Case studies using new methodology for company-oriented BIM training

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Abstract
Recent surveys show that Brazilian professionals are over-optimistic on BIM use. The above premise was based on several obstacles pointed by the authors: use of the BIM word as the acronym for a 3D design tool, lack of skilled professionals, and insufficient BIM-related content at Universities. The authors identified the need to create a new type of BIM training for enterprises. It was structured so that BIM is understood as a five-objective working system: collaborative process, technology, means of communication, understanding of real construction problems, and multiple uses. The training is supported by the synergy between theory and practice, with use of various software, stimulating experimentation, group research, and team collaboration. This training was applied to two teams: the first one from a construction company, and the other from an architectural firm, both in São Paulo. Using the action research methodology, the content was adjusted according to the student feedback. The results encouraged the continuation and improvement of the program.

Keywords: BIM training, BIM teaching

1 Introduction

There are many Brazilian AEC companies who are trying to adopt BIM on their working process. Behind those initiatives one can perceive different philosophies on implementation strategies, technological approaches, and action plans. Those attempts are motivated by the intention of learning more about BIM and making the company more competitive. There is no consensus about the best way to adopt BIM. The need for a standard method, which should be used as a single reference for any kind of BIM implementation strategy (so that it would be possible to compare efficiency gains on BIM skills on two completely different companies, as an example), is perceived as a goal by academics and companies. To complete this scenario, a recent research (McGrawHill-Construction 2014) indicates that Brazilian professionals are over-optimistic about their BIM skills, which is a sign that they lack important knowledge about what it means to effectively implement BIM.

The finding of unrealistic optimism is borne out by a recent official report of the Ministry of Planning (Kassem & Amorim 2014b), which brings important considerations about the current stage of BIM implementation in Brazil and contradicts the information published by McGraw-Hill survey mentioned above. The report surveyed 282 heads of construction companies and projects. Among the various data gathered by the survey, it points out that 46% of the executives experience BIM for less than three years; only 24% of the actions taken by organizations focus on training, while 70% are marketing-related. All these data indicate that the adoption of BIM is at a lower level than meets the eye. Regarding the importance of BIM, 70% of the executives are aware of its role as a main instrument of change; however, the extent and maturity in BIM process are still low, as only six responses indicate that there is some kind of internal documentation on the subject in their respective companies.

BIM Academic research has grown in recent years as (Kassem & Amorim 2014c) and (Barison 2015), but the education is still restricted to a few Brazilian universities. Most of the pioneering institutions

still mistake the teaching of BIM for teaching tools such as Revit, ArchiCAD, and others. In this way, they end up addressing almost exclusively the use of the software, focusing too little on changes in work processes. In most cases, BIM teaching is restricted to only one course, isolated and disconnected from other subjects. We note that this occurs, so far, due to lack of common understanding from educators, professionals and industry players about which contents, principles and methods should be used to include BIM in an effective way in the curriculum of universities. Thus, most of the companies in the segment that tend to follow the discussions and Academy studies often end up not properly understanding the magnitude of the impact of adopting BIM; in general, they see it as a mere problem of replacing 2D CAD platforms.

2 Goals

One of the great barriers to industry growth is the lack of people with skills and knowledge in BIM. (Fox & Hietanen 2007) state that the development of such skills is very important to promote BIM in companies; the less understanding there is on the subject, the greater the obstacles. From this scenario, the authors identified the demand for a new method for BIM training and implementation in companies, which is the purpose of this article.

3 Literature Review

According to (Hartmann & Fischer 2008), participants from the most diverse fields of AEC, which met in a major event held in Israel in order to discuss the BIM teaching, considered "the lack of knowledgeable practitioners who are ready to move the industry into the BIM age as a major bottleneck."

(Barison 2015) notes that the BIM is not yet being introduced broadly in curricula of Architecture and Urbanism and Civil Engineering at Brazilian universities; also states that companies do not have adequately trained human resources to work in BIM projects.

