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Implementation of BIM in infrastructure: the need to address it from the public sector

Implementación de BIM en infraestructura: la necesidad de abordarlo desde el sector público

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- The implementation of Building Information Modeling and its use is becoming much more popular and common throughout the world.
- BIM is being recognized as a technological tool, as a set of collaborative and interdisciplinary processes and as a management methodology, which allows the project to maximize its value throughout its lifecycle.

The implementation of Building Information Modeling (BIM) in infrastructure projects involves the private sector and the public sector. The participation of the first one is widely documented; however, the role of the second one has not been rigorously studied. Consequently, this paper raises the need to implement BIM in infrastructure projects in Colombia, demonstrating the importance of the government initiative, leadership and regulation. The role that the public sector must play is evidenced, both for acting as owner of the infrastructure projects and for the lessons learned from the leading and pioneer countries in BIM. It is established that the use of BIM is enhanced and accelerated from the moment that the public sector adopts a position to promote its implementation. Therefore, this article defines the different roles that the public sector can take to encourage the use of BIM. Likewise, it proposes a BIM governmental roadmap for Colombia that can be extrapolated to countries with an economy, an idiosyncrasy and a similar level of BIM implementation. Also serving as a starting point for the development of standards, strategies and programs that encourage the implementation of BIM at a national level.

BIM; Infrastructure; Public sector; Roadmap; Colombia.

- La implementación de Building Information Modeling y su uso se están volviendo cada vez más populares en todo el mundo.
- BIM está siendo reconocido como una herramienta tecnológica, como un conjunto de procesos colaborativos e interdisciplinarios y como una metodología de gestión, que permite al proyecto maximizar su valor a lo largo de su ciclo de vida.

La implementación de Building Information Modeling (BIM) en proyectos de infraestructura involucra al sector privado y al sector público. La participación del primero está ampliamente documentada, sin embargo, el rol del segundo no ha sido rigurosamente estudiado. Consecuentemente, este artículo plantea la necesidad de implementar BIM en los proyectos de infraestructura en Colombia, demostrando la importancia de la iniciativa, el liderazgo y la regulación del gobierno. Se evidencia la necesidad del rol que debe jugar el sector público, tanto por actuar como dueño de los proyectos de infraestructura, como por las lecciones aprendidas de los países líderes y pioneros en BIM. Se establece que el uso de BIM se potencializa y se agiliza desde el momento en que el sector público adopta una postura para promover su implementación. Por lo tanto, este artículo define los diferentes roles que puede adoptar el sector público para impulsar la utilización de BIM. Así mismo, propone una hoja de ruta gubernamental BIM para Colombia, extrapolable a países con una economía, una idiosincrasia y un nivel de implementación BIM similar. Sirviendo también como punto de partida para el desarrollo de estándares, estrategias y programas que incentiven la implantación de BIM a nivel nacional.

BIM; Infraestructura; Sector público; Hoja de ruta; Colombia.

1. INTRODUCTION

The supply of infrastructure by the construction industry plays a fundamental role in the generation of wealth in a country, as well as in its levels of competitiveness [1]. The second pillar to measure the competitiveness of a nation, according to the World Economic Forum, is infrastructure, referring, to the transport infrastructure (road, air, rail, and port), as well as to the electrical and telecommunications infrastructure. This happens since infrastructure is the means by which the other sectors of the economy grow and strengthen [2].

Framed in the Colombian context, it can be seen the impact that the construction sector (buildings and infrastructure) has on the economy of the country. The GDP of Colombia, taking

as a reference the second quarter of the year, increased from 2016 to 2017 by 1.3% [3]. In this variation, the construction sector contributed 0.3% of GDP [3]. Additionally, this sector occupied 6.2% of employees during the second quarter of 2017 [3]. Regarding competitiveness levels of Colombia, according to the report of the World Economic Forum of 2017, the quality of transport infrastructure is in the 98th position of 137 countries and the energy and telecommunications infrastructure in the 76th position [4].

Additionally, the inadequate supply of infrastructure by the country is established as the fourth most problematic factor for doing business in Colombia [4]. In synthesis, statistics show that, in Colombia, infrastructure is fundamental for the social and economic development of the country. However, it is in a state that claims for deep and significant improvements [5].

Infrastructure projects are commonly associated with over-costs, non-compliance with deadlines, changes in specifications during their execution and even corruption [2]. However, the architecture, engineering and construction industry (AEC) is constantly looking for techniques and methodologies that reduce costs, increase efficiency and quality and reduce delivery project time [6]. As a response to the above, Building Information Modeling (BIM) emerged, which is a set of policies, processes, and technologies that work in an integrated and collaborative manner, generating a methodology to manage the project throughout its life cycle [7]. BIM consists of generating a graphic representation of the physical and functional characteristics of a project. This creates a friendly and intuitive model, which integrates all the areas and components of the project harmoniously, allowing the integral and collaborative updating of its changes. However, BIM is not limited to the use of software; it requires adopting an integrated and collaborative work approach among all parties [8].

