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PROJECT MANAGEMENT AFTER THE BIM INTRODUCTION: PARADIGM SHIFT OR REITERATION?

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Abstract: By the early 2000s, the practical usage of Building Information Modelling (BIM) in the American construction sector was pu181shed by the US General Services Administration (GSA). Since then, BIM usage has been growing all over the world and several new possibilities regarding processes integration are emerging, as well as construction productivity enhancement. As a result, it is generally believed that the practices in project management could have been thoroughly transformed. Therefore, project management academics and professionals that have been working with traditional practices wonder how BIM changes their roles and the pre-existing methods for construction projects. Despite the 20 years of progression in BIM implementation, usage and the unquestionable results, it is still not clear how it is affecting project management and changing the roles in construction projects. Based on a survey with construction professionals and academicians, this paper discusses the effect of BIM over the processes, pre-existing methods and responsibilities, thus contributing to the understanding of what has truly changed and what remains the same in the field of construction project management during the transition from CAD (Computer-aided design) to BIM. Additionally, it contributes to the understanding on how the management professionals deal with the digital transformation regarding construction management, contracts, communication, professional roles, and collaboration.

Keywords: Construction, project management, engineering education, building information Modelling, management innovation.

1 INTRODUCTION

Eastman et al. (2011) describes how BIM (Building Information Modelling) emerged from intense industrial development and university researches in the 1980s. However, the practical introduction of BIM tools in the construction sector was pushed by the US GSA only in the beginning of the 2000s. The major difference between CAD (Computer-aided design) and BIM systems is that the latter allows the representation of more than just the geometry of an element in a building, integrating information to the model as well. Thus, these are object-based parametric tools where there is an input of a set of relations and rules to stablish geometric features and properties, through the parameters, model families and the hierarchy of parameters.

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Consequently, it seems to be an evolution of design, plan and representation, but would the transition from CAD to BIM be similar to what happened from paper drawings to CAD? When CAD emerged, there was a lot of ideas and insights for its usage, for instance 4D planning integrating schedule-related information (Mckinney et al. 1996; Zhou et al. 2009), virtual reality to enhance visualization of models (Dunston et al. 2003; Whyte et al. 2000) and collaboration design (Rosenman and Wang, 2001). Conversely, nowadays CAD is mainly used for 2D plan drawing and detailing, whereas schedule planning is not combined to it, for example. Therefore, even though BIM has a considerable potential for design and construction integration, planning, cost estimation, sustainability planning and facilities management, all these capabilities idealizations may not be feasible.

Despite that, BIM implementation is increasingly growing worldwide according to Chew and Riley (2013), McGraw Hill Construction (2014), Gledson (2015), Edirisinghe and London (2015), Madeira Filho (2016) and Null (2018). On the other hand, numerous bibliographies also report the difficulties that companies and professionals face when they try to integrate BIM in their work routines, regarding interoperability (Wu and Zhang 2019; Karan and Irizarry, 2015; Arayici et al. 2018; Muller et al. 2017), intellectual property and copyright rights (Porwal and Hewage 2013; Madeira Filho 2017), contractual inadequacies (Porwal and Hewage 2013; Madeira Filho 2017), unclear roles and responsibilities with the advent of BIM (Porwal and Hewage 2013), incorrect usage of BIM tools (Madeira Filho 2017) and imperfect data file with the potential to contain errors, omissions, conflicts, inconsistencies and other inaccuracies (Madeira Filho 2017).

The report from McGraw Hill Construction (2014) shows that BIM return of investment increases directly with a contractor's level of BIM engagement, represented by its BIM experience, skill level and commitment to doing a high percentage of its work in BIM. Therefore, it is clear that the AEC (Architecture, Engineering & Construction) industry is striving to innovate, but at the same time education, procurement techniques, construction laws and contractual arrangements are not following the same path nor the same pace of change. Additionally, these difficulties faced make it hard to have an effective construction project management with BIM, since there are so many challenges to overcome in the project processes, like communication and collaboration, which are not only technical issues but mainly socially and culturally driven.

2 Literature Review

The first commercial applications of three-dimensional computer-aided design (3D CAD) were in large companies within the automotive and aerospace industries, as well as in electronics in the 1970s. Moreover, since the 1980s the construction sector adopted it mainly as a two-dimensional tool, the CAD advent gradually changed the design process and professional roles, even if its impact in the construction site would not be considered as significant.

Further, in the 1990s the use of 3D CAD and the introduction of parametric Modelling appeared to be a promise of better connection between construction design and constructability issues. However, only in the 2000's when the BIM technology started to be adopted by the construction sector, the use of 3D representation started to be considered as a significant contribution, mainly because of the possibility to integrate information to the geometry.

According to the Report of the World Economic Forum (2016): "The industry has vast potential, however, for improving productivity and efficiency, thanks to digitalization, innovative technologies and new construction techniques. Consider the rapid emergence of augmented reality, drones, 3D scanning and printing, BIM, autonomous equipment and advanced building materials – all of them have now reached market maturity. By adopting and exploiting these innovations, companies will boost productivity, streamline their project management and procedures, and enhance quality and safety. To capture all this potential will require a committed and concerted effort by the industry across many aspects, from technology, operations and strategy to personnel and regulation."

The above cited also reports that: "the benefits of BIM are reinforced if companies exploit the new ancillary opportunities it offers – notably, a new way of collaborating and sharing information between stakeholders. Large productivity improvements can be achieved by optimizing existing processes: the broader use of "lean" principles and methods, for instance, could reduce completion times by 30% and cut costs by 15%. Another core lever is early project planning. To improve such planning, companies should promptly draw on the knowledge of all stakeholders, and should explore new contracting models."

