Potential use of BIM in the oversight of public works

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ABSTRACT

Every year, the Federal Government spends billions of dollars on infrastructure. The external control body audits part of these public works and usually irregularities are found, mainly regarding basic design and poor monitoring. Thus, there is a need for technologies and processes to improve effectiveness in these areas. Improving the quality of projects using Building Information Modeling (BIM) technology has been reported in several studies, which has led to the adoption of this technology in multiple countries of the world. In Brazil, the use of BIM technology to audit public works is not completely clear. This paper studies the potential use of BIM in auditing public works through a comparative analysis between external control activities guided by the Public Federal Administration and the uses and academic findings on the benefits brought about by BIM. This technology has the potential to assist in the main external control activities through more qualified information to oversee and demand the fulfillment of the contracts, thus increasing the probability of performing better quality, more cost-effective and more time-efficient public works.

Keywords: Building information modeling; Public works; External control; 4D and 5D Modeling.

1. INTRODUCTION

In 2014, 54 billion reais were invested in the Federal Government's Growth Acceleration Program (PAC) (BRASIL, 2014b, p. 40). In the same year, the Federal Court of Accounts – Brazil (TCU) conducted 102 audits in public works to which 12.38 billion reais of the budget were allocated. Severe irregularities were detected in 56.9% of these projects, other types of irregularities were detected in 38.2%, and only 4.9% were entirely clear of problems. Most irregularities were detected in the following fields: execution of public works (41.2%), basic or executive project (34.3%), and oversight of the construction work (20.6%) (BRASIL, 2014e, p. 5, 16 e 24).

In view of this scenario, we need technologies and processes to assist the execution, design and oversight of public works in order to ensure better investment of public funds. In this regard, BIM technology has emerged as an innovative way to manage projects; it offers predictability and increases collaboration among project teams, thus making projects more cost-effective and time-effective, in addition to improving costumer-client relations (AZHAR et al., 2008, p. 445). This is made evident by the rapid emergence of different handbooks and users' guide written by various public agencies all over the world that aim at defining the requirements and the final products of BIM (SUCCAR, 2009, p. 358). One example of this phenomenon is the adoption of BIM in the United Kingdom, where the use of this technology in all public sector contracts celebrated will be mandatory as of 2016. The aim is to solve the issue of imprecise, incomplete and ambiguous information that results in unnecessary costs, which end up increasing the value of goods by 20% to 25% (THE BRITISH STANDARDS INSTITUTION, 2013, p. V).

As previously stated, the advantages of BIM technology in designing and conducting public works are evident. However, regarding public works oversight, there are not enough studies that prove the benefits of BIM. According to TCU audits, this particular field is where most irregularities are found. The Federal Public Administration must oversee the contract to check whether all its aspects are being complied with (BRASIL, 2014d, p. 43). In this context, this paper intends to demonstrate the potential of BIM in public works auditing. In view of the lack of theoretical references on the topic and the early stage of the use of BIM technology in the oversight of public works in Brazil, this paper is based on bibliographic review and establishes a parallel between oversight duties and the applicability and results of BIM. Therefore, it may be considered an entirely new study in Brazil.

2. BUILDING INFORMATION MODELING (BIM)

According to Eastman et al. (2014, p. 1), BIM technology is the construction of an accurate virtual

model of building; it contains relevant and necessary data to support the construction process and includes functions that are necessary for the lifecycle of a construction project. "When appropriately implemented, BIM enables a more integrated design and construction process that results in better quality facilities, as well as in reduction of costs and project delivery time" (EASTMAN et al.,2014, p. 1). The BIM model can be used for various purposes, such as: visualization and 3D rendering; design for fabrication; analysis of the legal requirements for the project; cost estimation; construction sequencing; interference detection; analysis of simulations and conflicts; and management and operation of constructions (AZHAR,2011, p. 242-243). The use of BIM brings benefits from the project design to the execution phase. This occurs because it enables a more precise visualization of the project, automatic corrections of changes made in the project, automatic generation of 2D drawings, compatibility between all project information, automatic extraction of quantities, synchronization with planning, better management and operation of constructions (EASTMAN et al., 2014, p. 16-21). These benefits were confirmed in a study by Bryde, Broquetas & Volm (2013, p. 974-976) based on the compilation of 35 case studies dated from 2008 to 2010, in several countries, in which the positive and negative effects of the use of BIM technology were mentioned. The results were grouped based on project management fields of knowledge contained in the Project Management Body of Knowledge (PMBOK), and the summary of the study is presented in Table 1 below:

BIM may be classified in 3D, 4D and 5D. BIM 3D refers to the virtual construction of the public work using 3D modeling computer tools in which it is possible to automatically generate 2D plans and connect various pieces of information in a centralized model. This makes it easier to maintain an updated set of documents, in addition to enabling its use in the analysis of interferences and conflicts among the various aspects of the construction project. This minimizes problems during execution as well as the need for project designers in the construction site. The visualization of the 3D model, virtual tours and countless possibilities of cuts and views increase the level of understanding of the project, and enable the identification of errors in the project's execution phase. BIM 4D links the 3D components to the tasks in the schedule; in other words, it already includes the time aspect. In turn, BIM 5D refers to the intelligent connection made by BIM 4D and cost-related information.

The data obtained from the case studies suggest that BIM is an efficient tool that enhances key aspects in the delivery of construction projects. Among all the success criteria created to analyze the case studies, cost was the aspect most positively influenced by the implementation of BIM. It was followed by time, communication, improved coordination and quality. There were relatively few negative impacts or challenges in the implementation of BIM, and most of them were related to software or hardware issues. These challenges refer to how changes for the adoption of BIM were managed and may be overcome through better training of employees involved and activities that aim at engaging stakeholders (BRYDE, BROQUETAS & VOLM, 2013, p. 978).

Table 1: Ranking of BIM success criteria

	Positive Effect			Negative Effect		
Success Criteria	**Total occurrences**	**Total number of projects**	**% of total of projects**	**Total occurrences**	**Total number of projects**	**% of total of projects**
Reduction of costs or control	29	21	60,0	2	2	5,7
Reduction of time or control	17	12	34,3	3	3	8,6
Communication improvement	15	3	37,1	0	0	0,0
Coordination improvement	14	12	34,3	3	3	8,6
Increase in quality or control	13	12	34,3	0	0	0,0
Reduction of negative risks	8	6	17,1	1	1	2,9
Clarification of scope	3	3	8,6	0	0	0,0
Organization improvement	2	2	5,7	2	2	5,7
Software issues	0	0	0,0	7	7	20,0

Source: Adapted from Bryde, Broquetas & Volm (2013)

3. THE USE OF BIM IN BRAZILIAN PUBLIC WORKS

The Federal Government, through the Brasil Maior plan, has established the following objectives in its strategic civil construction agenda: intensify the use of information technology applied to construction projects and implement the information classification system for construction – BIM standards (BRASIL, 2013, p.64). To attain this goal, the following measures are being taken: implement the library of civil construction components, making it available on the Internet so that everyone will have no-cost access to it; implement BIM technology in the Army construction projects system; and disseminate and complement the Brazilian set of standards for BIM (BRASIL, 2014a, p. 78).

As for the adoption of BIM in the Federal Public Administration, the Brazilian Army and Petrobras have been using BIM in some of its projects. In addition to these examples, in 2013 and 2014, the Banco do Brasil opened various bids for projects using BIM within the scope of the Programa Regional de Aviação [Regional Aviation Program].

In terms of standards and handbooks on BIM technology, only the State Government of Santa Catarina has published its guidelines in the "Caderno de Apresentação de Projeto BIM" [BIM Project Presentation Handbook]. "It defines the standards and formats that shall guide the development of projects using BIM in contracts with the State Government" (SANTA CATARINA, 2014).

