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The use of BIM in public construction supervision in Brazil

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Abstract: The aim of this paper is to study the potential of using the building information modelling (BIM) technology to assist the activities performed by the team that is responsible for supervising the execution of the federal public building's contracts in Brazil. The paper describes, in short, the norms and the legislation of the external control body (Court of Auditors), as well as the federal norms and legislation, to understand what should be expected from the organizations' activities, as well as their obligations. In addition, the most frequent irregularities in public construction were pointed out; the main contributions of BIM, regarding each irregularity, were also identified to avoid the problem. The innovative aspects of this study are the suggestions that were proposed for the use of BIM's guidelines in public construction supervision in Brazil.

Keywords: supervision/surveillance, BIM, public construction

1 Introduction

In 2014, R$54 billion (Brazil, 2014) were invested only in the Growth Acceleration Program, known as PAC (Programa de Aceleração do Crescimento, in Portuguese), the main federal government program that aims to perform big social, urban, logistic, and energetic infrastructure projects. In the same year, the Federal Court of Accounts – Brazil (FCA), which is responsible for informing the National Congress about the public construction supervision, performed 102 audits in public construction, whose government budget was R$12.38 billion. Serious irregularities were found in 56.9% of the audits; there were other irregularities in 38.2% of them; and in only 4.9% of the audits there were no irregularities to be pointed out. The irregularities occurred the most in the following areas: building (41.2%), basic or executive project (34.3%), and building supervision (20.6%; FCA, 2014).

In the face of this scenario, to guarantee an improvement in the use of public resources, technologies and processes that could help in the areas of execution, projection, and building supervision are necessary. Thus, the building information modelling (BIM) has aroused as an innovative form of project management by updating and increasing the collaboration among project teams, which reduces costs, improves time management, and upgrades the relationship with clients (Azhar et al., 2008; Azhar, 2011).

This becomes clear when considering the fastest growing arising of several guides and manuals that are meant to define the requirements and the final products of BIM; various public organizations around the world elaborate them (Succar, 2009).

Underwood and Isikdag (2009) defined BIM as a model of building information that comprehends complete and enough information to support all the processes of its life cycle, which can be directly interpreted by computer applications. This includes information about the building itself, as well as its components, i.e. comprehends information about properties such as function, form, material, and processes of the building's life cycle. For didactic purposes, BIM is divided into dimensions as follows, just as some other recent study: (a) BIM 3D (Adán and Huber, 2011; Lee et al., 2015; Wang et al., 2015) refers to the virtual construction of the building by 3D modelling computer tools, through which it is possible to create two-dimensional (2D) automatic boards and a connection between various information in a centralized model – making it easier to keep a set of updated documents; (b) BIM 4D (Zhang et al., 2015; Matthews et al., 2015; Liu et al., 2015; Kim et al., 2015; Johansson et al., 2015; Han and

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Golparvar-Fard, 2015; Zhang and Hu, 2011; Hu and Zhang, 2011; Babič et al., 2010) associates the 3D components with the chronogram tasks, that is, time; (c) BIM 5D (Cha and Lee, 2015; Zhao and Wang, 2014; Schatz and Rüppel, 2014; Parker, 2014; Ma and Liu, 2014; Lee et al., 2014; Charalambos et al., 2014; Mahalingam et al., 2015; Forgues et al., 2012) refers to the intelligent link between the 3D components and costs, creating a model-based estimating and a construction cost planning. Some other studies focused on the relationship between 4D and 5D (Lee et al., 2016; Scheer et al., 2014; Lee et al., 2013).

The building supervision is connected to all BIM dimensions, but it is still necessary to identify the study areas that are associated with BIM. Recently, Yalcinkaya and Singh (2015) revised 975 abstracts about BIM from 2004 to 2014. The authors could identify 20 study areas. Among these various areas, the building supervision fits in the "construction and project management" and in "as-built" data. In both cases, the only study mentioned is the study by Kim et al. (2013), through which the measures are taken with regard to assist the building process.

