An Investigation of Contractual Requirements for BIM Adoption in the Brazilian Public Sector

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Abstract. Previous research has shown that Building Information Modeling (BIM) can reduce errors, rework, time and cost in project design and construction. Besides, it provides greater value delivered at the maintenance and operation stage, reducing owner-operating expenses. To maximize BIM use benefits, owners, such as the public sector, can directly affect the enterprise viability by selecting the project delivery system. That has led to the search for alternatives contractual requirements to traditional models. The main objective of this study is to investigate contractual requirements that influence BIM adoption process in public organizations. The research strategy adopted was a survey. Sixty-nine professionals from Brazilian Architecture, Engineering, Construction and Operation (AECO) sector answered a digital questionnaire. The target public was BIM adoption experts, academic professionals and public managers from fourteen public organizations that have already begun BIM implementation. The investigation revealed that project delivery systems considered with the greatest potential to maximize the benefits of BIM use were those less adopted and disseminated in the Brazilian public sector. The results also show that contractual requirements for BIM adoption might consider aspects, such as, technical qualification in public procurement, methods and tools for BIM deliverables quality checking, items that must compose a BIM mandate, and favorable cost-benefit factors for the development of BIM component virtual libraries by public organizations. The main contribution of this research is to provide a better understanding of contractual requirements that could be incorporated into project delivery systems to maximize BIM benefits in the public sector.

Keywords: BIM adoption · Project delivery system · Survey · Public organization · Contractual requirements

1 Introduction

BIM is a modeling technology associated with a set of processes to produce, communicate and analyze building models (Eastman et al. 2011). For Hardin and Mccool (2015), BIM is also an initial catalyst for a period of innovation and technology revival,

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generating innovations in many areas and changes in support processes, since new technologies do not fit in the previous processes.

For Sacks and Gurevich (2016), BIM adoption is a complex process that requires the development of a strategy that understands organization maturity, industry capabilities, national policies and regulations, education, hardware and software acquisition, changes in the project delivery systems, among other critical factors.

According to Bernstein et al. (2014), reduction of errors, rework, costs and time are some of the BIM use benefits for owners. Among the biggest beneficiaries are customers, maintenance and operation managers, as well as owners, according to Eadie et al. (2013).

Porwal and Hewage (2013) proposed a structure for public construction project delivery based on collaborative BIM processes and recommended studies in areas related to national guidelines, legal structure and specific contractual issues for implementation.

For Eastman et al. (2011), governments are usually owners and it also has control of the service provider's selection, contract type and delivery processes as well as general specifications and requirements. Even so, some public sector organizations do not realize their potential to change or control how a project is conceived, being unaware of the contractual requirements that are influenced by BIM adoption.

The main objective of this study is to investigate contractual requirements that influence BIM adoption process in public organizations, contributing to a greater understanding of this process and successful BIM implementations in the public sector.

2 Contractual Aspects in BIM Adoption

Brazil has unbalanced BIM diffusion areas and low levels of modeling, collaboration and integration capacity. Concerning maturity, the greatest performance was in the technological infrastructure component, while in measures and benchmarking; education; objectives and milestones; regulatory structure; and notable publications, had the lowest levels. Brazilian political actions were characterized as to raise awareness, encourage and observe, in a completely passive pattern (Kassem and Succar 2017).

Formal adoption in the Brazilian governmental sphere is still recent, having started from some states and federal agencies. However, in 2018, the Brazilian federal government launched BIM National Dissemination Strategy and an implementation committee responsible for various government actions, such as the development of company accreditation programs; BIM platform with national object library; stimulating demand in hiring; and vocational education.

For Eastman et al. (2011), some of the actions that owners can take as a way of encouraging BIM are: include specific pre-qualification criteria in the selection of contractors, such as knowledge and experience in BIM; build and educate a qualified network of BIM service providers; change requirements for deliveries, incorporating scope, detail and organization of model information and its uses; and propose performance-based contracts and shared incentive plans.

In this way, the choice of the project delivery system is one of the fundamental ways in which owners can affect in efficiency, productivity and profitability. Concerns

about the sector's inefficiency in recent decades have led to the search for alternatives to the traditional Design-Bid-Build (DBB) model, in which the design, contracting and construction stages are segregated and generally performed by different agents. Another system that was established was the Design-Build (DB), in which the contractor is responsible for project design and construction (BSI 2013).