The research of Doan et al. (2019) aimed to identify the elements potentially impacting on BIM adoption. The results indicate that leadership, client and other stakeholders, strategic planning, people, resources, process, measurement, analysis and knowledge management are the most relevant ones. Although many authors highlight most of those elements the approach used for "people" is generally connected to education and training. This paper aims to discuss the impact that BIM caused on the working routine of construction professionals, regarding pre-existing processes, roles, contracts, management, communication, collaboration and the difference between the generations to deal with the same innovation.

Moreover, the construction management process — the system of controls that optimize the design, procurement, and construction process— is the key to the ability of the construction industry to capitalize on technological innovations. According to Gu et al. (2019): "the disconnection between construction management education and the demand for professional talents in China's construction industry is becoming more and more serious. Construction management education faces new challenges." Their paper also states the most important dimensions of construction management demand for talents, including the professional practice skills, personal career development ability, and professional knowledge and application.

Concerning the use of digital tools in the construction site, a research published by Morin Pépin and Francis (2019) demonstrate how laser scanning can be a costly, long and even impossible process during construction. Instead, taking pictures as the project advances can be used for inputting information to a previously captured point cloud. The resulting files would then be compared to the 3D BIM model of the building in order to produce a 4D "as-built" simulation. However, this method is limited concerning the inside activities of a building and creating a 3D reconstruction of the building interior is complex. The multidimensional BIM should help project managers and there are several tools that are available to the on-site data acquiring. Nevertheless, the construction culture and its inertial behaviour can difficult their adoption.

3 Research Method

This research was based on a literature review and a survey to understand how project managers, construction professionals and academicians are dealing with the advent of BIM and their point of view regarding the impact of it. The method chosen for this research was the survey method, which is used to collect data from a specific sample of a defined population using a questionnaire, according to Visser_et al. (2000). The population selected was construction professionals and academicians from all over the world.

The survey questionnaire is composed with two sections. The first covers questions related to the person's profile, such as profession, age, country, gender, education level, years of experience in the field and company's sector. The second section presents questions regarding the experience with the use of BIM; the perception of the benefits by the individual; opinion related to project team collaboration, communication, construction site management and contracts. The full survey questionnaire is on the Appendix 1.

The possible answers for the questions in the survey questionnaire were multiple answer questions and Likert scale answers. The latter is a technique used to measure the behaviour towards a specific object of study, where the participants are presented with a statement and they must mark their level of agreement regarding it (Ankur et al. 2015).

The answers were collected from January to March 2020. There were 85 participants were anonymous professionals or academicians from 17 different countries. The results section of this paper reports the analysis and the findings on this research.

The questionnaire can be found on the following link: https://docs.google.com/forms/d/e/1FAIpQLSec3DWOmUqtfF1wdp79py3axr3KdaOyj2EPdD0mi-6hcGR35g/viewform

4 Results and Discussion

4.1 Survey Respondent Profile

The survey was answered by 85 professionals, according to Table 1 the participants were mainly from Brazil (66% - 56 answers) and Canada (11% - 9 answers), but also a considerable amount of professionals from Europe (10% - 8 answers) and Asia (7% - 6 answers). Therefore, the distribution of answers is clearly concentrated on the two countries of this paper's authors and the international characteristic of the research is limited.

Moreover, on Table 2 it is possible to see that the questionnaire was mostly answered by experienced engineers (54% - 46 answers) and architects (34% - 29 answers). As stated on Table 3 there is a high amount of the participants have a Bachelor's (40%) or a Master's Degree (48%), consequently the profile of respondents seems to be higher than professional average. Their ages vary from 26-40 years old (66%) to 41-55 years old (30%) - Table 4, thus the professional generations are not equally represented, consequently the study refers to young professionals mostly.

Table 1: Survey respondent profile - Country.

From	Percentage	Quantity
Brazil	66%	56
Canada	11%	9
Countries from Europe	10%	8
Countries from Asia	7%	6

Table 2: Survey Section 1 - Profession

Profession	Percentage	Quantity	Comments
Engineer	54,1%	46	This question offers the possibility of typing the professional category.
Architect	34,1%	29	
Construction Technologist	3,5%	3	
Other*	8,3%	7	

(*) Professors, BIM managers, consultants, interior designers.

Table 3: Survey respondent profile - Education level.

Profession	Percentage	Quantity
Master's Degree	48,2%	41
Bachelor's degree (University)	40%	34
Doctoral degree (PhD)	5,9%	5
Postdoctoral degree	3,5%	3
Associate's degree (College)	1,2%	1
Undergraduate student	1,2%	1

Table 4: Survey respondent profile - Age.

Age	Percentage	Quantity
26-40 years old	65,9%	56
41-55 years old	29,4%	25
Less than 25 years old	2,4%	2
56-70 years old	2,4%	2

Different construction sectors are concerned in this research, according to the answers on Table 7 there is a concentration of respondents working in the commercial and residential sector, but also a significant percentage of them in the infrastructure and industrial sector, thus helping to generalize the results. Also, the experience profile is concentrated on young professionals, mainly with 6-10 years of experience (37,6% - 32 answers), as it is possible to see on Table 6. In addition, the participants sex is close to equity 52,9% male and 47,1% female, according to Table 7, which is far from the professional reality where women are minority.

Table 5: Survey respondent profile - Activity time in the construction sector.