A search for the words "BIM" and "inspection" in the Web of Science and ScienceDirect database, held in April 2018, resulted in 20 scientific papers. However, only four papers have explored some aspects of inspection: Li and Wang (2016) focused on developing a BIM-based framework that can facilitate supervisors' coordination during construction; Charehzehi et al. (2017) dealt with construction conflict management that includes inadequate supervision; Ma and Liu (2014) proposed a BIM-based approach to improve the quality supervision of construction projects; and Mei et al. (2017) analyzed the behaviour between the supervision department and the contractor via the rent-seeking model based on the game theory. If this search included the word "public", only one paper was found, but it was related to final projects in engineering and architecture courses.

The benefits that come from the use of the BIM technology involving the building project and execution area are widely spread in both academic and professional fields. However, when it comes to avoid irregularities in public construction, there is a blank space related to studies that demonstrate the benefits of BIM. The aim of this study was to fill in the blank space by evidencing how the use of BIM could mitigate the occurrence of irregularities in public construction. Regarding the fact that there is no work in this area involving BIM in Brazilian public construction, this paper is based on a bibliographic revision that makes a connection between the irregularities detected in the public construction auditing, performed by the Court of Auditors, and the application and results of BIM.

2 Public construction supervision in Brazil

The Federal Constitution, in the article 37, subsection XXI, generically establishes hiring in public construction. This Constitution article was regulated by the Law no. 8,666, of 21 June 1993 (Brazil, 1993), also known as Bidding Law. It established general norms over bidding and contracts in the sphere of the union (federal government) powers, the states, the federal district, and the counties. Besides this law, there is the Law 12,462, of 4 August 2011, which instituted the Differential Public Procurement Regime (DPPR); it is applicable to the situations established in its first article (Brazil, 2011).

The Bidding Law has a more general, broader character, while the DPPR is more restrictive, so that its use shall be mentioned in the bid announcement. This becomes even clearer in the article 39 of the DPPR, which states that the administrative contracts shall be ruled by the norms of the Law no. 8,666, of 21 June 1993, except for the specific rules defined by the law itself (Brazil, 2011). Therefore, the Bidding Law should rule over what was not specifically established by the DPPR.

The Law 8,666/1993, in the article 6, subsection I, defines building as "any construction, reform, fabrication, recuperation, or amplification performed by direct or indirect execution". A direct execution occurs when the administrative organization or institution itself executes the building by its own means, according to the article 6, subsection VII, Law 8,666/1993. An indirect execution, on the other hand, occurs when the organization hires a third party to execute it, in accordance with the article 6, subsection VIII, Law 8,666/1993.

Most public construction is executed indirectly and, in this case, a bidding must precede it, according to the article 2 of the Law 8,666/1993, except for the legal hypotheses for dispensation and unenforceability that the Bidding Law predicts in articles 24 and 25, respectively.

From the initial idea regarding the need of a public building to its delivery, according to the expected goals, there is a series of phases that should be concluded so that the indirect execution of the public building is considered appropriate (FCA, 2014b).

These phases and activities are similar to both the contracts ruled by the Bidding Law and the DPPR, except for

the DPPR that is under the integrated hiring regime, which only requires a draft that looks to comply with the technical documents. These documents, in turn, are meant to make the characterization of the building or service possible, so that the bidding can take place, according to the article 9, paragraph 1, of the Law 12,462/2011 (Brazil, 2011). The remaining phases as shown in Figure 1 are still valid to the DPPR under the integrated hiring regime.

Therefore, we continued the analysis of the steps as shown in Figure 1. It is noted that, prior to the beginning of the bidding process for public construction, there is a preliminary phase with the following activities: program of needs, viability study, and draft. The purpose of this phase is to identify needs, estimate resources, and choose the best alternatives that will guarantee the satisfaction of the local society's requests (FCA, 2014b).

