International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 19 (2019) pp. 3797-3807

The Challenge of Using Building Information Modelling in Developing Countries: The Case of the Republic of Congo

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Abstract

The main objective of our work is to contribute to the impact of using BIM as a digital tool for modelling and optimising building projects, highlighting the performance achieved and the obstacles related to its adoption in the Republic of Congo. Building Information Modeling (BIM) is currently considered an innovative way to manage project information and improve construction performance. While it is gradually gaining ground in developed countries, its use in most developing countries is not yet well known. To achieve this objective, an in-depth qualitative study was carried out with 89 companies in the construction and public works sector. The high level of licensing fees has been identified as a major obstacle to the adoption of BIM. Similarly, the cost of purchasing BIM software, the low level of involvement of construction companies in BIM and its limited use were the main features of this study. In addition, the lack of technical expertise has not been a major problem for the use of BIM. Although this study is limited to the Republic of Congo, many of the recommendations could be applied to other developing countries.

Keywords: Building Information Modeling, project, software, performance, construction, developing countries.

1. INTRODUCTION

For two decades, the field of building construction has been engaged in BIM (Building Information Modeling), a new technology based on IT, digital and communication tools, to revitalize itself and seek more profit **[1]**. Indeed, BIM is a seven (07) dimensional software; it takes into account the geometric dimensions (x, y, z) that form the 3D, the time of realization, the costs, the sustainable development of a building as well as its life span. It is a digital world where all construction professionals are invited. Thus, it allows, not only the numerical modelling of all the data of a building project, but also, to all the actors concerned by the project, to access the same related computer files. The interest here is to encourage collaborative work between stakeholders on the same files in order to preserve data, optimize costs, and above all build better by considering all phases of the life of a construction, from its design to its management **[2]**. Consequently, the problem of taking into account the necessary measures on its use seems obvious both in developing countries (DCs) and in Congo-Brazzaville in particular. However, in a construction project, communication problems between the various actors, incorrect estimation of material quantities, deadline overruns and many other concerns are all concerns that BIM tries to resolve from the design phase of the project. Thus, in the face of the ever-increasing complexity of the environment for construction companies, the inevitable globalization of trade and therefore increasing competition, Congo must adapt more quickly to the digital economy and to the new information and communication technologies (ICTs). Similarly, the strategic management of technical and economic information has become an essential driver of the overall performance of construction companies, as well as the process of trade globalization, so it is necessary to adapt to the new balances between competition and cooperation.

1.1. Overview of Building Information Modeling (BIM)

Existing for nearly thirty years with the Archicad software, the BIM is undergoing a spectacular evolution in the world of construction, through various projects where the actors work in perfect synergy. However, according to popular belief, at the engineering or feasibility study stage of a building project, the elements of a project can be re-entered seven (07) times during a design process, because the different members of the design team such as: architect, civil engineers, surveyors, etc. do not use the same software and are not forced to understand the devices put in place by their colleagues **[3]**. This lack of understanding, efficiency and, above all, interoperability leads to significant losses of time and money every time. However, sustainable construction requires a new look at how an industrial company should design, build and operate its structures **[4]**. In Congo, the use of BIM is still in the primary stage. Yet, significant investment efforts are being made by the State as part of the strategic plan for infrastructure development in the various departments of the Republic. However, it should be noted that with regard to components four (04) and five (05) of the BIM, it is the financial estimation and execution times of construction projects that are very often poorly assessed given management shortcomings, especially in the informal and semi-informal sectors, with the result that work or projects are poorly managed. In these sectors, project interruptions due to supply or financing disruptions are most often found **[5; 6]**. Studies

