Assessment of BIM use in the early stages of implementation
Evaluación del uso de BIM en las primeras fases de aplicación

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Abstract

The construction companies have achieved different levels of BIM use and in some developed countries, it is very advanced. Traditionally, the use of BIM has been evaluated by maturity models; however, it does not provide an integral evaluation of BIM use. BIM Use Assessment (BUA) was proposed as a tool to satisfy this need, it is based on the evaluation of several states that compose necessary characteristics to perform each BIM use successfully. BUA was applied to measure projects that have BIM advanced use in Colombia, Chile, and Spain. However, there is none an integral evaluation in the early stages of BIM use. Therefore, the objective of this research was to evaluate the incipient BIM use. Accordingly, 23 private Ecuadorian projects, were evaluated using BUA. As expected, the analyzed projects have lower levels than the other projects evaluated by BUA. The high percentage of projects were at the levels that require the appropriate use of 3D models, and the collaboration issues were common deficiencies. This research results could be used in the development of strategies to reduce mistakes; thus, leading to an agile BIM implementation.

Keywords: BIM; Construction Industry; BIM Use Assessment; early stage

Resumen

Las empresas de construcción han alcanzado diferentes niveles de uso de BIM y en algunos países desarrollados está muy avanzado. Tradicionalmente, el uso de BIM se ha evaluado mediante modelos de madurez; pero, este no proporciona una evaluación integral del uso de BIM. La Evaluación del Uso de BIM (BUA) se propuso como una herramienta para satisfacer esta necesidad, se basa en la evaluación de varios estados que componen las características necesarias para realizar cada uso de BIM con éxito. El BUA fue aplicado para medir proyectos que tienen un uso avanzado de BIM en Colombia, Chile y España. Sin embargo, no existe una evaluación integral en las etapas tempranas de adopción de BIM, siendo este el objetivo de esta investigación. Se evaluaron 23 proyectos privados ecuatorianos, utilizando BUA. Como se preveía, los proyectos analizados tienen niveles más bajos que los otros proyectos evaluados con BUA. Un elevado porcentaje de proyectos estaba en los niveles que solamente requieren el uso apropiado de modelos 3D; y los problemas de colaboración fueron deficiencias comunes. Los resultados de esta investigación podrían utilizarse en el desarrollo de estrategias para reducir errores del uso de BIM, lo cual llevaría a una implementación ágil de BIM.

Palabras clave: BIM; Industria de la construcción; evaluación del uso de BIM; fase inicial

1. Introduction

Building Information Modeling (BIM) definition is controversial, but it could be synthesized as a methodology that combines technological tools with a series of work methodologies, based on the collaboration of all project areas. It improves the project quality and generates the optimization of time, money, and materials by reducing errors and unforeseen events, through a virtual simulation of the construction project.

The BIM use worldwide is heterogeneous, in some countries, it has been improving accelerated, but in others, it is incipient. The USA, France, UK, Scandinavia, and Singapore are at the highest level of BIM adoption and Germany, United Arab Emirates, Austria, China have significant BIM macro adoption (United BIM, 2020). A study on Latin America BIM macro adoption conducted by (Almeida et al., 2021) found that in terms of BIM documentation Brazil and Chile are the leaders followed by Mexico, Argentina, Peru, Uruguay and Colombia. Additionally, Brazil, Chile, and Colombia have BIM mandates; thus, they have greater potential for success in adopting BIM. All the countries of the BIM Network of Latin America Governments have BIM Forum in operation; Ecuador, Guatemala, Honduras, Nicaragua, Paraguay, Dominican Republic, and El Salvador, do not have this entity.

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To measure BIM the project teams used maturity models, the only tool available for many years. These have been changing and adapting over the years, having now a wide variety of maturity models, however, the use of some of these is suitable for projects in incipient stages of using BIM and others for advanced stages (Wu et al., 2017). Despite providing a measure, maturity models assume different positions in isolation, focus only on certain aspects, and takes different approaches of BIM maturity such as the evaluation of organization scales, tools to identify BIM performances, skills, and experiences of staff. Other maturity models include wider aspects but still do not provide a holistic BIM evaluation (Wu et al., 2017). Besides, the client should work with the same project team for a valid assessment of repeatability using maturity models (Rojas et al., 2019).