Even in countries with high adoption of BIM, such as Finland, the education of architects and engineers is still based on the old methods of drawing and not in modeling, which is recognized as a barrier to the adoption of BIM in the industry AEC as (Kiviniemi 2006).

(Barison 2015) researched BIM teaching in 103 universities, 75 in the United States, and noted different teaching strategies: the first focuses on offering a **specialized discipline** that lends itself well for a first contact with tools and for the understanding of technical concepts of BIM. This form can also occur through the incorporation of new content into existing disciplines. The second strategy, **collaboration between courses**, is a model that allows teaching how to create, develop and analyze BIM models, or teaching more subjective BIM concepts; also allows you to simulate the collaborative development of a project, but always with students in the same course, for example, Civil Engineering or Architecture. The third strategy is identified as **remote collaboration between students from different universities**. In this model, students of two or more universities interact and are exposed to situations and typical technologies of remote collaboration, increasingly important in the current globalization scenario. (Barison 2015) concludes that the BIM is being adopted gradually, but most schools are still struggling to understand what and how to teach.

(Sacks & Pikas 2013) prepared a comprehensive study of the state of the art related to BIM education, in order to test a comprehensive approach to teach BIM as part of university-level education in construction engineering and management.

The authors found that new teaching methods are emerging. (Sacks & Barak 2009) (Taylor et al 2008) have developed methodologies that enable BIM teaching for freshman and sophomore engineering students, with an emphasis on graphic communication or information technology disciplines for construction, between efforts to development of specific skills of modeling and basic analysis.

(Peterson et al 2011) show that the introduction of BIM-based project management tools helped the teachers of two courses to develop more realistic project-based class assignments that supported students with learning how to apply different formal project management methods to real-world project management problems.

(Boon & Prigg 2011) recommend that BIM can be understood as a teaching aid tool for educators to advance beyond traditional lectures. BIM can help students understand the complexity of the projects from the point of view of product and process. This is because BIM learning is a visual

(students need visual aids) and kinesthetic (learning by doing) experience, instead of a classic teaching one, based on speech and listening. The International BIM Education Workshop, held in June 2011 at the Technion - Israel Institute of Technology (Technion-ITT), according to (Sacks and Pikas 2013), has defined the following main issues: to define desired BIM competency levels (understanding and skills) for graduate architects and engineers as well as for postgraduate and continuing education; to define specific learning targets as a foundation for achieving competency; to develop candidate course outlines and curricula, and to define criteria for evaluating courses. The main conclusions of this meeting emphasized that:

> […] the understanding that BIM is a holistic process/tool that must be introduced into AEC curricula in a systematic fashion. Derived from that, BIM should be introduced into already existing courses and projects as well as taught as a standalone course. Each educational institution will need to decide where and how to incorporate BIM components, considering their unique context, policies, and strategies. Another conclusion was that there are several teaching methods that can be used for BIM education: immersed in existing courses, as standalone courses, or integrated in students' project work.

In a survey that sought to capture the perception of BIM senior professionals BCE (Teicholz & Sacks 2011), in a post on LinkedIn, launched the following questions: what is your opinion on the appropriate content for education in BIM? What skills do you look for in BIM Architects and Engineers? Should / can education in BIM take the place of technical drawing courses? Can education in BIM be used to improve interdisciplinary collaboration skills?

The discussion generated some consensus: one about the need for a balance between teaching the basics of design and construction using BIM and, on the other hand, teaching the use of software tools. Another point mentioned is that education in BIM should emphasize the understanding of this as a means and not an end in itself. An important consensus was that BIM learning depends heavily on the experience of the individual, since the parametric models mimic the real world, though still represent an idealized view of the same and in many situations will not match the virtual representation with real-world situations. This last point reinforces the need for **experience** and **maturity** to develop skills in BIM in organizations.

According to the experiments described above, and also in accordance with (Ozer 2004)[1], the authors found that many of the techniques based on constructivist learning theory are suitable for the development of educational processes related to BIM.