on the management of construction works in the informal and semi-informal construction sectors have highlighted inefficiencies in results, using existing management tools such as the Program Evaluation and Review Technique (PERT), the Critical Path Method (CPM) and Gantt tables. Researchers proposed as an alternative method, a sequential approach based on decomposition into sub-budgets and sub-budgets; and by looking for the sub-structure sequencing diagram (SSCD). Similarly, a new construction cost estimation model was proposed. The latter (cost) being considered as the most important factor in the realization of the project, was developed **[7; 8]**. This study based on the Work Breakdown Structure (WBS) and the statistical matrix approach emphasizes that conventional construction cost estimation methods generally omit the margin of tolerance that is an essential element in the summary or provisional estimation **[9]**. However, not all these studies have given rise to collaborative work with a view to predictability and anticipation in the management of these projects. The impact of this work is very limited. However, construction costs and time control are a major concern in project management. It therefore seems necessary to note that the means to fill some management gaps or skills development remains BIM. The use of BIM in projects has resulted in benefits reported in the following publications **[10; 11; 12; 13]**. Some projects include increased productivity, efficiency, infrastructure value, quality and sustainability, reduced life cycle costs, delays and minimized waste, except for opportunities for data sharing and exchange between several disciplines or trades. Thus, the research conducted on BIM has been the subject of several publications and is available in the literature. A 2014 study by Azhar et al of 32 projects reported some benefits, including the elimination of 40% of unbudgeted changes, accuracy of cost estimates within 3%, a reduction of up to 80% in the time required to produce a cost estimate, savings of up to 10% of the contract value through conflict detection and a reduction of up to 7% of project time. Other studies have reported a return on investment of 9.486% **[14]**. The main areas of the built environment in which BIMs have been applied include energy and carbon management **[15]**, sustainable building design **[16]**, quantitative study **[17]**, demolition and renovation waste assessment and planning **[18]**, disaster management, integrated energy calculation **[19]** and project management.

1.2. Common BIM software and market potential

In developed countries, the most commonly used BIM tools are Revit, Tekla structure, Digital Project, Micro station, All plan Architecture, All plan Facility Management, Bentley Building Suite, Vector works **[20; 21]**. These BIM systems have been designed to address the different phases of a project's life cycle. For example, All plan Architecture is the optimal solution for the planning and design phase, while All plan Facility Management is designed for use in the operational phase. Some of the above tools are better suited than others to the different phases of a project's life cycle. Also, key studies have been published on feasibility **[15]**, design **[22; 23]**, pre-construction (detailed design and tendering) **[15; 24]**, construction **[25; 26]** and operation and management **[27]**. Given the exploratory nature of this study, there are no restrictions on the application phase of the BIM software packages.

However, the global BIM market is expected to grow from an estimated $1.8 billion in 2012 to $6.5 billion **[25]**, while North America and Western Europe have enthusiastically embraced BIM, Latin America, Eastern Europe, the Middle East and Africa are still lagging **[28]**, although demand for BIM software and BIM services has increased in South Africa. One of the key factors that influenced the adoption of BIM in North America and Western Europe was the introduction of mandatory policies on the use of BIM in certain projects by government or public agencies **[28]**. For example, in the United Kingdom, BIM level 2 is mandatory for all projects purchased by the government since 2016 **[29]**.

2. MATERIAL AND METHODS

2.1. Geographical coordinates :

- Brazzaville :
  - Latitude : 4°15.9678’S
  - Longitude : 15°16.9908’E
- Pointe-Noire :
  - Latitude : 4°46.5654’S
  - Longitude : 11°51.8112’E.

2.2. Analytical approach

For this work, the surveys were conducted in the cities of Brazzaville and Pointe-Noire respectively. This study aims to collect some application activities, motivations and impacts of the use of BIM by these construction companies. It focused on two fundamental modules (knowledge and use of IT tools) outside the standard identification module, namely the legal status of companies.

2.3. Research methodology

Various types of research methodologies were adopted, including in-depth qualitative interviews and a literature review. The data collected were synthesized as part of the research process. Although most BIM software is stand-alone and can be used for different applications, models developed in non-BIM software are exported to BIM software.