Activity time	Percentage	Quantity
6-10 years	37,6%	32
21-30 years	18,8%	16
11-15 years	16,5%	14
Less than 5 years	16,5%	14
16-20 years	8,2%	7
31-35 years	2,4%	2

Table 6: Survey respondent profile - Sex.

Sex	Percentage	Quantity
Female	47,1%	40
Male	52,9%	45

Table 7: Survey respondent profile - Company's sectors.

Item	Percentage	Quantity
Commercial	47,1%	40
Residential	47,1%	40
Infrastructure	36,5%	31
Education/Research	27,1%	23
Industrial	20,0%	17
Healthcare	14,1%	12
Other	6,4%	

(*) Non-mutually exclusive answers.

4.2 Answers to the questions about the use of BIM

The second part of the survey is composed by questions regarding the use of BIM and its impact over professional activities. Questions from Figures 1 to 6 show the answers' distribution on each topic of the survey questionnaire, which are multiple answer questions. Moreover, Figures 7 to 16 shows the Likert Scale answers, where the opinion of the participants was taken into account. All the graphics below considers a total of 85 answers.

From the pie chart - Figure 1 - it is possible to see that almost half of the participants (47,1%) are beginners' users of BIM, using it only for two years, even though this method came up more than a decade ago. Also, a considerable amount of people has been using BIM for a few more years, from 3 to 5 years, but it is still considered a short time when compared to when this innovation emerged. This seems to suggest that professionals are still adopting BIM in their routine, so there is a long way to go until reach the adequate maturity level.

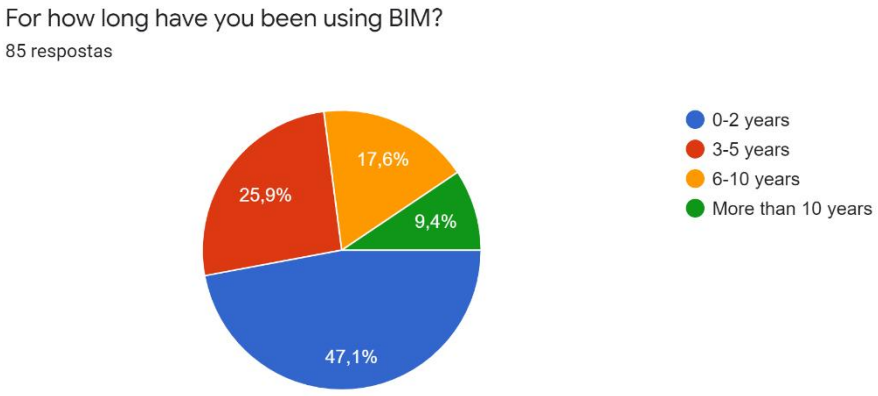

Fig. 1. Answers concerning the time of BIM practice.

Despite this, it is possible to conclude from Figure 2 that most professionals believe that BIM represents an improvement in their processes, since they stated that they partially (44,7%) and fully (48,2%) accomplished their aimed BIM benefits. It is important to set goals when adopting BIM, to track the project's improvements and to ensure when they are achieved.

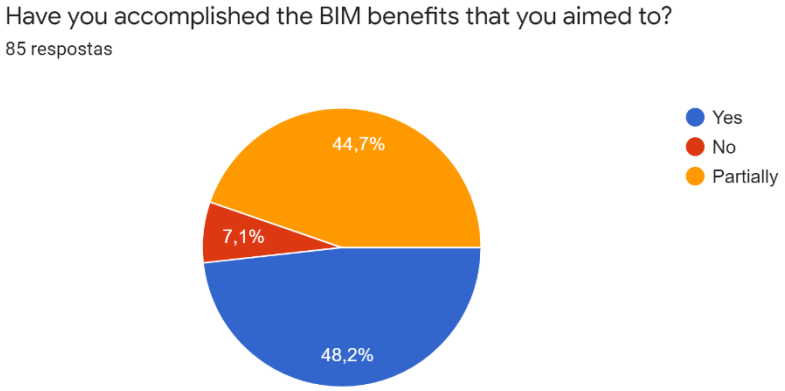

Fig. 2. Answers concerning the accomplishment of benefits through BIM use.

According to Figure 3, when questioned about the BIM impact over project contracts the sample's majority (37,6%) believes that it induced changes on most contracts, 30,6% think that this influence is only on specific projects and 23,5% considers that it always has an impact. A small proportion (8,2%) still believes that BIM doesn't cause an impact on project contracts. However, the World Economic Forum (2016) indicates that BIM proposes "a new way of collaborating and sharing information between stakeholders", thus considering this statement, clearly there must also be a change in the contracts and an impact because of BIM.

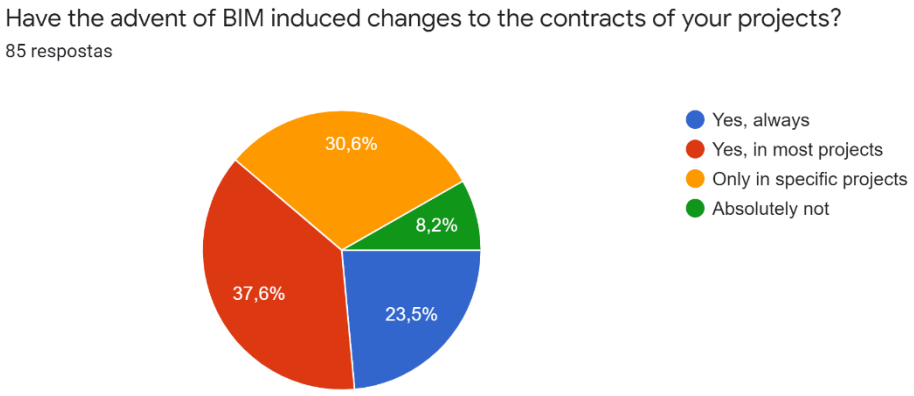

Fig. 3. Answers concerning the BIM impact over project contracts.

