Understanding the diffusion of Building Information Modeling among contractor SMEs in the Quebec construction industry

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Abstract
Most of contractors in the construction industry are small and medium-sized enterprises (SMEs).However, very few research works have been dedicated to the practices and challenges associated to their use of Building Information Modeling (BIM). The aim of this research is to assess the BIM maturity of contractor SMEs, in order to better understand their needs regarding the ongoing digital shift in the industry. To do this, we conducted a survey with the *Corporation des entrepreneurs généraux du Québec* (CEGQ) during the 2020 Congress, to assess the BIM awareness, uses, perceived benefits, issues and investment visions. The study found that the majority of construction companies are aware of BIM, but more than half of them do not use it. Most respondents who use BIM consider themselves to be beginners and use it primarily for coordination purposes. As a result of the data analysis, it was possible to draw conclusions and recommendations, in particular with regard to the importance of focusing on staff training, of working with clients to increase the number of mandates requiring BIM and carry out economic studies to demonstrate the concrete benefits of BIM on businesses and construction projects.

Keywords: Building Information Modeling, BIM diffusion, SME, Survey, Contractors

1 Introduction

Building Information Modeling (BIM) has recently developed rapidly in the construction industry. Initially, BIM was a 3D digital model (Eastman, Teicholz, Sacks, & Liston, 2011). However, nowadays, it is not only a mock-up bringing together all disciplines, but also a technological approach where collaboration plays a central role (Andújar-Montoya et al., 2020). BIM is also a set of digital tools that help the Architecture, Engineering and Construction (AEC) industry to effectively manage projects by improving the planning, design, construction and operation processes (Aryani et al., 2014). There are a multitude of definitions, but in general, BIM is defined as a model-based interactive approach of cooperation and information sharing between engineers, architects, consultants and the general contractor, as well as subcontractors, to succeed in a project (Doan et al., 2019).

Several studies have demonstrated the benefits that BIM can bring. For example, that of Newton and Chileshe (2012) identifies nine benefits that BIM can provide, including improved visualization, quality, customer satisfaction and competitiveness (Newton & Chileshe, 2012). Another research on 35 construction projects by Bryde, Broquetas and Volm (2014) reveals the

usefulness of BIM for spotting geometric conflicts, but also for ensuring good project management that reduces costs and schedule. Madanayake (2019) explains that despite the increasing adoption of digital technologies in construction, reports of productivity are still daunting. The author concludes that BIM can improve performance which can be linked to productivity gains, but this depends on the skills and knowledge for which training is required. Additionally, implementing IT in construction SMEs can be particularly challenging and lack of leadership can limit the impact of IT on overall productivity, leading to stagnant productivity. Some companies that create new technologies claim that they help improve productivity, but their ability to be efficient is not always established.

In Canada, SMEs in the construction sector represent 99% of businesses (Statistics Canada, 2020) and yet there is little documentation on those that use BIM. Indeed, the literature does not sufficiently study these companies since, according to Tezel et al. (2020), there are only 73 publications concerning SMEs and BIM between 2004 and 2018. The majority of these publications (27) are in the United Kingdom, while there are only four in Canada and most of the studies (26) are in the form of a questionnaire. In addition, almost half relates to the supply chain. It is important to assess the levels of use of BIM among SMEs since contractors need to know where the industry is at during calls for tenders in order to have the largest number of bidders. In addition, as we will see, most entrepreneurs are small or medium-sized businesses and they play an important role in the use of BIM.

The purpose of the research work reported in this paper is to assess the levels of use of BIM in the construction industry for small and medium-sized businesses. It will then be possible to understand where SMEs are at in the application of BIM and then draw recommendations for the continuous improvement of practices. The research also aims to identify the benefits and challenges of implementing BIM, from the perspective of entrepreneurs. The paper is organized into three chapters. First of all, in order to understand the subject, in the first section we will perform a review of the existing literature in order to fully understand the concepts relating to the different levels of use of BIM, specifically among entrepreneurs. Then, in the second section, we will explain the methodology used to support the results of the survey. Then, in the third section, we will present and analyze the results. Finally, we will present a conclusion to summarize the study, as well as recommendations to enrich research in this area.

