 1998); and

(h) late delivery or poor quality of materials (KOUSHKI; KARTAM, 2004; RAHMAN *et al.*, 2017).

Also, there are unpredictable events, poor technical capacity of local teams of contractors or consultants, poorly designed projects, adverse climatic conditions, increased production, among other causes of delay (AL-MOMANI, 2000; BIRGONUL; DIKMEN; BEKTAS, 2015; HASEEB; BIBI, 2011). Gebrehiwet and Luo (2017) also highlight corruption, inflation and unavailability of supplies in the construction sites as causes of delay in services.

However, most of the studies in the area mention inefficient management and coordination in construction projects are reported as one of the main causes adding to the delay of construction works (ALSEHAIMI; KOSKELA; TZORTZOPOULOS, 2013; MUIANGA; GRANJA; RUIZ, 2015; ZIDANE *et al.*, 2015). It is further observed by Filippi and Melhado (2015) that the companies delay their construction works basically due to non-observance of the previously established planning, obtaining no intrinsic benefit therefrom. And according to Adam and Josephson (2017), efficient project management is a key factor with an impact on decision-making adopted in the early phases of the project concerning the construction cost and schedule criteria.

It should finally be emphasized that a large part of the authors that were surveyed is restricted only to cataloging and description of countless causes of delay in construction works without aiming at a broader understanding of this phenomenon through factor analysis of their causes. This observed knowledge gap limits the studies in the area and is configured as one of the main objectives of this paper.

Methods

The adopted research methodology can be classified, in relation to approach, as a quantitative research and according to the objectives, this paper represents an exploratory and explanatory research, as it pursues greater understanding of the problem, which makes it more explicit, thus helping build up hypotheses (GIL, 2002). Regarding this matter, Fellows and Liu (2015) highlight that both approaches tend to be exploratory - both the quantitative procedure, which uses the scientific method, and the qualitative procedure, whereby the theme is studied, often without having the research formulations been previously established. Thus, aiming at reaching the research objectives, the proposed methodology was developed in the following steps:

Systematic Literature Review (SLR)

The SLR was developed between March 4 and May 31 2019 to identify the most frequent causes related to the construction work delays found in the literature. The advantages of the SLR include the traceability of the process, the grounds on a specific strategy, their reproducibility and application through explicit and systematized search methods, thus allowing for objective criticism and analysis (GREEN *et al.*, 2008; SAMPAIO; MANCINI, 2007).

In sum, four steps made up the SLR, namely:

- (a) definition of research parameters (bases, key words, language of the studies, and inclusion and exclusion criteria);
- (b) the actual search for publications, identifying possible duplicates (which are immediately removed);
- (c) the selection of publications, identifying adherence to the topic of the SLR by assessing the titles and abstracts according to the inclusion and exclusion criteria (previously stipulated); and
- (d) the data extraction step, which takes place after the complete reading of the publication.

In the latter step, application of the inclusion and exclusion criteria is repeated, since at this point the work is recognized in full.

The method that was applied in the SLR starts with an exploratory study aiming at better knowledge of the research related to the topic and at defining the search parameters. The research bases that were used included: Science Direct, Web of Science, Scielo and Engineering Village; which were defined according to the recommendations by Dresch, Lacerda and Antunes Júnior (2015), and according to the empirical knowledge of the authors. The following terms were searched: “delays in construction industry”, “construction delays”, “construction industry delays”, “construction sector delays” and “delays in construction”. The researches were conducted in the fields title, abstract and keywords using the “OR” Boolean operator between the research terms. It should be emphasized that there was no limitation as to the

language or the period of publication. However, papers should have the title or abstract in English, at least, since the search terms were in English. The following exclusion criteria were adopted:

- (a) import errors;
- (b) literature review papers;
- (c) editorials, abstracts and calls for congresses, conferences, and journals;
- (d) publications that do not represent causes for construction delays;
- (e) publications unavailable for research; and
- (f) publications with 2 pages or less.