4. EXTERNAL CONTROL OF PUBLIC CONSTRUCTION PROJECTS

Two laws govern the celebration of contracts for conducting public works in Brazil: the Lei de Licitações [Open Bids Law] and the Regime Diferenciado de Contratações públicas [Differentiated Regime for Public Contracts] (RDC). The Lei de Licitações is more comprehensive and establishes general rules on bids and contracts for the Three Branches of Government, States, Federal District and Municipalities (BRASIL, 1993, art. 1º). The RDC is more limited and used only in certain public works provided by law (BRASIL, 2011, art. 1st).

Art. 67 of the Lei de Licitações provides that the execution of the contract must be overseen by a representative of the Administration and allows the hiring of third parties to assist it and provide it with pertinent information on the task (BRASIL, 1993, art. 67). The RDC does not provide this, but it establishes in its Art. 39 that administration contracts must follow the norms established by Law nº 8,666 of June 21 of 1993, except for the specific rules defined by the Law itself (BRASIL, 2011, Art. 39). Therefore, the RDC also provides that the oversight of the contract execution process is mandatory.

As guidance for public works oversight, the Federal Government makes available on the Governmental Purchases webpage, the publication "Manual de Obras Públicas – Edificações –Práticas da SEAP – Construção" [Public Works Handbook – Buildings – SEAP Practices – Construction], written by the Secretaria de Estado da Administração e Patrimônio [Administration and Assets Secretariat] (SEAP) of the Ministry of Planning, Budget and Management (MPOG). The publication establishes general guidelines for oversight of public works (BRASIL, 1997, 10-2 to 11-2). The same document is also indicated as reference for oversight activities in the publication "Obras Públicas: Recomendações Básicas para a Contratação e Inspeção de Obras de Edificações Públicas" [Public works: Basic Recommendations for Public Buildings Construction Projects Contracts and Oversight] produced by TCU (BRASIL, 2014d, p.44).

5. DISCUSSION

Observing the activities described in the SEAP handbook, it is evident that they are very interconnected with project management. This fact suggests the benefits of the use of BIM as shown in Table 1. In the following sections, available references and research will guide an analysis on how BIM can assist audit activities described in the SEAP Handbook (BRASIL, 1997, p.10-2 a 11-2). The titles of the following sections refer to a summarized description of the activities contained in the SEAP Handbook and follow the same order found in the publication.

5.1 KEEP A COMPLETE AND UPDATED FILE CONTAINING ALL DOCUMENTS RELATED TO THE WORKS

One of the characteristics of BIM is the model developed in 3D, in which parametric rules are used and where generation of 2D plans is automatically extracted from views and section cuts of the model.

This significantly reduces the amount of time and the number of errors usually involved in the generation of drawings (EASTMAN et al., 2014, p.17). Another feature of BIM is the availability and connection of all pieces of information in one centralized model made accessible through links (KYMMELL, 2008, p. 49). For example, the specifications may be linked with libraries of objects in such a way that one specification is automatically applied when an object from the library is included in the project. It also offers IT applications for the selection and editing of specifications that are relevant to a given project and cross-references them with relevant model components (EASTMAN et al., 2014, p. 185). These features make it easier to update documents that compose the basic/executive project, mitigating inconsistencies among its various elements and, therefore, it helps the work of the construction inspector regarding the organization of the project's documentation.

5.2 ANALYZE AND APPROVE TEMPORARY FACILITIES AND CONSTRUCTION SITE PROJECT

Biotto, Formoso & Isatto (2015, p.87-88) observed the limitations of common planning techniques in terms of identifying space conflicts involving temporary facilities, inventories and equipment. These activities are related to BIM 4D modeling. In one of the case studies conducted by the authors, BIM 4D enabled the identification of several interferences between the execution of services and the fields of inventory, access and other elements of the construction site. In addition, BIM 4D assists with construction layout planning and anticipate future space-related problems involving the supply of the towers using a mobile crane, and even identifying obstructions to the equipment operator's visual field that would hamper its safe operation. To make these benefits possible, the scope of BIM modeling must be expanded to include transportation equipment, collective protection equipment, temporary facilities, among others (BIOTTO, FORMOSO & ISATTO, 2015, p.93). So, if the use of BIM 4D includes temporary facilities and construction site, the construction project inspector is able to do carry out a more accurate and better quality analysis of these elements.

