

Architectural Model of Implementation of Building Information Modeling - BIM in the Colombian Construction Industry

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Abstract

In the last decade It has been experienced the strengthening and dissemination of the concept BIM, as an information management methodology for the construction sector based on the precise and detailed modelling of a constructive model. At the international level, a variety of standards and policies have already been defined in both the private and public sectors; in Colombia, the adoption of this methodology has been initially promoted by private companies, generating an individualization in the strategies, policies and standards of implementation according to the field of action, the address and market position of each company. This article, as an initial part of the research process in the Masters of Construction, presents in detail the state of art and the problematic situations, the homogeneity of language in the research of a success adoption of BIM as a driving force for competitiveness and a flow of transparent information that enables decision-making and problems solving.

Keywords

(1) BIM; (2) Information Management; (3) Construction; (4) Strategic Decisions; (05) Implementation.

Introduction

This article describes in detail the current conditions of the BIM implementation in Colombia, starting with an overview of the construction sector in Latin America and Colombia, through the description of terminology, BIM history and implementation states, a development was developed. Research of primary information from a sampling in 5 regions of the country, together with the Capital with a total participation of 52 sole, small, medium and large companies in the construction sector in the different types of services which are construction, design, promotion, consulting and / or suppliers, in the construction of the state of the art. The identification of problems is also presented through a Focus Group with different BIM Manager, socializing the findings in the construction of the state of the art of BIM implementation in Colombia. This state of the art makes an approach to the problems of fragmentation from

an exclusive implementation of the private sector, without the support or promotion by state agents, also shows the needs that are being presented to the great diversification of the Colombian construction industry in the BIM implementation according to the particular needs of the companies; allows identifying the gaps generated by the heterogeneity of the implementation and of the information languages used by the company.

Generalities

Acronyms:

1. Promoter: It is the one that intervenes between the construction company and the final customer.
2. PEB: BIM Execution Plan, structuring document of the projects that are developed under BIM methodology, in which the scopes, uses, main characteristics of information among other factors are defined.
3. EIR: Employer Information Requirements, main document in which the needs, scope, general project information, requirements and other contractual factors are defined.
4. BIM Manager: Implementation Manager, is responsible for directing and structural BIM implementation and management of processes and standards.
5. BIM Coordinator: It is the implementation manager that is responsible for verifying compliance with standards, information auditing and processes.
6. BIM Modeler: He is the professional in charge of the three-dimensional development of the project and the requested information (International Organization for Standardization - ISO , 2018).
7. Top - Down: Direction of a government initiative towards private actors.
8. IPD: Integrated Project Delivery, characterization system, order and delivery of the information of a project.
9. LEAN: Clean Production, a management model that focuses on minimizing the losses of manufacturing systems while maximizing the creation of value for the final customer.
10. COBie: Construction Operations Building Information Exchange

The Construction Sector in Latin America

Globalization has driven industries to create and implement R + D + I methodologies that allow them to be competitive with the market; The construction sector in Latin America has shown a dynamic growth compared to the first quarter of 2019, the highest value-added growth in construction is Peru with 1.8% and Chile with 2.8% otherwise in Mexico and Colombia with a decrease of -0.8% and -5.6% respectively (DANE, 2019), despite this, in Colombia, the construction sector is the third largest market in Latin America, it is expected that in the next 5 years grow 5% coinciding with the country's growth (DANE, 2019). This future growth has created challenges and has encouraged the sector to respond and modify its production systems. In Colombia, the National Development plan defines that by 2032 it will be the third most competitive economy in Latin America and the Caribbean, due to this, the National System of Competitiveness, Science, Technology and innovation was developed which strengthens the constraints on competitiveness (PROCOLOMBIA, 2018).