2 Related works

2.1 BIM adoption among contractors

A study conducted in Australia (Ahankoob et al., 2018) explores the relationship between BIM adoption and organizational learning by studying a company's BIM maturity, as well as its absorptive capacity. The study concludes that there is no significant relationship between these two elements. Nonetheless, of the 56 respondents who are licensed construction contractors, 24 consider themselves at a low level, 23 consider themselves at a medium level and nine consider themselves at an advanced level. Regarding the number of employees, 35 companies had less than 50 employees, while 10 had between 50 and 500 employees, and 10 respondents represented companies with more than 500 employees. Thus, 80% of the respondents are construction contractors representing SMEs and almost half consider themselves low-level, which means that they still work in silos.

A qualitative study was carried out in the United Kingdom looking at the prospects for BIM implementation depending on the size of a contracting company (Gledson et al., 2012). The results showed that 7.7% of small entrepreneurs are aware of the planning of the implementation of BIM, while 53% of large entrepreneurs are aware of it. Additionally, 77% of small contractors do not plan to use BIM, while 59% of large contractors plan to use BIM between 1 year and 5 years (Gledson et al., 2012). It is therefore understandable that the majority of small entrepreneurs do not plan to implement

BIM and are poorly informed about it. A study in the United States looked at the challenges, the business philosophy for adopting BIM and the expectations of BIM skills among general

contractors (70%) and subcontractors. It turns out that 61% of respondents oversaw or led the company's BIM implementation, while 16% indicated that they had a basic understanding of BIM and 23% had no involvement with BIM (Ku & Taiebat, 2011). In this study, which is almost ten years old, we can nevertheless observe that a large percentage of general contractors have used BIM, which shows that they have tried it. However, in light of other studies carried out, the majority has little skills in this new field and do not plan to implement it, which may indicate that entrepreneurs are reluctant to face BIM.

A Canadian study by Poirier et al. (2015) assessed the performance of BIM implementation within a small specialized outsourcing company through performance indicators such as predictability of project costs, scope, productivity, schedule and quality. The research project spanned two years and the data came from six projects in which BIM was used significantly and two projects that did not involve its use. The results demonstrated that the cost of BIM to the organization will remain stable or decrease over time as more experience is gained.

2.2 Factors influencing adoption of BIM and main obstacles

A study conducted in 2016 explored the factors affecting BIM adoption among SMEs. The results show that the top three factors influencing respondents' decision to adopt or reject BIM are BIM awareness, innovation and ease of use (Hong et al., 2016). In a similar study, it is observed that the key factors to implement BIM in SMEs, especially among contractors in the construction sector, are tools such as software, work procedures, training, resistance to changes, the return on investment, the risks and the existing standards (Kouch et al., 2018).

A more recent article (Hochscheid & Halin, 2020) mentions the factors that can influence the success or the failure of BIM adoption in SMEs. The factors include, among others, the risks, the value of an innovation, the company culture, the legal and tax barriers, and the change management. The main obstacles according to (Ku & Taiebat, 2011) are the lack of qualified personnel and the investment costs. Other significant obstacles were mentioned, including the difficulty of sharing models, the lack of standard working procedures, interoperability issues and the lack of legal and contractual agreements. The study by (Gledson et al., 2012) found that the implementation barrier was the costs associated with process change and technology. Among SMEs, this change is seen as a reduction in revenue, while for large companies, such a change is seen as a source of time and cost savings. According to Gledson et al., Respondents from a large contracting organization have positions such as estimator and engineer and, therefore, these cannot understand all the concerns of a person working for an SME, which may have a wider range of roles and responsibilities.

A UK study on BIM adoption among SMEs shows that familiarity with BIM software is particularly low and that financial capability is the main barrier (Vidalakis et al., 2019). Indeed, over 85% of respondents do not know how to use BIM software suites and 50% have knowledge of Revit, Navisworks, ArchiCAD and 3ds-Max. These tools have mainly been used for visualization and detection of conflicts such as (Ku & Taiebat, 2011). The study highlights that SMEs understand BIM concepts like Hosseini et al. and that knowledge exchange is a catalyst for the adoption of BIM. Moreover, to maximize the benefits of BIM, all players in the AEC sector must participate in the BIM process. In addition, the study by (Ahankoob et al., 2018) revealed that contractors mainly used BIM for visualization, conflict detection, site management, quantity survey, estimation and schedule. , which confirms the main uses mentioned by other authors including (Vidalakis et al., 2019) and (Ku & Taiebat, 2011).