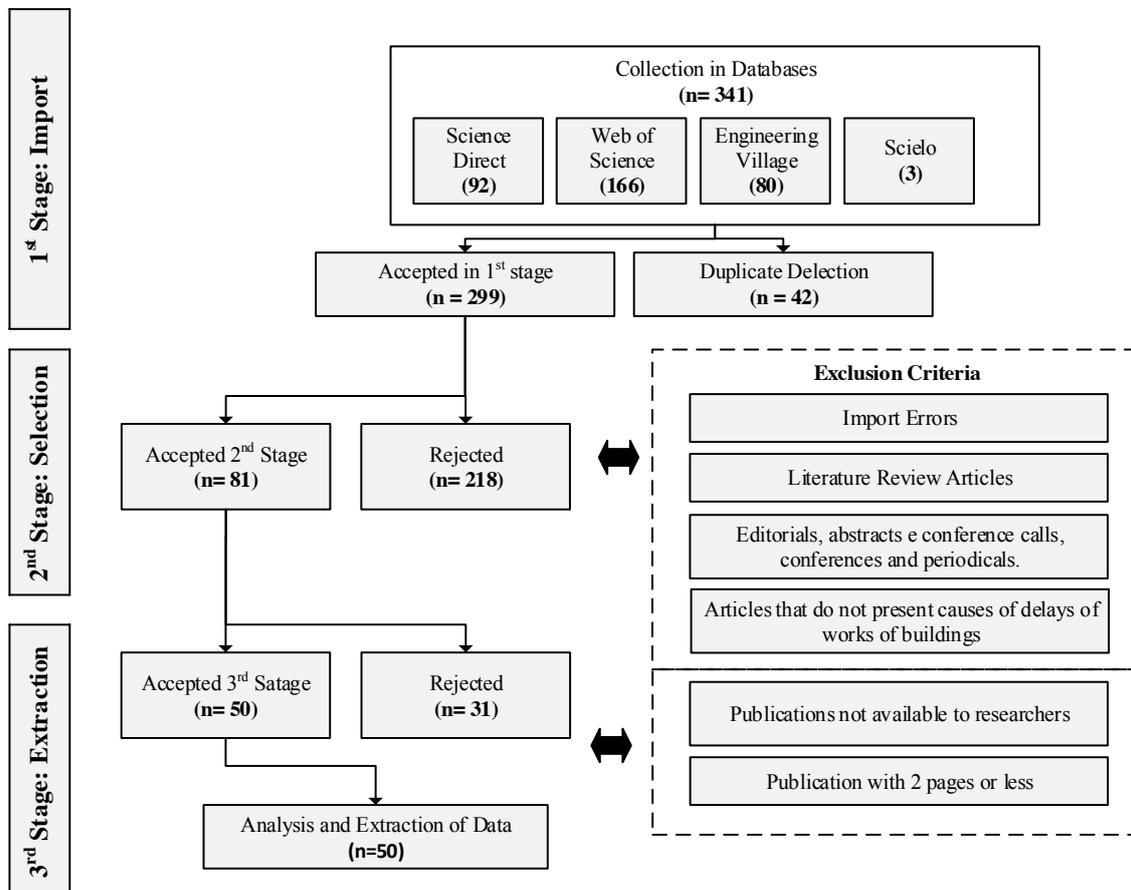
Finally, the following data were extracted from each paper in the extraction phase: paper title, authors, year of publication, country where the research was conducted, and the causes for delay indicated by the authors.

By strictly observing the review steps and the acceptance criteria for the publication, papers and causes related specifically to the delays in the construction industry were obtained. Finally, the steps of research are presented in Figure 1.

Survey research

It should be emphasized that, according to Freitas *et al.* (2000), the selection of the appropriate research method must be in line with the objectives of the work; whereas according to Dresch, Lacerda and Antunes Júnior (2015), the Survey research features a quantitative approach and one of its specific goals is to generate reliable data that allow for a robust statistical analysis, in addition to exploring, describing and explaining a phenomenon or a given population. This way, conducting a Survey research in the data collection step in this paper was decided in order to identify the more frequent possible causes of construction work delays.