Two of these programs, commonly used in Congo, are MS Project and AutoCAD. Given the emerging nature of BIM and the lack of research in this area for Congo, directed sampling was adopted. A survey package was designed to capture key aspects such as: knowledge and awareness, types of BIM software packages, different uses, motivations, impacts and obstacles due to the adoption of BIM in Congo.

The investigation file consists of three parts.

The first part concerns the identification that gives the profile of the respondents' companies in relation to the survey. Optional questions such as the name and address of the company have been included. Given that this study focuses on Congo, it was imperative to include a mandatory question to identify the country in order to ensure that responses from outside the country can be identified and processed. Other key issues addressed in this first part include: the company's

business situation, business activities, number of employees, annual turnover and longevity in the use of BIM.

The second part reports on the level of awareness of BIM in the construction industry in Congo. Respondents must indicate whether they are aware of one or more software packages used in the design and management of construction projects.

The third section examines the use and impact of BIM by construction professionals in Congo. In the exploitation and analysis of the results, particular attention will be paid to raising awareness of BIM, its use and impact. Eighty-nine (89) companies were arbitrarily selected from a list of companies related to the construction and public works sector obtained through authorized organizations. After the investigators had been trained on the survey file, data collection was carried out through direct interviews, i.e. face-to-face interviews between the investigator and the company representative. Regarding the availability of respondents to this study, eighty-three (83) companies (93.26%) indicated that they understood the purpose of this survey, while six (6.74%) did not respond. The latter case is explained by the lack of personal managers in their companies. Of the 89 companies surveyed, 82.26% were willing to participate freely and 1.12% contested this choice.

However, 16.85% of respondents were hesitant. The latter cases justify the category of non-respondents. Eighty-one (81) companies (91.01%) agreed to participate in this study compared to 8.99% hesitant. This high acceptance rate once again confirms the credibility of our results. 89.89% of respondents suggested that the results of this study should remain anonymous while 9.11% responded positively. 61.80% of respondents said they were available for group interviews compared to 6.74% and finally 31.46% were hesitant.

The acceptance rate of more than half once again confirms the credibility and reliability of the data collected. Indeed, by adding the "No" respondents to the "No" respondents, we obtain nearly 38%. About 72% of respondents agreed that their answers should be published, while 27% were hesitant. In all the companies surveyed, the proportion of those who say they have read and understood the survey file is 93.26%, including 40.96% for private establishments, 20.48% for public limited companies and 30.36% for limited liability companies (LLCs). State public institutions have 2.74%. There is a low "Non-response" score for all companies in relation to their status.

This study aims to determine the factors that explain the knowledge and use of BIM in Congo. According to the responses of the companies interviewed, the analysis of the results here makes it possible to measure the impact of certain key parameters such as the level of knowledge of BIM, the type of activities in relation to the use of BIM, the motivations and impacts of its use and the possible obstacles to its adoption **[30; 31]**.

3. RESULTS AND DISCUSSION

3.1. Interpretation of the results

✓ **Legal status and type of activities of the company using BIM**

Out of a sample of eighty-nine (89) companies, thirty-eight (38) companies have the status of private establishments, or 42.70%, while 20.22% represent the public limited company (SA), 34.83% the limited liability company (SARL) and 2.25% the other companies. This high level of private establishment status is explained by the financial constraints for the creation of a company, where there are more requirements. With regard to the type of activities, eighty-three (83) companies specialize in building work (93.26%); fifty-nine (59) companies specialize in public works (66.29%); two (2) companies specialize in environmental studies (2.25%); forty-nine (49) engineering design offices (55.06%) and thirty-five (35) architectural firms (39.33%). Only one (1) company is specified in the drilling work (see Figure 1).