On the contrary, BUA was proposed as an integral tool to measure the BIM use at any BIM adoption level, however, BUA was validated and applied in projects that are placed in Chile, Colombia in Latin America, and Spain in Europe; countries that already have an advanced BIM level and significant incentives for macro adoption.

However, the BUA has not been used to evaluate projects where BIM adoption is just beginning. In these projects, the tool would have greater benefits as it would provide a benchmark so that companies in the early stages of employing BIM can soon catch up with advanced companies. Countries such as Ecuador, where only a few private firms implement BIM and there is no government incentive, offer the unique research space to apply BUA in the early stages of BIM adoption. Evaluating construction projects in BIM early adoption by using BUA could generate clues to an accelerated and effective BIM implementation.

2. Background

Worldwide the benefits of applying BIM are evident, this has led to an increase in awareness of the importance of BIM adoption (Saka et al., 2020). However, most construction projects in some countries are in the early stages of BIM adoption. The global status of BIM varies from developed to developing. The BIM implementation in Africa depends on the country. In Nigeria, the level of BIM awareness is high in but there is a very slow level of BIM skills; meanwhile, South Africa is facing huge challenges in BIM awareness (Matarneh et al., 2015). The application of BIM in the Kenyan construction industry is very low and slow (Nasila and Cloete, 2018) as well as Jordan, where a survey to 137 members of the regulatory bodies of the AEC industry resulting in that 95% of organizations are not using BIM in any level.

Finland, Netherlands, and Denmark are examples of early BIM adopters of Europe (Charef et al., 2019). In Western Europe, around two-thirds of the industry (64%) has not adopted BIM (Matarneh and Sadeq, 2017). In Poland and the Check Republic a survey revealed that even if there is a theoretical knowledge of BIM, these countries are far from the implementation (Juszczyk et al., 2015).

In the Middle East region, the BIM adoption is 25%, Dubai is the only country that has BIM as a mandate for most large-scale projects (Sawhney, 2014). In Lebanon, the construction market is in the early stages of BIM use and the adoption process is slow; the small and medium companies are reluctant to the change (Awwad and Ammoury, 2013). Malaysia is living a similar situation; there is a low BIM status in the construction industry and the difficulties in BIM adoption are evident (Hanafi et al., 2016). On the other hand, BIM use in Egypt is currently in the phase of spreading and is improving continuously (Khodeir and Nessim, 2018).

In Asia, most of the developing countries are at a low BIM level, but the necessity of using this methodology has been recognized (Ismail et al., 2017). Indian is in a very infancy stage with the adoption of BIM having as common problems data acquisition and a fragmented construction industry (Nanjakar, 2014).

Chile is the leader of South America with a plan that aims to mandate BIM use in public projects for 2025. Mexico, Argentina, Peru, Uruguay, and Colombia, Brazil, and Colombia are improving the BIM adoption. However, there is not any data in Ecuador, similar to Central America and the Caribbean countries except Costa Rica and Guatemala that have done structured efforts to encourage the BIM adoption.

Even though the existence of several barriers to overcome in the BIM adoption, the construction industry ultimately will end up implementing it but it is important to reach this goal efficiently. Strong government support is critical to driving the BIM implementation process involving the active participation of the AEC industry members alongside the academia (Smith, 2014). Most of the aforementioned countries lack government support, which is also a sign of incipient BIM implementation.

As stated before, most construction projects worldwide are in the early stages of BIM adoption. These can benefit the most of BUA since they have a long way to reach a high BIM use level. BUA can prevent mistakes for an agile BIM adoption. The evaluation results would not be used only by the companies but also by the governments to implement sustained strategies to reduce the gap between companies in early BIM use and the companies that already are fully benefitting from BIM. Helping them to penetrate markets abroad or collaborate with developed companies, in other words, survive in an increasingly challenging industry. Besides, the increase of the BIM use would cause a competitive environment in the countries where BIM is incipient.