Figure 1 - Steps of the research



To this end, preliminarily, a bibliographic research on the delay of works was carried out, aiming to obtain the most relevant research that addressed this theme. Among the various authors analyzed, the work of Reis *et al.* (2016), who identified 56 reasons for the most common delay in construction projects, in addition to having identified and hierarchically classified the delay factors in line with the literature and data obtained from a Survey carried out in the engineering market in the metropolitan region of Belém.

Therefore, it is emphasized that the present work is an in-depth study of Reis *et al.* (2016) and started from the results obtained from a questionnaire prepared by the aforementioned researchers, which was organized in eight groups:

- (a) project feasibility and initial documentation;
- (b) project management throughout the works, (technical consultation and amendments);
- (c) owner (customer);
- (d) construction company (administrative, management and execution);
- (e) labor;
- (f) materials;
- (g) equipment; and
- (h) external factors.

The strategy to apply the questionnaire was through interviews, either in person or via e-mail.

The sample being surveyed was made up by 83 construction industry professionals in the metropolitan area of Belém. It should be noted, therefore, that the objective was to verify the impact in the Amazon region of the causes of the delay identified in the literature and which were also observed by the interviewees, who analyzed the level of significance of the causes of delay, which were organized in a Likert scale with 5 options of answers, namely:

- (a) little (1);
- (b) little to medium (2);
- (c) medium (3);
- (d) medium to high (4); and
- (e) high (5).

Identification of the main causes of construction delays

In order to rank the results that were obtained in the survey, the relative importance index (RII) of each of cause of delay is based on the frequency of occurrence of said causes. Then, the causes of work delays could be identified through stratification by the highest RII values, and by using the ABC Curve methodology the main causes of construction delay could be identified and grouped in class A of the ABC Curve, corresponding to approximately 30% of the total sample value.

According to Mota *et al.* (2012), the main objective of the ABC Curve is to help in decision making and quick action by the managers, thus providing for a great positive impact on the final result of the company. The researchers also affirm this methodological tool has both internal and external factors related to the company's policy and culture, including the region and its operation market, which influence management and classification thereof.

It should also be emphasized that, according to Martins and Alt (2009), the items in class A of the ABC Curve are the most significant ones and may account for 35% to 70% of the total sample value, while those in class B are considered intermediate (10% to 45%), and the remaining (less important) ones would be placed in class C. However, according to Ballou (2006), there is neither an exact way of grouping the items into any of the categories nor to determine the number of categories to be used.

Factor analysis

After this step, the factor analysis of the identified causes of delay was performed in order to identify the correlation between them. According to Fávero *et al.* (2009, p. 236), factor analysis “[...] is a multivariate statistical technique aimed at reducing data and creating indicators that represent original variables.” Still

according to these authors, the use of factor analysis is based on the assumption of the existence of a correlation between the original variables and the sharing of one or more factors, which explain the relationship between said variables. It is also worth noting that according to Hair Junior *et al.* (2009), the sample size should never be less than 50 observations; otherwise, conducting a factor analysis would be difficult.

As discussed in the literature, there are countless causes that can contribute to the delay of work, so the use of factor analysis was used to group these causes into factors, since these causes of different origins may converge or contribute to one for the same most comprehensive group.

Results

SLR Results

The most relevant authors found in the 50 publications are listed in Table 1, which also provides an overview of the major countries where the studies were developed and where the largest number of publications occurs.

When analyzing the frequency of publications of these studies, a significant increase in the number of papers, especially over the last seven years, is observed. Indeed, between 1995 and 2003 there were 5 publications; while from 2004 to 2011, 12 papers were published; and from 2012 to the current year (2019), more than 33 research papers have been published. It is important to highlight that these results refer to cases of delays in (residential or commercial) construction works, that is, no delays related to infrastructure services were addressed. Such limitation directly interferes with the amount of studies reviewed in this SLR.

Survey research results

The partial results of the Survey are shown in Table 2, which exhibits the 12 main causes of work delays ranked by the higher values of the relative importance index (RII) and stratified by the ABC curve, which are classified in group A. The identified causes of delay account for 30.77% in relation to the original sample, which was made up by 55 variables. The accumulated values of the RII and the percentage of representativeness of each cause of delay are also represented.