A study conducted by McKinsey in the company of the Colombian Chamber of Construction - CAMACOL (2017) concludes that there is a decrease in productivity in the construction sector between 1995 and 2015, it is shown that the compound rate of "Growth of the Value Added by Worker" was 1.0 although the general economy was 2.7% and if a comparison is made with the manufacturing industry the gap is larger, with a growth of 3.6%. The study concludes that there are several reasons why there is a drop in productivity in the sector, which are attributed to three large External groups, Industry and business; Among the External ones is excessive regulation, complexity in projects, informality and illegality, high dependence on state demand, economic cycle; On the other hand, in the Industry the factors are attributed to a fragmented economic sector, inadequate contractual arrangements between chain agents, custom designs and finally the factors attributed to the company are inadequate designs, low human capital and low investment in technology (Cámara Colombiana de la Construcción - CAMACOL , 2018). This decline in Productivity makes companies in the construction sector not competitive against international markets, in this sense McKinsey identifies 7 fronts to advance in the decline in productivity, which are: 1. Regulations and laws; 2. Redesign of contractual models; 3. Standardization of construction designs and implement methodologies; 4. Improve BIM

planning tools; 5. Improve the relationship with suppliers; 6. Adoption of planning tools and 7. Training of the actors involved in the construction life cycles.

Building Information Modeling – BIM

Building Information Modeling - BIM is the participatory and collaborative construction in a virtual space based on a set of international, national and business technologies, processes and policies for the construction of buildings or infrastructure (BIM DICTIONARY, 2019). That is, from a technology and the different actors involved throughout the life cycle of the construction project, information is generated and managed, which allows the understanding of the entire project holistically, articulating the areas that make up the company in the execution of the project, allowing interdisciplinary work (COMITÉ DE TRANSFORMACIÓN DIGITAL - CORFO y PLANBIM, Junio).

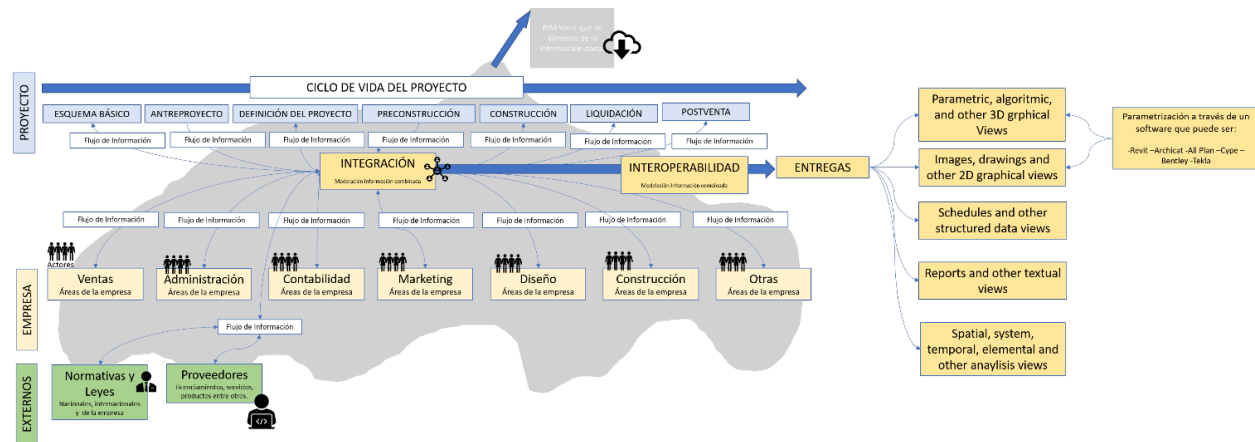


Illustration 1 Conceptual Generalities of BIM
Elaborated by: The Authors

In this sense, BIM is able to model and parameterize through the linking of data, mathematical calculations and probabilities, thus generating precision, fluid exchange of information and feedback, it is considered the current expression of digital innovation in the construction sector, as it also supports decision-making focused on the optimization of resources in all cycles of the project life (BIM DICTIONARY, 2019). Bilal Succar proposes maturity levels in the BIM implementation, these are associated with the BIM Excellence matrix, which is described as follows:

No.	Acronym	Definition
1	AD-HOC	Pre-BIM state, unpredictable process, immature and answer only to a need.
2	Defined	Answer to different needs, however, there are established processes and protocols.
3	Managed	Answer to needs and strategies of the company, counts with protocols, standards and processes, begin to involve other actors in the life cycle of the project.
4	Integrated	All the processes and protocols are directed towards the company strategy, and the information transfer answer to the needs of other areas of the company.
5	Optimized	The complete information of the project allows the different users and processes to be integrated.

