The Process Of Implementing Project Management and BIM In The Colombian AEC Industry.

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Abstract

Since 2006 the Engineering and Construction Management research group at Universidad de los Andes has documented 20 case studies of Colombian companies using or implementing Project Management and BIM tools. Results showed that knowledge and understanding of Project Management and BIM principles, top management support, and organizational culture are the most influential factors when formulating an implementation strategy. It was also observed that some of the requirements for implementing BIM, such as transparency, process efficiency and new decision making procedures, made the process particularly challenging for some actors in the supply chain. The purpose of this paper is to present the results of a comparative review of these research projects. After analysing common failures described on the industry, it was found that most of BIM principles involve managerial improvements, therefore implementing contractual mechanisms to demand BIM in private and public biddings would surely improve industry's efficiency.

Keywords: Project Management, BIM, literature Review, Colombian AEC industry.

1. Introduction

Over the past decade, the Colombian Architecture, Engineering and Construction (AEC) industry has grown significantly. The AEC industry has been analysed in several MA dissertations in order to identify the failures and advantages of project execution. The most concurrent topics in such dissertations from Universidad de los Andes since 2006 will be analysed in order to identify the recurrent themes, main failures and propose future research subjects.

The approach proposed describes recurrent subjects found in the dissertations treating two main topics: Project Management and Building Integrated Modelling (BIM). These topics were selected based on the importance and advantages evident when leading construction

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industry; therefore, identification of the main barriers are relevant for improving Colombian productivity and success rates in Architecture Engineering and Construction (AEC) projects.

With respect to Project Management, two main categories arise as the most recurrent, Risk Management and Cost Management, each is described based on the main failures identified, and compared to international standards. Similarly, an identification of BIM's advantages and requirements for implementing this technology is analysed and compared to internationally defined maturity levels.

Nevertheless, the themes that will be treated on this paper are among a variety of project management strategies such as Lean and sustainable construction, that Universidad de los Andes has studied and published on different academic works.

2. Research methodology

The selection of dissertations for the elaboration of this paper was based on filter criteria according to the project's title and topic. The topic must be related to the main work areas established by the PMBOK which include Knowledge Management, Risk Management and Cost Management.

Several of the dissertations reviewed suggest the inclusion of an instrument for improving practices. Therefore, documents regarding Building Integrated Modelling (BIM) were included in the review and searched for, in the Uniandes database.

Examining the content of these papers, the common trends and propositions for future studies were analysed and compared with international trends. The most frequently cited academic papers were included in this research document. Table 1 lists all the documents and main topics reviewed. The methodology proposed is based, in the first place, on a local literature review that includes the most relevant documents presented since 2006 at Universidad de los Andes; and secondly, an international literature review based on the most frequently cited documents and new trends in such topics,. Finally, according to the literature reviews, a classification of the state of Risk Management and BIM development in Colombia was completed.

3. Project management

Project management has been defined as the standard to deal with and create changes within several management practices such as creation of new products, services or changes in organizational processes (Cleland & Gareis, 2006). Several changes have occurred over the past years whereby Project Management turned from being a rudimentary process—part of general management—to an independent, well-structured and defined process recognized by several associations such as PMI (Project Management Institute) and IPMA (International Project Management Association). These associations have documented and guided the best practices in order to undertake an accurate analysis based on cost, schedule and technical performance. According to the PMI, the main areas of focus for

successful project execution are: time, cost, quality, scope, risk, procurement, human resources and integration management.