Table 1 - Main countries, authors and frequency percentage

Countries	Authors	(%)
Iran	Asnaashari <i>et al.</i> (2009), Pourroostam and Ismail (2011), Pourroostam, Ismail and Mansourenejad (2011a, 2011b), Saeb, Khayat and Telvari (2016) and Shahsavand, Marefat and Parchamijalal (2018)	12.0
Turkey	Bilgin, Dikmen and Birgonul (2018), Birgonul, Dikmen and Bektas (2015), Gunduz, Nielsen and Ösdemir (2013, 2015) and Kazaz, Ulubeyli and Tuncbilekli (2012)	10.0
Egypt	Aziz (2013), El-Razek, Bassioni and Mobarak (2008), Marzouk and El-Rasas (2014) and Marzouk, El-Dokhmasey and El-Said (2008)	8.0
USA	Arditi and Robinson (1995), Trauner <i>et al.</i> (2009), Arditi, Nayak and Damci (2017) and Kog (2018)	8.0
India	Rathinakumar, Vignesh and Dhivagar (2017), Doloi <i>et al.</i> (2012) and Hasan and Jha (2019)	6.0
Malaysia	Abdul-Rahman <i>et al.</i> (2006), Hasmori <i>et al.</i> (2018) and Mydin <i>et al.</i> (2014b)	6.0
Pakistan	Gardezi, Manarvi and Gardezi (2014), Khahro and Memon (2018) and Khan and Gul (2017)	6.0

Table 2 - Most relevant causes of construction work delays

Item	Causes of delay	RII	RII - Accum.	% Accum.	ABC Curve
1	Delay in delivery of materials, inefficiency of the purchasing sector	0.716418	0.71641791	3.09%	A
2	Delay in delivery of materials by suppliers	0.698507	1.414925373	6.11%	A
3	Rework due to errors during construction	0.629851	2.044776119	8.83%	A
4	Delay in payments throughout the project, customer's financial difficulty	0.626866	2.671641791	11.54%	A
5	Low level of labor productivity	0.602985	3.274626866	14.15%	A
6	Lack of workforce commitment	0.597015	3.871641791	16.72%	A
7	Delivery of incomplete projects	0.59403	4.465671642	19.29%	A
8	Increase of services (project changes)	0.561194	5.026865672	21.72%	A
9	Shortage of construction materials	0.528358	5.555223881	24.00%	A
10	Climate/Weather conditions (heat, rain etc.)	0.525373	6.080597015	26.27%	A
11	Delays in works by workforce	0.522388	6.602985075	28.52%	A
12	Difficulties in obtaining financing for the project	0.519403	7.12238806	30.77%	A

Factor analysis results

As discussed in the section on research methodology, factor analysis was used in the treatment of the collected data. And among the statistics to check the correlation matrix and the FA adequacy, the Kaiser-Meyer-Olkin (KMO) test and the Bartlett's Test of Sphericity (BTS) are used, the results of which being exhibited in Table 3. Thus, according to the criteria of the statistical tool, the KMO value found (0.761) corresponds to a mean factor analysis; since the values close to 0 indicate a weak correlation between the variables and the closer to 1 they are, the stronger the correlation. Regarding the Bartlett's Test of Sphericity applied, the obtained result (0.001) shows that the factor analysis is adequate, since the null hypothesis was rejected and there are indications that there are significant correlations between the original variables (FÁVERO *et al.*, 2009).

Afterwards, the total explained variance of the sample was conducted, as shown in Table 4. The results showed that the 12 identified causes of delay are correlated to only 4 delay factors, which account for 69.179% of the variance of the original data and have the eigenvalues of their components with significance, that is, greater than 1. It should be noted that the factor analysis aims at changing one set of values into factors, that is, the goal of the method is to explain the largest part of the data variance.