During the bidding's internal phase, the object is specifically detailed, and the requirements for receiving proposals from bidders are defined, subject to rules that allow competition between the participants, to obtain the most advantageous bid for the administration. Among this phase's activities, basic design is the most important, because it defines the object in detail, and its elaboration and approval are necessary conditions for construction bidding – article 7, paragraph 2, I, Law 8.666/1993 – while concomitant development with construction is allowed for the executive project, if authorized by the administration, article 7, § 1, Law 8.666/1993.

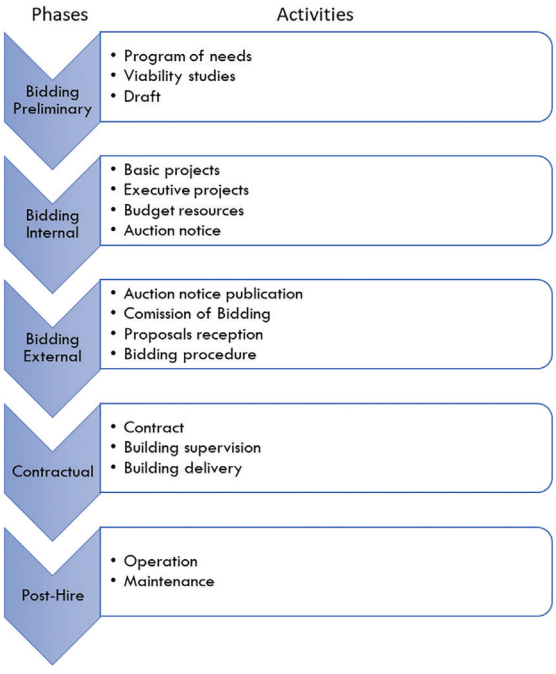

Fig. 1: Flowchart of indirect execution procedures in public building.

The basic design may be executed by the appropriate body, if a specialized technical staff is available. Otherwise, a specific bid for the hiring of a third-party company may take place.

The bidding's external phase begins with the publication of the auction notice and ends with the declaration of the winner of auction. Throughout this phase, various procedures are made by the bidding committee concerning the receipt of proposals, qualification, proposal analysis, resource analysis, ratification, and bidding grant. These procedures differ from biddings governed by the Public Procurement Law and the DPPR. However, these differences are related to administrative law and they are not part of the scope of this article.

After the bidding's external phase, there is a contractual stage, which begins with the contract signing and emission of the service order and ends with the construction delivery. Construction surveillance is part of this stage. Article 67 of the Public Procurement Law requires that the contract should be monitored by an administrative representative with the engagement of third parties allowed to assist and subsidize him/her with information relevant to this assignment.

Usually, the designation of a monitor or inspection team is given after the contract signing, during which the team is aware of the contract's object. It would be more productive if the inspection team took part in the development of technical documents from the bidding's internal phase – as in the basic design – to evaluate these elements, which could prevent future problems during the contractual phase (Bonatto, 2012).

As soon as legal requirements, concept, and construction surveillance issues are overcome, the question remains as to how it should be executed and what activities are involved in the supervisor's daily life. The Brazilian Association of Technical Standards (BATS) "Brazilian Standards (BRS) 12722 – Services Discrimination for Buildings" (BATS, 1992) express in section 6.2.2 some services pertaining to inspection that may occur during construction. This list of services is to be considered as possible occurrences and not as activity guidelines required to be followed by the supervisor in the performance of his/her function. In addition, BATS states that these standards are minimum guidelines which are the results of a consensus on the matter, as all technical standards are, hence, being of voluntary use.

However, the supervision of public construction is the result of legal obligation, and it would be expected that the requirements for its performance would be regulated by the Public Administration. Such regulation has been made

according to ordinance no. 2.296 of 23 July 1997 from the now extinct Ministry of Administration and State Reform, whose minimum requirements of construction, acceptability, maintenance, and demolition of federally owned buildings are described in article 1 (Brazil, 2011). Among the attachments of this order, there is a manual written by the Secretary of State for Administration and Patrimony (SSAP) "Manual of Public Construction – Buildings – SSAP Practices" (SSAP, 2016), which establishes the general guidelines, non-exhaustive, for construction supervision.