Similarly, the survey also covers questions regarding the BIM impact on Team Collaboration, Communication and Construction Project Management on Figures 4, 5 and 6. The BIM experience of these professionals shows that their expectation of improvement on team collaboration and project management was met to most of them (43,5%), according to Figures 4 and 6. On Figure 5, regarding Communication the expectation was met to a considerably amount of respondents (37,6%), but to the majority (49,4%) there was a improvement smaller than they expected on this matter.

Despite the answers on Figure 2 indicate that only 7,1% of professionals believe that they didn't accomplish the benefits through BIM usage, a slighter higher proportion didn't see an improvement on team collaboration (12,9%), communication (10,6%) and project management (20%) with BIM adoption. These are main subjects regarding BIM usage and its benefits. However, these failures to reach better results with BIM can have many reasons related to the adoption process, according to the research of Doan et al. (2019).

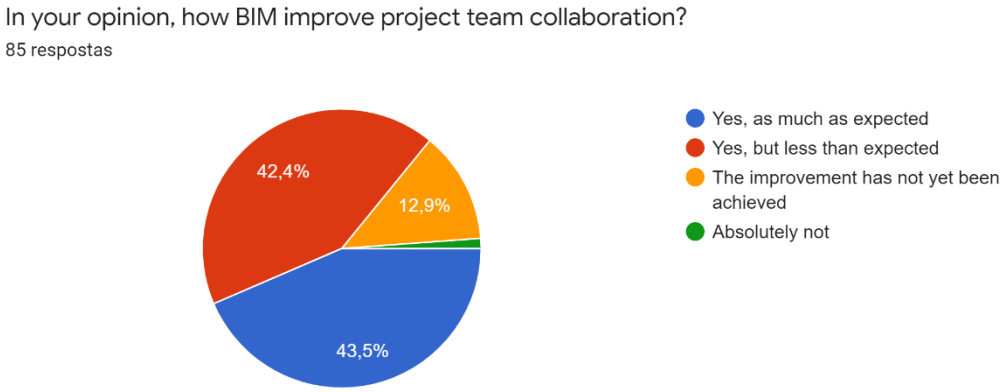

Fig. 4. Answers concerning the BIM impact over project team collaboration.

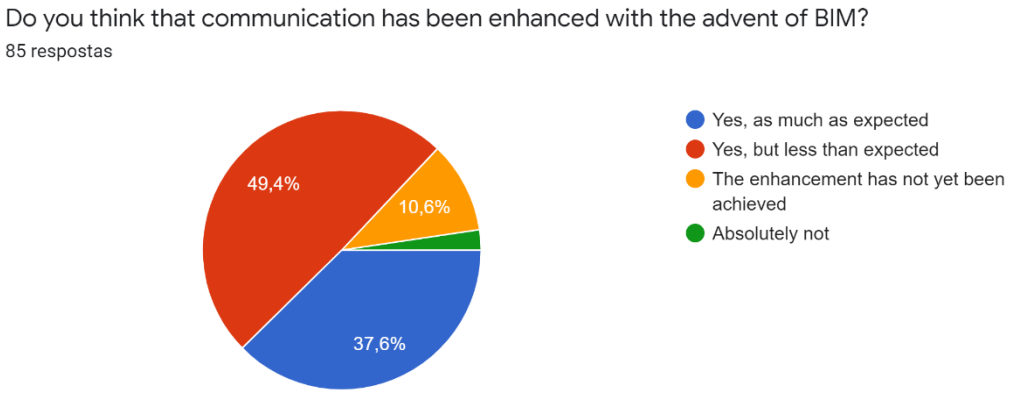

Fig. 5. Answers concerning the BIM impact over communication.

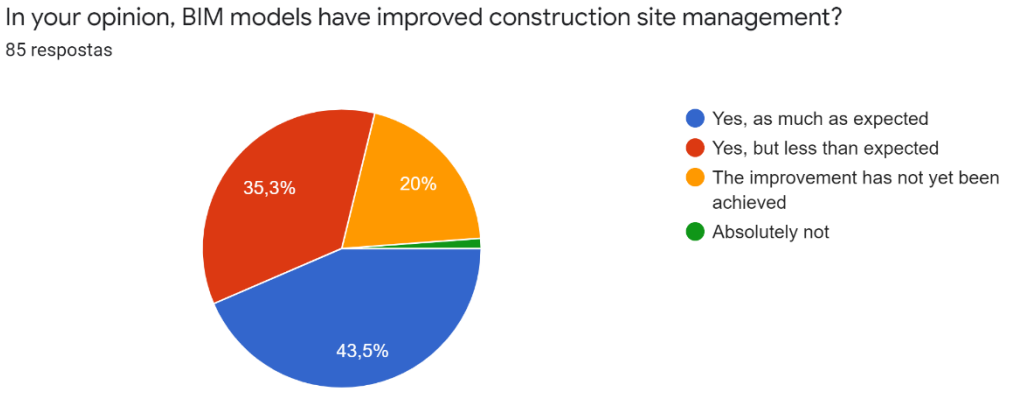

Fig. 6. Answers concerning the BIM impact over construction project management

Figure 7 provides evidence that BIM not only improve internal team collaboration (according to Figure 4), but also enhances collaboration throughout the building lifecycle and among all construction project's stakeholders and disciplines. This is of the utmost importance in a sector where there are so many participants and interactions. In addition, increase on productivity is one of the main goals of the field, which an evaluation of the data from Figure 8 suggests that it is achievable with the use of BIM. Therefore, a considerable amount of professionals that are positive about the outcomes with BIM usage.