Table 1 Maturity of BIM Implementation – From Maturity Matrix of BIM Excellence
Elaborated by: Adaptation from (BIM INITIATIVE, 2019)

The development of BIM it's attached with the evolution of the computer components and go back in time to the XIX century, thanks to the machinery prototyping innovations, which allowed the mathematical calculation of operations, that were getting more complex little by little, until the 50's decade with the appearance of the transistor in the computers, marking the beginning of a new generation of perfected and sophisticated computers, the history and the development of the methodology are described in the table 2.

1962	Douglas C. Englebart presents a mysterious vision of the future in his work Augmenting Human Intellect
1963	he roots of the SAGE graphic interface and Ivan Sutherland's Sketchpad program appear
1970-1980	Constructive solid geometry (CSG) and boundary representation (brep) appear.
1982	Version 1.0 of AutoCAD appears
1977	astman presents GLIDE (Graphical Language for Interactive Design) created in CMU, exhibited most of the features of a modern BIM platform.
1982	ArchiCAD developed in Budapest, Hungary by Gábor Bojár, a physicist who rebelled against the communist government and started a private company.
1884	Using technology similar to that of the building description system, the Radar CH software was released for the Apple Lisa operating system. This later became ArchiCAD
1985	Shortly after Graphisoft began selling the first Radar CH licenses, Parametric Technology Corporation (PTC) was founded in 1985 and launched the first version of Pro / ENGINEER in 1988.
1986	he RUCAPS software system developed by GMW Computers in 1986 was the first program that used the concept of time phase of construction processes and was used to assist in the construction phase of Terminal 3 at Heathrow Airport (Laiserin - History of BIM).
1988	The foundation of the Integrated Facilities Engineering Center (CIFE) in Stanford, by Paul Teicholz, marks another milestone in the development of BIM as this created a source of PhD students and industry collaborations to encourage the development of construction models with time attributes for construction.
1993	A later but prominent example of a simulation tool that gave feedback and "suggested" solutions based on a model is the Building Design Advisor, developed at the Lawrence Berkeley National Laboratory.
2000	Irwin Jungreis and Leonid Raiz separated from PTC and founded their own software company called Charles River Software in Cambridge, MA. The company had developed a program called 'Revit', a compound word that is supposed to involve revision and speed, which was written in C++ and used a parametric change engine, made possible through object-oriented programming.
2002	Autodesk bought the company Charles River Software in Cambridge, MA. and began to strongly promote competing software with its own object-based software 'Architectural Desktop'
2003	Some of the BIM platforms that have a small market share, but have had major impacts in the design world, include Generative Components (GC), developed by Bentley Systems in 2003. The GC system focuses on parametric flexibility and The sculpture geometry and supports NURBS surfaces.
2004	Collaborative or multi-user work appears. This feature published in Revit 6 in 2004, allows large teams of architects and engineers to work on an integrated model, a form of collaborative software.
2006	Digital Project a similar program developed by Gehry Technologies around 2006 based on CATIA, a design program (and one of the first CAD programs) that was developed as an internal project by Dessault systems, a French aircraft manufacturer.
2007-2011	ArchiCAD has made substantial profits in the user base, mainly as a tool to develop residential projects and small commercial projects in Europe. 2008 Patrick Schumacher has coined the movement of parametric construction models in architecture, specifically those that allow NURBS surfaces and scripting environments as 'parametricism' in his 'Parametricist Manifesto'.
2012	At the end of November 2012, the development of formit, an application that allows the conceptual beginnings of a BIM model to start on a mobile device is a leap for Autodesk.
2013	Some of the BIM platforms that have a small market share, but have had major impacts in the design world, include Generative Components (GC), developed by Bentley Systems in 2013. The GC system focuses on parametric flexibility and sculpture geometry and supports NURBS surfaces

Table 2 Chronology of BIM
Elaborated by: (López Ruiz, 2017)