3. building information modelling

Building Information Model has been defined by several authors agreeing that it is the combination of a collaborative work methodology with the use of technological tools, it is based on the Lean philosophy; therefore, its objective is to obtain efficiency from the very conception of the project to maintenance and even demolition (Azhar, 2011).

The anticipation of design mistakes, design optimization, the reduction of contingencies, rework, risks, waste of construction materials, as well as better precision and a higher degree of stakeholders satisfaction, are some characteristics of the projects carried out with BIM, that leads to a reduction of time, cost, and improvement of project quality (Fernández and Yepez, 2018).

During the building's operation, it is possible to reduce the consumption of non-renewable resources cutting maintenance costs and causing a positive impact on the environment. The BIM model tools combined with an analysis of alternatives related to environmental, energy, financial, and social factors would contribute to making appropriate decisions in the project.

Agile and efficient communication is essential within BIM; there must be constant participation between the multidisciplinary working groups. This scenario becomes effective by having an intelligent digital model, in which all areas of the project converge in a unique and accessible structured database containing physical and functional characteristics of the building. Hosting the data on a common cloud platform ensures the availability of information anywhere and at any time, avoids loss of data, favors coordination and connectivity of the project's stakeholders, and generates analyses of the project's progress (AUTODESK, 2017). To comply with these requirements, prepare the AEC industry actors to be able to respond to the demands of BIM implementation is essential as well as continuous feedback of the processes based on the evaluation of BIM use.

4. Bim implementation around the world

The statistics clearly show the benefits of BIM and the increase in its adoption. A study conducted by (Rittinghouse and Ransome, 2005) involving 727 contractors in 10 of the world's largest construction markets, reflects the great benefits of BIM just a few years after its implementation. Another of his surveys conducted in North America, Brazil, Europe, and the Asia Pacific found that 75% of AEC companies have a positive return on capital by investing in BIM. The companies also predicted that they would increase the BIM use by 50%.

The difficulty to change people's habits, interoperability problems, and the absence of a BIM use mandate are issues that limit the BIM implementation (Gonzáles Pérez, 2015). (Khodeir and Nessim, 2018) adds insufficient budgets, lack of knowledge on methods to implement BIM, superior administrative support, experience, and staff skills. One of the most important difficulties for any development is not having a benchmark that allows comparisons to improve and avoid making the mistakes that others have already made. Therefore, measure the BIM level is essential since it works as the foundation for the other strategies (Almeida et al., 2021).

Several strategies have contributed to the adoption of BIM in other countries, most notably the BIM Forum. The BIM forum is a common strategy held in Chile, Brazil, Colombia, Peru, Argentina, Costa Rica, Uruguay, Panama, Bolivia, and Paraguay. Most countries were the initial organization in the pathway to BIM adoption and consequently the standardization (BIM forum Chile, 2019). The existence of the BIM Forum warns that there is significant progress in the adoption of BIM, its absence could be interpreted as a sign of incipient stages of implementation; this is the case of Ecuador.

Countries from all over the world promote annual surveys, the awarding of scholarships for BIM studies, the inclusion of BIM in education centers, forums, among other strategies that lead countries to mandate the BIM use for public projects (Loyola, 2019). The latter has given very satisfactory results, according to (Edirisinghe and London, 2015) who made a comparative analysis between the BIM level and BIM standardization efforts at the international level. On the contrary, in Ecuador, private companies adopt BIM in isolation without the guidance of any organization.

The diagnosis provided by the BUA tool in combination with strategies used in BIM experienced projects is an advantage for companies that are in the process of implementation because having benchmarks the BIM adoption will be more efficient.

5. Evaluation of bim use

The benefits of BIM use must be evaluated, compared, and certified because organizations need to have foundations for optimizing processes. Before the creation of BUA, maturity models were the only option to address

this need; they were created to assess the capacity of U.S. government contractors to carry out a software project (Succar, 2009a). These did not consider the different phases of the construction project life cycle, stakeholders, final products, and supply chain issues; therefore, they were not proper to the AEC industry. Later on, they were adapted to models that measure the BIM maturity level, such as the Interactive Capability Maturity Model (ICMM) and the BIM competence matrix (Succar, 2009b). "The term 'BIM maturity' refers to the quality, repeatability, and degrees of excellence BIM" (Succar, 2010). "A maturity model is a set of performance improvement levels' that an organization or project team can achieve" (Succar, 2009a). The main maturity models' limitation lays in that they measure only the capacity and the state of BIM but not its employment level. Another disadvantage is that the usage of the same maturity model in different projects is appropriate only if they have the same specific factors, for example, if the project keeps working with the same teams, which is very unlikely (Rojas et al., 2019).