BIM is intended to serve as a resource for the exchange of information and shared knowledge. As a result, it is a reliable basis for decision-making throughout the life cycle of the project. BIM must be understood in three ways: as a product, as a collaborative process and as a management requirement for the entire life cycle of the project. That is to say, BIM does not focus on addressing only technical, operational or technological issues, but also focuses on the management of information exchange, multidisciplinary interrelation and the organizational structure of projects [9]. Since the emergence of BIM, in the 70s and its development in the 80s and 90s, its implementation has been gradually increasing, making traditional processes based on 2D designs, obsolete [10]. Currently, BIM is commonly used in vertical construction, that is, in building and real estate projects. On the contrary, its implementation in horizontal construction is uncommon and undocumented. However, its use in infrastructure projects has a great potential to add and generate value throughout the life cycle of the project [11].

Focused on the Colombian construction industry, the use of BIM is modest, and it is in its early stages of maturity. Although its advantages attract a large number of professionals, there is still an apparent fear, caution or ignorance, associated with the change in technology and methodology required [8]. The implementation of BIM is presented only as separate and independent proposals in private real estate projects. While its use in infrastructure projects is scarce.

Regarding the implementation of BIM, two main actors can be identified: the private sector and the public sector [12]. The role of the first one is bright and widely studied. However, the position that the second one must play is less common and poorly documented. Even though, it can be established that government support is a force that encourages the use of BIM and potentiates its implementation. The intervention of the public sector generates an environment of acceptance towards new technologies since it gives them credibility and also a legal or regulatory weight [12]. Therefore, the adoption of BIM by the industry is streamlined and made more effective.

Consequently, the purpose of this paper is to identify the need for the leading role that the public sector must take to potentiate and speed up the implementation of BIM in a country. Likewise, it seeks to define the different roles that the public sector can adapt to favor and stimulate the implementation of BIM. Finally, a BIM roadmap for the Colombian government is proposed, to come up with a first scenario that allows a large-scale promotion of BIM implementation in the infrastructure projects of the country.

2. METHODOLOGY

In order to carry out this study and generate the road map that the Colombian government should follow to promote the implementation of BIM in public projects, the following steps were followed. Initially, a bibliographic research of the actions adopted by the different leading BIM countries in the world was carried out, allowing to identify patterns of decisions and actions that have allowed them to successfully implement BIM. Likewise, road maps proposed by various governments were studied, standing out the most effective and successful actions and decisions. Next, the Colombian context of the architecture, engineering and construction industry was studied and documented, focusing on the delivery methods used by the Colombian government. Subsequently, based on the state of the art previously generated, the roles and actions that the public sector can adopt to promote the use of BIM in infrastructure projects were identified. Finally, the actions taken by the leading countries and pioneers in BIM were adapted to the Latin American context, allowing to create the government road map for the Colombian government.

3. STATE OF ART: BIM IN THE PUBLIC SECTOR

The public sector plays a fundamental role in promoting the development and use of BIM in infrastructure projects. The diffusion of BIM advances with greater agility in the countries in which the government adopts BIM strategies [13]. As a result, the level of BIM implementation in each country is closely related to the current government legislation and the intention to promote BIM in public contracts [14].

Figure 1 was constructed to outline the level of implementation of BIM according to the obligation or recommendation of its use by the public sector. It must be borne in mind that said map takes into account the use of BIM both in infrastructure projects and in real estate projects. The implementation of BIM in different countries was divided into three categories:

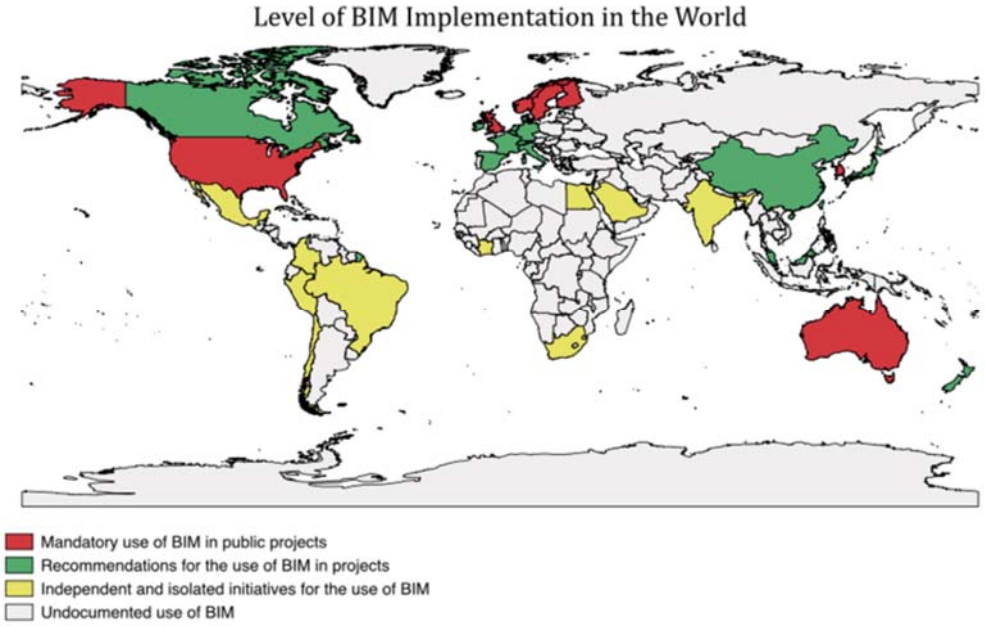

Figure 1: Level of BIM implementation in the world.