Regarding the correlation matrix analysis, the results demonstrated that the causes of delay with the highest correlation are related to problems with supplies and difficulties with labor, as per the correlation indexes of the most significant variables, namely:

- (a) delay in delivery of materials, inefficiency of the purchasing sector/delay in delivery of materials by suppliers - correlation index of variables: 0.686;
- (b) low level of labor productivity/lack of commitment by the workforce - variable correlation index: 0.696;
- (c) low level of labor productivity/labor delays - variable correlation index: 0.674;
- (d) lack of labor commitment/low level of labor productivity - variable correlation index: 0.696;
- (e) delay in delivery of materials by suppliers/delay in material delivery, inefficiency in the purchasing sector - correlation Index of variables: 0.686;
- (f) delayed delivery of materials/shortage of construction materials - correlation Index of variables: 0.610;
- (g) labor delays/low level of labor productivity - correlation Index of variables: 0.674; and
- (h) shortage of construction material/delay in material delivery - correlation Index of variables: 0.610.

Finally, intending to help interpret the resulting factors in the extraction phase, the analysis of the rotational component matrix was performed (Table 5).

As shown in Table 5, the variables that make up the factors can be seen and that each variable has only one significant load factor for each of the factors. This way, the interpretation and identification of the construction work delay factors is facilitated.

Table 3 - KMO and Bartlett's tests

Reliability	Results
Kaiser-Meyer-Olkin (KMO) measurement of sampling suitability	0.761
Barlett's Test of Sphericity (BTS) - Significance	0.000
Chi-square X	308.355
Degree of freedom	66

Table 4 - Total variance explained

Var.	Initial own values			Square load extraction sums			Square load rotating sums		
	Total	% variance	% accum.	Total	% variance	% accum.	Total	% variance	% accum.
1	4.403	36.689	36.689	4.403	36.689	36.689	2.569	21.407	21.407
2	1.654	13.781	50.470	1.654	13.781	50.470	2.495	20.792	42.198
3	1.241	10.340	60.810	1.241	10.340	60.810	2.116	17.637	59.835
4	1.004	8.369	69.179	1.004	8.369	69.179	1.121	9.344	69.179
5	0.921	7.674	76.854						
6	0.780	6.502	83.356						
7	0.524	4.367	87.723						
8	0.391	3.254	90.977						
9	0.350	2.920	93.897						
10	0.305	2.541	96.438						
11	0.231	1.929	98.367						
12	0.196	1.633	100.00						

Note: Extraction Method - Principal Component Analysis.

Table 5 - Rotational component matrix

Causes of delay	Component			
	1	2	3	4
Delay in delivery of materials by suppliers	0.866			
Shortage of construction materials	0.759			
Delay in delivery of materials - inefficiency of the purchasing sector	0.691			
Rework due to errors during construction	0.595			
Low level of labor productivity		0.893		
Delay in labor works		0.811		
Lack of workforce commitment		0.802		
Delivery of incomplete projects			0.868	
Increase of services (project changes)			0.774	
Delay in payments throughout the project, customer's financial difficulty			0.568	
Difficulties in obtaining funding for the project			0.395	
Climate/weather conditions (heat, rain etc.)				0.960

Notes: Extraction Method: Principal Component Analysis.
 Rotational Method: Varimax with Kaiser Normalization.
 Rotation converged in 5 iterations.

Next, the 4 factors were identified and interpreted as follows:

- (a) Factor I – Supply Management: delay in delivery of materials, shortage of construction materials, delay in delivery of materials/inefficiency of the purchasing sector and rework due to errors during construction;
- (b) Factor II – Labor Management: low level of labor productivity, delay in labor works and lack of workforce commitment;
- (c) Factor III – Project Management: delivery of incomplete works, increase in services (project changes), delay in payments throughout the work, customer's financial difficulties and difficulties in obtaining financing for the project;
- (d) Factor IV – Management of Climate Conditions: weather conditions (heat, rain etc.).

Finally, in order to measure the reliability of the factor statistical analysis, Cronbach's Alpha Test was conducted and produced the results shown in Table 6. It can be seen that the value 0.857 of the coefficient is found to be in line with the minimum value acceptable in the literature, which is 0.70 (TORRES; MONTEIRO; ARICA, 2010).

Discussion

Considering the results presented and aiming at a more specific analysis of each identified delay factor, the understanding the fundamental causes that influence the occurrence of the event by the corresponding factor was pursued; the causes of delay, organized in their respective factors and according to the percentage of frequency of occurrence obtained, being identified as follows.