(Wu et al., 2017) recommend IU BIM Proficiency Index and NBIMS CMM maturity models for incipient stages of BIM adoption and VDC Scorecard, Characterization Framework, and Owner's BIM CAT for advanced stages, which includes more aspects of BIM. However, (Succar, 2010) mentioned that there is not a complete maturity model/index that can be applied to BIM, its phases, members, deliverables are absent.

There are different maturity models to be used depending on the BIM level of the project, each of them having different conditions that are taken into account for the analysis. To choose the right maturity model it is necessary to have an idea of the level of BIM maturity in the project, which makes it difficult to make the right choice because it is precisely this starting point that the model is supposed to deliver. In addition, if different maturity models are used depending on certain characteristics, it is very difficult to make comparisons between projects because the same measurement tool is not being used.

Consequently, (Rojas et al., 2019) developed BUA (BIM USE ASSESSMENT), a tool to evaluate integrally BIM use, regardless of the level of BIM adoption, BIM maturity, and project size. It allows comparative evaluations since the same measurement system is being used in all the projects.

6. An overview of bua

BUA classifies each BIM use into characteristics, which respond to the necessary actions or conditions for the successful application of each BIM use. The characteristics are evaluated in several states that are not necessarily mutually exclusive, in other words, a project may have one or more states, which represent the complexity levels of a BIM use (Rojas et al., 2019). (Table 1) shows the BIM uses with their corresponding characteristics.

Table 1. BIM uses and their characteristics

Phase	BIM Use	Characteristics
Planning	Cost estimation	Source of quantities, type of model, and applied systems.
	Phase planning	4D model, type of use, and link type.
	Site analysis	Type of model and type of analysis.
	Space programming	Type of model and distribution analysis.
Design	Design review	Type of model, immersive lab, and list of requirements.
	Code validation	Type of software, type of model, applied systems, and level of mock-up.
	Sustainability analysis	Type of model, type of software, and applied systems.
	Engineering analysis	Type of model, compatible software, applied systems, and documentation.
	Design authoring	Type of models, generative models, and applied systems.
	3D Coordination	Type of models, analysis method, and applied systems.

Note. Obtained from: "BUA Tool for Characterizing the Application Levels of BIM Uses for the Planning and Design of Construction Projects.", by (Rojas et al., 2019), Advances in Civil Engineering, p.5.

BUA utilizes a range of 1 to 5 to evaluate the BIM use level of a project, based on independent rating templates for each BIM use. This value is obtained from the combination of states, which were defined by answering the question: What produces the greatest benefit for the project in the application of a specific use? (Rojas et al., 2019). (Table 2) illustrates the description of each of the BIM levels.

Table 2. BIM Levels: General description

Level	General Description
1	Traditional methods (2D model)
2	Low use of BIM and little information in the model.
3	Medium use of BIM and sufficient information for BIM.
4	High use of BIM.
5	Full use of BIM; the best tools are utilized to realize all its applications.

Note. Obtained from: "BUA Tool for Characterizing the Application Levels of BIM Uses for the Planning and Design of Construction Projects.", by Rojas et al., (2019), Advances in Civil Engineering, p.3.

As an example, the Design Review qualification template has the characteristics: model type, immersive labs, and requirements list, the first of them have the states: 2D, 3D, and BIM, then if in the project a 2D modeling type is used for the design review, a level 1 is assigned, regardless of whether the requirements list is done formally or informally.