In recent years, another delivery systems have emerged and brought about more radical changes, such as the Design-Build-Operate/Maintain (DBO/M) that expands the role of the project contractor up to operation and maintenance phase. Integrated Project Delivery (IPD) is another emerging delivery system that proposes risks and responsibilities sharing between parties since the project beginning, integrating people, systems, business structures and practices in a process that leverages everyone's talents to reduce waste and optimize efficiency (BSI 2013).

Bernstein and Laquidara-Carr (2014) investigated AECO sector perception regarding the selection of these delivery systems, verifying that there is no absolute consensus on the benefits and obstacles of the most used systems such as DBB and DB. As an exception, there is a greater perception of a positive impact on time, risks and responsibilities sharing for DB use, as well as search for cost reduction with a greater tendency in the DBB selection.

Emerging systems such as DBO/M and IPD tend to have an increasing use since the latter was considered the best delivery system to achieve improved communication between those involved, productivity and increased efficiency. This makes most owners who seek better control of the schedule, costs and increased quality, analyze its use (Bernstein and Laquidara-Carr 2014).

The main public project delivery systems in Brazil are Law no. 8.666/2013; Public-Private Partnerships (PPPs) law; and the law of the Differential Contracting Regime (DCR). They are similar to the following delivery systems: Law no. 8.666/1993 with the DBB system; DCR with the DB system in the integrated contracting regime for design, construction and pre-operation stages; PPP law with the DBO/M system, encompassing stages of design, construction, operation and transfer to the public sector.

The project delivery system selection by the owner usually correlates his level of control with the risks assumed. The DBB method is at the intermediate level of risk, offering a high degree of control over the project, reliable information on the cost before construction and clearly defined parts roles, although it may be a choice that does not favor for schedule and creates a non-collaborative culture between the parties. In the low level of risk are the IPD and DB systems that significantly reduce the owner risks, however, if their ability to generate value for the investment or the building performance is reduced, it can result in increased operating costs (Bernstein and Laquidara-Carr 2014).

Porwal and Hewage (2013) proposed a structure for contracting public construction projects based on collaborative BIM processes, aiming to maximize the value delivered by the Canadian construction industry. A case study was conducted in a public project contracted at the lowest price, with the DBB system, to prove the viability of the proposed method.

The results indicated that guidance is needed from where to start, what tools are available, how to face legal, contractual and cultural challenges, among others.

Compared to the traditional DBB contracting method, the proposed BIM collaborative partnership was considered suitable for the public sector because the selection process was open, objective, fair and free from political influence, with significant improvements in terms of cost, value delivered and performance in carbon emissions Porwal and Hewage (2013).

According to Eastman et al. (2011), another central issue for the public sector involves the current processes based on the lowest price, which usually diminish the importance of criteria such as time and quality, without guaranteeing the return of maximum value. With BIM adoption, the sooner the model can be developed and shared, the greater its usefulness. For this reason, DB contracting models provide a great opportunity to explore the benefits, as the contractor is responsible for the design and construction, and both can participate in the design phase. Other systems can also make progress with BIM, however, achieving partial benefits if there is no collaboration during the design (Eastman et al. 2011).

Becerik-Gerber and Rice (2010) investigated the BIM use in the United States with a sample of 424 respondents and identified that although the traditional DBB system was still the most used, it was already possible to notice that many of the projects adopted delivery methods latest and most collaborative, including DB, IPD, performance-based contracts and alliance. IPD was cited as the most effective in facilitating the BIM use, as it seeks to create a more comprehensive collaborative atmosphere, aligned with the objectives of all members, encouraging them to work together throughout all phases.

In addition to selecting the project delivery system, public organizations should consider the influence of the BIM adoption process on other contractual aspects. Kassem et al. (2015) analyzed guides, protocols and mandates, documents that are published for a wide audience and that aim to promote understanding, regulate the implementation or demand requirements for BIM use.

BIM guides are characterized as descriptive and optional documents, clarifying goals, reporting research and simplifying complex topics. Protocols are also optional, however, they are prescriptive, providing, in detail, steps or conditions to achieve a measurable goal or result. In contrast, mandates are prescriptive and dictated by an authority, identifying what should be delivered and, sometimes, how, when and by whom (Kassem et al. 2015).