2.3 Recent trends

According to Le et al. (2019), the main trends in construction supply chain management are additional external integration among actors, BIM flexibility to meet complex project needs, role of general contractors as engines of coordination, the exchange of information between actors and advanced technologies and innovations for integration.

A recent article on BIM outsourcing among General Contractors in the United States, noted that 72% of responding contractors said they had used BIM in the past ten years and 45% said they had outsourced BIM to some extent (Fountain & Langar, 2018). BIM outsourcing means that

a company hires an information technology company to perform tasks related to BIM rather than using in-house BIM staff for the creation and the use of their BIM models. In fact, the functions most often outsourced are conflict detection, visualization and as-built drawings and shop drawings. Additionally, although respondents felt that implementing BIM internally had a more favorable impact on the project than outsourcing BIM and that several contractors have internal BIM capabilities, 41% of them still choose to outsource BIM. This method makes it possible to temporarily relieve internal teams who are overloaded, to mitigate the impacts related to the transition from a non-BIM environment to the BIM implementation on projects and to outsource BIM functions for which general contractors do not. do not have the in-house expertise to execute them, while remaining competitive for projects that could potentially require a BIM implementation. This trend exposes the fact that entrepreneurs will opt for this short term solution which seems to be simple, easy and efficient to be more competitive.

A study on BIM asset management and facilities at a mechanical and electrical contractor shows workflow gaps and proposes to put in place tailor-made BIM processes to improve BIM integration (Jang & Collinge, 2020). According to the authors, collaboration and communication between key stakeholders in the early stages of the project remains an issue for Tier 2 entrepreneurs who provide a vital link to the supply chain. The implementation of personalized processes will therefore be used more and more in the years to come, which will allow better collaboration and data management, definition of requirements for shared information and better coordination between construction phases.

3 Research approach

The investigation took place on February 21, 2020, on the occasion of the 23rd convention of the *Corporation des entrepreneurs généraux du Québec* (CEGQ). The survey was distributed in the morning, that is, at breakfast before the start of the corporation's annual general meeting, in order to obtain as many respondents as possible.

The choice of questions was inspired by various BIM surveys, such as the Annual BIM report by the University of Toronto and the National BIM Report by the National Building Specification (NBS) to compare the results. Copies of the questionnaire and pens were placed on chairs at each table to ensure that everyone read the document. The responses collected were entered into a Google form in order to analyze the results by creating a spreadsheet containing all the data.

The 2020 edition of the CEGQ congress had nearly 400 participants. The members of the corporation are general contractors. However, at the conference there were speakers (eg, consultants, lawyers, software companies, etc.). In the context of our study, the results will focus mainly on general construction companies, suppliers and subcontractors. A total of 104 responses have been collected, representing a response rate around 25%.

4 Main results

In this section, we present the main results of the study, including the profile of the respondents, the level of awareness and use of BIM, the level of BIM competency, the main BIM uses and the main software used.

4.1 Profile of the respondents

Figure 1 shows the distribution of the respondents.