7. Research methodology

The methodology to meet the objectives of this research is shown in (Figure 1), this consisted of literature research to find a reliable tool to measure the BIM use that eliminates subjectivity, then chose private medium-sized projects that have used BIM in the planning and design phase and finally analyze the results.
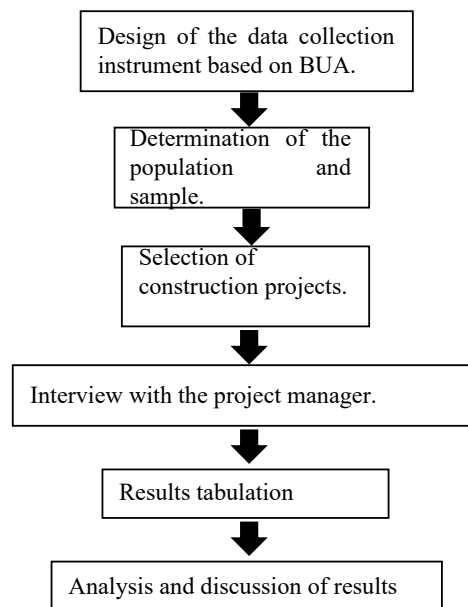
Design of the data collection instrument based on BUA.

Determination of the population and sample.

Selection of construction projects.

Interview with the project manager.

Results tabulation

Analysis and discussion of results

Figure 1. General diagram of the research methodology

The evaluation was done in the planning and design phases, which according to the MacLeamy curve have the greatest influence on the project deadline and cost compliance.

To conduct the interview, a template based on BUA was created for each BIM use where the different states (options) that compose each characteristic are described. These questions guide the interviewer in the data collection; moreover, ensure that the interviewee is clear about the required information, thus minimizing subjectivity in the results.

The interviews were conducted in 2020, on a non-probabilistic sample of 19 medium-sized Ecuadorian private commercial and residential building projects, and 4 roadway projects, who answered that they used BIM in the planning and design phases.

The interview results were analyzed, using central tendency measures and represented by bar graphs comparing with the results from 9 projects in Chile, 12 in Colombia, and 4 in Spain obtained by (Rojas et al., 2019).

8. Results and discussion

8.1 Results

The data corresponding to the results, when applying BUA in 23 Ecuadorian private construction projects are presented in bar graphs, some of the 'BIM Uses' results and the analysis are shown from (Figure 2) to (Figure 8).
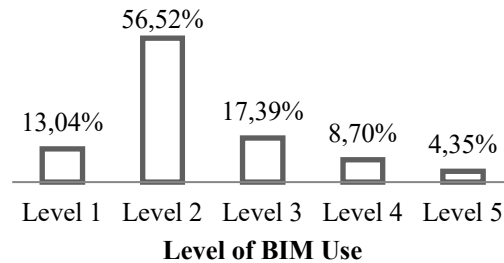
8.1.1 Planning phase

Figure 2. 'Cost Estimation' use, percentage of application level

In the cost estimation, it can be noted that most projects are in level two, while approximately 30% are higher than this level. Only one project has reached the maximum, so it can be generally said that the projects studied do not use a BIM model that interacts with costs.
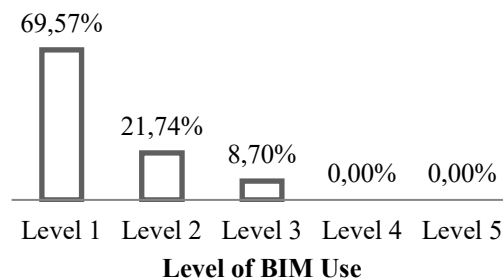

Figure 3. 'Phase planning (4D)' use percentage of application level

Level three in phase planning (4D) is the highest and almost 70% are in the first level, which does not include the use of 4D models and is characterized by the inclusion of the time in the modeling. Approximately 70% of the projects studied use only 3D models and the processes that include proper time management, for example, schedules are not linked to the model. In level three only two projects are positioned, which means that although these projects use a 4D model, it has not been managed automatically (Figure 3).
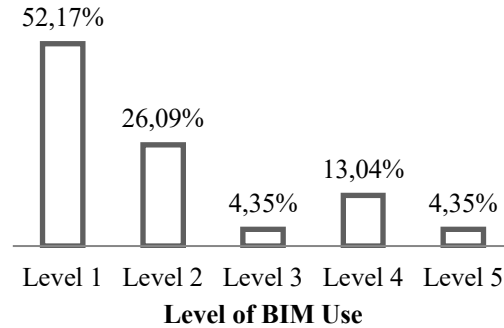
8.1.2 Design Phase.