BIM in Latin America

The process of implementing the BIM methodology in the world has not had an expansion as it had been projected in the large BIM associations in the world, it has seen a greater boom in the updating of technologies and implementation, according to the survey conducted by the researcher Peter Smith in 2018, the implementation of BIM taken since 2001, found significant and dramatic changes in particular in North America in which it intensified with 28% in 2007 to 71% in 2012, it was shown that There is a greater implementation in the United Kingdom, United Arab Emirates, Australia and Canada, considering that these countries have legalization initiatives (Smith, 2018). In Latin America, the integration of the BIM methodology into large projects has not been homogeneous; in Colombia, Peru or Chile it

has been adopted in large Public projects, in which personnel specialized in the methodology have been hired and where the companies have carried out training processes, however, the implementation of BIM has not grown in its proportion to the rest of Latin countries, being a very slow progression methodology (EDITECA, 2019).



Illustrationn 2 Adoption of BIM in Latin America
Elaborated by: (EDITECA, 2019)

BIM Forum Chile stood out for the completion of the first BIM Latin American survey, in this survey 552 responses were obtained in which 32% correspond to construction companies, the study highlights that 40% (223) are regular users of BIM, discriminated against as follows: in Brazil of 149 respondents 33% are a regular user, in Chile of 177 respondents 46% are a regular user, in Colombia of 99 companies surveyed 42% are regular users, in Costa Rica of 28 respondents 53 % is a regular user, in Mexico of 34 surveys 48% are regular users, in Panama of 16 respondents, 27% are regular users (FEDERACIÓN INTERAMERICANA DE LA INDUSTRIA DE LA CONSTRUCCIÓN, 2017). Finally, the survey provides relevant information about the most important benefits of the implementation and delivery of BIM, which highlights conflict reduction, fewer documentation errors and improvement in the quality of the final project, in illustration 4, You can see the benefits found by respondents.

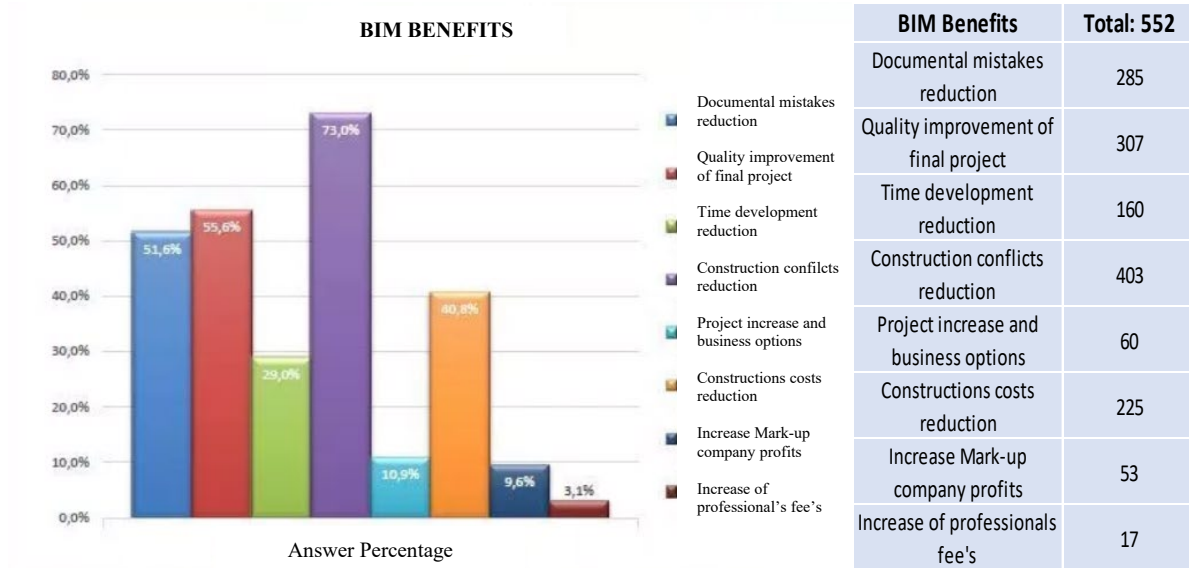


Illustration 3 Benefits of BIM

Elaborated by: Secretaria Ejecutiva INCONTEC, Corporación de Desarrollo Tecnológico CDT