> Constructivism is a new approach in education that claims humans are better able to understand the information they have constructed by themselves. According to constructivist theories, learning is a social advancement that involves language, real world situations, and interaction and collaboration among learners. The learners are considered to be central in the learning process. Learning is affected by our prejudices, experiences, the time in which we live, and both physical and mental maturity. When motivated, the learner exercises his will, determination, and action to gather selective information, convert it, formulate hypotheses, test these suppositions via applications, interactions or experiences, and to draw verifiable conclusions. Constructivism transforms today's classrooms into a knowledge-construction site where information is absorbed and knowledge is built by the learner (Ozer 2004b).

4 BIM teaching methodology

The discussions by (Teicholz & Sacks 2011) led to the synthesis of some principles that were adopted for the creation of the proposed training program: BIM is a technology, a means of communication, a collaborative process, requires the understanding of construction in the real world and can cater for multiple perspectives and uses. Another guideline of the program is support the BIM education under the managerial point of view, leaving the learning of tools for a next step. Figure 1 illustrates this principle.

[1] The author states that the main theorists of education, as Piaget and Vygotsky, advocate the use of constructivism as a teaching methodological support.

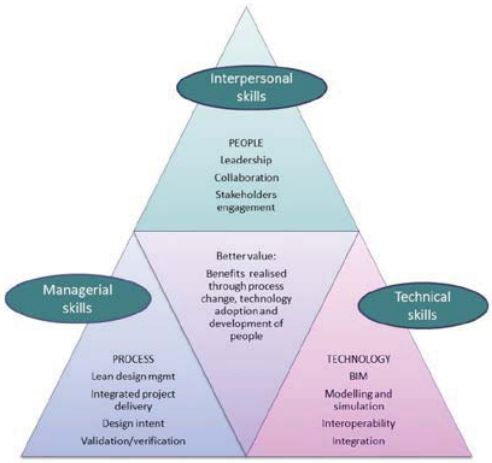


Figure 1 Managerial skills to be developed in training program

The program consists of four steps: diagnosis, 48-hour training, in modeling tools and analysis models and quarterly audit. The diagnosis is the beginning of the process, where the company is studied with the intention of observing its operation, its main characteristics and problems, so there is a correct understanding of the expectations on the objectives and uses of BIM there. It is a process of interviews and observations that also aims to commit the owner and directors to the implementation process.

The 48-hour program is divided into 16 sessions of 3 hours (Table 1). The training is strongly supported by the synergy between theory and practice, with intensive use of various software, stimulating experimentation, group research, and team collaboration with the application of serious games and learning-by-doing strategies, which develop logical reasoning and reinforce the idea of BIM as collaborative work system. It focuses on the application of these concepts to promote changes in work processes, so that technical, interpersonal and management skills can be developed in the team.

Table 1 Details of the training program in BIM

Class	Theme	Topics/Activities	Software / Resources
1	Introduction	What is BIM? Benefits and challenges. Why does BIM have a big impact on the AEC industry? Which aspects of the construction activity are affected? Uses and applications.	Quiz
2	Introduction	Playful exercise for understanding the limitations of conventional methods of representation of projects	Lego game, using real pieces, and Lego Digital Designer software.
3	Technology	BIM tools and parametric models. Historical overview. Restrictions and rules that define the behavior of objects. Use of IT in AEC when compared with other sectors.	Quiz
4	Technology	CAD/BIM History. Overview of the main BIM modeling tools, skills, and limitations.	ArchiCAD, AECOsim, Vectorworks, SketchUp, Revit
5	Collaborative process	What kind of information each agent should provide in the collaboration domain. Interoperability - IFC	Quiz
6	Collaborative process	Collaborative exercise that simulates the relationships among the various design disciplines.	ArchiCAD Teamwork, Tekla BIM Sight, BIM Collaboration Format. BIM Collab Kubus.
7	Means of communication	BIM sharing platforms. Classification systems for information. Information repository central database.	Quiz
8	Means of communication	Tools for communication between partners and teams. Data repositories and their characteristics.	Dropbox, Google Drive, BIMsync, Trimble Connect