Sacks and Gurevich (2016) consider that the preparation of adequate guidelines on how to use BIM, to offer value, to be demanded in contracts is one of the main steps that can be exercised by large clients in the construction sector (companies, authorities and public departments) for a guided and systemic implementation. Based on the analysis of fifteen mandates, a set of requirements was recommended for organizations to develop, evaluate or update their documents. Of the ten main topics, interoperability, BIM manager role, collaboration modes, requirements for operation and maintenance, BIM Execution Plan (BEP) and simulations showed similarities in the documents, although content, frequency, specificity and level resolution have varied.

Faria et al. (2016) also analyzed mandates of pioneering countries in adopting, as the United States, United Kingdom, Finland, checking that have: BEP; definition of file

formats for exchanging information; expected uses; roles and responsibilities; intellectual property of deliverables; Level of Development (LOD) of the components; and quality control of models.

Regarding delivery systems, although the DBB system is still the most traditional, some documents address the DB and the IPD trend towards increased collaboration and integration, even though there are many practical, legal and logistical obstacles, especially in organizations that have their procurement processes and legislation (Sacks and Gurevich 2016).

Planning for BIM adoption involves BEP preparation, which is prepared by the client to explain how the information modeling aspects of a project will be carried out (BSI 2013). According to Sacks and Gurevich (2016), BEP is an essential adoption component, as it contains the intended modes of collaboration and information sharing, roles and responsibilities of those involved, software to be used, scope and LOD to be achieved, quality control procedures, object composition and naming conventions.

The procedures for quality control of BIM models must be performed before integration with the federated model and made available as a reference for other designers. This verification involves aspects of both the model itself and its components and aims to ensure information consistency and conformity of the components and their use.

The following aspects must be verified: objects with correct typologies defined; duplicate, very small or overlapping objects; LOD established for a given type of component in the corresponding milestone or phase; and objects following intended uses (Eastman et al. 2011).

Gurevich et al. (2017) conducted action research and case studies in five public agencies in the United Kingdom that adopt BIM to propose an Adoption Impact Map, which lists possible actions taken by the agencies, intermediate results and possible social impacts in the value delivered to the occupants and in its functionality.

The results showed that the artifact of BIM objects library would have an impact on standardization implementation by the organization, generating positive effects on time, cost and maintenance. The five agencies studied emphasized the importance of the asset information value obtained at the end of a BIM design and construction process, bringing benefits to operation and maintenance activities. (Gurevich et al. 2017).

3 Method

The research strategy adopted in this research involved the following steps:

- Literature review on contractual aspects that are influenced by BIM adoption according to the literature;
- Development of a digital questionnaire on Google Docs on BIM adoption by public organizations, having, as part of it, five questions on the evaluation of contractual requirements that are influenced by BIM use in organizations;
- Surveying by sending questionnaires to a sample of Brazilian professionals from the AECO sector, including public managers, academics and specialists in BIM adoption;
- Analysis of the responses to the questionnaire by calculating agreement percentages and degree of importance average in questions with Likert scale.

The questionnaire comprised a section to identify the respondent's profile and another with evaluation containing the five questions on contractual aspects. In two questions, participants could select items considered to be priorities to compose a mandate and choose one or more existing Brazilian public procurement systems with the potential to maximize BIM benefits. The other questions evaluated by a Likert scale covered the degree of importance of requirements for technical qualification in hiring, methods and tools to verify BIM models quality and factors that generate a favorable cost for the development of a BIM component library. The five-level Likert Scale ranged from 1 - Very Low; 2 - Low; 3 - Medium; 4 - High; up to 5 - Very High.

A pilot questionnaire previously assessed the survey questions through two BIM implementation specialists. Subsequently, the questionnaire was sent by email to approximately 300 Brazilian professionals, obtaining a sample of 69 respondents, between May and July 2018. Those who did not respond to the survey in the first three weeks were reminded of the invitation via a new email.

4 Contractual Requirements for BIM Adoption in the Brazilian Public Sector

The initial part of the questionnaire consisted of identifying the survey participants, followed by the evaluation questions.

The respondents' profile involved aspects such as age, gender, education, areas of expertise in the AECO industry and the time of personal experience (studies and applications) with BIM, as shown in Figs. 1 and 2.