- Mandatory use of BIM in public projects: countries that have public policies or with governmental entities (at least one) that require the use of BIM throughout the life cycle of the projects and that incorporates it in its procurement methods.
- Recommendations for the use of BIM in projects: countries whose public sector has developed some effort to promote the use of BIM through the development of standards, guides, pilot projects, BIM implementation programs, among others. However, the use of BIM is not mandatory.
- Independent and private initiatives for the use of BIM: countries whose government has not taken any action to promote the implementation of BIM. However, in these countries, there is evidence of the use of BIM by private companies in an isolated and independent way.

It can be seen that many countries around the world use BIM tools and technologies. However, the vast majority is limited to the implementation through isolated initiatives that are mainly focused on the vertical construction sector, which is in fact, the case of Colombia.

On the other hand, few countries have been incorporating BIM into public contracts and government legislation. The United States is one of the pioneer countries in the adoption of BIM since it has included this technology and methodology to several bodies of the public sector, which promote its implementation [10]. The US has established programs, has set goals and has defined different standards and guidelines regarding BIM [13]. Another country that stands out as leader of BIM implementation from the public sector is the United Kingdom because in 2011 it launched The Government Construction Strategy, which established that by 2016, all projects with the government should be using BIM. Other countries whose public bodies have mandatory use of BIM are Norway, Finland, Sweden, Singapore, Hong Kong, South Korea, and Australia [7] [12] [13] [14] [15] [16].

Moreover, some countries whose governments recommend the use of BIM, acknowledge its benefits and have made efforts to encourage its use and have a leading role in the implementation of BIM are Netherland, Denmark, Belgium, Luxembourg, France, Germany, Italy, Malaysia, Spain, Switzerland, Ireland, Japan, China, Taiwan, New Zealand, Canada, among others [7] [12] [13] [14] [15] [16].

In the present paper, only the cases of the United States and the United Kingdom will be mentioned, taking them as a reference for how BIM should be implemented from the public sector. Subsequently, a brief mention will be made about state of the art in the Colombian context.

Currently, the US is one of the largest manufacturers and consumers of BIM products [10]. Its implementation covers all fields of the architecture, engineering and construction industry [13]. In the public sector, the entity that has the most active participation in the promotion of BIM is the General

Services Administration (GSA) [13], which is responsible for the construction and operation of federal facilities [15]. In 2003, this agency, through the Public Buildings Service (PBS) and the Office of Chief Architect (OCA), launched the national program 3D-4D BIM [16], which sought to implement BIM in more than 200 projects valued at more than $ 12 billion dollars [13] and thus, optimize designs and increase the efficiency and quality of construction. Additionally, it established the goal of requiring the use of BIM in all its projects since 2007 [15]. In support of these policies, the GSA has been progressively developing 8 BIM guidelines [13]. For the year 2007, 28% of the industry used BIM and five years later (2012) of the effective date of the legislation, 71% of the industry implemented BIM in their projects [16].

Furthermore, The National Institute of Building Sciences (NIBS) is another entity of the public sector, which has played a relevant role in promoting the implementation of BIM [16]. This institution has published two versions of The National BIM Standard-United States. These are a series of documents, guidelines, and standards, which aim is to define the best practices of the use of BIM, standardize the language and exchange of BIM information among the different stakeholders, recommend the best methods and processes, among many other topics [13]. State governments and other government institutions followed these behaviors, promoting the use of BIM in various projects [10]. Additionally, they created research groups and generated guidelines to implement BIM [7].

Simultaneously, the public sector launched BIM programs and committees, as well as it held training courses and conferences. Also, the US created different standards to implement BIM efficiently. By 2015, 47 BIM standards had been developed and were public, of these, 17 were formed by the government and 30 by non-profit organizations [13]. Most standards are execution plans and modeling methodologies [13].

Finally, it is worth mentioning that in the US has been developing different contracts in order to incorporate BIM in them, seeking to make the procurement methods compatible and profitable for the use of BIM. The ConsensusDOCS 301, the AIA E202 and the AIA E203 can be highlighted. The first is aimed to be used in projects where the owner and the main contractors agreed, from very early stages, on the use of BIM. The contract includes legal and administrative issues about BIM, and its purpose is to be used as an appendix to the agreement for all participants. This also includes a plan for the execution of the project to establish the dependence on the BIM model and reflects in the document the best BIM practices through standardized formats. The other two mentioned contracts, created by the American Institute of Architects, make contributions on the definition of levels of development (LODs) to unify the reliability of the information of the models and standardize the contracts that define the authorship of the knowledge of the models. These contracts are updated and improved periodically. Likewise, it can be seen that in some infrastructure projects IPD has been implemented as the project delivery system [14].

In the case of the United Kingdom, the use of BIM began to become widespread since May 2011, when The Government Construction Strategy was published [13]. This document established the goal of having savings of up to 20% in construction [16]. To achieve this, one of the strategies defined was to make mandatory that all public projects should implement BIM Level 2 for 2016. Consequently, to accompany this goal and increase the capacity to implement BIM by the public sector, the BIM Task Group was created that same year [15]. This is a group that brings together experts from industry, government, clients, professionals from different disciplines and the academy, with the objective of providing support to the government and companies, in making the transition to the BIM implementation and thus meet the goal for 2016 [16]. This group begins to carry out training programs and begins to publish guidelines regarding the implementation of BIM. Similarly, other government institutions begin to implement protocols and standards that support the government's goal, such as the Construction Industry Council and British Standards Institution B / 55 [13].