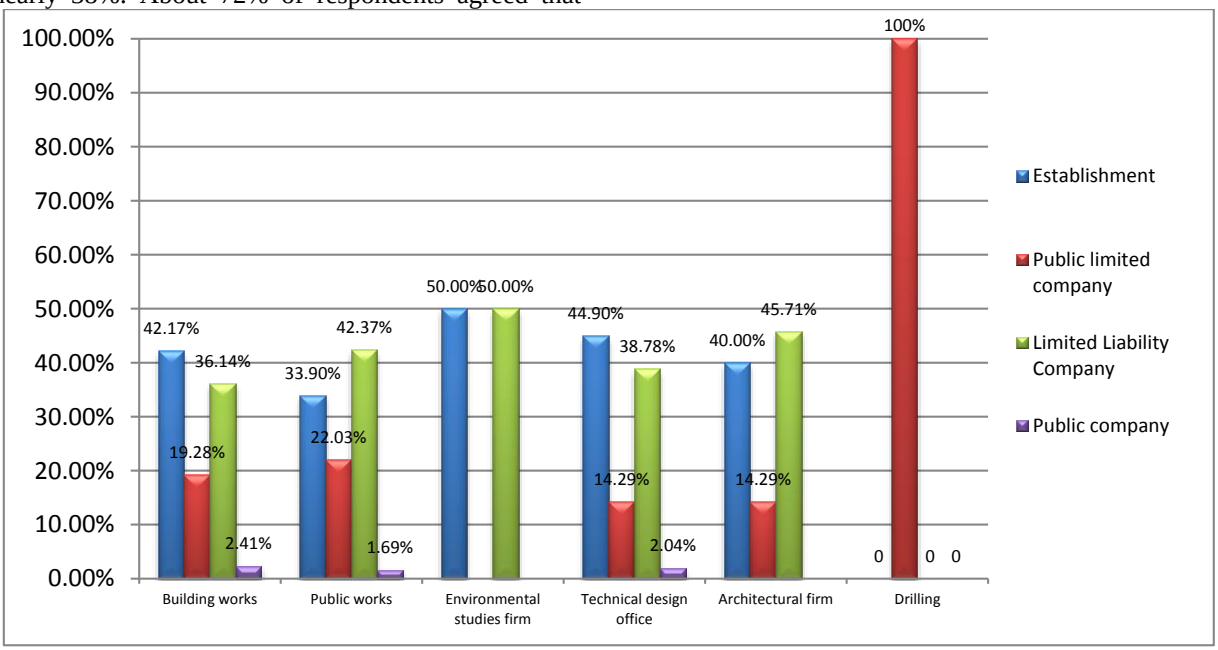

Figure 1: Legal status and type of activities of the company using BIM tools

The major orientation of companies towards construction and public works is explained by the fact that Congo has been involved in major construction and public works projects for more than fifteen years. Environmental studies and drilling activities accounted for 2.25% and 1.12% respectively and remain poorly explored.

Based on the number of permanent employees of a company, 37 companies have between one and five permanent employees (41.57%), 34 companies have between six and ten permanent employees and 18 companies have ten or more permanent employees (Figure 2).