Table 1: Documents revised for the elaboration of this document

		Author and year of publication	Main topics
Project Management	**General topics**	Liberatore, Pollac, & Smith (2001); Cleland & Gareis(2006); Caycedo(2007); Galán(2007); Imbeah & Guikema (2009); López (2010); Morales (2010); Zandin (2011); Morales (2011).	Tools for controlling cost, time and quality on projects; Project Management organizational schemes. Better practices; Methodology and software design; Management Model (APRAM) for managing schedule, cost, and quality risks in the construction industry; Project Management generalities and evolution; Evaluation of human resources on a project management group.
	Cost / financial management	Hegazy & Perzold (2003); Rivera (2007); Correa (2007); Lucero (2008); Cuello(2008); Lipke, Henderson, & Anbari (2009); Zapata(2010); Piedrahita(2010); Velasco (2012); Garvin & Ford (2012).	Cost optimization and dynamic project control; Scheduling, resource management and cash-flow-analysis; Financial modeling; Profitability on priority housing projects; Real projects best practices; Cost control structure; Budget control standards; Budget database actualization and completion; Earned Value Method (EVM) improvements; Free cash flow of a project based on risks and mitigation measures; Influence of inflation in the variation of prices of raw materials and services; Real Options on financial evaluation of projects.
	Risk Management	García (2007); Redondo (2007); Mendoza (2007); Salgado(2008); Guevara (2008); Puentes (2008); Acevedo (2010); Rodriguez (2010); Abdelgawad & Robinson (2010); Zou, Chen, & Chan-(2010); Beltrán (2011); Duque (2011); Alarcón, Ashley, Sucre, Molenaar & Ungo (2011).	Risk analysis; Methodology for implementing a "learned lessons" philosophy; Common risks presented during planning phase; Corrective actions that must be done to avoid risks; Risk identification, register and analysis during the operation and maintenance phase on construction projects; Case of study, identify, quantify, analyze and control risks present; Uncertainty management of activities' duration; Mode and Effect Analysis (FMEA) in the construction industry for mitigation of risks; Development and prove of a tool for evaluating state of risk management; Risk Analysis on public contracts; Comparison between the PMBOK and the NTC 5254 (Colombian regulation) on risk management procedures; Contingency model via Monte Carlo simulation for risk analysis and for providing contingency assessments.
BIM		Torres (2007); Isaza (2008); Succar (2009); Castañeda (2009); Iguarán (2010); Eastman, Teicholz, Sacks, & Liston (2011); Sánchez & Valencia (2011).	BIM influence on design, cost and scheduling on projects; BIM implementation plan for Colombian companies; Revision of BIM implementation on a Colombian AEC company; International guidelines and BIM Framework; BIM generalities and most relevant aspects for implementing BIM in Colombian industry; BIM literature review. Feasibility of BIM implementation; BIM generalities regarding definition, requirements, stakeholders and advantages of this implementing this technology; Case of study a Colombian AEC company and the methodology for implementing BIM in the organization.

3.1 Risk Management

Project Management Body of Knowledge (PMBOK) defines Risk Management as “the process concerned with identifying, analyzing and responding to project risk” (PMI Standards Committee, 1996). An effective risk management leads to the minimization of negative impacts on the objectives, cost time and quality of a project, through improved practices to deal with uncertain events.

3.1.1 Local Literature review

According to Colombian studies undertaken by MA students in Project Management for Construction, the importance of risk management is related to the nature of the Architecture, Engineering and Construction (AEC) industry; catalogued as one of the most dangerous (Sura, 2012) and recurrently affected by risks. Therefore, it is essential to qualify and identify the risks that companies involved within this sector and projects are exposed to.

The current state of project success in Colombian public biddings is alarmingly low, according to Beltrán, only 44% of the total projects planned by a public entity during the years 2006 and 2007 (311) were delivered based on the initial plan (Beltrán Real, 2011). Such statistics suggest that the initial phase of projects (planning phase) is not being appropriately developed; which naturally reflects the importance of this process where uncertainty is prevalent, risks are more probable and the basic decisions that define a project’s scope, requirements and success are made (Muñoz Redondo, 2007).

In relation to analyses undertaken over the past 6 years, the main causes involved with project failure on scope, quality, cost or schedule is initially related to the lack of a well-structured definition of projects, caused mainly by the inexistence of a serious planning methodology and unreliable control entities. All Colombian AEC projects must be validated by a local public entity, responsible for checking that normativity on urban, structural and architectural designs is in accordance with the regulations. Although, these entities do not have a standardized process for construction license approval, the criteria used is based on particular concepts and different interpretations of legal regulations, which consequently lead to major problems during and after construction (Mendoza Paternina, 2007).