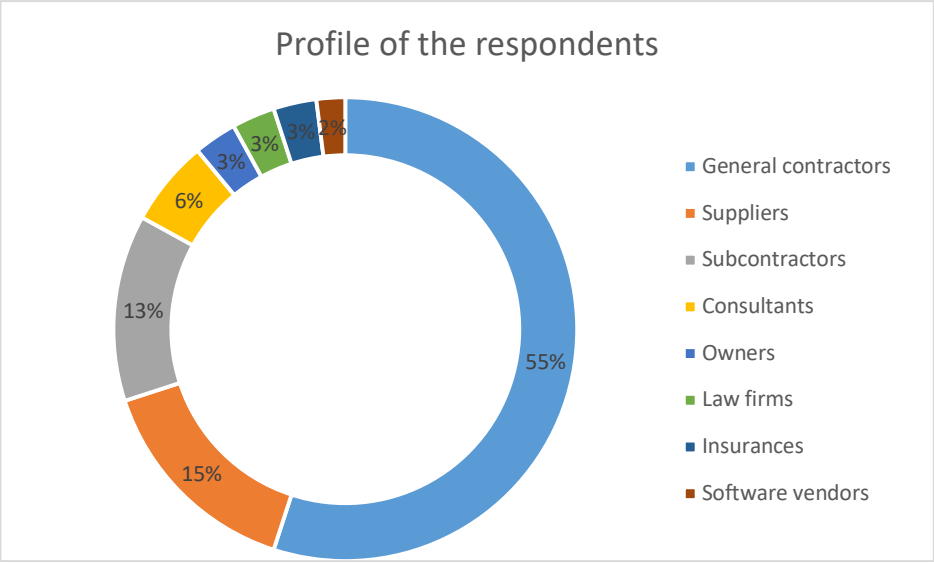

Figure 1. Profile of the respondents

Note that 55% of the respondents were general construction companies, while 15% were suppliers and 13% were subcontractors. The other types of businesses, at 17%, included consultants, owners, law firms, etc. As seen, some of the respondents did not come from an environment conducive to the use of BIM, including law firms and insurance companies, etc. The rest of the results presented below will focus on the responses of the general contractors, while suppliers and subcontractors, withdrawing those non-relevant responses.

4.2 Awareness and use of BIM

Figure 2 shows that the vast majority of all companies (91%) say they know about BIM, but about half (44%) of suppliers are not aware of BIM.

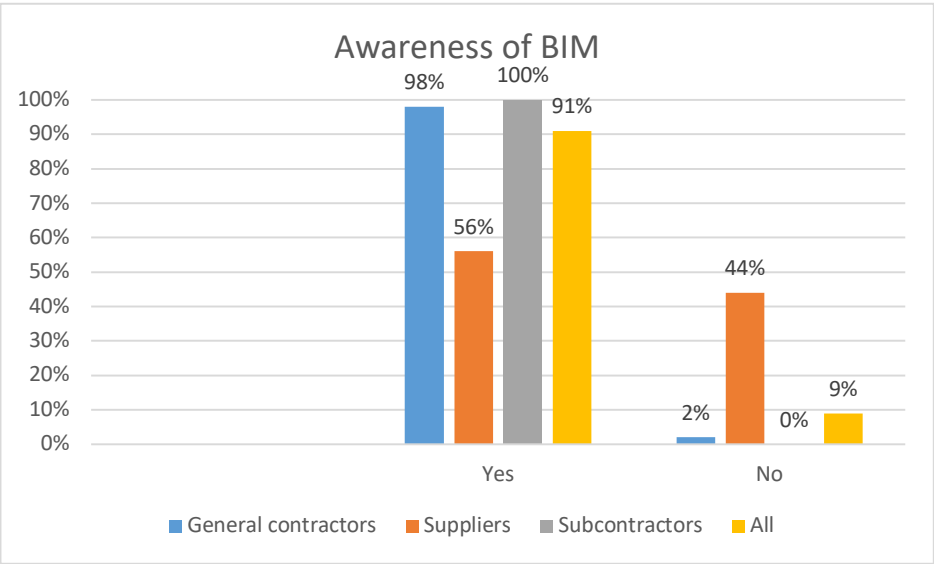

Figure 2. BIM awareness

We note that almost all contractors (98%) and all subcontractors (100%) are aware of BIM. According to the 2nd Annual BIM Report of the University of Toronto in 2019, 83% of all respondents answered that they knew BIM while in our case, it is 91% of respondents, this which is still high considering that the majority of BIM Report respondents represented architectural firms and only 20% of contractors. In addition, according to the same study, 74% of construction

companies (project managers, estimators and contractors) know about BIM and in Quebec, 89% are aware of the existence of BIM. According to our study, there would have been a potential growth in the number of people knowing about BIM. However, we cannot say for sure, since our sample is different.