BIM in Colombia

In the construction of information that allows to discern the procedures of implementation of BIM in Colombia, its key actors, architectures or models of execution it is concluded that there are few primary and secondary sources of information, in this way interviews with experts were conducted and implemented a quantitative investigation based on different Colombian companies with diverse services regarding the implementation of BIM; This concludes that 36% belong to the department of Antioquia; 44% to the city of Bogotá D.C.; 12% to the department of Cundinamarca; 4% to Santander and 4% to Valle del Cauca. Of these companies, 38.5% are micro or sole proprietorships; 30.7% are large companies with more than 250 employees; 15.4% are medium businesses and 15.4% small businesses. 42.3% are mainly dedicated to construction, while 26.9% to design, 11.5% to promotion, another 11.5% to consulting, and 7.7% as suppliers.

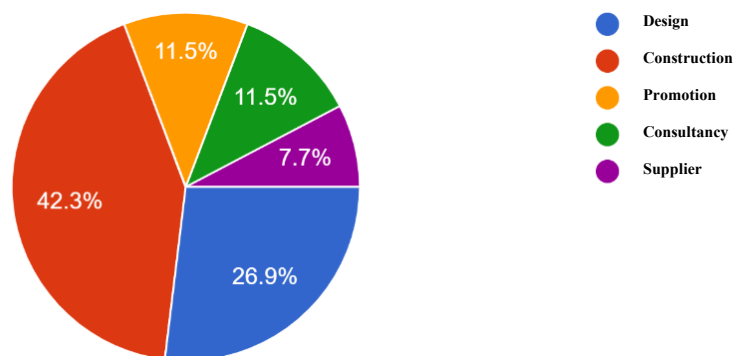


Illustration 4 Percentage of Main Services of the Companies in the Construction Industry.

Elaborated by: The Authors

This quantitative research was carried out on 52 companies in the construction sector in Colombia; with specificity in 5 departments which are, Antioquia, Valle del Cauca, Santander, Cundinamarca and the Capital Bogotá. Of the total of the participants 88.5% are in the BIM implementation process and 11.5%, those that are in the BIM implementation, the totality has been supported by managers and / or management teams, the development of This implementation has taken more than 2 years in 47.8% of the companies, 21.7% those that have been between 1 and 2 years, 17.4% have developed it between 6 months and 1 year, and 13% have less than 6 months in the implementation process. The

maturity of these processes, according to the BIM Excellence maturity matrix, of implementation is divided into 39.1% at a managed level, 26.1% are in an AD-HOC or Pre-BIM state, 8.7% in a integrated level, 83.7% in a defined state and 4.3% in an optimized level, 13% of respondents do not know the status of their maturity. Against an international guideline, the development of this implementation has an orientation of 30.4% towards compliance with ISO 19650 but 69.6% does not have this objective.

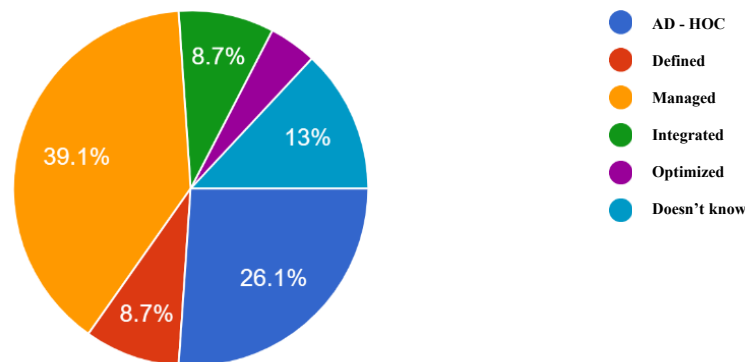


Illustration 5 Maturity of BIM Implementation (Terms from Maturity Matrix BIM Excellence)
Elaborated by: The Authors