Afterward, the BIM Task Group, state entities, and non-profit organizations, published standards for the implementation of BIM. By 2015, the United Kingdom had 18 standards, of which three were created by the government and 15 by non-profit organizations. Among these, most are execution plans, modeling methodologies and presentation styles of the components [13]. Additionally, a significant number of BIM technical guides have been developed that respond to the government's goals. Moreover, the United Kingdom developed three new project delivery systems that involve the contractor from the early stage of the project, promoting the integration of all stakeholders. These programs were designed to accompany the goals of the Government Construction Strategy. The procurement methods are Cost Led Procurement, Integrated Project Insurance and Two Stage Open Book [14]. These contracting methods have been implemented in several pilot projects, evidencing lower costs. Simultaneously, the United Kingdom developed contracts involving BIM, such as the Project Partnering Contracts (PPC200) and the Joint Contracts Tribunal (JCT Contracts) [14].

In the Colombian scenario, the implementation of BIM is limited applied to the independent initiatives of private companies separate, since no action taken by the public sector, concerning BIM, is documented. The application of BIM in Colombia is particularly in the real estate industry, using BIM tools mainly in the execution of architectural work [17]. While BIM is little known in the infrastructure.

In summary, BIM in Colombia is in an initial stage of maturity since its use is modest, due to fear, caution, ignorance and/or costs associated with the implementation of new technologies

and methodologies [8]. Therefore, it is clear that great efforts must be made by the industry, academia and, above all, the government, to raise awareness of BIM and encourage its implementation in infrastructure projects.

4. IMPLEMENTATION OF BIM IN INFRASTRUCTURE FROM THE PUBLIC SECTOR

4.1. PROJECT DELIVERY METHODS

Infrastructure projects in Colombia are contracted by the State, so the government owns them. However, it does not design them, nor build them, and is rarely in charge of operating them. On the other hand, its main task is to select the contractor. Additionally, another main actor in the infrastructure projects in Colombia and which is also chosen by the contracting entity is the auditor. This is in charge of supervising and approving the work executed by the constructor.

Consequently, the government, not only because it owns the project, but also because of its nature as a regulatory body, is the one that defines the specifications, establishing the way the project should be done throughout its life cycle.

Therefore, the best way for new methods and technological systems to be accepted is that the owner and/or client demands them within the contract, abolishing the possibility of negotiation [18]. Thus, the government should be the leading promoter of the adoption of BIM, including it as an obligation for participation in the execution of public infrastructure projects, since this would be the most efficient way to stimulate BIM implementation [18].

In Colombia, the most common method of public procurement is known as Design - Bid - Build (Figure 2). This is a linear method of contracting in which the government entrusts a team to the design and subsequently, a tender is made to define the contractor that will build it [19]. Therefore, the team that designs the project is independent of the contractor who will build it [20]. Also, when the different contractors make their offers, the project is already wholly defined allowing them to estimate the costs [21]. This bidding process has as a criterion of selection, in most cases, the lowest bid [19]. This was the case for the Agencia Nacional de Infraestructura (National Agency of Infrastructure) in 2016, which used the lowest bid as the selection modality in 46% of its processes. Thus, the factor with the most significant weight in the public sector, when choosing a contractor, is the price that this offers.

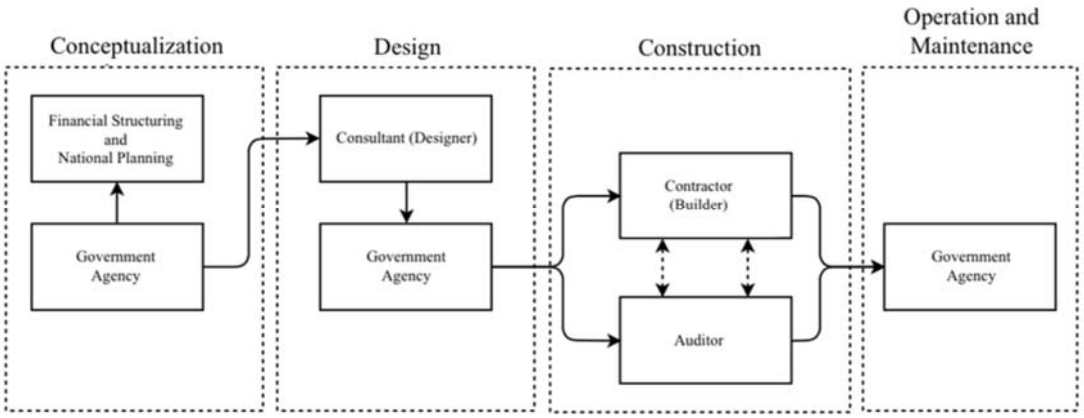

Figure 2: Design – Bid – Build project delivery method.