On the whole, the importance of classifying risk is to find possible mitigation methodologies. Some of the strategies identified lean towards the implementation of new technologies and simulation tools (Puentes Hernandez, 2008) in order to improve planning, control and efficiency so that differences between executed and planned projects can be reduced (Salas Callejas, 2008).

Particularly in the case of the Colombian AEC industry, it has been shown that the construction of the basic unit model not only improves sales efficiency, but helps to identify and correct design errors before the construction phase begins (Salgado, 2008). However, the most recurrent and important method identified was the implementation of knowledge management, discussed next.

3.1.2 Knowledge Management

In Colombian practice, knowledge management has been one of the least developed practices involved with project management (Galán, 2007). The importance of this area is based on the supply of tools to positively influence the decision-making process during project execution (risk mitigation). The main input is a representative database resuming the history, projects executed and influential decisions made with their impact.

As mentioned previously, the Colombian sector does not understand the relevance and does not provide the personnel required to manage, store and analyse information regarding projects in the private and public sectors. Not even the most important company in the Colombian AEC industry, in charge of representing the public contractors, manages its information appropriately (Galán, 2007).

In order to evade the negative effects that risks could entail, several studies suggest that a complete database, that involves internal and external rules such as requirements on legal normativity (Caycedo, 2007), must be put together. To achieve success on any construction project, all the members of the company must be involved with the risk management process and contribute to the risk database at all the phases of the project. (García Villamizar, 2007). This database shall be used as the main input for the construction of a Risk Breakdown Structure that clearly characterizes and identifies risk and the respective mitigation, based on a learned-lessons philosophy (Duque Tejeiro, 2011).

3.1.3 International literature Review

After reviewing some studies developed globally and cited by several academic papers, it is evident that efforts are continuously increasing and even the most important projects such as the Panama Canal expansion, develop and invest in leading risk management techniques. In particular, the conventional concept of analysing cost and time effects separately has been replaced by an integrated view of these dimensions to obtain common risk factors and perform and adequate analysis of vulnerability during the different phases of the project. According to Alarcón et al (2011), a successful view of risk management is a 10 steps iterative-process where risks should be identified, analysed, prioritized, managed, triggered, measured, tracked, so a critical risk analysis and additional mitigation actions can be defined. Using this methodology, risks can be more accurately identified and the project managers can develop specially designed strategies to mitigate vulnerability and contingency levels.

3.2 Cost Management

Cost management is defined by the PMBOK guide as the processes that involve estimating, budgeting and controlling costs so that the project can be completed within the approved budget (PMI Standards Committee, 1996). Compared to risk management, cost management in Colombia is in a higher stage of development, possibly because the importance of budget control, the evident impact on project success and the nature of financing projects lead to better practices in this area.

3.2.1 Local Literature review

As defined by Rodriguez (2010), most private Colombian AEC projects are based on a capital structure that involves equity and debt, the latter in a much higher proportion. Therefore, the project must be clearly defined on cost and schedule in order to formulate a cash flow based on expenditures and obtain a construction loan via building societies (Correa, 2007).

Local research has uncovered the need for the implementation of a general economic Net Present Value model for each project. It must be designed to modify the most important variables regarding participation of the whole cost, to identify the critical elements and design a proper business structure (Zapata, 2010). The main variables that influence budget on typical Colombian construction projects are Workforce, Concrete and Steel prices (Cuello, 2008); hereafter research into project development must be based on sensibility analyses of these main variables.

3.2.2 International literature Review

Among international trends, Real Options have turned into a recurrent topic related to project evaluation regarding cost management. These options are strictly related to “real” projects based on the production of services or wells such as AEC projects, which are usually analyzed via Net Present Value. In terms of Real Options, an analysis is made according to the different decisions and scenarios that the environment and project execution can present with their respective probability of occurrence. After such analysis, the project manager has the flexibility to study the whole project and decide whether to continue, resize, freeze or abandon the project.

As already mentioned, AEC project environments are very variable and directly affect the development of any project, so a proper Real Option analysis can be very helpful in providing the necessary tools for making the right decisions that will lead to positive results (Garvin & Ford, 2012).