5.3 ANALYZE AND APPROVE THE EXECUTION PLAN AND THE DETAILED SCHEDULE OF SERVICES AND PUBLIC WORKS

BIM 4D model allows testing different sequencing alternatives of the construction project, anticipating constructability issues in the planning phase (STAUB & FISCHER, 2006, p. 2-3) and increasing the probability of the project to be completed as planned and designed (FISCHER, HAYMAKER & LISTON, 2005, p. 30). To attain these benefits, the development of the BIM 4D model must consider the suitable level of detail for project items that must be communicated, the capacity to reorganize or create groups of the geometric entities, representation of temporary structures, decomposition of objects shown with single view line drawings, and inclusion of other schedule properties. It must also consider the start and finish dates (EASTMAM et al., 2014, 231-232). The most popular BIM tools do not have functions to respond to all the mentioned guidelines, but there are specialized 4D tools that produce 4D models based on 3D models and schedules that include such features. (EASTMAN et. al, 2014, p. 211 and 226-229). So, the use of BIM 4D models will offer a better visual communication of the schedules, increasing their feasibility and reliability, thus maximizing chances to finish the project in the established deadline, which will make oversight planning easier.

5.4 OBTAIN THE QUALITY MANUAL FROM THE CONTRACTOR AND CHECK WHETHER IT IS USED

Considering that demanding qualification in the Programa Brasileiro da Qualidade e Produtividade do Habitat [Brazilian Program on Habitat Quality and Productivity] (PBQP-H) to determine technical qualification has been repeatedly considered illegal by the TCU (BRASIL, 2014c, item 9.10.3), the bids for public construction projects at the federal level no longer require this certification. Therefore, checking whether the Quality Manual is being used does not apply.

5.5 PROMOTE MEETINGS ON THE DEVELOPMENT OF THE PROJECT AND TAKE NECESSARY MEASURES TO FULFILL THE CONTRACT

In this case, BIM is not used to promote the meeting, but to establish its agenda. One of the benefits of the 4D model is that is allows professionals to compare schedules and monitor the progress of the construction works. This enables professionals to identify if the project is on time or delayed (EASTMAN et al., 2014, p. 224). To offer these benefits, the model should provide a report on the phase of the project and on the construction of each component, aiming at monitoring and validating the progress of the project's components; however, no BIM tool meets this demand (EASTMAN et al., 2014, p. 210-211). These limitations are mitigated by using specialized 4D tools that enter information contained in the 3D model in more sophisticated schedule functions offered by the app itself, such as the software Sychro 4D or Vico Sofware, which allow professionals to compare the actual performance with the anticipated performance (EASTMAN et al., 2014, p. 222-229). Therefore, having more qualified information, the meetings on the control of the project's progress may attain their goal of monitoring and guiding the project to ensure their purposes will be fulfilled.

5.6 CLARIFY OR SOLVE INCOHERENCIES, FLAWS AND OMISSIONS IN THE PROJECT'S ELEMENTS, AS WELL AS PROVIDE NECESSARY INFORMATION AND INSTRUCTIONS FOR THE DEVELOPMENT OF PROJECTS.

BIM modeling "enables a better visualization of the project, and its development process allows the identification of interferences related to lack of or incoherence in information, when there is any." These geometric interferences and inconsistencies found based on BIM modeling are not found in the conventional process due to the limitations of two-dimensional representation (GOES, 2011, p. 132). Thus, the systems of all fields can be put together and compared; interfaces with multiple systems are easily verified; and conflicts are identified before they are seen in the building process (EASTMAN et al., 2014, p. 19). Therefore, the use of BIM minimizes the chance of errors and conflicts in the project, which will decrease the inspector's workload in this task.