73.9% have already defined BIM roles, while 26.1% maintain conventional roles with an adaptation to the functions required in the implementation and development of BIM. Given the different BIM processes, 65.2% have specific standards and documents, while 34.8% do not have them and readjust those existing before implementation. Given the different uses that are glimpsed in the list of uses of BIM Excellence, 87% of companies design and plan, 60.9% quantify and simulate, 52.2% capture and represent, 43.5% build and manufacture, 21.7% they link and extend, while 13% monitor and control with the remaining 13% that operate and develop maintenance. Given the different uses, 65.2% manage their software and hardware according to them, 34.8% manage it under other requirements. 43.5% are managing their processes and flows with BIM as a guideline, while 56.5% are maintained with other strategic guidelines or approaches. For the monitoring and measurement of the processes, 21.7% have indexes and review processes, or KPI's specifically for the BIM implementation process, and 78.3% do not track or index.

The codification of the companies is maintained without some standardization in 91.3% and only 8.7% have implemented some type of international standardization. Another important aspect is if there is an additional system or methodology to manage your projects with 47.8% that if you develop it, IPD, LEAN, PMI among others, and 52.2% that is only being implemented by BIM.

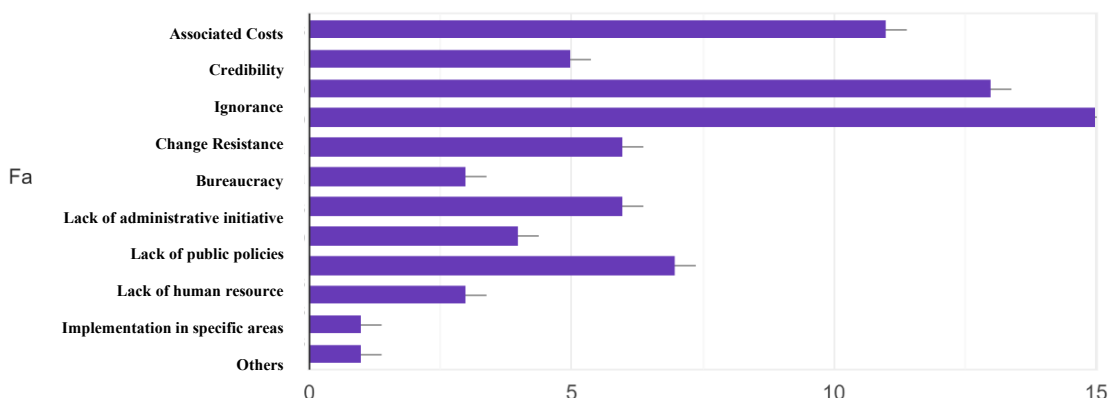


Illustration 6 Main Difficulties of BIM Implementation in Colombia
Elaborated by: The Authors

Given the difficulties of implementation, it was identified that 57.7% consider resistance to change as the main difficulty, also 50% see the ignorance of the sector before BIM as a difficulty, with 42.3% the costs associated with its implementation, 26.9% ignorance of the appropriate software and hardware, with 23.1% for bureaucracy, another 23.1% for the absence of public policies for BIM, lack of credibility with 19.2%, lack of specific human resources for implementation with 15.4%, lack of administrative initiative and implementation in specific areas with 11.5%, and 3.8% implementation in specific areas together with the factor that designers who have a recognition in the market are maintained with the conventional system.

BIM Implementation in Colombia

From the construction of information with primary and secondary sources, a Focus Group was held at the BIM Forum Colombia with the different BIM Manager of the 10 largest construction companies in the country, socializing the findings in the construction of the state of the art of the BIM implementation in Colombia based on their professional experience, concluding that in Colombia the BIM concept is young in the construction industry, with a diffusion of no more than 3 years, it was initially associated as a technological tool that would rely on the conventional methodology and his understanding was limited to the capabilities of the software that was used. Seeing the maturation of this concept worldwide and how the construction of the rest of the countries was transformed, the Colombian sector did not remain static, through the exchange of knowledge and communication possibilities of innovation in the international field, some participants The construction market began to understand BIM as a methodology and not as a simple tool.