Although, international evidence emphasizes the importance of Probabilistic and Net Present Value project analyses, the Colombian AEC industry presents some limitations brought about by traditional risk management techniques still implemented by most project managers. Project managers are prone to making decisions that reduce uncertainty, therefore professionals in this industry usually do not select new ideas, they prefer to use conventional processes instead of investing time and resources on well-structured decision making methodologies (Garvin & Ford, 2012).

However another three main elements were identified as common deficiencies. Managers in this industry are loyal to the first budget made; they don’t refresh values, so budgets that could initially lead to successful projects, prove not to be profitable once execution begins (Piedrahita, 2010). Another critical element that must be considered for determining the prices and consequently the success of any housing project is sales speed as this implies loan costs from the early phases if the project is not sold rapidly (Velasco, 2012). Finally, the

lack of a defined methodology for time control and analysis of work planned vs. work performed leads to cost control failures when deciding which strategy should be implemented to finish with the initial budget (Lucero, 2008).

3.3 Maturity level

In addition to process definition, several attempts have been made to analyse the state and the culture of an organization's risk management capabilities. RM3 (Risk Management Maturity Model) was a tool created to develop a maturity assessment model, in which 5 main attributes were identified: Management, Risk Culture, Ability to identify risk, Ability to analyse risk and Application of standardized risk management system (Zou, Chen, & Chan, 2010)

In order to be in the highest level or maturity of risk management according to Zou et al. (2010) the company must: Continuously improve to maintain mature in risk management capabilities, ensure continued commitment by upper management and perform regular reviews of processes and techniques to guarantee the quality of risk management applications and practices. Other practices include investing in improving risk processes, identification techniques, risk analysis tools, employee skills and provide regular training to employees to maintain high levels of knowledge and skills.