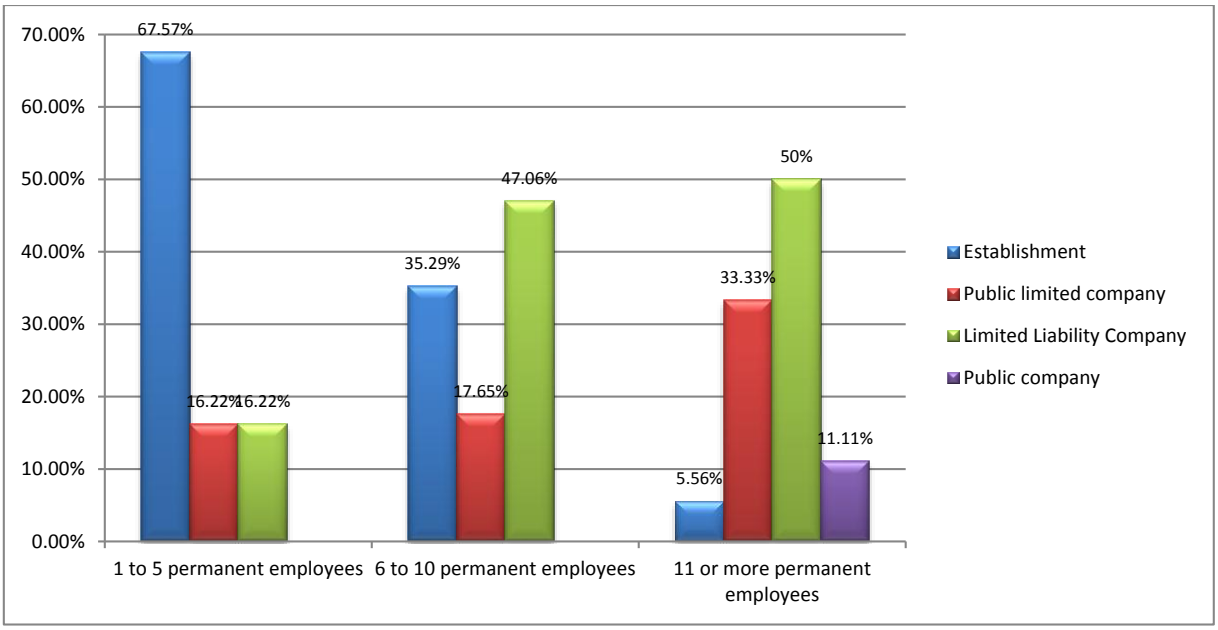

Figure 2: Number of permanent employees in the company

✓ **Awareness and knowledge of BIM**

In the survey file, all these companies confirmed that they were aware of the existence and information on the use of BIM tools in construction projects. In addition, it appears that all these companies have used the BIM tool in construction project management. On the basis of these questions, the different types of BIM tools used, the frequency of use and the level of expertise were examined in more detail.

Figure 3 shows some of the software used by companies.