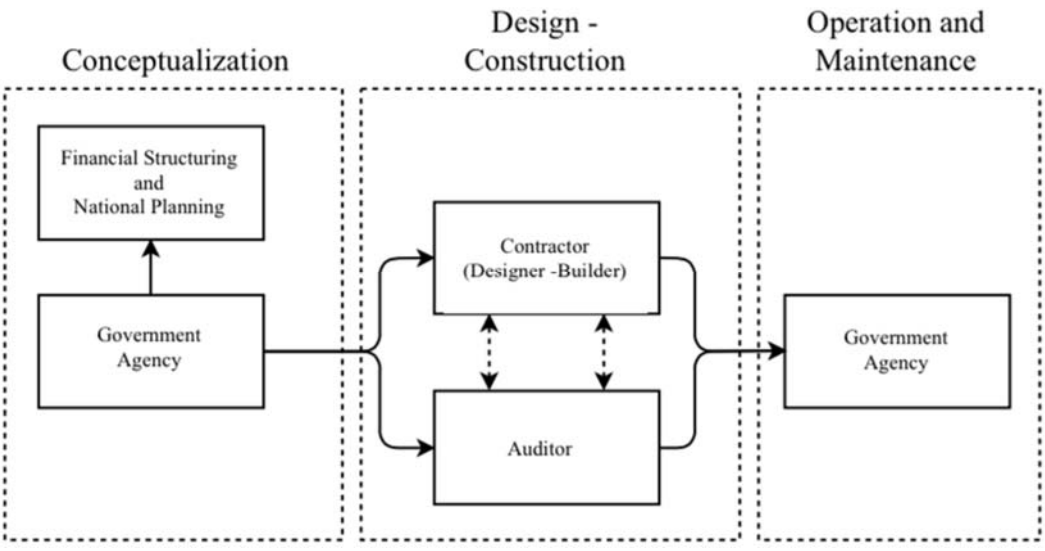

Figure 3: Design – Build project delivery method.

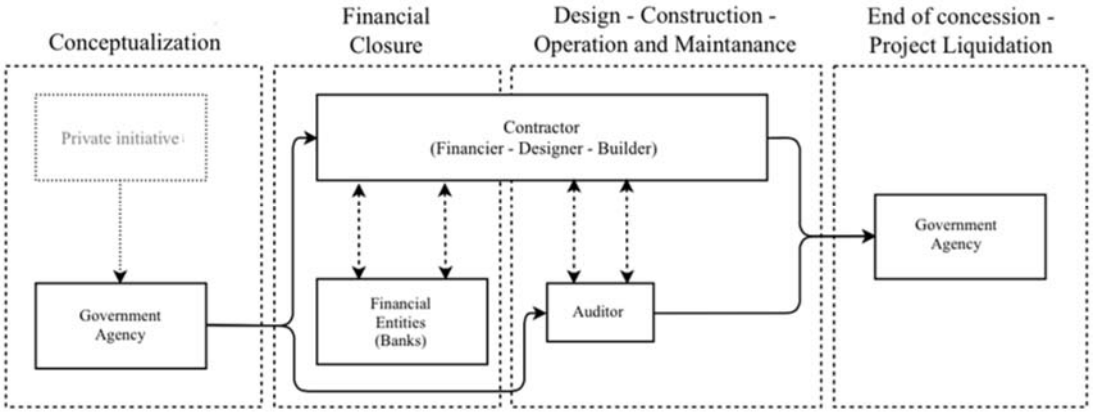

Figure 4: Public-Private Partnerships project delivery method.

However, this criterion ignores other relevant aspects such as time and quality, so it does not guarantee the maximization of the value of the project [18]. Likewise, this selection criterion encourages bidders to submit proposals with low prices, and then seek to recover their losses through changes in conditions, as well as to generate additions to the initial contract, resulting in higher costs for the government [18].

Furthermore, there are other less used procurement methods such as Design-Build (Figure 3). In this case, the same contractor is responsible for the design and construction of the project [22]. The bidders make technical and economic proposals based on the requirements and parameters defined by the client [20].

Other project delivery methods are Design - Build - Operate or Design - Build - Finance – Operate [20] (Figure 4). These methods are used in the Public-Private Partnerships. In these cases, the same contractor is responsible for the design, construction, part of the financing and operation of the project. Hence, the contractor, also to being responsible for the entire project, it must also finance part of the project, and then recover its investment through its operation [23]. Additionally, these projects may be born of government initiatives or through private initiatives that must be approved by the responsible government agency.

Analyzing the procurement methods used in Colombia, it can be established that these do not contemplate the implementation of BIM. As a result, together with the development of BIM, innovative contracting methods must be used to facilitate can be compatible with the development of this methodology [20]. The implementation of BIM, by the public sector, must come up from the way of presenting and awarding contracts [15].

Project delivery methods must focus on promoting collaborative work among the parties involved in the project, seeking to align the interests of the stakeholders and thus, reduce waste and optimize efficiency throughout its life cycle [24]. It should maximize knowledge from the early stages of the project, through the integration of all the technical areas, which favors the use that can be given to BIM [25]. This is made to minimize future uncertainty and reduce decision making during construction. The process of procurement of these methods consists on selecting the contractor taking into account its experience, ideas, and proposals for the project, based on the guidelines defined by the client and their economic offer.

Also, BIM generates effective planning, regarding project scope, budget, and schedule, as well as defining and communicating methodologies and project requirements. Consequently, implementing BIM from the procurement process increases the value that this can generate for the project and its stakeholders.