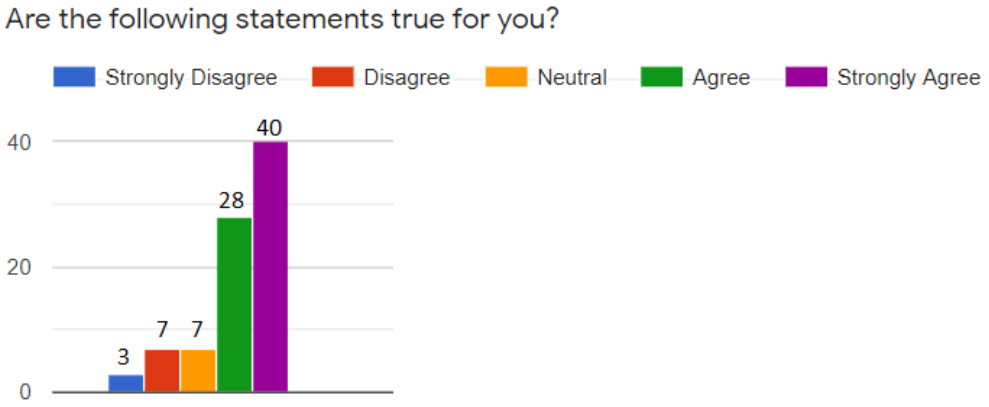

Fig. 7. Opinion question: "BIM facilitates collaboration among all construction project stakeholders and disciplines, from early design to operation and maintenance, so that they can contribute information to and extract information from the central model"

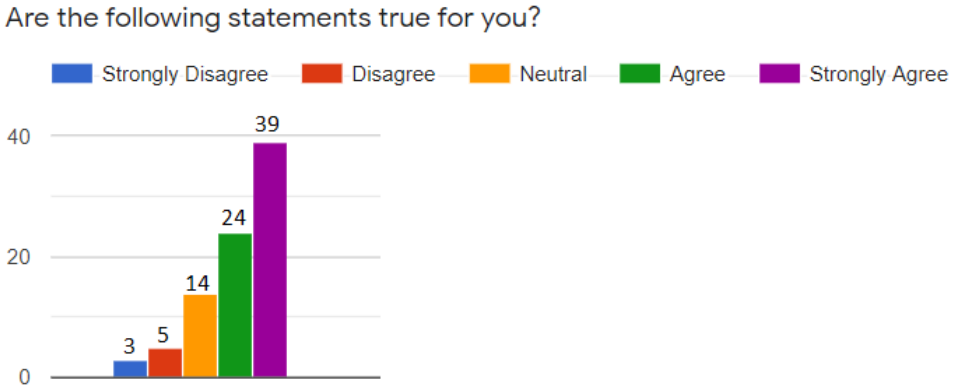

Fig. 8. Opinion question: BIM enhanced productivity in my work

It is common for different generations of professionals to perform daily activities in a distinct way, which differs from the other. One reason for this could be the difference on the education that they received through the years. The advent of BIM and the technology that came with it, demanded a change of behaviour on these daily activities. Even though it is an innovation that came to different generations at the same time, according to Figure 9 most professionals believe that they behave different when performing project management tasks. It is not possible to analyse the motive or the efficiency of this difference. Moreover, the communication between these professionals' generations have also been improved with the advent of BIM according to 56 answers on Figure 10.

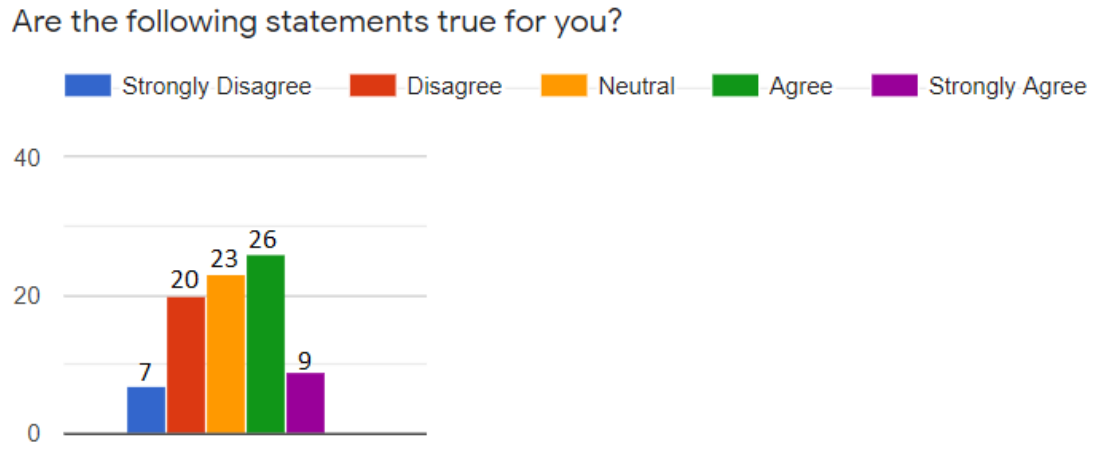

Fig. 9. Opinion question: With the advent of BIM, different generations of professionals perform project management tasks equally