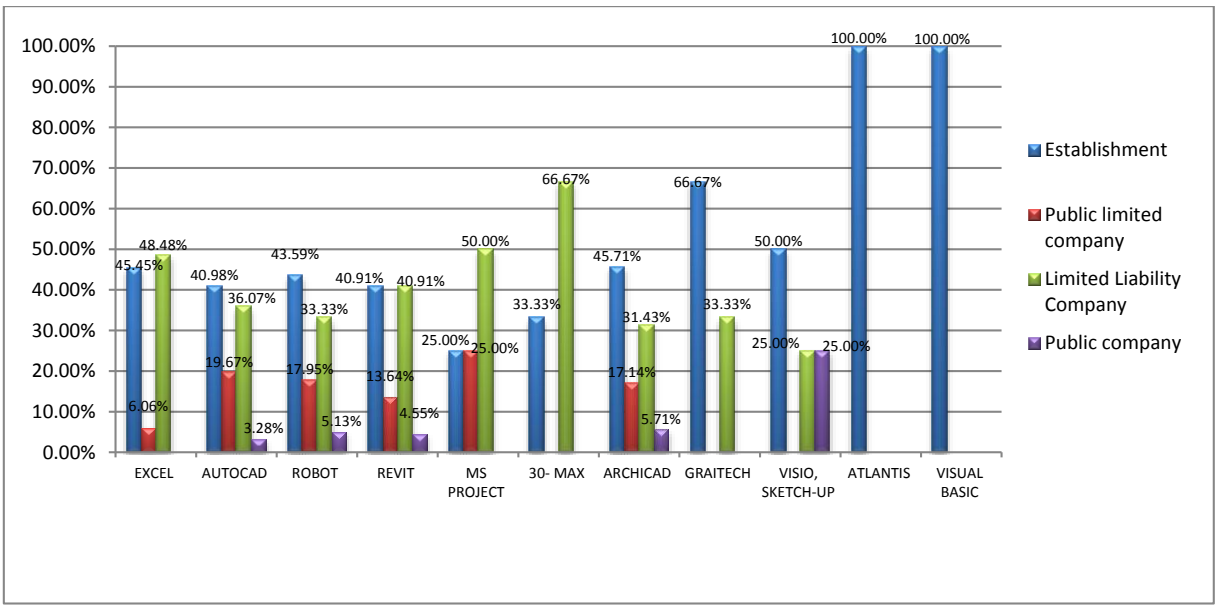

Figure 3: Some BIM software and tools used by companies

There are more satisfactory levels precisely for Autocad, Archicad, Robot and Revit. Private institutions use only Excel, MS Project, 3D Max, Graitech Atlantis and Visual Basic. Public limited companies and limited liability companies are more competitive and more demanding in the use and knowledge of optional software such as Autocad, Robot, Revit, and Archicad. All companies are in favour of a possible supply of software. Overall, 93.26% of companies report using computer tools. This opportunity confirmed the high level of IT use in these companies. All companies used more than three software packages. Open establishments use Robot, Revit and Archicad, while public limited companies use Robot, Revit, 3D-Max and Archicad. Private limited liability companies use Robot, Revit, MS Project, 3D-Max, Archicad and Graitech. Finally, Private Unlimited Liability companies use the entire range of software as a complement for exclusive use. The level of software usage remains a complete representation for the exclusive use of Private Unlimited Liability companies including Visio, Sketch-Up and Atlantis (100%). Exempted MS-Project software used by private limited liability companies and Graitech software used by private unlimited liability companies, the use of most software is important alternately between 30 and 44%. The use of Autocad, Robot, Revit, Archicad software remains quite negligible in public companies. Based on the use of BIM, five levels of expertise were studied: "No knowledge at all", "Beginner", "Intermediate", "High" and "Expert". The "Non-respondent" represents less than 13% (Figure 4). The "High" and "Expert" levels represent more than 72%. The two public companies use 5% for the "high" level and 5% for the "intermediate" level. The null offers a peak of 100% by Private Unlimited Liability companies, while the "intermediaries", "beginners", "non-respondents" are about 50% and more (75% for non-respondents). We note a good level of software mastery by all companies for the "expert", "high" and "intermediate" levels.