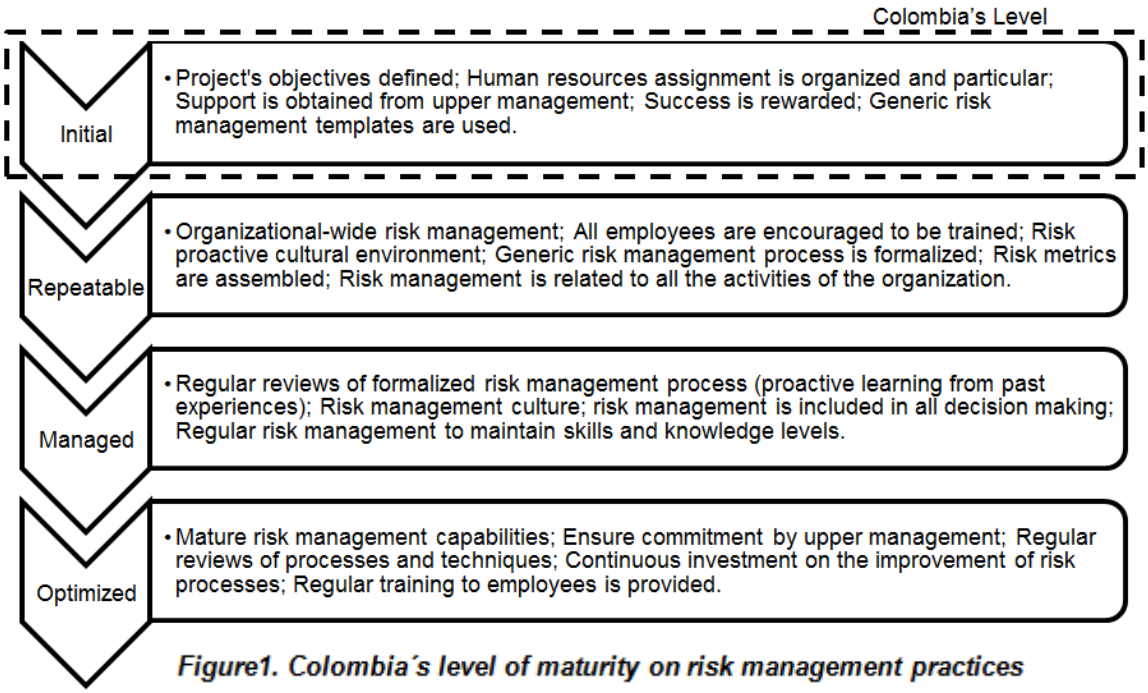

Figure1. Colombia´s level of maturity on risk management practices

According to these parameters, the Colombian AEC companies analysed are in the lowest phase of development, the main characteristics described in the case studies highlight the involvement of the upper management and their attempts to create a generic risk management process. Nevertheless, very low levels of training within the employees are identified and, as mentioned above, there is a huge failure in terms of documentation and even conceptual definition of the projects. Figure 1 summarizes the level of risk management in Colombia based on Zou et Al. (2010) levels.

4. BIM

BIM (Building Integrated Modeling) has been defined as one of the worldwide predominant trends to manage projects in the AEC industry. It is a representation of projects that changes the conventional 2D CAD model into an nD model that, instead of representing elements as lines, describes a series of objects with attributes (materials, team leaders, cost, etc.) that allows a better visualization and, therefore, avoids clashes between various systems (Eastman, Teicholz, Sacks, & Liston, 2011).

The main advantages of implementing this model are the reduction of industry fragmentation, improvement of efficiency, lowering of the high costs of inadequate interoperability, design support throughout the phases, project control throughout its life cycle, and regulation of the project team providing a well-defined mechanism to identify changes in roles and relationships (Succar, 2009).

Consequently the whole project is of better quality, lower costs and shorter durations, which can be understood as improvements in terms of knowledge and cost management, treated previously in this document.

4.1.1 Local Literature review

On Colombian companies, BIM is not a common trend, although among the studies included in the research methodology, two companies had already begun the process of implementing BIM as their modeling strategy for projects. According to Sánchez & Valencia (2011), the main barriers found in this process are the initial cost of acquiring the software, training personnel, technical support and the cultural change of modifying the standard process that has been used for a long time.

One of the companies analyzed had already begun this process, but the whole concept of implementing this technology was understood as the acquisition of the basic software and basic training. Only a few designers from different areas of expertise were instructed and, mounting the whole project in BIM has turned into the responsibility of those few, meaning that the work kept being fragmented (Iguarán, 2010). The second company that uses BIM technology began to do so because its main contractor demanded this technology as the standard for planning and developing their projects, therefore this process and the better practices were basically obligatory if they were going to stay in the business (Isaza, 2008). Although, the analysis proved that the technology was not being completely exploited and the main improvements that BIM assures were not being accomplished, a huge and recurrent mistake is that companies do not have the level of detail required to take advantage of the program and the model is only being used during the design phase. Therefore, the improvements in terms of the whole process and results are very limited (Castañeda, 2009).

4.2 Maturity level

Based on the maturity stages of BIM proposed by Succar (2009), it was found that the companies studied in the theses included in the literature review, are divided into two levels; Pre-BIM status and Object based modeling synopsis. The former is the basic stage in which project documentation is 2D, quantities and costs are not related to the model or documentation, work flow is linear and asynchronous and there is a low investment in technology and lack of interoperability. The object based modeling synopsis is characterized by single-disciplinary models, a lack of collaborative philosophy and disjointed communications. In order to get to the Integrated Project Delivery (IPD) level, which is the highest, coordination, communication, decision support, and other work processes enabled by integration of data in all directions must be implemented and standardized. Figure 2 locates the Colombian level of maturity regarding BIM based on Succar (2009) maturity