4.2. ROLE OF THE PUBLIC SECTOR IN THE IMPLEMENTATION OF BIM

The most critical factor to ensure the successful implementation of BIM is government leadership and coordination, seeking to maximize efficiency and avoid problems generated by fragmented and disjointed approaches [15]. Moreover, it can be established that the government's mandate is one of the most efficient ways to encourage the use of BIM. The public-sector acts as a catalyst in the transition of the industry towards the use of new technologies, because if the contractors do not adopt BIM, they will become obsolete, lose competitiveness and job opportunities [15].

The public sector has a wide field of action to contribute and to be benefited from the implementation of BIM, as well as a great effort to do to promote its successful use. Each role and/or decision adopted by the government will have a different effect on the efficiency, the way to stimulate the use of BIM and its acceptance by the industry. Based on the study conducted by Cheng & Lu (2015), the potential efforts and roles of governments to promote the use of BIM can be summarized as follows:

4.2.1. PIONEER AND LEADER:

Any activity or decision directed by the public sector pushes the industry to adopt BIM. Therefore, the public sector must be a pioneer in generating programs and action plans, establishing policies and how BIM will be implemented in new

projects [10]. Likewise, roadmaps, programs, goals and/or promises must be developed, requiring the use of BIM in public contracts to encourage its use. Also, BIM working groups, programs and committees must be created, and the government must serve as leader seeking to support the implementation of BIM.

4.2.2. REGULATOR

The government should serve as a regulatory agent developing guidelines, protocols, and standards that instruct and standardize the implementation, modus operandi and scope of BIM in projects, avoiding the problems generated by fragmented and disjointed approaches [15]. The public sector must provide a common understanding and a consistent approach to BIM to the entire industry.

Making these standards and guidelines must be accompanied by a contractual framework [14]. In other words, all BIM information must be part of the official documentation. Therefore, the use of BIM would become a mandatory requirement in all public projects, as required by each one. Therefore, the government would have the responsibility to generate quality BIM information to provide to those present in the procurement process, regardless of the project delivery method [14].

Open communication channels and protocols must be created, so that the information is transparent, understandable and unified for the different stakeholders. This will allow a clear workflow between the different actors and generate a common language among all [10].

The BIM standards developed by the public sector can be summarized as follows: project execution plans, modeling methodology, levels of detail (LoDs), presentation style of components and data organization, open and neutral formats for the exchange of information (IFC: Industry Foundation Class), BIM dictionaries, among others.

4.2.3. EDUCATOR

The government must take the initiative to educate the entire sector involved. Education can be exercised through training methods, offering courses, conducting a process of accompaniment throughout the process of transition to BIM technologies and including BIM in professional education.

4.2.4. FINANCER

One way to encourage the use of BIM is to provide financial support, through alliances with BIM software companies, or by giving privileges (e.g. tax benefits) to those organizations that use BIM

4.2.5. DEMONSTRATOR

The government must be a leader in how to demonstrate the advantages of BIM and the added value it provides. This role of "demonstrator" can be made through pilot projects which show the success stories, as well as the lessons learned. In the same way, the pilot projects demonstrate the commitment of the public sector to the implementation of BIM and, additionally, they can be used to evaluate and promote new BIM tools.

3.2.6. INVESTIGATOR

The government should encourage and support innovation and research, regarding BIM. Research should be promoted by organizations, universities and also within the public sector itself, to go hand in hand with the rapid evolution of these technologies and, in this way, maintain a process of continuous improvement. The government should be at the forefront of international BIM issues, including regulations, standards, protocols, etc. Simultaneously, the progress made by the government should be compatible with the tools of the rest of the world.

5. BIM GOVERNMENTAL ROADMAP IN COLOMBIA

A point of inflection can be identified during the BIM implementation process from the moment the government decides to get involved and play an active role. This means that the leading role of the public sector produces a positive effect on the use of BIM, since it potentiates, speeds up and makes its implementation more efficient. Not to mention the economic, temporary and social benefits that the use of BIM can bring to the government and the country if it is used in public projects.

Consequently, the next step is to propose a BIM roadmap that the Colombian government should follow, with the objective of promoting BIM use in public and private projects. Additionally, the roadmap is intended to establish a framework for the development of collaborative environments and the execution of projects that use BIM. Moreover, the roadmap seeks to align all the actors and stakeholders of the industry that are involved in the transformation towards BIM. Finally, this is developed to propose a scope and a sequence of activities to follow with the purpose of guiding, encouraging and supporting the collective transition towards the implementation of BIM.

On the other hand, it is expected that this BIM governmental roadmap can be extrapolated and useful for countries with an economy, an idiosyncrasy and a level of use of BIM similar to the present in Colombia, as are different countries in Latin America.