9	Collaborative Process Management	Management model of the collaborative design process. Compatibility.	Technion Leapcon Game (Figure 2)
10	Collaborative Process Management	Analyses using rules (accessibility, escape routes, legislation parameters, simulation project approval). Simulations (energy, sustainability, etc.).Level of detail and level of development of the model. Testing a workflow that begins in the feasibility study, through model checking using rules, sustainability, ending in matching design.	Solibri Model Checker, Revit.
11	Budget and Planning	Feasibility and preliminary studies. Classification of costs. Quantitative takeoff. 4D planning.	Quiz
12	Budget and Planning	Exercise to generate budgets and virtual simulation of 4D construction.	DProfiler, SketchUp, bim.bon, 4D Virtual Builder, Microsoft Project.
13	Construction management and facilities	Supervision of measurements and other items in a construction project. Quality control. Usage of mobile devices (cell phones, tablets, drones). As-built. Laser scanning. Facilities Management.	
14	Virtual and augmented reality.	Augmented reality usage, 3D Point Cloud experiences, and facilities management and quality control using BIM models	Trimble Scan Explorer, iVisit, AR-Media, Dalux QA
15	Implementation in companies	Obstacles in the implementation of BIM. Maturity and Capacity levels of the use of BIM by companies. New forms of contracts (includes IPD), ROI, benefits, changes in practice. Selection and evaluation of tools, processes and /or BIM technologies.	Debate
16	Implementation in companies	Exercise: development of a BIM implementation plan for the company.	Final exam

Figure 2 Company "A" training, using the Technion Leapcon Game

5 Case studies

The course was attended by two companies: a construction firm (which will be called Company A) and an architectural firm (Company B). In both cases, the training content was adjusted, from the backbone shown in Table 1, according to the feedback given by the students, following the methodology of action-research. Both companies had an incorrect perception about BIM, and at the end of each training, there was clear evolution in the understanding of the theme, as the teams were successful in evaluating their work processes in order to develop a BIM implementation plan according to their needs and purposes. However, this occurred in a very different way for each company, as demonstrated below.

5.1 Company A

Company A is a medium-sized construction company that operates in many cities of São Paulo building high-standard residential and commercial developments. Their initial goal concerning BIM was to obtain quantitative surveys of projects to improve the assertiveness in budget planning. The company has well-defined and documented work processes, however oriented to practices defined by

(Succar 2010) as "Pre-BIM." Before the training, the company had undergone an unsuccessful experience with what it was thought to be the BIM: they bought a 3D model of one of their projects, which had not reached sufficient maturity (Manzione 2013). The model had many errors (geometric and non-geometric) and contained several elements that were incompatible to construction standards. It was a frustrating experience, so they decided to abandon any kind of BIM initiative. With the entry of a new collaborator, a scholar in BIM, the company decided to return to the subject, hiring the authors of this article.

The group of students was very heterogeneous, composed by one of the managing partners, the chief engineer, and those responsible for planning, costs, budget and projects. Early in training the team demonstrated to have understood BIM as an agent of change in all its work processes, and this was crucial to create a successful BIM implementation plan with clear goals to run at a horizon of six months. Following the methodological approach of training, the feedback given by the students (related to their own learning about BIM), the teachers opted to create the BIM Implementation Model Canvas (BIM-IMC, Figure 4), which is based on the business model canvas (Osterwalder & Pigneur 2010) and studies (Succar 2010b). Figure 5 shows the group of students developing the Canvas.