The "Manual of Public Construction – Buildings – SSAP Practices" is currently available on the web portal of government procurement, maintained by the federal government, which provides a series of booklets and manuals with guidelines on practices and management of acquisitions and contracts, to provide managers with tools to support the execution of their tasks. In addition, it is indicated as reference for activities that are attributed to surveillance in the publication "Public Construction: Basic Recommendations for Hiring and Supervision of Public Buildings" elaborated by the FCA (2014b).

Such facts determine the validity and relevance of these regulations for the performance of public construction supervision. Another point is that by comparing the guidelines established in the "Manual of Public Construction – Buildings – SSAP Practices" with those listed in section 6.2.2 of the "BRS 12722 – Service Discrimination for Building Construction", it is noted that the services listed in the standard are encompassed, and other unplanned activities by the BRS 12722 are added, as well as the demanded agency of the public construction supervisor with highest proactivity and involvement with work progression, which reinforces the technical adequacy of the SSAP manual.

Thus, considering that the guidelines set out in the "Manual of Public Construction – Buildings – SSAP Practices" are the federal government's regulations for surveillance activities, validated by the FCA, and encompass the listed services in the BATS prescript, they are used as reference for construction surveillance activities in this paper.

3 Potential use of BIM

One of the biggest irregularities detected in public construction is the lack of a source to guide surveillance work; with this prior knowledge, it is possible to take actions to reduce such occurrences. Since 1998, the Budget Guidelines Law charges the FCA inspection of the major indicated construction sites to identify the occurrence of serious irregularities. Every year, the FCA forwards a list of the enterprises to the National Congress, where the evidence of serious irregularities has been identified, particularly those in which a standstill is recommended.

These reports point out irregularities detected in audits performed by the FCA and constitute as reference for surveillance operation in public construction. To analyze what were the most frequent irregularities found in public construction, a timeframe from 2011 to 2014 – the last government administration – was employed, obtaining the description of their findings and quantities, as well as the number of audits in which they were detected, as summarized in Table 1.

Tab. 1: Summary of FCA's audit findings between 2011 and 2014 period (FCA, 2014).

Item	Audit findings	Number of findings			Audits	
		Quantity	%	% cumulative	Quantity	%
1	Overpricing/over-invoicing	415	15.8	15.8	253	38
2	Poor or outdated basic/executive design	341	13.0	28.9	255	38
3	Poor or missing supervision	291	11.1	40.0	77	12
4	Existence of unjustifiable delays in construction and services	195	7.4	47.4	48	7
5	Poor quality in service execution	131	5.0	52.4	42	6
6	Restriction on the bidding's competitive nature	115	4.4	56.8	95	14
7	Failure to comply with legal and technical requirements for the accessibility of people suffering from disabilities or reduced mobility	88	3.4	60.2	17	3
8	Incomplete or inadequate budget notice/contract/amendment	69	2.6	62.8	63	9
9	Other findings with percentage <2%	974	37.2	100.0		
	Total	2,619			668	

As summarized in Table 1, the irregularities related to overpricing/over-invoicing, poor or outdated basic/executive design, poor or missing supervision and existence of unjustifiable delays in construction and services may be mitigated by the benefits of the BIM usage. Overall, such irregularities account for nearly 50% of those found in public construction and occur in approximately 40% of audits during the study period. Audits focus on most of these irregularities. We analyzed, with the aid of the available literature and study, the BIM's potential to mitigate the most frequent irregularities in public construction, as given in the following subsections. Other audit findings are related to other technical problems.