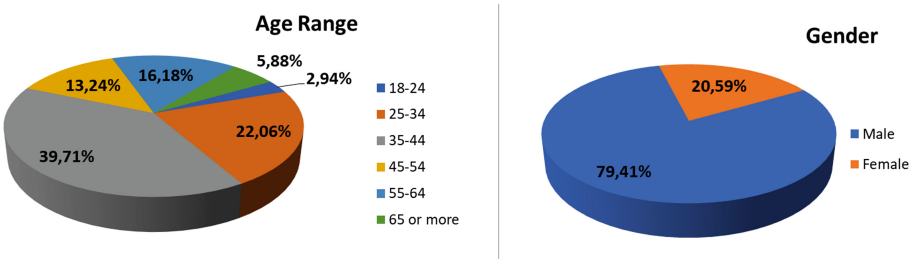

Fig. 1. Age range and gender of participants

About half of the professionals are architects, followed by civil engineers. Regarding the education level, 42.65% have a master's degree, followed by 25% who have a specialization/MBA. The sample covers ten states in four Brazilian regions. Also, 64.71% of respondents have at least 5 years of personal experience with BIM, with 48.53% reporting 8 years or more of experience.

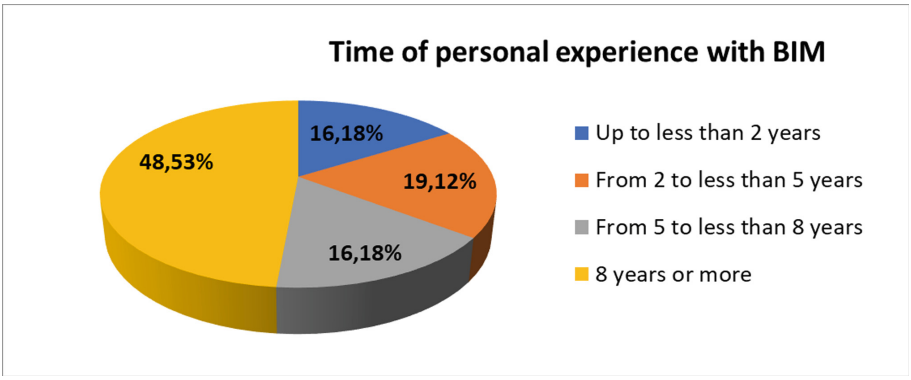

Fig. 2. Time of personal experience with BIM of participants.

The first contractual aspect evaluated was the organization's BIM adoption policy through the mandate publication, a prescriptive and mandatory document that guides implementation planning and execution. A set of fourteen items present in these documents were identified, according to the literature review, so that those considered priority by the respondents were chosen, as shown in Table 1.

Table 1. Evaluation of priority items in a mandate

Ranking	Priority items in a mandate	% Agreement
1	Interoperability for information exchange	82,61%
2	Requirements or template for BIM execution plan	81,16%
3	Data naming and organization conventions	79,71%
4	Levels of development (LOD) and models structuring	76,81%
5	Model quality control procedures	72,46%
6	Roles and responsibilities of those involved	69,57%
7	Project delivery systems and qualification	63,77%
7	Patterns of graphic representation and components	63,77%
9	Desired collaboration modes	62,32%
10	Uses, functions and analysis/simulations expected by life cycle phases	60,87%
11	Payment schedule (especially with definition of the design phase remuneration)	53,62%
11	Operation and maintenance requirements (COBie)	53,62%
11	Intellectual property rights of models and their components	53,62%
14	Software specification	30,43%
15	Outro	2,90%

The results revealed that almost all items were considered necessary by more than half of the evaluators, with five of them being chosen by at least about 70%: interoperability (82.61%); requirements or template for BEP (81.16%); data naming and organization conventions (79.71%); LOD and models structuring (76.81%); model quality control procedures (72.46%); and roles and responsibilities of those involved (69.57%).

On the other hand, only 30.43% of the sample considers that these documents should specify the software that will be used and only 2.9% chose another item, indicating that the proposed set was comprehensive for mandates scope composition, based on previous studies such as Sacks and Gurevich (2016) and Faria et al. (2016).

Another contractual aspect influenced by BIM adoption is the criteria definition for selecting project delivery systems. For this, it was investigated which existing Brazilian public delivery systems for construction projects would have the greatest potential to maximize BIM benefits, among them, Law no. 8,666/1993, DCR and PPP regimes, or otherwise not yet regulated.

Although this question had a higher percentage of respondents (11.59%) who indicated that they did not know how to answer, the systems considered most appropriate were those that are still less used and disseminated in Brazil. DCR with variable remuneration for performance, which has variations that can be associated with the DB or DBB system (49.28%) and PPP encompassing design, construction and operation with variable remuneration, according to performance, equivalent to the DBO/M system (42.03%), as shown in Fig. 3.