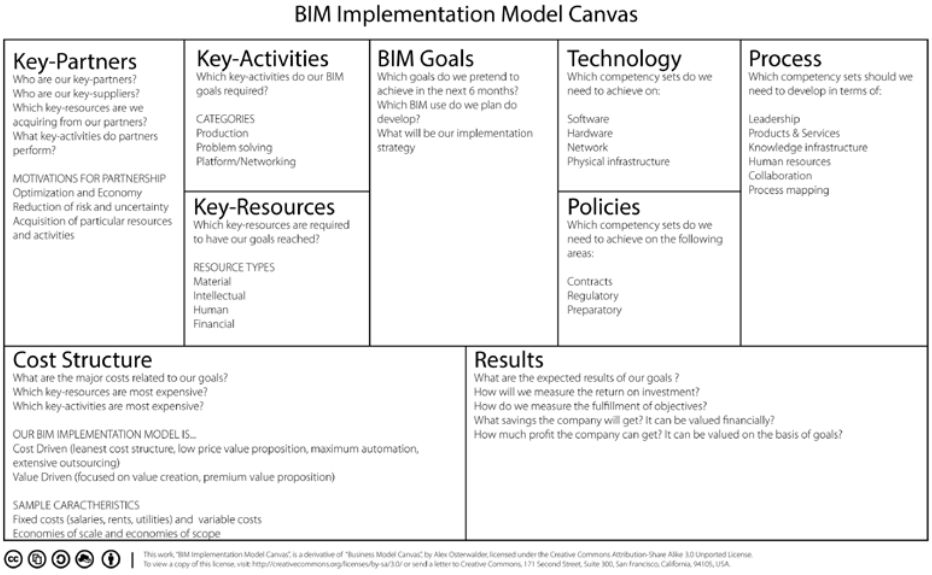


Figure 4 BIM Implementation Model Canvas

Figure 5 Company A doing the assembly of the BIM implementation plan

After training in BIM (and following the guidelines of its own implementation plan), the company decided to study changes in old processes used for modeling, sequencing and quantitative works in customizing the apartments, using "SketchUp" and "4D Virtual Builder ". The group was divided in four pairs, and each one aimed to model an apartment-type to test the method and the proposed software. The first review meeting of the new process, which took place three months after the training, the teams demonstrated progress regarding the understanding of how process modeling in BIM should be structured, as shown in Figure 6.

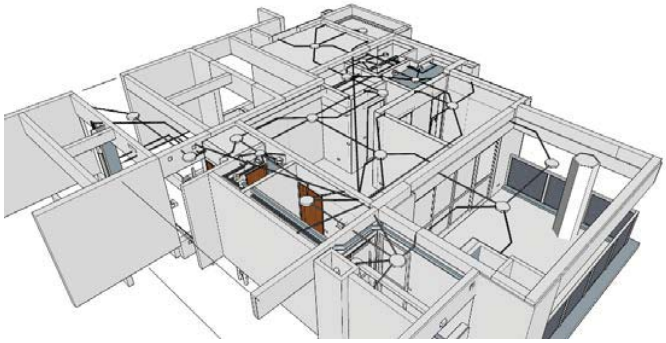
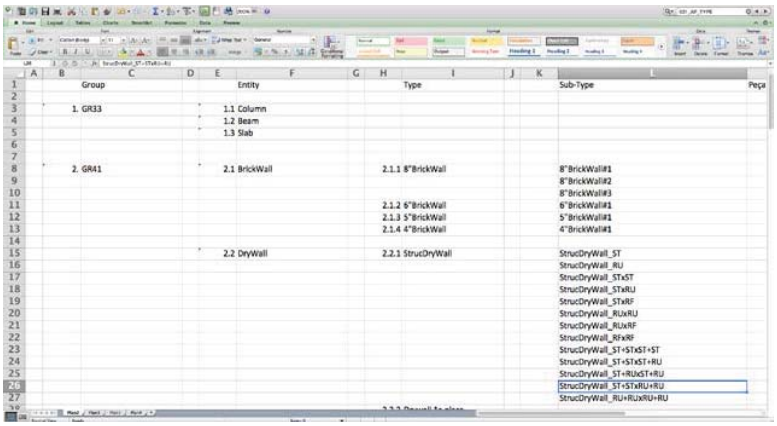


Figure 6 Apartment model produced by Company A, as part of the pilot project that began after the training program in BIM

Figure 7 shows an Excel spreadsheet with the organizational structure of the model created by the team before the first review meeting.