Figure 3 shows that more than the majority of general contractors, as well as suppliers and all respondents, do not use BIM, while a majority of contractors say they use it. An Australian study showed that subcontractors are the ones who adopt BIM the least (Hosseini et al., 2016). Compared to the results of our study, one might think that over the past four years, more and more subcontractors have been using BIM.

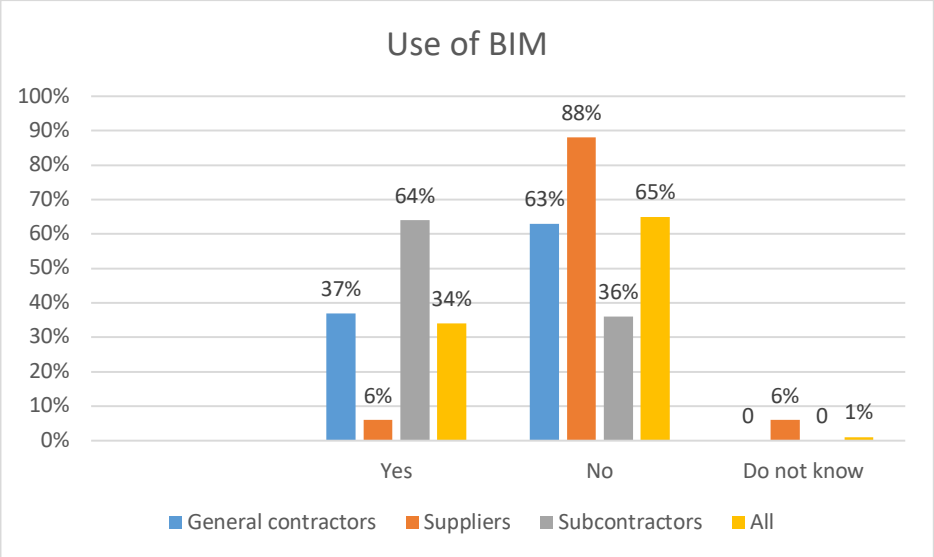

Figure 3. Use of BIM

Only one in 16 suppliers say he use BIM. Surprisingly, only 37% of entrepreneurs use BIM. According to the University of Toronto's 2nd Annual BIM Report in 2019, 57% of construction companies use BIM. Our study therefore calls into question this percentage. However, as we have found, there is little documentation on the adoption of BIM among contractors in Quebec. In our study, we observe a low rate of use.

4.3 BIM competency

Figure 4 shows the BIM skill levels according to the perception of respondents who use BIM. The data used therefore concerns only those respondents who answered with affirmative to the question relating to the use of BIM.