Figure 4. 'Sustainability analysis' use, percentage of application level

In sustainability analysis, about 80% of the projects are between the first two levels, of these more than 50% manually use 2D and 3D models to analyze the facility sustainability, while a quarter of the total use 3D models for consultations related to sustainability analysis. Some projects reach the maximum level, which involves the use of BIM automatically applying it to more than 50% of the areas that constitute the building (Figure 4).
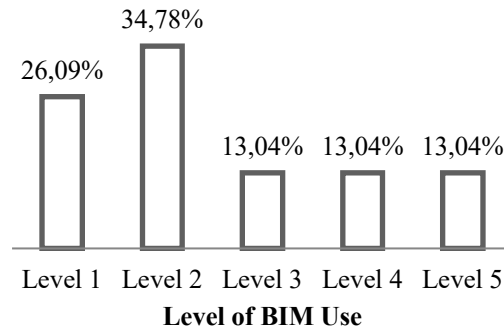
Figure 5. '3D Coordination' use, percentage of application level

In 3D coordination, there are projects placed at all levels, but more than 35% of them are equally distributed from level 3 to level 5 and the highest percentage are placed in level 2 in which a 3D model is used to analyze geometric conflicts (Figure 5).

9. Discussion

(Figure 8) is a comparison of this research in Ecuador (Figure 7) with the one carried out by (Rojas et al., 2019) in which BUA was applied to measure advanced BIM projects in Spain, Colombia, and Chile (Figure 6). The comparison was made between the statistical measures (average, median, maximum, and minimum).
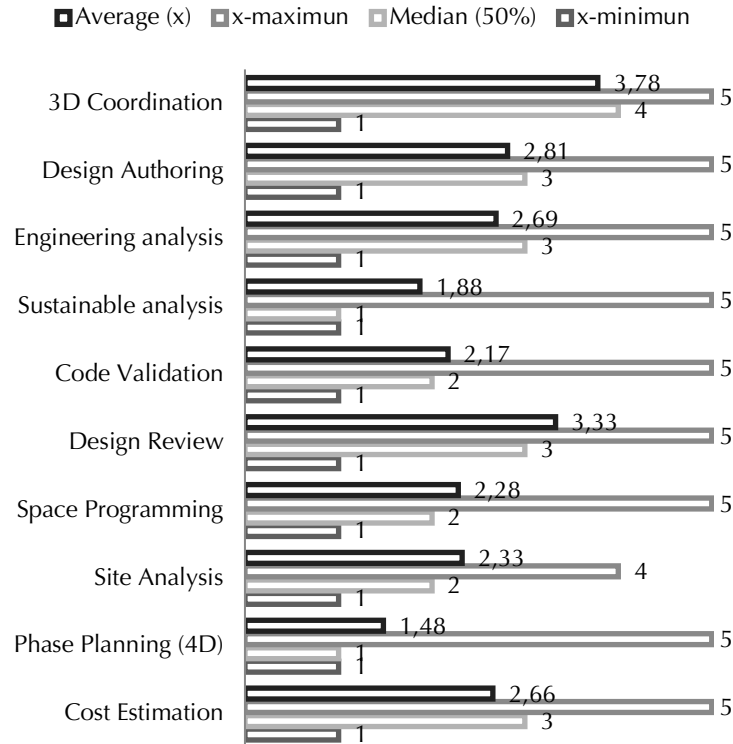
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■Average (x)   ■x-maximun   ■Median (50%)   ■x-minimun

Figure 6. Summary of the statistical data of the BUA application, carried out by (Rojas et al., 2019)