	Group	Entity	Type	Sub-Type
3	1. GR33	1.1 Column		
4		1.2 Beam		
5		1.3 Slab		
8	2. GR41	2.1 BrickWall	2.1.1 8"BrickWall	8"BrickWall#1
9				8"BrickWall#2
10				8"BrickWall#3
11			2.1.2 6"BrickWall	6"BrickWall#1
12			2.1.3 5"BrickWall	5"BrickWall#1
13			2.1.4 4"BrickWall	4"BrickWall#1
15		2.2 DryWall	2.2.1 StrucDryWall	StrucDryWall_ST
16				StrucDryWall_RU
17				StrucDryWall_STxST
18				StrucDryWall_STxRU
19				StrucDryWall_STxRF
20				StrucDryWall_RUxRU
21				StrucDryWall_RUxRF
22				StrucDryWall_RFxRF
23				StrucDryWall_ST+STxST+ST
24				StrucDryWall_ST+STxST+RU
25				StrucDryWall_ST+RUxST+RU
26				StrucDryWall_ST+STxRU+RU
27				StrucDryWall_RU+RUxRU+RU

Figure 7 Table with the structure that supports the modeling, developed by the team of Company A, before the first meeting to review the use of SketchUp software

On the left, Figure 8 shows the structure created in Excel, reproduced within the SketchUp model file. It is possible to observe that the design elements are classified, but the file structure is not hierarchically mature. At the end of the meeting, the team reached the modeling structure shown on the right side by Figure 9, which is very close to the IFC standard structure.

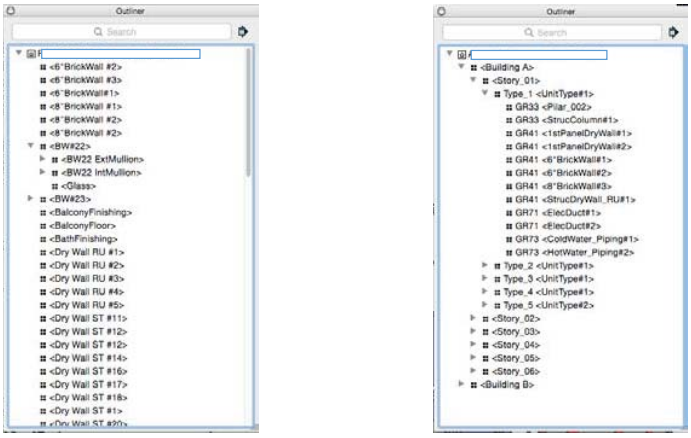
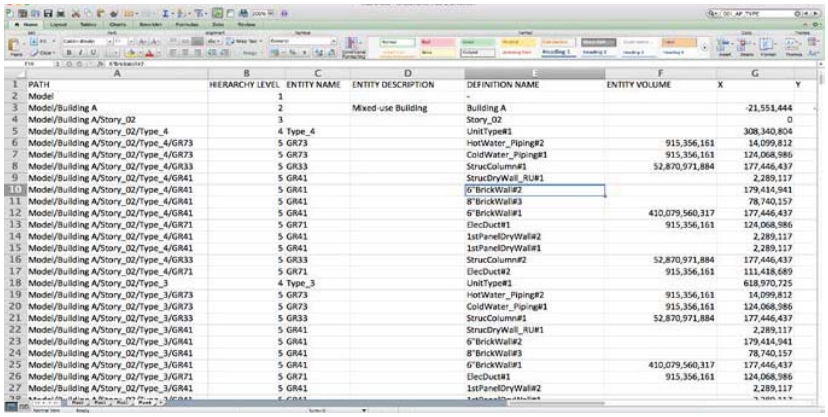


Figure 8 To the left, a structure that supports the modeling in SketchUp, developed by the team of Company A, before the first meeting to review the use of the software. On the right, the revised file structure.