3.1 Overpricing/over-invoicing

According to the FCA in a course about "construction budget audits", overpricing and over-invoicing are defined as (FCA, 2011): "overpricing occurs when the price of construction/service/input is unjustifiably higher than the price given by the paradigm" and "over-invoicing occurs when the cost of construction services are inflated, or charged and not executed (when measured quantities are superior than those effectively executed)".

One of the other causes of over-invoicing involves quantitative problems. In this aspect, the BIM technology allows the extraction of quantities in various modelling materials, in virtue of physical information inherent to the modelling elements (Kymmell, 2007). The estimated cost of production will be the product of the quantities obtained in the model at the cost of a database, allowing construction value to be predicted and controlled (Kymmell, 2007).

Some of the items found in the public construction budget are not part of the BIM model – for instance, the local administration of construction, testing, executive project development, etc. –, and therefore, may not be extracted from the model, its estimate instead being accomplished through conventional process. Nevertheless, using the BIM to extract the quantities of services in construction allows for agility and precision throughout the process, for most quantities, may be extracted automatically, avoiding errors inherent to the manual procedure.

3.2 Poor or outdated basic/executive design

The traditional process of project elaboration, which makes use of 2D sketches and written instruction, is a non-perfect model for complex contemporary projects: planning and building, once the use of 2D instructions in a 3D world presents limitations concerning representation and interpretation of the information (Kymmell, 2007).

In terms of BIM technology, the model is designed in 3D, which makes the representation of the project, in all aspects, more accessible to all the ones that participate in the action. The unique model representation guarantees the consistency of the information, and it is allied to BIM's capacity to generate sketches (Eastman et al., 2011). This reduces significantly the amount of time and errors related to sketching (Eastman et al., 2011). Besides providing a better visualization of the project and conceiving precise and consistent 2D sketches, the generation process of the BIM model inevitably finds out errors and inconsistencies along its elaboration with regard to a virtual building (Azhar, 2011). Moreover, it allows the user to detect interferences resulting from the absence and incoherence of information – in case these occur – which would not be found through the conventional process because of the limitations of the 2D representation (Goes, 2011). These characteristics of the BIM technology result in project improvements once the proposals could be rigorously analyzed, simulations could take place, the performance could be evaluated, and the documentation would be more flexible and automatic (Azhar, 2011).

3.3 Poor or missing supervision

In Section 2, the activity of supervising public construction was described; in the federal government sphere, its reference is the "Public Construction Manual – Buildings – SSAP Practices – Construction", elaborated by the SSAP, of the Ministry of Planning, Budget, and Administration, which establishes general guidelines, non-exhaustive, for building supervision (SSAP, 2016).

Observing the activities described in the SSAP manual and the benefits of BIM in terms of project improvement, 4D/5D planning, and quantitative extraction, it is possible to verify that BIM could be helpful to most activities, as summarized in Table 2.

3.4 Existence of unjustifiable delays in constructions and services

Problems resulting from the building planning are not an exclusivity of the public sphere. In the study that took

Tab. 2: Relationship between the advantages of BIM and the supervision attributions of SSAP manual.

Advantages of BIM	Supervision activities of the "Public Construction Manual – Buildings – SSAP Practices"
Project quality improvement	Keeping a complete and updated archive involving all the documentation related to the work
	Clarifying or solving incoherencies, flaws, and omission in the project elements and providing information and instructions that are necessary to the work development
	Promoting the presence of the designers in the building site to verify the exact correspondence between the real execution conditions and the parameters, definition, and concepts of the project
	Verifying and approving the sketches "as built ones"
4D/5D planning	Analyzing and approving the temporary installation of the project and the service site
	Analyzing and approving the execution plan and the detailed chronogram execution of building and services
	Promoting meetings about the construction progress and the necessary measures to meet the contract
	Solving doubts in terms of service sequences and interferences between work teams
	Controlling rigorously the chronogram, approving eventual adjustments
	Verifying and issuing periodic reports on the execution of services and building
Automatic extraction of quantities	Approves the executed services, attests measuring, and refers invoices to be paid
Non-identified relation to BIM	Obtaining from the contractor the Manual of Quality and checking its effective utilization
	Paralyzing and/or requesting a remake of an unsatisfactory service
	Requesting the substitution of defective or inappropriate material and equipment
	Requesting tests and examinations to control the quality of services and building
	Checking and approving the substitution of materials, services, and equipment
	Requiring the substitution of any contactor's employee