Factor I: supply management

This factor represents 21.407% of the total variance (refer to Table 4) and is made up by the following variables.

Delay in delivery of materials (inefficiency of the purchasing sector)

This cause has a load factor of 0.866 and is related to the inefficiency of the purchasing sector of the companies, which is responsible for the supply management of the works, including the contracting of suppliers, breaking down the pre-established conditions of delivery deadlines and costs for supplying the materials. And in the event that the criteria established for the contracting of these suppliers are not adequate, there may occur delays in the delivery of materials or supply of products that do not meet the minimum quality specifications by companies that do not have the necessary infrastructure for the correct fulfillment of the construction schedule.

In relation to the above, Hwang, Zhao and Ng (2013) state that the availability of materials at the construction site is considered to be one of the critical factors affecting the performance of the public housing sector schedule in Singapore; the authors further recommend that contractors should make long-term contracts to reduce the impact of uncertainties and potential risks of availability and prices of materials and equipment. It is also worth noting that according to Serna *et al.* (2018) the lack of materials needed in the project in the scheduled period is characterized as one of the most influential factors regarding the cost variance in the projects and may indicate lack of planning and, mainly, control by the professionals.

Table 6 - Reliability statistics

Reability testes	Results
Cronbach's Alpha	0.857
Cronbach's Alpha, based on standardized items	0.857
Number of items	12

Delay in delivery of materials by suppliers

The load factor for this cause is 0.759 and its focus is on the deficiencies alluding to suppliers of materials to the works, that is, they can be related to delays in the delivery of materials due to poor management, poor planning, inadequate logistics, amongst other factors that lead to the disorganization of the executive process of these companies. It should be emphasized, therefore, that the performance of the supply sector of the company responsible for the enterprise is not considered in the analysis of this cause, regardless of whether or not this action is effective.

According to Enshassi, Alnajjar and Kumaraswamy (2009), the main causes that influence the delays in construction works are related to lack of materials in the markets, shortage of construction materials in the construction site and delays in the delivery of materials for the construction works. And according to Ogunlana, Promkuntong and Jearkjirm (1996) the adequate supply of materials is a fundamental precondition, which is present in almost all construction activities, while the shortage of construction materials could cause the project to be delayed and consequently closed.

Rework due to errors during construction

This cause has a load factor of 0.691, being related to the need to redo a previously performed service due to failures during the execution thereof. The reasons for this phenomenon may be the use of materials out of the design specifications, that is, materials with lower-than-required performance, inadequate dimensions or which have poor quality. According to Pereira *et al.* (2011), rework in civil construction negatively impacts the work schedule due to the delay that is generated, as well as the financial losses arised. Still according to the researchers, the types of rework identified include the delay prompted by defective material being delivered and the changes in the type of material and specifications during the construction.

Shortage of construction materials

The cause for shortage of materials has a load factor of 0.595 and is related to the small amount of a given type of supply at the construction site. There is a number of reasons for said shortage; and this may be a consequence of logistics, waste of material during the execution of the works, and, in this case, due to losses. There is also the possibility of theft or the purchased quantity of the input to have been badly estimated due to errors in budget calculations; for example.

Within this context, Asnaashari *et al.* (2009) report that there are several problems in the procurement of materials, components and machines that can bring about delays and that the most serious problem is the lack of cement, steel and concrete, which are considered critical inputs to the works. Corroborating with this assertion, Sambasivan and Soon (2007) consider that the lack of basic materials may prompt significant delays in the projects, especially when the demand exceeds the supply.

Factor II: labor management

This factor accounts for 20.792% of the total variance, being made up by the following variables.

Delays in labor works

Delays in the works, pertaining to labor, have a load factor of 0.893 and may be related to inadequate work methods adopted in productive processes, including construction techniques, workforce training and the equipment available for the services; which compromises safety and quality standards and consequently affects productivity; which Doloi *et al.* (2012) proved in their research.

Another issue to be considered is the inadequate sizing of work teams or even the shortage of labor, which according to Abdul-Rahman *et al.* (2006) is one of the major causes of work delays. These researchers also highlight the need for greater investment in improving the expertise and skills of human resources to minimize the construction work delay phenomenon.