Figure 9 shows that, with the framework developed by the team, the export of SketchUp report to Excel already display all the information in an organized fashion. In this sense, the team showed maturity in relation to the understanding of BIM. At a future meeting,, the aspects related to the plugin 4D Virtual Builder will be reviewed, which will be used to guide the work of staff and the assembly of customized apartments should be made.



	A	B	C	D	E	F	G
1	PATH	HIERARCHY LEVEL	ENTITY NAME	ENTITY DESCRIPTION	DEFINITION NAME	ENTITY VOLUME	X	Y
2	Model	1			-			
3	Model/Building A	2		Mixed-use Building	Building A		-21,551,444	
4	Model/Building A/Story_02	3			Story_02		0	
5	Model/Building A/Story_02/Type_4	4	Type_4		UnitType#1		308,340,804	
6	Model/Building A/Story_02/Type_4/GR73	5	GR73		HotWater_Piping#2	915,356,161	14,099,812	
7	Model/Building A/Story_02/Type_4/GR73	5	GR73		ColdWater_Piping#1	915,356,161	124,068,986	
8	Model/Building A/Story_02/Type_4/GR33	5	GR33		StrucColumn#1	52,870,971,884	177,446,437	
9	Model/Building A/Story_02/Type_4/GR41	5	GR41		StrucDryWall_RU#1		2,289,117	
10	Model/Building A/Story_02/Type_4/GR41	5	GR41		6"BrickWall#2		179,414,941	
11	Model/Building A/Story_02/Type_4/GR41	5	GR41		8"BrickWall#3		78,740,157	
12	Model/Building A/Story_02/Type_4/GR41	5	GR41		6"BrickWall#1	410,079,560,317	177,446,437	
13	Model/Building A/Story_02/Type_4/GR71	5	GR71		ElecDuct#1	915,356,161	124,068,986	
14	Model/Building A/Story_02/Type_4/GR41	5	GR41		1stPanelDryWall#2		2,289,117	
15	Model/Building A/Story_02/Type_4/GR41	5	GR41		1stPanelDryWall#1		2,289,117	
16	Model/Building A/Story_02/Type_4/GR33	5	GR33		StrucColumn#2	52,870,971,884	177,446,437	
17	Model/Building A/Story_02/Type_4/GR71	5	GR71		ElecDuct#2	915,356,161	111,418,689	
18	Model/Building A/Story_02/Type_3	4	Type_3		UnitType#1		618,970,725	
19	Model/Building A/Story_02/Type_3/GR73	5	GR73		HotWater_Piping#2	915,356,161	14,099,812	
20	Model/Building A/Story_02/Type_3/GR73	5	GR73		ColdWater_Piping#1	915,356,161	124,068,986	
21	Model/Building A/Story_02/Type_3/GR33	5	GR33		StrucColumn#1	52,870,971,884	177,446,437	
22	Model/Building A/Story_02/Type_3/GR41	5	GR41		StrucDryWall_RU#1		2,289,117	
23	Model/Building A/Story_02/Type_3/GR41	5	GR41		6"BrickWall#2		179,414,941	
24	Model/Building A/Story_02/Type_3/GR41	5	GR41		8"BrickWall#3		78,740,157	
25	Model/Building A/Story_02/Type_3/GR41	5	GR41		6"BrickWall#1	410,079,560,317	177,446,437	
26	Model/Building A/Story_02/Type_3/GR71	5	GR71		ElecDuct#1	915,356,161	124,068,986	
27	Model/Building A/Story_02/Type_3/GR41	5	GR41		1stPanelDryWall#2		2,289,117	

Figure 9 Table with the structure that supports the modeling information, exported from SketchUp, developed after the first review meeting.