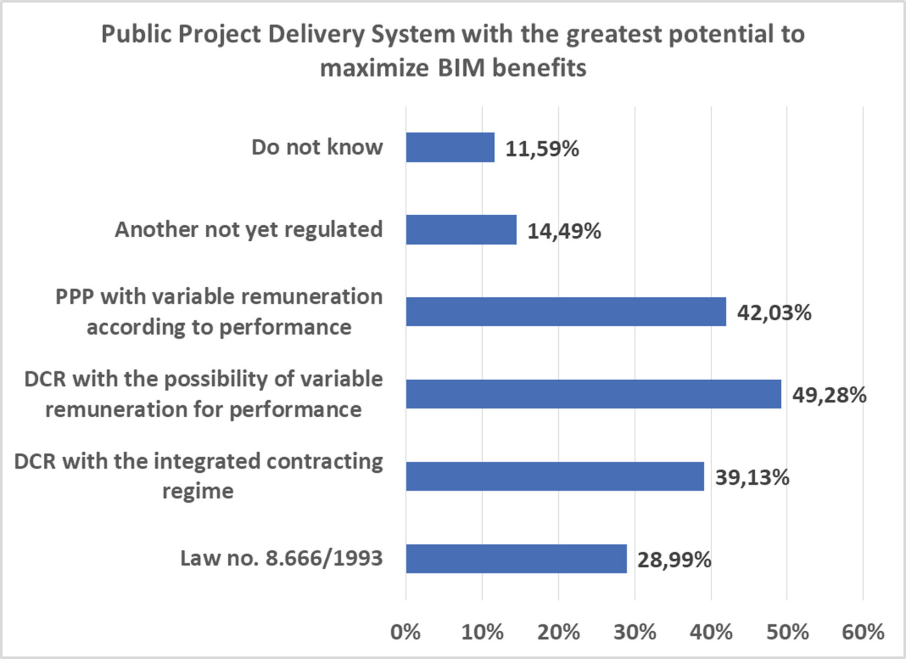

Fig. 3. Public project delivery system to maximize BIM benefits.

The percentage of participants who selected another form not yet regulated (14.49%) and who cited the IPD corroborates the growing trend in the valuation of new delivery systems that use alternative mechanisms, as previously identified in other markets as in the survey by Becerik-Gerber and Rice (2010) in the US. Similarly, one of the comments suggests that the Brazilian public sector should study the modalities known in the US as IPD and DB, reducing the current segregation and disintegration between project stages and results.

It is noteworthy that the DCR regime with the integrated contracting of the design, construction and pre-operation stages, the closest to the American DB system, obtained 39.13% of the answers. On the other hand, Law 8.666/1993, with separation of the stages of project design, contracting, construction and operation, equivalent to DBB system, reached the lowest percentages with 28.99%, reinforcing the existing criticisms about their deficiencies regarding integration, cost and time control and low generation of value delivered in the operation and maintenance stages.

In addition to the appropriate delivery system selection in public projects, another important action to be taken is the criteria definition for qualifying in BIM of interested bidders, maintaining equality and ensuring that the contractor provides the expected performance.

Among the four requirements assessed through the degree of importance in a Likert scale, the highest averages were obtained by team qualification and professional experience in BIM use (4.20); and assessment of the quality of the deliverables in previous projects (4,19), both considered highly or very highly important for more than 80% of the professionals, as shown in Table 2. These results highlight the need for public organizations to develop objective criteria for analyzing the qualification of professionals and the quality of BIM models.

Table 2. Evaluation of requirements for technical qualification

Requirements for technical qualification in contracting for BIM use	% (4) or (5)	Average	Standard deviation	Ranking
Team qualification and professional experience in BIM use	87,0%	**4,20**	0,70	**1**
Assessment of the quality of the deliverables in previous projects	82,6%	**4,19**	0,83	**2**
Availability of company adequate technological infrastructure	71,0%	**3,87**	0,84	**3**
Company experience in similar projects	62,3%	**3,78**	0,78	**4**

Among the comments of the participants, there is the importance of companies having managers or coordinators of BIM processes, or even a group that plays this role with proven experience, not only based on documentation. Another way of guaranteeing professional qualification would be to create certification processes for professionals or companies in skills necessary for the use of BIM.