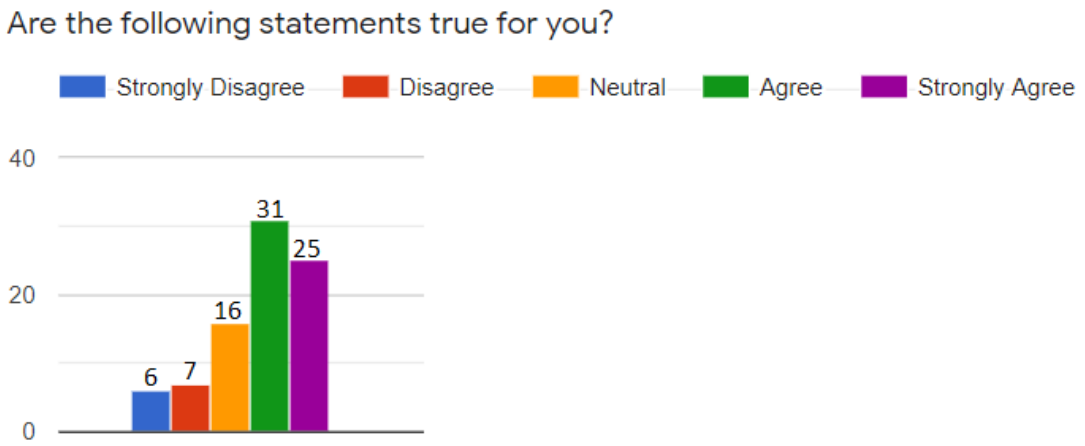

Fig. 10. Opinion question: BIM enhanced communication between different professionals' generations

On the other hand, on Figure 11 it is possible to see that the work routine for 70% of the professionals had a significant impact with the advent of BIM. New guidelines, standards and regulations guide the changes on the way of working with the method, what also have been impacting the professional's daily routine, according to Figure 12. Moreover, from Figure 12 it is possible to conclude that the pre-existing roles are suffering modifications as well, for instance project managers are also becoming BIM managers, because of the new method of working.

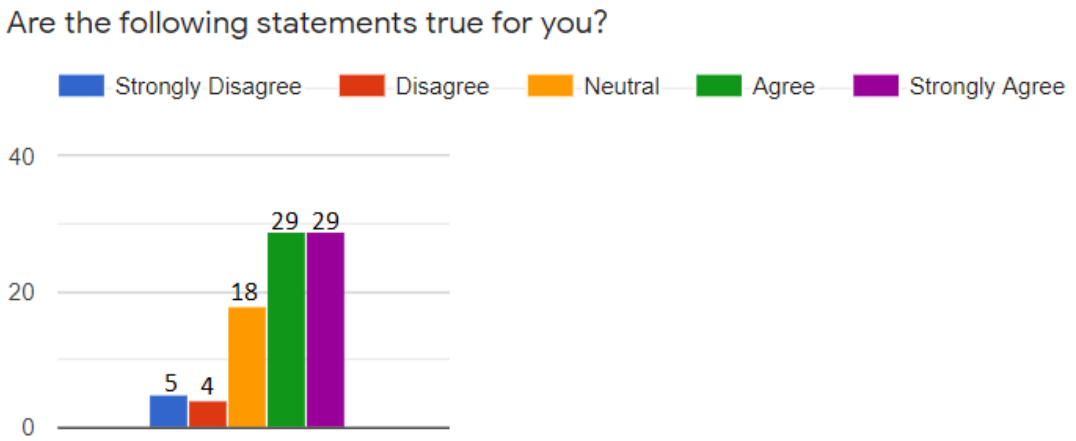

Fig. 11. Opinion question: With the advent of BIM my work routine changed

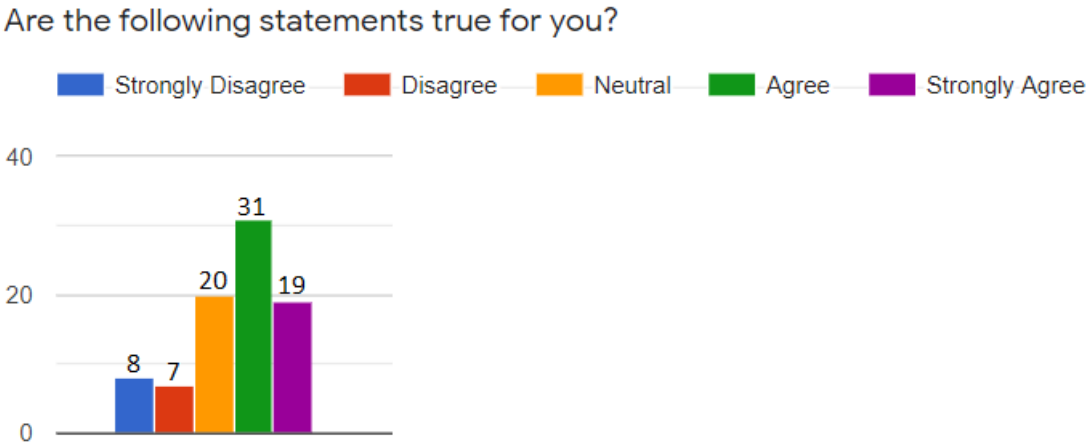

Fig. 12. Opinion question: With the advent of BIM the professional roles changed in my company