5.2 Company B

Company B is an architectural firm with approximately 30 employees (with offices in São Paulo and Rio de Janeiro), which designs residential and commercial buildings of the highest standard, to the luxury market in Brazil. For many years, the company has been making use of an inappropriate design process, based primarily on AutoCAD, however, depending on employee skills and/or design stage, SketchUp, ArchiCAD, and Revit are also used. Aiming to switch to using only one program throughout the process, the company sought one of the authors of the article for ArchiCAD training. However, after the first meeting with the team, it was clear there was the need for specific training on BIM, without which the implementation of the software at a later stage could present a high risk of failure.

Therefore, the trained group was composed by the chief architect, who is the managing partner, an executive who is responsible for the administration and the company's finances, and five architects who act as co-authors of the projects and coordinators of the design teams. Both the chief architect and the administrator had no knowledge on design software; the architects had good command over AutoCAD, and some had basic skills in ArchiCAD and SketchUp. For this group (as per their

requirement), the training had some of the classes suppressed, and the focus was to promote understanding of BIM related to changes in design processes, which was found by the researchers as the weakest point of the company, because the group was not able to understand the importance of having a well-defined and documented work process to maintain the quality of the project and its deliverables.

During the training, the team proved to be very interested, but very tough to take on the responsibility regarding the promotion of changes related to BIM, which are fundamental to the improvement of its processes (as opposed to company A). The reluctance of the staff to take on its role in the new process was quite large (except for the chief architect, who was the one that best understood the importance of the changes).Consequently, an extra lesson was necessary so the group concluded their BIM implementation project. Only at the end of the training, the team had eventually understood that the correct implementation of a BIM modeling software would positively impact on all office areas, with the commitment of all, especially the members of this team (Figure 10).

Figure 10 Company B discussing the BIM implementation plan

This training was completed in May 2015 and the first ArchiCAD classes, software chosen by the team itself, with no influence from the researchers whatsoever, started in July 2015 (with the participation of the chief architect, the administrator and all the coordinators), according to the implementation plan schedule designed by the company.

6 Conclusion

The increasing widespread use of BIM technology shows that a new paradigm for collaborative work on project needs to be created. In different countries and situations, we can see many barriers to be overcome for the full exploitation of the benefits of BIM. There is little knowledge about how this new technology can be integrated into design processes in a beneficial way. There is no comprehensive understanding of the non-technological factors (regarding the interaction between business partners and designers of different disciplines) that can occur at the intersection of project management process and BIM. In this context, the shortage of theories to teach and to encourage integration between the field of design process management and BIM motivated the development of this article. The use of the proposed methodology as a structural framework has been proved effective for both case studies. However, there will always be a fine tune of the BIM teaching strategy and its subsequent implementation, which will vary depending on the needs and scope planned for the company's business improvement. The main features of teaching strategy and the implementation of BIM are properly clarified after the diagnosis phase. Later, during the classes, the strategy is redesigned according to the results, where the maturity degree of existing people and processes in the company are being explained to teachers by a feedback mechanism. In both cases, the program respected the current limitations of the companies, and enabled the creation of implementation plans, supervised by teachers, which meant that there was an increased commitment and understanding from the part of the team members.. We therefore support that the BIM approach as process must happen before any specific training on modeling tools. In the case of Company A, with no experience in

modeling, but with a very adherent training, it was observed that, with a relatively rapid training, professionals have learned the basics of BIM very easily and without resistance. On the other hand, Company B, which already had some knowledge of modeling software, showed a much higher resistance, which was only broken after insistent questions about the nature of the current process, and the realization of the need for an adjustment, involving all actors and not only the operational team. Two different companies had positive results with the application of the method, which reinforces the need for its improvement, and reaffirms the conviction of the authors that an appropriate methodology teaches students to think BIM, while a simple training in modeling tools only teaches students how to model.

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