Note. Data obtained from: "BUA Tool for Characterizing the Application Levels of BIM Uses for the Planning and Design of Construction Projects.", by (Rojas et al., 2019), Advances in Civil Engineering.
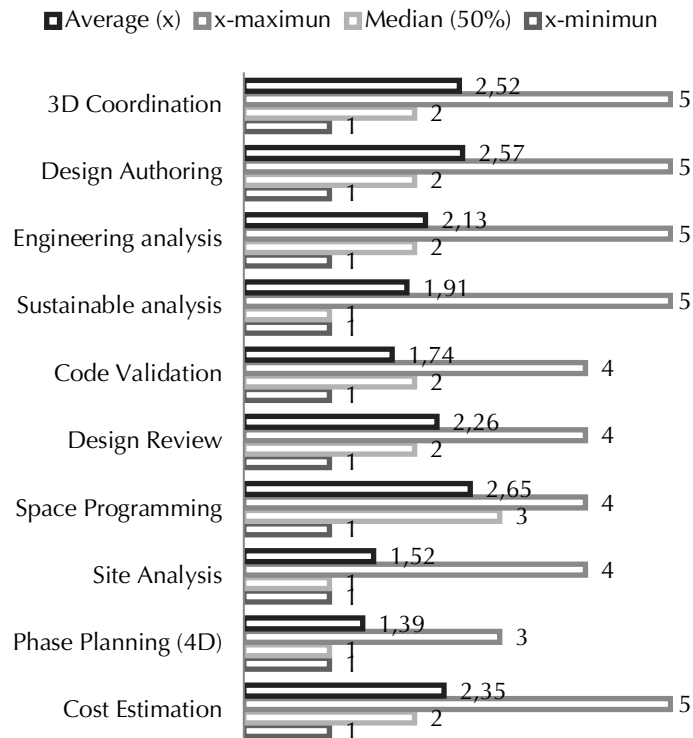
■Average (x)   ■x-maximun   ■Median (50%)   ■x-minimun

Figure 7. Summary of statistical data on the application of BUA in Ecuador

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◧Average - Present research (Ecuador)

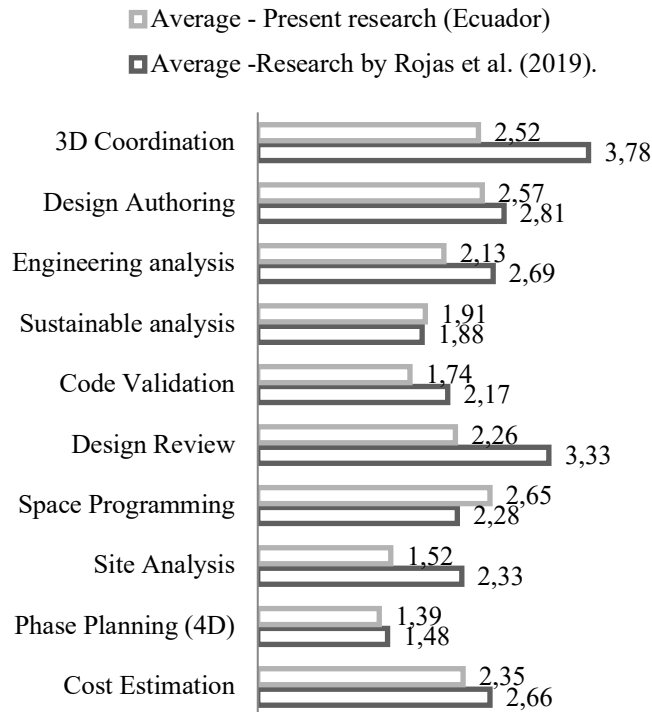◼Average -Research by Rojas et al. (2019).

Figure 8. Comparative analysis of the average level of BIM use

The only BIM use in which Ecuadorian projects surpass the projects evaluated by (Rojas et al., 2019) is space programming. Besides, in the sustainability analysis and 4D spatial planning, very similar averages close to 2 and 1.5 respectively are reflected in both researches, showing that there is a lot to improve especially in sustainability terms even in advanced projects. Ecuador's level of design review and 3D coordination of specialties is considerably low, it is worth mentioning that these last two BIM uses are more related to teamwork; thus, this would be one of the deficiencies that should be strengthened in the BIM early adoption.