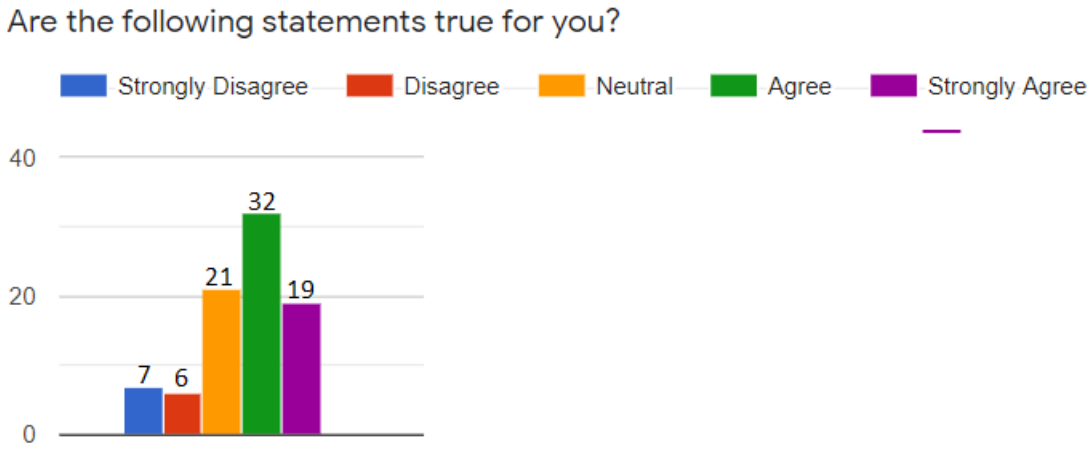

Fig. 13. Opinion question: BIM guidelines, standards and regulations have impacted my work routine

According to a significant proportion of professionals that took part on the survey, BIM is applicable to any size and type of construction project (Figure 16). However, it must be correctly implemented to achieve the aimed benefits. Thus, from Figures 14 and 15 it is possible to see that they also believe that it is crucial to organize the method of working with BIM through the development of a BIP (BIM Implementation Plan), a BEP (BIM Execution Plan) and finally pilot projects.

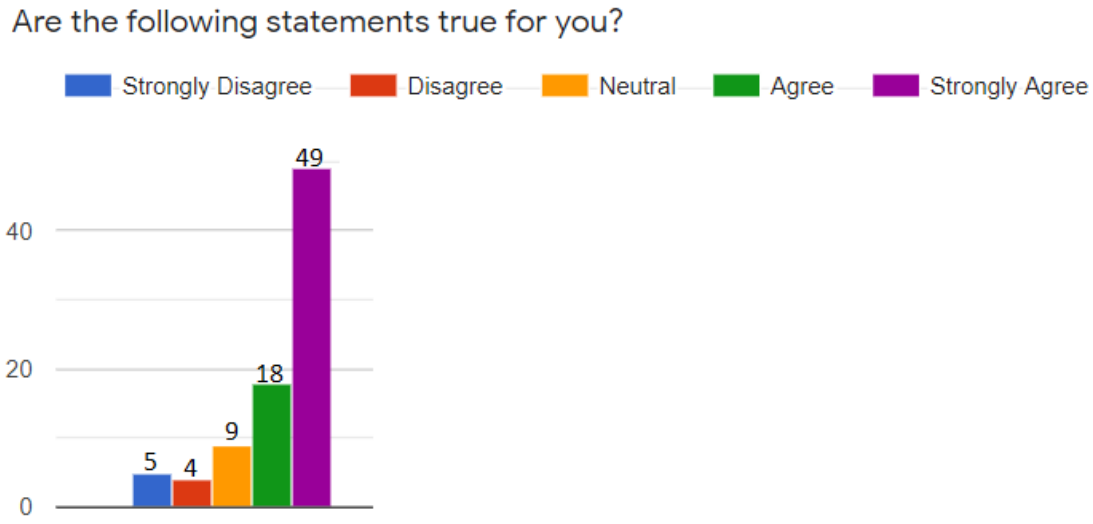

Fig. 14. Opinion question: It is crucial to develop a BIP (BIM Implementation Plan) and a BEP (BIM Execution Plan)

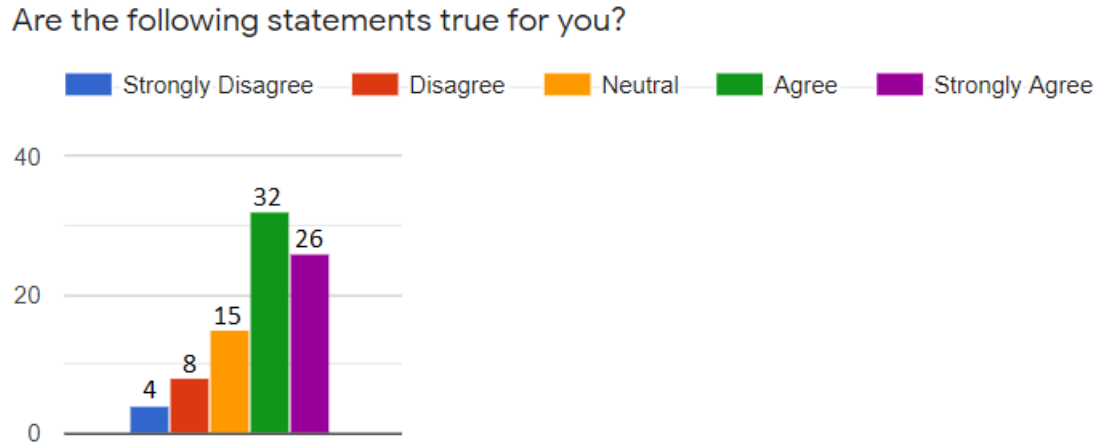

Fig. 15. Opinion question: Pilot projects are the best way to implement BIM in a company