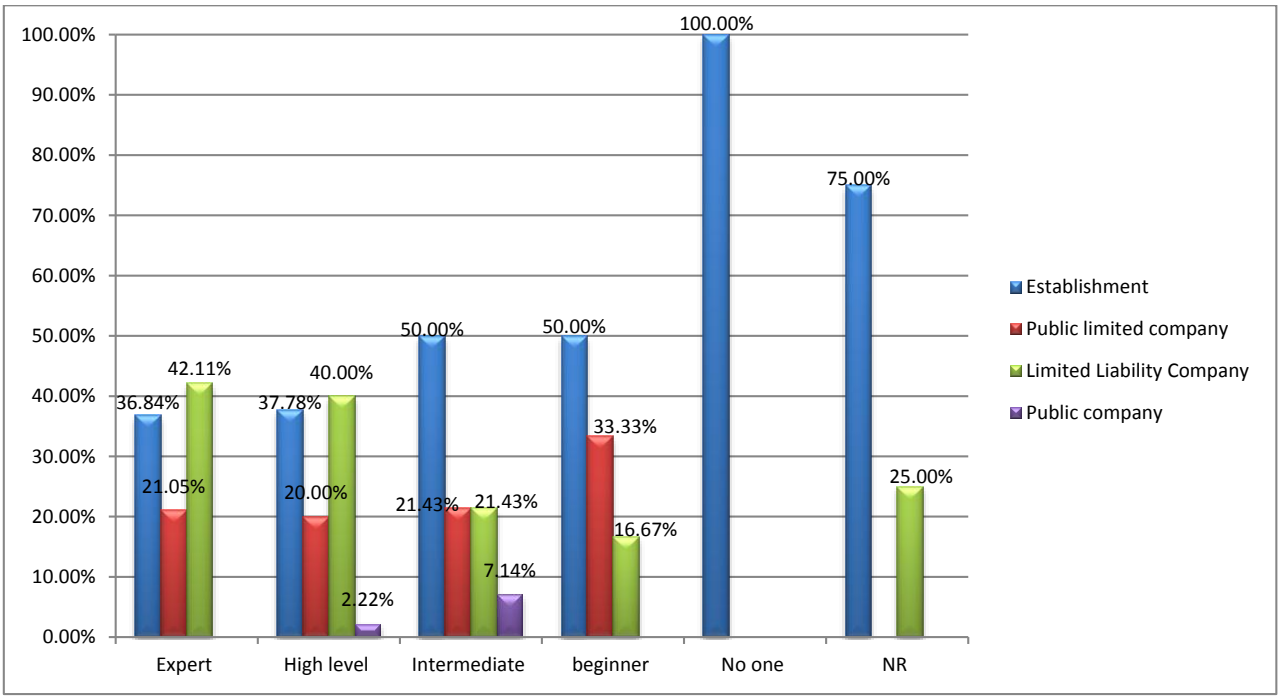

Figure 4 : Level of user expertise in relation to the type of business

✓ Longevity of the use of BIM in construction projects

The good level of software mastery is confirmed by the practice of longevity in the use of BIM (Figure 5) which is more than 3 years (i.e. 80%).

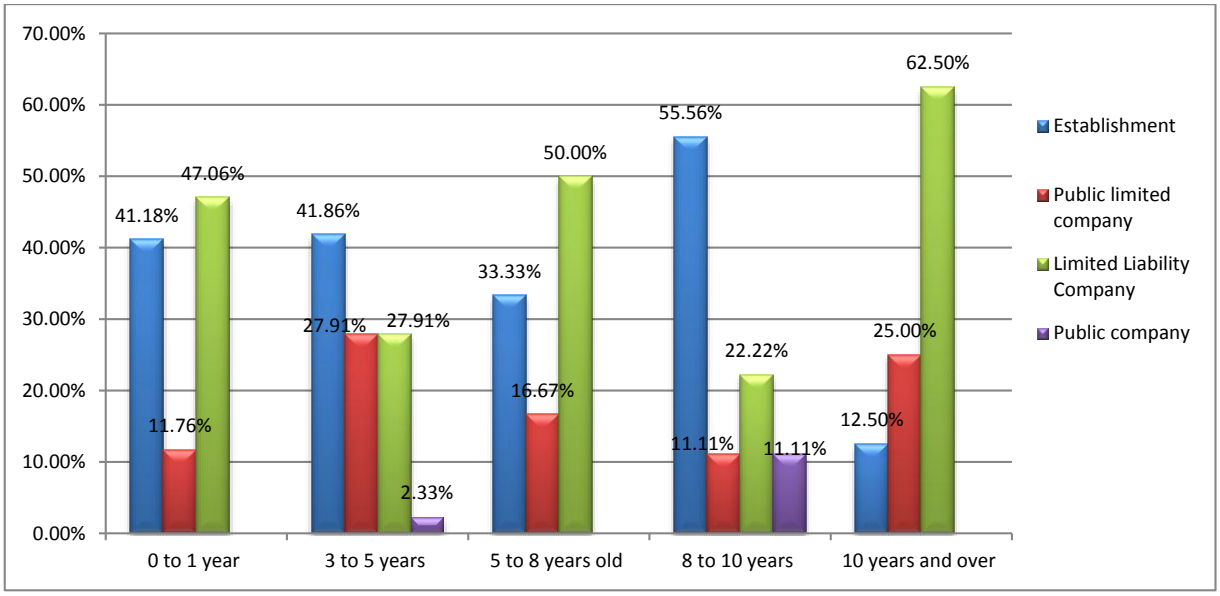

Figure 5 : Longevity of the use of BIM

The one-year longevity concerns only 8 private limited liability companies; two (2) public limited companies and seven (7) private unlimited liability companies (20%). In fact, the longevity of using BIM for more than three years can be guaranteed. However, the situation remains obvious for a normal distribution with a modal class of 3 to 5 years for all categories of enterprises.