5.7 SOLVE DOUBTS REGARDING THE SEQUENCE OF SERVICES AND INTERFERENCES AMONG WORK TEAMS

The previous sections addressed the benefits regarding communication regarding planning, sequencing of services, evaluation of constructability and logistics of the construction site brought about by the 4D model. This model helps the construction team to coordinate the work flow and the use of the space of the construction site. This gives contractors and subcontractors more productive and safe operations, which contribute to the obtention of more cost-effective and time-efficient construction projects (FISCHER, HAYMAKER and LISTON, 2005, p. 30). Therefore, the use of the BIM 4D model allows professionals to anticipate in the planning phase the problems that would surface during the construction process regarding sequencing and interferences among services, and, consequently, decrease the inspector's workload regarding these aspects.

5.8 PROMOTE THE PRESENCE OF PROJECT DESIGNERS IN THE CONSTRUCTION SITE TO CHECK WHETHER THE ACTUAL CONSTRUCTION FOLLOWS THE PARAMETERS, DEFINITIONS AND CONCEPTS OF THE PROJECT

The presence of project designers on the construction site aims to fill the gaps caused by the project's deficiencies. According to Azhar (2011, p. 243), the BIM model generation process inevitably discovers errors and inconsistencies as it is created, since it is a virtual building. Azhar also affirms that the features of BIM technology allow the creation of an improved project since it rigorously analyzes proposals; performs simulations; benchmarks performances; offers flexible documentation; and exploits automation. In view of the above-mentioned

benefits, projects designed using BIM tend to have better quality than those designed in 2D and anticipate issues that could exist during the construction process. Therefore, it decreases the need to have designers going to construction sites to solve doubts or adjust the design to the real conditions of execution.

5.9 STOP AND/OR REQUEST THAT "NON-COMPLYING" SERVICES BE REDONE

According to Eastman et. al. (2014, p. 235-236), the model of the construction may be used to verify whether the actual construction process reflect those shown in the model. As an example, he mentions the Letterman Digital Arts Center, in California, United States, a project that adopted traditional verification processes through daily rounds on the construction site and model reviews to identify possible errors. However, the qualitative verification of services conducted by the construction work inspector is still essential, and the use of BIM will make it easier to understand the project by means of virtual rounds, 3D models and countless possibilities of automatically generated section cuts and views.

5.10 REQUEST REPLACEMENT OF DEFECTIVE OR UNSUITABLE MATERIAL AND EQUIPMENT

This activity is similar to requesting that non-complying services be redone, and the same considerations presented previously apply here.

5.11 REQUEST THE PERFORMANCE OF TESTS TO CONTROL THE QUALITY OF SERVICES AND CONSTRUCTION WORKS

As mentioned about the organization of documents that make up the construction's basic/executive project, the BIM model can include the specifications of constructive elements and the necessary tests aiming at quality control. However, the inspector's critical sense and the role are essential to ensure an effective quality control.

5.12 HAVE RIGOROUS CONTROL OVER THE SCHEDULE, APPROVING OCCASIONAL ADJUSTMENTS

In previous sections, the following advantages of the 4D model were described: schedule simulations; identify interferences between the execution of services and the fields of inventory, access and other construction site elements; assist the construction project layout; possibility to test different sequencing alternatives, anticipating constructability issues in the design phase; increases the probability of the project to be completed as planned and designed. Therefore, the use of BIM 4D helps to control deadline and to make schedule adjustments, assisting the inspector in these activities.