Finally, one cannot but mention absenteeism, bad organizational climate, alcoholism, depression, as well as workplace accidents, which may lead to a total or partial cessation of activities. Kiviniemi *et al.* (2011), for example, mention that in 2008 there were 35.2 accidents involving construction workers in Finland and that it resulted in at least four days of employee absence from work.

Lack of workforce commitment

The aforementioned cause has a load factor of 0.811 and is related to the non-professional conduct adopted by some of the company's workers, whether an employee or a contractor, which contributes to the delay of the services in the project. In this case, negligent, disrespectful and non-aligned (focused) behaviors are included in their functions and activities designated by the management of the works. On this aspect, Dolo *et al.* (2012) state that one of the most critical factors of construction work delays is the absence of commitment.

While Iyer and Jha (2005) warn that to achieve the completion of the work within the contractual term for any project, the commitment of everyone involved in it is essential. Finally, Arantes, Silva and Ferreira (2015) recommend that greater attention be given to the lack of communication and commitment by subcontractors, as these are relevant causes of work delay and that they impact on all other identified causes.

Low level of labor productivity

The cause of low labor productivity has a load factor of 0.802 and may be related to inadequate (or non-existing) training to perform their activity, inefficient work methods, and failures to select or recruit an employee who is not qualified for the job; said conditions being corroborated by Dolage and Pathmarajah (2015).

In relation to low labor productivity, Palikhe, Kim and Kim (2018) state that this is one of the most significant issues in the construction industry because it directly affects the cost and enables the occurrence of delays in work schedule. The authors also report that the main causes affecting workers' productivity include the lack of financial incentives, unavailability of tools, not enough periodic meetings, and unsafe work conditions.

The influence of inspection that is not very demanding on the performance of the workforce should also be considered, as well as the absence of a compensatory financial mechanism for the execution of a job, such as payment for production results; as demonstrated in the research of Odeh and Battaineh (2002). Other relevant reasons include organizational culture and climate, and Arditi *et al.* (2017) emphasize that organizational culture is one of the causes of delay in construction projects and that it is important that the organizational culture is aligned with the local culture of the country.

Factor III: project management

This factor accounts for 17.637% of the total variance, involving the following variables.

Delivery of incomplete projects

The lack of information or deficient breakdown of the projects has a load factor of 0.868 and corroborates for the delay in construction works due to possible difficulties of interpretation and occurrences of errors, a frequent practice being the delivery of some projects or complementary parts still during the construction work execution phase. This situation could be avoided or minimized by taking management actions that allow for meeting the deadlines for project delivery, as well as the collaboration between the designers and engineers of the company in the preparation of project parameters and the planning of the project.

This theme was approached by Kog (2018), who identified as the main cause of construction work delay the late issuance of incomplete instructions, information or drawings, the preparation of inadequate drawings and delay in the revision and completion of the project. In addition, Santos, Starling and Andery (2014) observed in his research that the main problem in the contract amendments of periods, consequence of the delay in construction works, is related to deficiencies in the projects, more specifically the lack of compatibility, insufficient specification and unsatisfactory breakdown.

Khanzadi *et al.* (2019) further emphasize the complexity of the processes related to the projects, highlighting the various existing interconnected jobs as well as their variability and unpredictability, and that would bring about variations and delays found in the schedules.

Increase of services (project changes)

Projects changes have a load factor of 0.774 and may occur due to several factors, such as technical issues, economic circumstances, and even at the customers' request. And regardless of the existing context, when any changes in projects occurs, there will be an increase in services due to the need to adapt the production

system to the proposed change, including the costs and deadlines involved in this new scenario. Consequently, the construction work will be delayed.

In this scenario, Tarigan and Subroto (2018) mention that one of the main causes of construction work delays is the requests for work changes by the owner during the construction phase, as well as with the changes/errors in the project documents, according to Marzouk, El-Dokhmasey and El-Said (2008). There is also research by Kazaz, Ulubeyli and Tuncbilekli (2012), who identified design and material changes as the most significant factor of construction work delay.