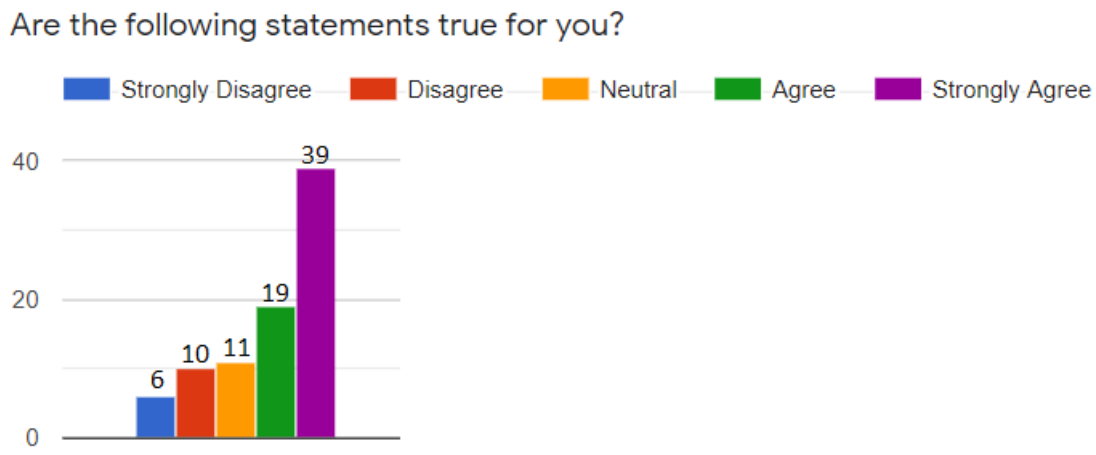

Fig. 16. Opinion question: BIM is applicable to any size and type of construction project.

5 Conclusion and Future Research

The transition to the digital era in the construction sector is still in progress. Some structural barriers are hindering the expected evolution in the BIM adoption on the construction section. Legal obstacles, as the obsolescence of contractual models; the evident need to renew roles and responsibilities; the limited educational and cultural basis; the collaboration and communication constraints; and the inertial management practices are some of the factors that originate a low satisfaction of construction professionals with the BIM adoption results.

The usage of this new method is still in the beginning and the innovation must get to a maturity level where it is easy to use it as CAD is nowadays. Despite the limitations of the survey, there are barriers on the way of reaching the highest potential of improvement with BIM. Furthermore, this research will be followed by a set of selected interviews, oriented to a wide range of construction project managers, in order to get a deep understanding on the BIM impact on the professional practices concerning project management.

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7 Appendix (Survey Questionnaire)

PROJECT MANAGEMENT AFTER THE BIM INTRODUCTION

1. Which is your profession? (please inform the highest or main degree) *

- Engineer
- Architect
- Construction Technologist
- Building Technician

2. Which is your education level? *

- Undergraduate student
- Associate's degree (College)
- Bachelor's degree (University)
- Master's degree
- Doctoral degree (PhD)
- Postdoctoral degree

3. How old are you? *

- Less than 25 years old
- 26-40 years old
- 41-55 years old
- 56-70 years old
- More than 70 years old

4. How long have you been working in the construction sector? *

- Less than 5 years
- 6-10 years
- 11-15 years
- 16-20 years
- 21-30 years
- 31-35 years
- More than 35 years

5. What is your sex? *

- Female
- Male

6. In which country do you work? *
- Choose your country

7. Company's Sector *
- Infrastructure
- Residential
- Commercial
- Hospitality
- Oil & Gas
- Energy
- Sanitation
- Healthcare
- Industrial
- Education/Research

Your practice in the use of BIM (Building Information Modelling) - Please answer only regarding your personal experience.

8. For how long have you been using BIM? *
- 0-2 years
- 3-5 years
- 6-10 years
- More than 10 years

9. Have you accomplished the BIM benefits that you aimed to? *
- Yes
- No
- Partially

10. Are the following statements true for you? * (Likert Scale Answers)

Strongly Disagree Disagree Neutral Agree Strongly Agree

- BIM facilitates collaboration among all construction project stakeholders and disciplines, from early design to operation and maintenance, so that they can contribute information to and extract information from the central model
- BIM enhanced productivity in my work

- With the advent of BIM, different generations of professionals perform project management tasks equally
- With the advent of BIM my work routine changed
- With the advent of BIM the professional roles changed in my company
- BIM guidelines, standards and regulations have impacted my work routine
- BIM enhanced communication between different professionals' generations
- It is crucial to develop a BIP (BIM Implementation Plan) and a BEP (BIM Execution Plan)
- Pilot projects are the best way to implement BIM in a company
- BIM is applicable to any size and type of construction project.

11. Have the advent of BIM induced changes to the contracts of your projects? *

- Yes, always
- Yes, in most projects
- Only in specific projects
- Absolutely not

12. In your opinion, how BIM improve project team collaboration? *

- Yes, as much as expected
- Yes, but less than expected
- The improvement has not yet been achieved
- Absolutely not

13. Do you think that communication has been enhanced with the advent of BIM? *

- Yes, as much as expected
- Yes, but less than expected
- The enhancement has not yet been achieved
- Absolutely not

14. In your opinion, BIM models have improved construction site management? *

- Yes, as much as expected
- Yes, but less than expected
- The improvement has not yet been achieved
- Absolutely not