The other requirements were also considered highly important, according to the following sample averages: availability of company adequate technological infrastructure (3.87); and company experience in similar projects (3.78), which indicates that they should not be discarded by public managers and can be evaluated as complementary criteria in the qualification process.

The creation of objective criteria for assessing BIM models quality is not only strategic for the initial contracting phase, but it is also during the design phases until the project's operations.

To verify BIM models quality, the evaluation of the methods and tools that obtained the highest averages of importance have some degree of automation and validation software support and specific electronic spreadsheets, such as automatic verification of duplicate, overlapping or inconsistent objects (4.44); and automatic verification of specific programmable rules (4.44). Then, specific checklists to control the quality of data and projects were evaluated with a sample mean of 4.06, as can be seen in Table 3. As proposed by Sacks and Gurevich (2016), these criteria may be included in the project's BEP.

The manual visual verification of specific views and manual verification with filters use were evaluated with average degrees of importance of 3.31 and 3.52, respectively, which reinforces the tendency that they are methods with less productivity, being useful in certain situations that require qualitative analysis. One of the respondent's comments emphasizes the importance of these qualitative analyses to meet functionality, flows, aesthetics, budget, among others, which would depend on a holistic interpretation of the project coordinator for decision making.

Table 3. Evaluation of methods and tools for checking BIM models quality

Methods and tools for checking BIM models quality	% (4) or (5)	Average	Standard deviation	Ranking
Automatic verification of duplicate, overlapping or inconsistent objects	93,9%	**4,44**	0,61	**1**
Automatic verification of specific programmable rules	89,4%	**4,44**	0,68	**2**
Specific checklists to control the quality of data and projects	81,8%	**4,06**	0,74	**3**
Manual visual verification of specific views	54,7%	**3,52**	0,94	**4**
Manual verification with filters	43,1%	**3,31**	0,98	**5**

Other requirements to be verified, according to some participants, including checking of the modeled objects, LOD compatibility among disciplines and identification of possible information and elements that still need to be modeled. Furthermore, it was mentioned the need to review some technical standards that have subjectivities in the interpretation of their requirements so that they can program objective rules for measuring compliance.

Still, regarding the requirements and guidelines for receiving deliverables, another potential action investigated was the cost-benefit analysis in the development of BIM

components libraries. Bearing in mind that the elaboration, maintenance and updating of a specific BIM components library by a public institution is not a decision widely accepted by the Brazilian sector, professionals were questioned about the agreement with this issue, as shown in Fig. 4.

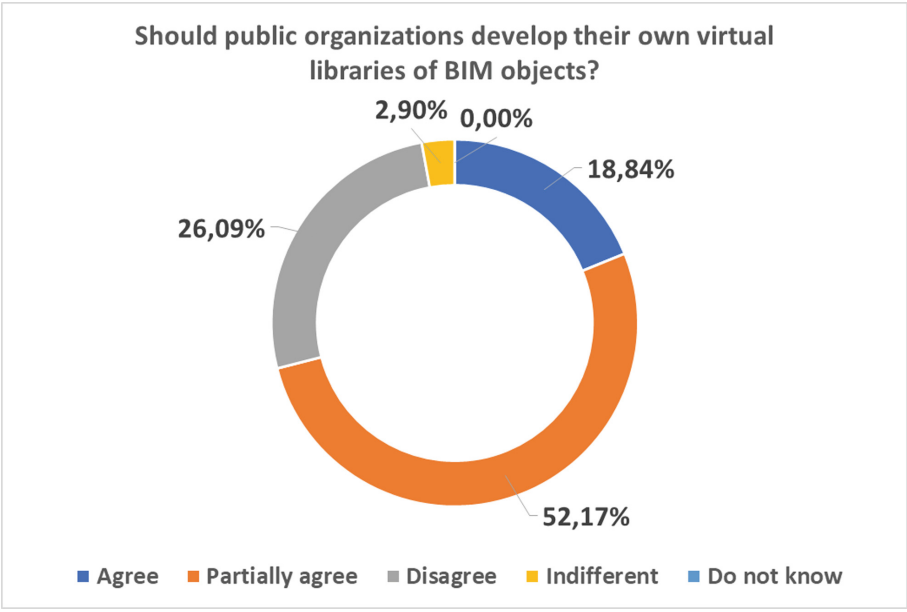

Fig. 4. Development of BIM objects libraries by public organizations.