The behaviour of the Colombian construction responds to the bidding or tender model and the own management, and these in turn respond to government and market policies, however, the end users tend to be the same regardless of which model they are Develop construction projects. This allows the projects despite having similarities, be it for their type, classification, uses, users, among many features, have a different life cycle. By taking this life cycle, the different actors in the value chain can continue to vary, and similarly the processes that each one, generating a large number of possibilities for the information of the same project to be different. Builders, consultants, promoters, designers, suppliers or supervisory entities, as well as the different areas they contain, will see the same project and its information with a different perspective consistent with their particular interests. That is when BIM becomes not only a methodology for construction, but also a driver of change in the industry.

In the Colombian construction industry, BIM implementation has been developed from large companies mostly dedicated to construction, and microenterprises mostly dedicated to consulting, each has generated its implementation from different business perspectives and its position In the construction value chain, this has represented the creation of a differentiated documentation that supports implementation such as modeling protocols, PEB, EIR, Technical Annexes, Formats and Flows, among others. With what the field of processes and national protocols that are being generated is of a wide magnitude that is prone to have a language that is not unified. The different companies that are in the implementation of BIM have specific professional profiles for the development of the methodology processes aligned to ISO 19650, such as BIM Manager, BIM Coordinator, BIM Modeler, however, there are also adapted roles BIM functions and other companies have maintained their existing profiles with responsibilities for implementation. The great differences of protocols, roles, market between the different companies of the industry generate a heterogeneous general maturity, there is a large volume that is in a state of defined implementation and a few are already with an integrated implementation which is manifested in a different amount of information generated that may or may not be effectively used and similarly few ways of impacting it on the industry or the market.

In a time, greater than 2 years of the development of the BIM implementation in the large percentage of companies that have maintained a leadership in their development, the different companies have derived in the exchange and mutation of their own information that was already being established based on the conventional methodology. The entry of technological changes and new market needs has driven autonomous search and innovation to maintain competitiveness that meets the margins of industry needs. All this own development that has been generated in the private sector so far has found it difficult to be transferred to those entities that intermediaries or adjudications of the construction and regulatory development processes that do not have the same approach to innovation and technological development.

The innovation of the different internal processes, which are manifested in a benefit of the market objective of each company of the Colombian industry, reaches a focal point in the information relations with external agents; The legalization and treatment of transfer information to macro processes that are required for the development of construction projects, have a system that maintains the flows of the conventional methodology by not having a “TOP-DOWN” initiative in the implementation of BIM at the state level. With an implementation developed from large companies, the market adapts to meet its requirements, however, from the perspective of the supplier, it must adapt to each of the information flows of each of its customers, which in this case are the Different companies that develop the implementation. For this actor in the industry value chain, a customizable system would be needed to meet the requirements of its customers totally away from a standardization. When entering BIM as a new construction methodology, an initiative or support is required by the company's executives to be able to make the modifications according to the digital transformation of the company, creating new flows, processes, policies and managing the transformation of the Technological infrastructure. In the companies surveyed, the BIM implementation has the support of executives, despite this, the general flows and processes of the companies are not structured based on the methodology, forcing a gradual transformation through the different areas. This transformation also implies that the methods of monitoring, or valuation of the process, remain fragmented or remain absent, which hinders the monitoring, control and continuous improvement of the BIM implementation process.

The different companies complement the implementation of BIM with the support of other methodologies for the development of processes and projects, such as IPD, LEAN, ISO, PMI among others, optimizing these according to the needs of the company and its interests in the market. The processes and elements do not have a mostly standardized coding, which promotes the individualization of languages, generating transcription and translation processes within companies and among the different participants of the value chain, likewise does not allow them focus on regulations that have become widespread internationally as is ISO 19650, and COBIE, generating heterogeneity in the construction industry. The software that allows to develop the different uses is not managed according to these and to the particular requirements of the company, which promotes the underutilization of computer tools hindering the maturation of the implementation processes and depending on the offers of suppliers available in the Colombian market . BIM has had a greater development in the uses of design and quantification, in a smaller number for construction and capture and representation, the uses of analysis and extension do not have a large number of companies dedicated to it, slowing down the services that can be generated.