Delay in payments throughout the project (customer's financial difficulty)

The delay in payments throughout the work, due to financial difficulties experienced by the customer, has a load factor of 0.568 and this is possibly a significant cause of delay of construction works, as it can promote tensions and distress on the relations between the contracting company and its employees, suppliers and stakeholders. The immediate results include noncompliance with the goals, cost increases due to the variation in team productivity, possible claims, standstills or even workers' strike; besides the interruption in the supply of the inputs for the works.

Within this context, Park *et al.* (2019) state that the two risk factors with the highest impact on the construction management companies are project delay and payment delay; and that is characterized as a financial difficulty under the responsibility of the project owner and which affects the company's operation. As a result, Assaf and Al-Hejji (2006) point out that payment to contractors, without delay, for the services performed is fundamental in order not to hinder the ability of contractors to finance the works. The respective authors also point out that one of the significant causes of delay is the fact that, in the biddings, companies with the lower value propositions are contracted; this may preclude work completion in certain situations - something also observed by Abbasnejad and Moud (2013).

Difficulties in obtaining funding for the project

This cause has a load factor of 0.395 and will have more or less importance, within the context of the execution of the project within the contractual terms due to the size of the works and the economic conditions of the company, that is, its capability to carry out the services without resorting to a financial institution. Delay in the execution of the works may occur if the company does not have sufficient financial reserves and the requested funding is not approved or if it takes time to be obtained.

Regarding this theme, El-Razek, Bassioni and Mobarak (2008) point out that the two main causes of work delays are related to problems with contractor financing during construction and late payment of contractors by the owner. Marzouk and El-Rasas (2014) further recommend that a comprehensive cash flow and financing plan be developed for the venture, since the financial issues and the complete payment of the executed services are configured as one of the main focus of concern on the part of both the owners and the contracted companies.

Factor IV: management of climatic conditions

This last factor accounts for 9.344% of the total variance and has the following variable and comprises variables related to climate and weather conditions (heat, rain, etc.).

Weather conditions have a load factor of 0.960 and are characterized as one of the main causes of work delays; as attested by the studies by Senouci, Al Abbasi and Eldin (2018), who state that weather conditions have a high impact on labor productivity, especially temperature. Ahsan and Gunawan (2010) also consider that natural disasters should also be considered as critical causes of project delays. However, according to Ballesteros-Pérez *et al.* (2015), only a few studies have approached the climatic influences on open-air construction activities in detail.

It is observed that the data reported in such research do not differ from the reality in the northern region of Brazil, which has typical characteristics of the tropical climate, such as intense heat and high relative humidity, which influence significantly the planning of the works and facilitate the occurrences of delays to the original schedule, especially in the rainy season.

Conclusions

The main objective of this paper was to study the delay in construction works and the analysis of the causes of this phenomenon by observing the correlations between them through the statistical factor analysis technique. The results demonstrated that the 12 causes of delay that were identified are correlated to only 4 delay factors, which account for 69.18% of the variance of the original data and have the eigenvalues of its components with significance, i.e., greater than 1:

- (a) management (21.41%);
- (b) manpower management (20.79%);
- (c) project management (17.64%); and
- (d) management of climatic conditions (9.34%).

It should be noted that the delay factors mentioned above can be considered as deficiencies in the management process of the works, which is considered to be one of the most relevant causes in the occurrence of time and cost deviations and influences all other categorizations in terms of coordination and decision making, a fact that is corroborated by several authors. Thus, the focus of coordination and decision making should be on managing the enterprise.

Therefore, it can be concluded that this research extended the knowledge of the area when performing the factor analysis of the causes of delay in construction works and not only the identification of the main causes, a common objective to several papers. And, mainly, it allowed for understanding how these causes relate to each other and the consequences of this correlation in the increment of the negative impacts of the construction work delays. Another contribution provided by this article is to have prompted a deep analysis on what issues should be prioritized in the strategies of actions that aim to minimize the occurrence of delays in the execution of projects in the civil construction; which directly influences the costs of the works, social issues, low quality, litigation and other consequences.

Future works

Finally, the execution of future research is recommended in order to prepare study proposals to minimize the impacts caused by the above-mentioned delay factors, mainly analyses focused on Production Planning and Control (PPC).

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