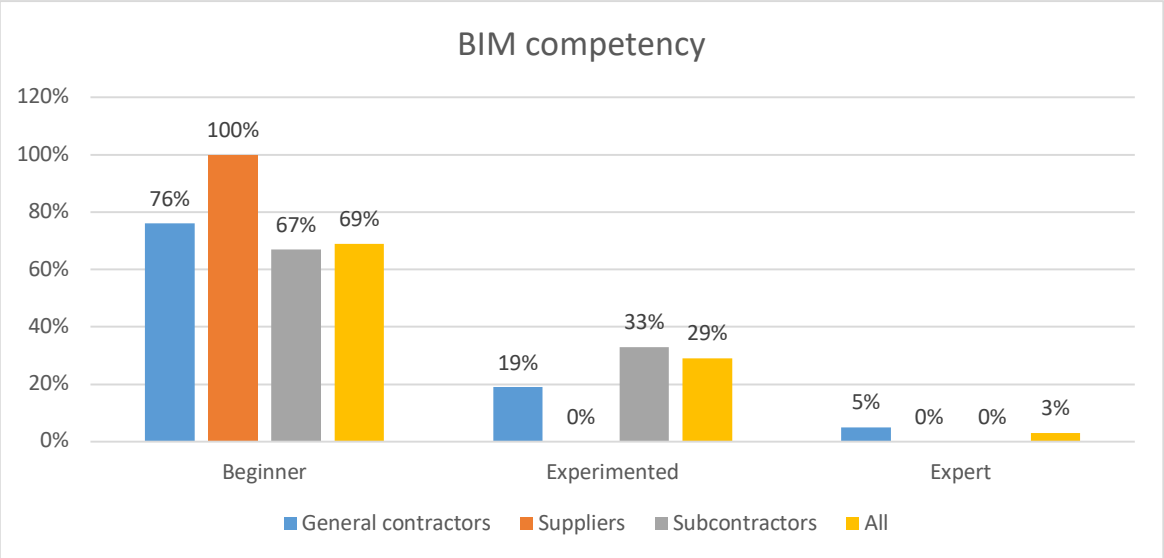

Figure 4. Level of BIM competency

We note that the vast majority of general construction companies (76%) consider themselves to be beginners when it comes to the level of BIM competency. Such a result could be considered a delay, since in the Australian study of contractors, 43% consider themselves beginners, 41% consider themselves experienced and 16% consider themselves experts. In the "experts" category, we find only 3% of all companies (Ahankoob et al., 2018). Surprisingly, it has also been noted that subcontractors seem to be more experienced than contractors.

4.4 Main BIM uses

Figure 5 shows the most common uses by respondents who use BIM, namely 3D coordination, planning and logistics management.

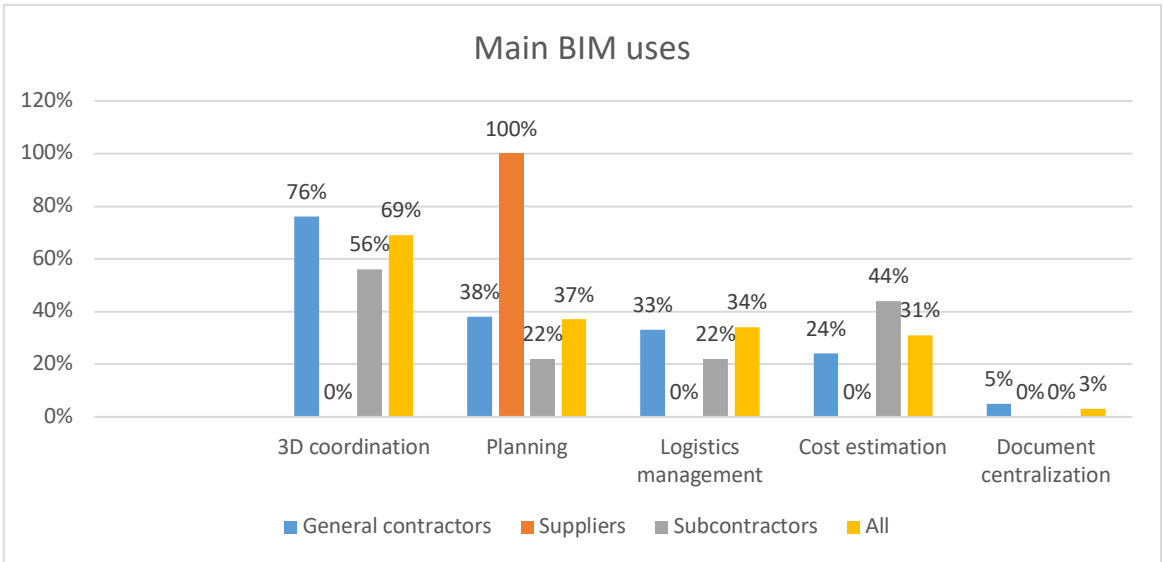

Figure 5. Main BIM uses

According to the University of Toronto, the most common uses are indeed coordination, visualization (second) and then collaboration. Coordination is the second most common use, according to the NBS National BIM Report in 2019. We can then say that coordination is indeed one of the most frequent BIM uses. We also note that general construction companies most often use BIM for planning followed by logistics management.

4.5 Main BIM software known

Figure 6 shows the software known by the respondents. We note that Revit, BIM 360 and Navisworks are the most known software and that few people know about Tekla Stuctures. In our study, 36% of all respondents do not know any of the software mentioned, while a recent study on UK SMEs (Vidalakis et al., 2019) found that over 85% of their respondents did not know how to use BIM software suites. Obviously, knowing software and knowing how to use it are different, but the majority of respondents are still aware of the existence of some BIM software.