5.13 APPROVE EXECUTED SERVICES, ATTEST MEASUREMENTS AND SUBMIT INVOICES FOR PAYMENT

By using BIM technology, it is possible to extract a list of quantities of elements from the model (EASTMAN et al., 2014, p. 18). The cost estimate of construction will be the product of the quantities obtained in the model and the cost of a database; this connection between the model and the database will vary depending on the software, allowing the cost of the construction project to be anticipated and controlled (KYMMELL, 2008, p. 58). Once the connection with the cost is established and the work progress is controlled in BIM model, the latter can be used to control cash flow. In addition, it is possible to control invoicing, tracing and representing the completed work in BIM so that the measurement quantities are removed from the model and invoiced accordingly, making it possible to visualize graphically the completed work for each measurement with the help of the model (KYMMELL, 2008, p. 113). It is worth highlighting that no BIM tool contains all the functions of an electronic spreadsheet or budget software (EASTMAN et al., 2014, p. 218). Some items contained in public construction projects budgeting are not part of BIM modeling – such as the local administration of the work, tests, executive project development etc. – and, therefore, they cannot be extracted from the model. Thus, their measurement must be carried through the conventional process. However, the use of BIM to extract the quantities of measured services is a substantial advantage that assists this oversight activity. because most quantities may be automatically extracted and, if it is connected with the progress of the construction project in the model, the completed and invoiced service may be visualized and this increases even more the benefits in terms of measurement control.

5.14 CHECK AND APPROVE THE REPLACEMENT OF MATERIAL, EQUIPMENT AND SERVICES

As said about the organization of documentation that is part of the basic/executive construction project, the BIM model can include the specifications of constructive elements and substitution alternatives; however, the activity depends directly on the inspector's activity to ensure that equivalence among components is maintained.

5.15 CHECK AND APPROVE PERIODICAL REPORTS ON THE EXECUTION OF SERVICES AND CONSTRUCTION WORKS

The advantages of the use of 4D and 5D BIM models to control and follow the deadlines and costs of construction projects have already been addressed in previous sections. The use of these models allows the visualization of completed services, cost analysis and phase of project in relation to what was planned. Therefore, the use of BIM makes it easier to verify the project execution reports.

5.16 REQUEST REPLACEMENT OF ANY CONTRACTOR EMPLOYEE

This is an administration activity in the field of human resources not related to BIM technology.

5.17 5.17 CHECK AND APPROVE PROJECT DRAWINGS "AS BUILT"

An up-to-date BIM model will correspond to the actual "built project" when the construction is completed. To achieve this, the model of the project phase must be adapted and continuously updated during the construction phase so that it will be an updated and precise reflection of the state of the construction project and, at the end, the project "as it is built" (KYMMELL, 2008, p. 75). Therefore, when BIM is adopted since the beginning of projects and the model is updated constantly, the project "as it is built" is automatically generated, which makes it easier for the inspector to check the drawings.

6. CONCLUSION

The oversight activities described in the "Public Works Manual – Buildings –SEAP Practices – Construction" (BRASIL, 1997, 10-2 a 11-2) – which is a reference for the oversight tasks conducted by the public federal authorities and by TCU – were analyzed in the light of the state of the art BIM technology to evaluate its potential use in this activity. In each activity, the main BIM contributions to public construction projects oversight were identified. Some of the aspects are below:

a. BIM 4D is able to identify the problems related to interferences among the various services and elements of the construction site already in the planning phase. Thus, it is possible to better plan the construction process and its construction site. This increases the chances of the project to be completed in the established deadline. By using specialized 4D tools, it is possible to compare what was planned and what was actually executed to evaluate compliance with the schedule and allow re-planning to ensure the project deadline.

b. adoption of the BIM 5D model offers the exact quantities of building components related to cost, which allows professionals to control cash flow and invoicing during the project, in addition to enabling the graphical visualization of the

finished work, which makes it easier to monitor the project.

c. c)some oversight activities – identification of defective service and material, request for tests, substitution of employees – cannot be assisted by BIM technology, because these activities must be done on the construction site and depend on the inspector's activity.

As a new approach in the construction field, BIM still has limitations; however, its use in all phases, from the design to the execution of the project, will make the inspector's task easier, offering inspectors better quality information to control and demand from contractors the fulfillment of the contract. This will increase the probability to execute projects with better quality, complying with the established prices and deadline.

Based on this work, the suggestion is to conduct in-depth studies in the following areas: guidelines to create BIM models in public construction projects; analysis of BIM tools that are more suitable to monitor public construction projects; and case study of a public construction project using BIM technology in its design and monitoring.

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