Challenges

The fragmentation that occurs in the industry makes it difficult to transfer information efficiently between the different actors that can intervene in the development of a project, one of the main challenges is to achieve the unification of communication between suppliers-designers-builders, in this way ensures that the information that is used from the moment of conception and configuration of the project is in accordance with that necessary in the field at the time of materialization, a coding in which the inputs and construction elements can be identified in the different instances and uses of the project , the most propitious coding that will allow to align to ISO 19650 is OmniClass, since it is the one that is used in a standard way through it; as well as another relevant aspect is to align with ISO 19650-1 & 19650-2 to allow homogeneity in the industry sector in the BIM implementation. Another important challenge in the industry is in the homogenization of standards, protocols and monitoring processes, through this point the different actors will be able to understand and value each other according to their indexes and provide information about their services.

Model Outline

Given the findings, a BIM implementation model architecture is proposed based on the **Assembly** system, structuring a correct and efficient execution that adapts to the specific requirements of each company, which speeds up the development of the BIM Implementation Plan, the foundation is based on the transfer of clear and precise information according to the different uses, framed in the requirements of ISO 19650, in which each of the uses has a predefined process and standard, together with the use the software and hardware are managed required to have clarity of the efficiency of these uses, the processes and standards have a measurement system that allows to identify the efficiency of the process.

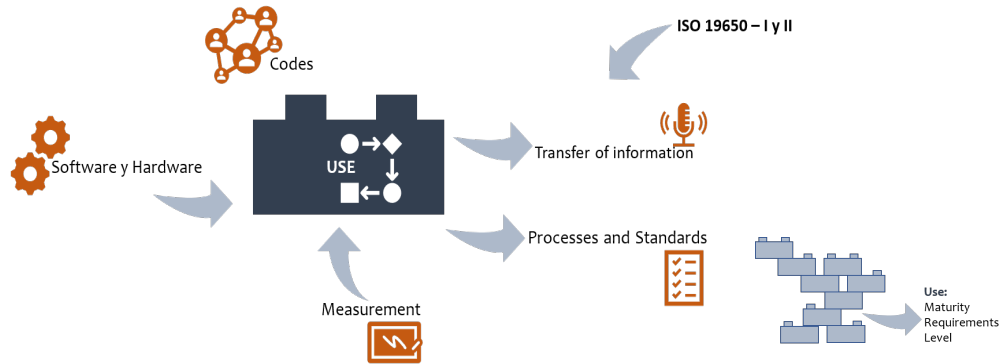


Illustration 7 Architecture Model Scheme
Elaborated by: The Authors

Each of these uses is considered as an individual piece, which can be replicated in different types of companies and maintain its logic in the management and transfer of information, the set of these pieces is defined by the objectives, interest and strategies of the company, allowing the updating of the structure and configuration of these towards the implementation, in the measurement of the general progress and maturity of the implementation. From the measurements generated from each of these pieces, the information that determines the requirements, the level of implementation and the maturity of the company in general can be extracted. The different unions of these pieces of uses will have a specific coding according to the OmniClass standardization system.

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Biographies

Camio Vaca, architect graduated and current Construction Mastery student at Universidad Nacional de Colombia. He works as a BIM Manager of Colpatria construction company and is part of BIM Forum Colombia. He has experience in institutional and housing construction. He has participated in research projects under the line of construction project management and construction digital model as well as, BIM implementations in different states of maturity.

Nataly Alvarado, is an industrial designer with a Masters degree in industrial engineering from the National University of Colombia. She works within this university as well as in the Global Campaign, 100 million for a 100 million, led by the Foundation for a Better world. Her investigative projects can be classified in three lines of study within innovation: competence strategies, as she won the award for the undergraduate thesis for her development of new products and processes in small businesses; communication strategies for her work obtaining the Guinness World Record with the creation of a mobilization strategy that enforced public policy within the country and finally social innovation with the creation of an investigative group on this topic for her alma mater. She was an Incae Business School scholar and a trustee in the Social Entrepreneurial Summit hosted by the international non profit VIVA for her work in socially innovative projects.