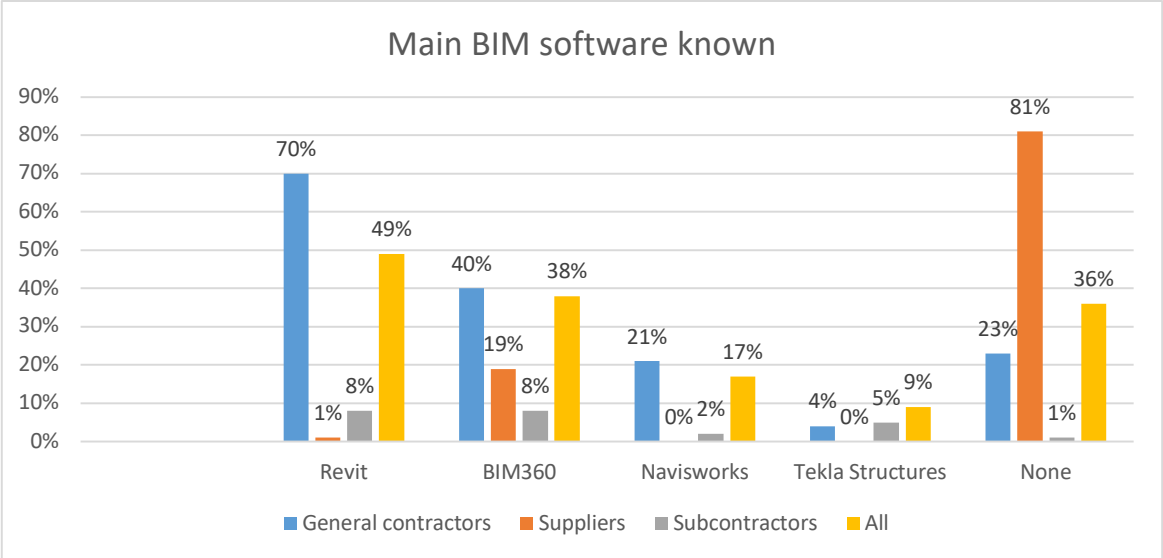

Figure 6. Main BIM software known

4.6 BIM-related benefits and obstacles

The first perceived benefit is "improving collaboration", the second one is "saving costs" followed by "respecting the schedule" (Figure 7). These findings are consistent with the NBS report, as collaboration is also among the top three benefits (National Bureau of Standards, 2019). In addition, cost reduction is also one of the top three perceived benefits according to the University of Toronto report (University of Toronto, 2019). Finally, meeting the schedule was also addressed in the study mentioned above as part of the major benefits.