The roadmap (Figure 5) was prepared based on the plans designed by different governments to promote and implement BIM, as well as on the actions carried out and the decisions taken by the different countries or government institutions. Within those countries, it outstands the road map of the United

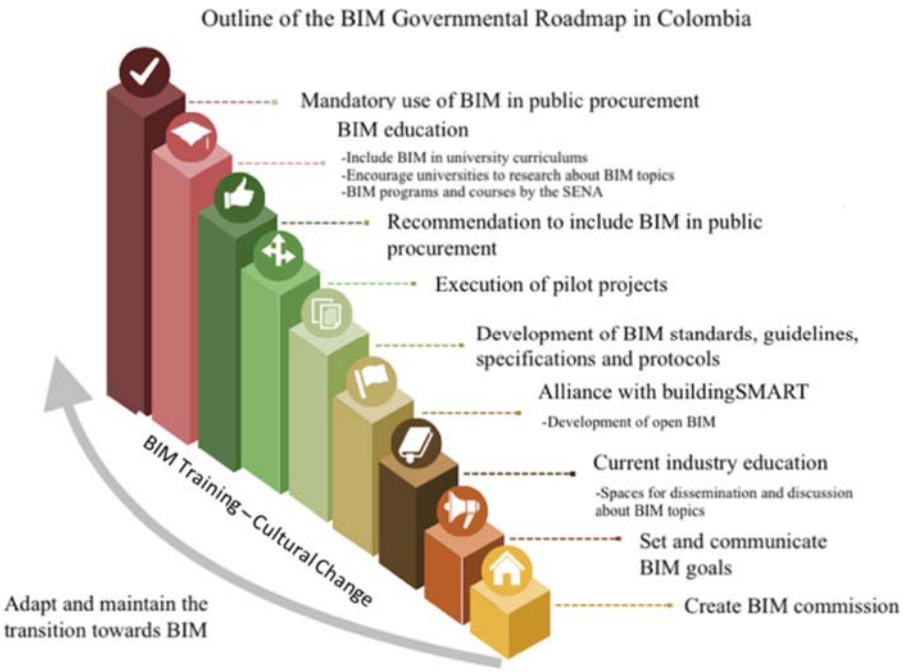

Figure 5: Outline of the BIM governmental roadmap in Colombia.

Kingdom, Canada, Spain, and Singapore. This roadmap is based on four pillars: BIM Commission, BIM Goals, Standards, guidelines, protocols, and BIM contracts and, finally, BIM Education. Below is the roadmap outline.

5.1. BIM COMMISSION

The first step for the public sector to begin to have a dominant role in BIM's field of action is to create a BIM commission supported by a government entity.

The purpose of the commission will be to lead and encourage the use of BIM. The BIM commission will be the entity with a mandate that manages and promotes all BIM development through collaborative work between the different actors of the public and private sector. This must be composed of a multidisciplinary group that has the participation of all the stakeholders of the industry.

The commission must determine the strategies to adopt to progressively increase BIM maturity levels in the industry. Simultaneously, it will have the role of educator seeking to train industry in BIM issues and generating a cultural change. Likewise, it will be responsible for the creation of guides, standards, protocols, specifications and BIM contracts, with the objective of regulating and standardizing the implementation of BIM. On the other hand, the commission must be informed and inform about the technology (software and hardware) required to satisfy the implementation of BIM. Additionally, it will be responsible for guaranteeing interoperability, the use of a BIM open source language and generating a collaborative work environment. Finally, it will be in charge of monitoring and being aware of the different actions related to BIM in the world, to learn from experiences from other countries and keep updated with the latest BIM trends.

5.2. BIM GOALS

Once the commission is formed, it must set goals and commitments against the levels of BIM implementation that it will seek to achieve in a certain period.

These goals can be set as national targets, as was the case in the United Kingdom when the goal was established in 2011, stating that all public projects should have BIM implementation level 2 for 2016. Or, goals can be arranged at an institutional level as the USA did, in which each government body defined its BIM strategies and goals, as was the case of the General Service Administration [10], the US. Army Corps of Engineers or the National Institute of Building Sciences [16].

The importance of setting goals and commitments falls on the fact that these objectives generate demand for BIM and therefore, its implementation is streamlined. Consequently, at the moment when the public sector sets goals regarding future requirements to be able to contract with the state, the industry reacts immediately seeking to evolve and migrate towards the use of new technologies.

Additionally, the goals manage to impact all the sectors involved in the architecture, engineering and construction industry. Therefore, all stakeholders must be actively committed to the transition to BIM. This allows the interests of the entire industry to be aligned and consequently, the change towards BIM is potentiated and maintained.

5.3. BIM STANDARDS, GUIDELINES, PROTOCOLS AND CONTRACTS

The BIM commission must support all sectors of the industry to make the transition to BIM. Said help must be based on the elaboration of BIM standards, guidelines, specifications and protocols. These should be prepared according to the sector

of the industry to which it is addressed and the objective it pursues to satisfy. Moreover, all the tools, processes or documents generated must be consistent with each other, just as they must be updated and maintained over time. In this way, the commission homogenizes the way BIM should be implemented and generates recommendations on best practices.

Furthermore, the commission must generate BIM contracts. Hence, contracts and specifications should be developed to include in them BIM clauses, where the use of BIM is obligatory or not, as well as the scope and objectives that BIM has in the project. Given that the migration towards BIM must be progressive, initially, the contracts should suggest and encourage the use of BIM and subsequently, make its use mandatory.

On the other hand, the BIM commission must generate an alliance with buildingSMART and create a Colombian chapter, to receive the support, knowledge, and experience of this association, as well as its members. This would allow a better development of standards, guides, and protocols adjusted to international guidelines and open BIM, generating a transparent exchange of information.