place in 2014 and performed by the consulting company EY (2014; its former name is Ernst & Young), concerning the productivity of the construction field, 92% of the participants indicated blank spaces in the planning area as a factor that has an impact on the current productivity. This area was also pointed out as the most relevant one to boost productivity as well as the area where most of the efforts and investments are concentrated for the next 2 years.

Thus, BIM 4D model allows its user to: spatially visualize the service execution sequence by identifying various interferences between the stock and access areas as well as other elements of the construction site (Biotto et al., 2015); test different alternatives in building sequencing by foreseeing constructability problems along the planning phase (Staub and Fischer, 1988); help the construction team to coordinate the work flow and the use of the construction site, allowing contractors and subcontractors to operate in safer, more productive conditions, which contributes to more economic and faster construction (Haymaker et al., 2003); compare chronograms and the building progress flow, which makes it possible to check whether the project is on time or behind schedule (Eastman et al., 2011); and increase the probability that the building will be concluded according to its planning and project (Haymaker et al., 2003).

4 Proposals for the use of BIM in public construction supervision

To maximize the benefits of BIM technology in public inspection activity and avoid many of the problems described earlier, the authors suggested the following:

a. The basic design should be developed in BIM technology with a minimum detail level of LOD (Level of Development) 400 defined in American Institute of Architects (AIA).
b. All documentation that composes the project, including text documents and spreadsheets (specifications, memorandums, and spreadsheets), should be elaborated with a bidirectional connection to the BIM model.
c. During the contract phase of the basic project, an audit should be performed on the BIM model to ensure the quality of the project. This audit could be performed through a contracted company to assist in the inspection activities.
d. In the auditing of BIM model, at least the following items must be verified: the consistency of modelled elements with their specifications and characteristics; uniformity of specifications and descriptions of the constructive elements between all the documents that compose the project, assured by the bidirectional

connection to the BIM model; detection of interference between the various systems that make up the project; automated extraction of project quantities.

e. For the contracting of the executive project concomitant with its execution, the following are required:
   i. Delivery of the project management plan, containing the work schedule until the short-term programming level, prepared according to the principles of project management established in BRS ISO 21500: 2012 – Guidelines on Project Management;
   ii. Integration of the planning described in the previous item to the BIM 4D and 5D. Depending on the complexity of the work, some services should be included: temporary services such as excavation, trenching, shaping, and shoring systems; vertical transport equipment on site, with cranes, external elevators, suspended scaffolds; construction site with the office areas, storage areas and internal horizontal transportation areas of the construction site.
f. Considering the degree of complexity described in the previous item, an external company should be hired to assist the team supervising works in these activities.
g. The analysis of the work planning and its subsequent monitoring should be performed by BIM 4D and 5D model, using the virtual simulations.

5 Conclusion

The general objective of this study was to verify the potential of the use of the BIM technology with the aid of the inspection activities of federal public works. A study was performed in the legislation and norms of the federal government and external control body (FCA) to assess which are the obligations and what is expected of the work supervision performance. The most frequent irregularities detected in public works were identified.

It was found that irregularities related to overprice/over-invoicing, poor or outdated basic/executive design, poor or missing supervision and unjustifiable delays in works and services could be mitigated with the benefits coming from BIM. In each irregularity, the main contributions of BIM were identified to avoid the occurrence of the problem.

Finally, the important points were identified in which BIM can assist in the inspection of public works. The important aspects of this paper are the proposed suggestions for guidelines on the use of BIM in the supervision of public works in Brazil.

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