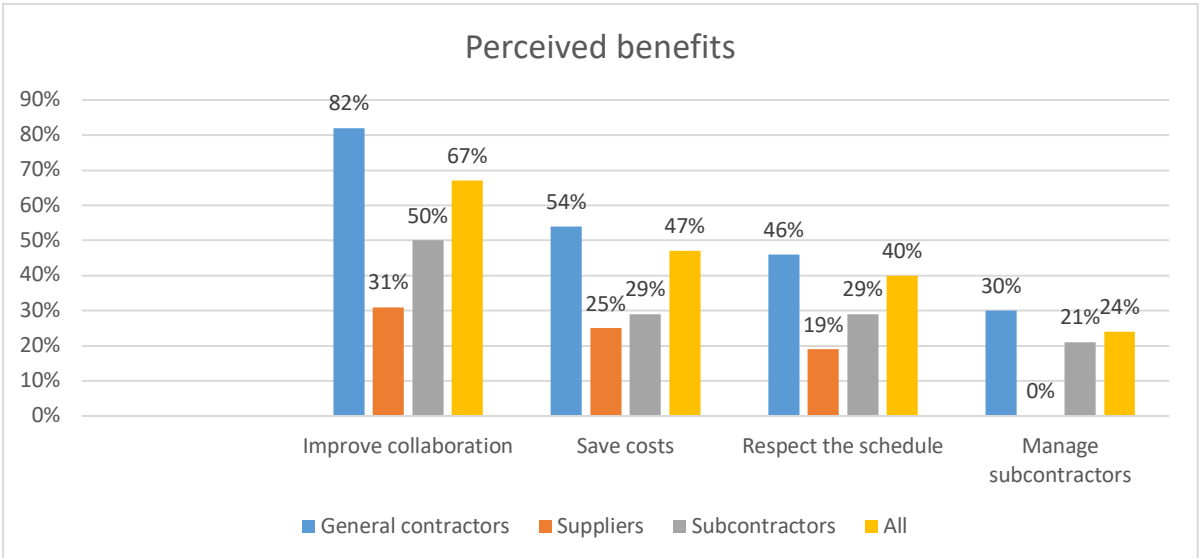

Figure 7. Perceived benefits

The main obstacles for general construction companies in using BIM are lack of qualified personnel, lack of mandates and doubt about return on investment (Figure 8). For contractors and suppliers, the main obstacle is the cost of software. The main barriers identified in the literature are indeed lack of demand and lack of skills (Hosseini et al., 2016). The National BIM Report 2019, also corroborates the main barriers which are lack of demand, lack of expertise and cost (National Bureau of Standards, 2019). The issues mentioned are also consistent with the results of the 2nd annual BIM Report of the University of Toronto where the obstacles mentioned are lack of requests, lack of knowledge and doubt about return on investment, etc. (University of Toronto, 2019).

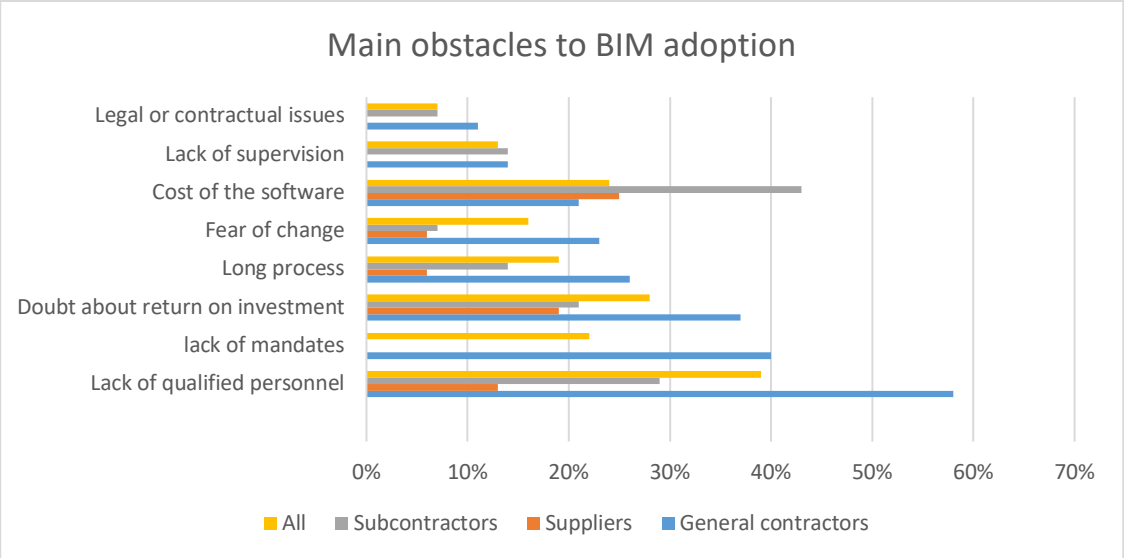

Figure 8. Main obstacles to BIM adoption

5 Conclusion and future works

The article presented the results of a survey on the diffusion of Building Information Modeling among contractor in the Quebec construction industry. The results show that the majority of construction companies are aware of BIM, but more than half of them do not use it. Most respondents who use BIM consider themselves to be beginners and use it primarily for coordination purposes. However, our study has its limitations. Although at the CEGQ convention there were large companies, we consider that 99% of the respondents were SMEs, which agrees with the figures from Statistics Canada. Moreover, the data suggest that it would be important to continue research through economic studies in order to demonstrate the potential of BIM. Currently, for the contractors, it is necessary to direct the calls for tenders towards this level to have the most competitive bidders. If the government of Quebec plan to establish obligations for the use of BIM, it will then be necessary to work to raise the level of skills of companies. Thus, it is important to focus also on staff training, since 76% of the companies consider themselves to be beginners.

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