The purpose of this association is to generate improvements in the life cycle of civil engineering projects, reduce costs and times, increase quality and maximize the value generated through the implementation of BIM. For this, buildingSMART seeks to integrate all phases of the project life cycle through open BIM. That is, create open and compatible channels to share information between different software, generate open standards for information exchange and develop BIM guidelines, protocols, certifications and specifications that are international, open and neutral. This makes it possible to have a collaborative, transparent and unified workflow.

5.4. BIM EDUCATION

Simultaneously, the BIM commission, together with the support of the national government, should be the leaders in training the industry on BIM issues and generate a cultural change. Consequently, short and long-term strategies must be proposed to incorporate BIM in the academy, as well as in the organizations and professionals that currently make up the architecture, engineering and construction industry.

First and as a short-term strategy, the BIM commission must support the training of the leading players in the Colombian industry today. For this, the commission must supply the deficiency of education offered on BIM. Training spaces should be created on software, methodologies and collaborative processes that support the adoption of BIM. As well as areas to discuss BIM issues, present the procedures required to make the transition towards BIM and its possible impacts, expose and publish success stories of the implementation of BIM in pilot projects, present best practices and emphasize the benefits that bring the implementation of BIM. All this, to generate a cultural change that convinces the different actors about the need to migrate towards the use of BIM.

Also, for the long term, it must be sought to generate a profound cultural change. Therefore, universities should be encouraged to include BIM subjects in the curriculum of careers related to construction, civil engineering, and architecture. Similarly, the different faculties should be encouraged to carry out research on BIM. BIM education should not focus exclusively on the management of software that support its implementation, but should also taught about BIM's methodologies and collaborative processes. Furthermore, industry training should be supported by the SENA, which is a public institution that offers free technical, technological and complementary programs. Consequently, the SENA should include BIM training programs and courses for the management of different software, as well as the teaching of BIM methodologies and processes.

It is important to emphasize the constant effort that the commission must maintain to educate and lead the industry to a change of thought, where they recognize the benefits and the need to use BIM. Consequently, the commission must continually generate spaces to teach and communicate BIM's cutting-edge topics, projects where it has been implemented, lessons learned, transition processes towards BIM and other aspects to be addressed.

6. CONCLUSIONS

The implementation of Building Information Modeling and its use is becoming much more popular and shared throughout the world. BIM is being recognized as a technological tool, as a set of collaborative and interdisciplinary processes and as a management methodology, which allows the project to maximize its value throughout its lifecycle. The architecture, engineering and construction industry is migrating worldwide towards the use of BIM because it recognizes the benefits of this, both in building projects and in infrastructure projects.

On the other hand, in Colombia, the implementation of BIM is in its early stages of maturity since its use is only of private companies, as an independent initiative. Additionally, in the vast majority of cases, the use of BIM is presented in building projects. While, in the field of infrastructure projects, BIM is virtually unknown. Therefore, this paper establishes the need to implement BIM in infrastructure projects in Colombia. This is proposed in response to the regrettable state of the Colombian infrastructure, which does not contribute positively to the country's economic growth. In addition, BIM is presented as a new and better way to design, contract, build, operate and maintain infrastructure projects.

Additionally, this paper demonstrates the need for the participation of the public sector to achieve the use of BIM in infrastructure projects. This can be affirmed since the public sector is the owner and contractor of these projects, which

allows him to recommend its use or to make the implementation of BIM mandatory in his projects. Similarly, the experiences of the leading countries in BIM such as the US, the United Kingdom, and others, show that an active and leading role of the public-sector speeds up and potentiates the implementation of BIM by the industry, maximizing the value that it can produce for both, the public and private sectors. Consequently, the public sector can adopt different positions to speed up, unify, optimize, favor and/or encourage the use of BIM and generate the transition of the industry towards its implementation. These roles can be defined as pioneer and leader, regulator, educator, financer, demonstrator or researcher.

Accordingly, a BIM roadmap for the Colombian public sector is proposed, to define the direction the government should take to stimulate the implementation of BIM in the country. This roadmap focuses on the need to create a multidisciplinary and integrated work among the different actors in the architecture, engineering and construction industry, both in the private sector and in the public sector. Similarly, the emphasis is placed on the importance of generating a cultural change through BIM education, seeking to teach the benefits of it and eliminating the abstaining from change. All this with the purpose to provoke and maintain the transition to BIM, allowing to maximize the benefits that can be obtained from its implementation.

In summary, it can be concluded that the Colombian infrastructure claims for profound improvements. These improvements should not only seek to obtain better financial results but should also aim to create quality infrastructure, promoting collaborative and transparent processes. BIM not only manages to reduce costs, optimize execution times and guarantee quality, but it also causes a change of thinking and a cultural reform, since its most valuable tool is the way it demands to manage people. BIM aligns the interests of all those involved in the project, towards the absolute maximization of the value created by it. Therefore, to optimize, stimulate, favor and get the most out of BIM, its implementation must be headed and regulated by the public sector. Hence, the value of the contributions of this paper, regarding the knowledge of BIM implementation, lies on the demonstration made of the need of an active and leading role of government to successfully spread the use of BIM in the industry. Also, the proposed BIM government roadmap for Colombia provides the first field of work and a starting point to develop strategies and programs to implement BIM on a large scale in Colombian infrastructure projects or countries with similar conditions.

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