The results showed that just over half of the professionals partially agree, while 26.09% disagree and 18.84% agree, confirming the existence of different perceptions on the topic. Among the participant's comments, some consider that public agencies should develop, as well as integrate, libraries developed by the industry, or that they should develop for their items with greater specificity, while for components in common use a more comprehensive library should be created from a federal agency or association.

Other observations of respondents mention that libraries should be restricted to specific situations, such as when the institution has projects with standardized components. Among those who disagree, it is argued that this is an attribution of the market, materials manufacturers with software companies, and that library management needs qualified professionals, elaboration covering the diversity of existing competing software and updating to be continued.

Adopting the definition of the 71.01% who agree, even if only partially, with the development of virtual libraries by public organizations, seven organizational factors were assessed as to the degree of importance in generating a favorable cost-benefit.

The factors considered with the highest degrees of importance were: existence of requirements for projects modulation and/or standardization (3.96); personnel and technological infrastructure availability for development (3.94); and repeatability in projects typology and specifications (3.91), with emphasis on the latter, which obtained 76.6% of responses with a high or very high degree of importance, as shown in Table 4. It is also observed that these three factors bring together aspects related to the processes, people, technologies and characteristics of organizations, considered important for cost-benefit analysis.

Then, the factors considered the fourth and fifth most important were: high complexity of the projects (3.74); and existence of a BIM objects national repository or library (3,67), comprising a factor that corresponds to a characteristic of the organization and another that involves external environment, which reveals a diversity of aspects that would influence the cost-benefit.

Table 4. Evaluation of generating cost-benefit factors to BIM component libraries

Generating cost-benefit factors favorable to the development of BIM component libraries	% (4) or (5)	Average	Standard deviation	Ranking
Existence of requirements for projects modulation and/or	70,2%	**3,96**	0,81	**1**
Personnel and technological infrastructure availability for development	66,7%	**3,94**	0,95	**2**
Repeatability in projects typology and specifications	76,6%	**3,91**	0,75	**3**
High complexity of the projects	59,6%	**3,74**	1,05	**4**
Existence of a BIM objects national repository or library	56,3%	**3,67**	0,95	**5**
Variability in the projects typology and specifications	44,7%	**3,32**	0,93	**6**
Low complexity of the projects	29,8%	**3,00**	1,10	**7**

On the other hand, the factors that obtained an average degree of importance in generating favorable cost-benefit were: variability in the projects typology and specifications (3, 32); and low complexity of the projects (3.00). These characteristics are opposed to factors that obtained high importance related to projects repeatability and high complexity, possibly indicating greater relevance of repeatability and potential for standardization in the use of own libraries. These findings reinforce the results obtained by Gurevich et al. (2017) that associated the creation of a BIM objects library with standardization implementation by an organization, generating positive effects on time, cost and maintenance.

Among the comments made by the participants, the gain obtained by standardization was reinforced, which would be reduced when there is no significant volume of repeat projects. In these cases and, when the organization does not design, it was mentioned that the public organization would simply be concerned with defining what information is necessary for contract fulfillment.

5 Conclusions

The study main objective was to investigate contractual requirements that influence the BIM adoption process in public organizations. The contribution of this research is to provide a greater understanding of the contractual aspects of this process and to promote implementations that achieve the objectives established by the organizations.

A survey using digital questionnaires was used to evaluate these contractual aspects, based on the responses of a sample of 69 Brazilian professionals involved with BIM use in public organizations, among public managers, academics and experts.

The results showed a set of items considered a priority in the mandate composition and indication of the Brazilian public project delivery systems considered with the greatest potential for maximizing BIM benefits. Emerging delivery systems that are still less used and disseminated in Brazil were considered the most appropriate.

Besides, the participants highlighted as technical qualification requirements the need for public organizations to develop objective criteria for analyzing qualification of professionals and BIM models quality. The quality verification methods and tools considered to be of the greatest importance were those that have some degree of automation, support of validation software and specific spreadsheets.

The research also evaluated the factors that generate cost-benefit favorable to the development of a BIM components library, especially those related to the project repeatability and high complexity. The findings may indicate the greater relevance of repeatability and the potential for standardization in the use of own libraries.

As for recommendations for future research, it is expected that these contractual requirements assessed according to the professional's perception involved in the BIM adoption can be investigated as to their influence on the implementation process by public organizations.

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