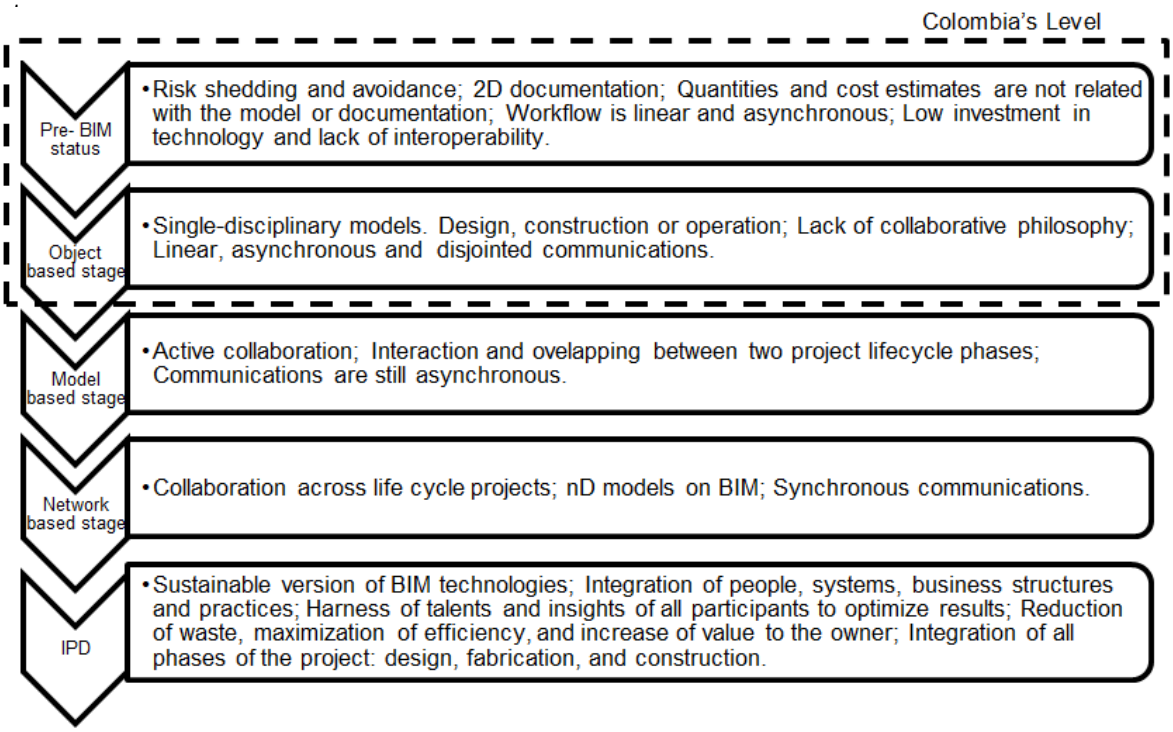

Figure2. Colombia´s level of maturity on BIM practices

5. Conclusions

Most of the documents reviewed in this paper, studied individual cases related to specific areas of project management regarding practices among small and mid-sized companies. Nevertheless, other studies have been made to define the process of implementing managerial techniques among most relevant companies in the industry; as detailed studies of practices implemented by leader companies on innovation, planning and management. It is worth to mention that an effort is being made to spread and implement better practices among agents involved in this industry, and big companies have proven to comprehend them.

As described above, it is evident that the mid and small sized Colombian AEC industry companies present very low grades of development according to the scales established

internationally with respect to risk management, knowledge management and BIM implementation. Therefore, a well-defined strategy must be employed to reduce the main deficiencies present, and improve the poor rates of success that are present on the execution of Colombian projects. Among the malpractices that should be highlighted, are the inner and outer fragmentations present within companies that hinder integration, knowledge management and the constant learning process that leads to the implementation of better practices.

According to the studies analysed, the most common risks present in the Colombian AEC industry are related mainly to planning and financial failures. In order to mitigate planning risks, a better-established process for approving construction licenses must be developed with the intention of reducing the adversities present during construction and encourage better planning phases for projects. The definition and standardization of the approval parameters is suggested as future work for the local planning authorities, which surely will ensure better success rates on public and private projects.

Insofar as financial failures, international trends such as real option evaluation and Net Present Value sensibility analysis of the most important materials that determine the viability of projects must be made.

The advantages of BIM were continuously cited as present failures of the AEC industry, consequently the implementation of this technology can be identified as one of the most feasible options to improve industry results. Although it was also observed that some of the requirements for implementing BIM, such as transparency, process efficiency and new decision making procedures, made the process particularly challenging for some actors in the supply chain.

The impacts and requirements of implementing a contractual methodology to overcome these difficulties and boost positive results via demanding the use of BIM for participating on public and private biddings are suggested as a future work.

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