In the early BIM adopters as advanced ones, most of the BIM uses have an average that does not exceed level three. If we analyze BUA, in most of the uses we can notice that comply with 'use of BIM models', a characteristic of a BIM use corresponds to a level 3, 4, or 5. The factor that will define in which of these levels the project is located, is how the BIM model is used, consequently, the other characteristics are analyzed. In other words, BUA evaluated if the methodology is adequately applied within the BIM model. For example, if a project has a BIM model, but verification of structural codes is not done automatically; although BIM modeling corresponds to a level 3 is rated as level two. In this case, the team would be investing time and money in a BIM model, however, the score would be 2, which means that the team is not getting the full benefit of the investment. This model is probably not composed of structured data, does not have interoperability and there is no proper communication in the work team.

According to the results, one of the notable deficiencies of the analyzed Ecuadorian projects was found in the characteristics that have a greater relationship with collaborative work, which undoubtedly includes efficient communication. Among the evident consequences of such deficiency we find the rework, because each discipline carries out its model from the beginning, while when adequately using BIM a single database is used, this problem of communication has been detected by (González, 2015), who labels it problem as part of the cultural mindset. It is worth mentioning that the participation of the stakeholders was commonly underestimated. Unlike countries that are early adopters of BIM, governments promote the adoption of methods and technology aligned with BIM in all participants of construction projects.

Looking at the sustainability analysis, both researches have the lowest median and average compared to the other BIM uses, showing that the project teams have not given it the importance it deserves. Probably because its benefits are more evident in the operational phase of the project, where the consumption of non-renewable resources, environmental impact, and operating costs are minimized. A strategy that is working in other countries is to raise

awareness through incentives, such as public entities that only authorize the purchase of energy-efficient buildings and grant housing loans only if the building is sustainable.

This research allows us to identify the common shortcomings among the BIM uses, the degree of importance that each one has had for the project teams, and the relationship that exists between them to generate strategies that can notably improve the BIM use particularly in the first stages of its implementation.

The results obtained in the evaluation of the Ecuadorian projects were expected judging by the lack of information about BIM in Ecuador, the absence of incentives for BIM adoption, the absence of the BIM Forum group, and the absence of BIM-related subjects in the curricula of the universities.

10. Conclusions

After evaluating projects in the early stages of BIM adoption using BUA, it was possible to compare between projects regardless of the degree of BIM implementation, which could not have been done using maturity models. The comparison showed that both projects with an advanced level of BIM and projects with incipient levels share a low level of Sustainability usage. One of the reasons for this result may be that this use is not valued because its benefits are obtained in the long term. This finding shows that an awareness of the importance of some specific BIM uses is necessary.

Several researches on the state of BIM in the Middle East, South America, small Asian countries, and Europe prove the need for agile adoption strategies, in this scenario BUA assessment is a solution. The results of previous BUA assessments certainly provide a basis for continuous improvement of advanced BIM projects, but since most companies worldwide are in the process of BIM implementation, its assessment can help even more.

The use of BUA made it possible to evaluate not only the use of BIM tools but also the integral use of the methodology as such and to avoid the results being affected by the current confusion between the use of the methodology and the isolated and partial use of a 3D model.

Most of the analyzed projects were at levels characterized by the complete use of 3D models, suggesting the need for training in the modeling tools. The most common shortcoming is the inadequate and limited way in which the models are used since not all the benefits are obtained. The average BIM level was approximately three, so it can be anticipated that the following phases will not have better results since the evaluation focused on the planning and design phases, which have more influence on cost and time compliance than the later phases.

The '4D spatial planning' is another use in which the analyzed projects are at a low level. To successfully comply with this BIM, use the team must use a 4D model automatically. This is one of the BIM uses that has the greatest impact on the other BIM uses and consequently on the efficiency of the project. If a 4D model is not used properly, the possibility of avoiding unforeseen events, rework, and time savings is reduced, since it will not be possible to detect collisions, obtain the sequence of processes, critical path, and project schedule updated, and there will not be possible to model in greater dimensions. This indicated that to an agile BIM implementation is important to work before on collaboration between the teams and in the compatibility of the 3D models between the different specialties

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