As for the question of the frequency of use of these IT tools in companies, almost all of them use them daily, and five companies use them once a week (Figure 6). The five (5) marginal companies are known to be two (2) private unlimited liability companies, one (1) public limited liability company and two (2) private limited liability companies.

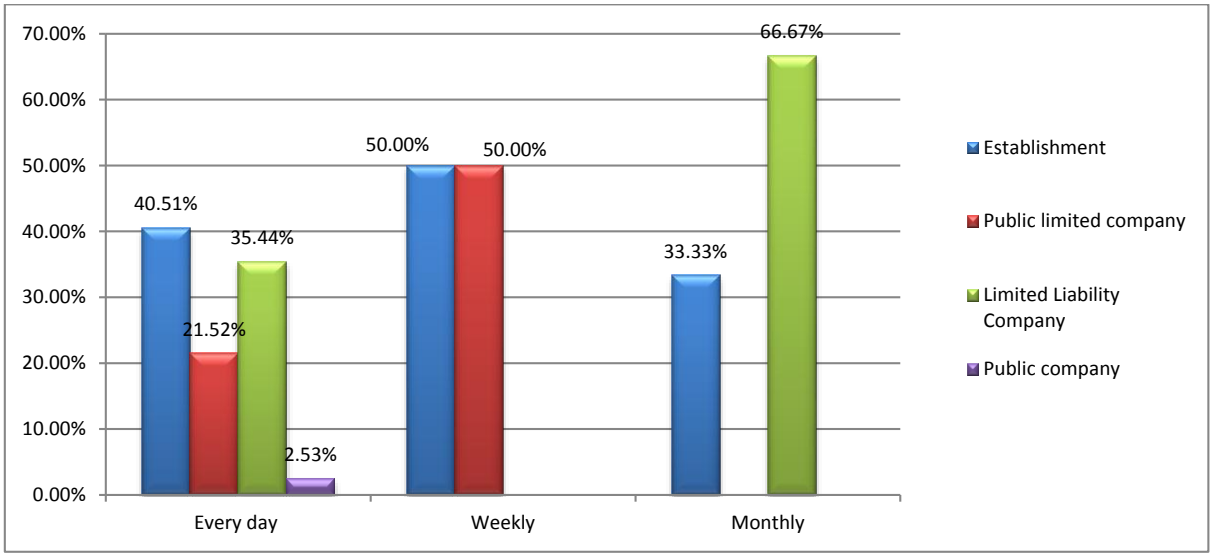

Figure 6: Frequency of BIM use in relation to the type of business

In Figure 6, the focus is on the comparability of the frequency of BIM use (once a day, once a week, once a month). It seems that there is the same level of frequency between the Private Unlimited Liability and Private Limited Liability Company types. Both types are more than 75% for daily use. Public limited companies refer to the frequency ¼ for daily use. Public companies remain perfectly negligible with 2.5% of daily use frequency but remarkably absent for the other frequencies (per week, and per month). The frequency per week is only observed for companies with limited liability, and establishments in a parity proportion of 5%. While limited liability companies, absent in the "once a week" frequency, dominate the "once a month" frequency with more than 2/3. The Private Unlimited Liability companies provided the remaining third frequency "once a month". All motivations

outside building design for the use of BIM were almost all preferred by more than 80%.

The BIM application and its impact on project performance

Figure 7 shows the application of BIM, including structural analysis, structural design, quantity takeoff or energy modelling.

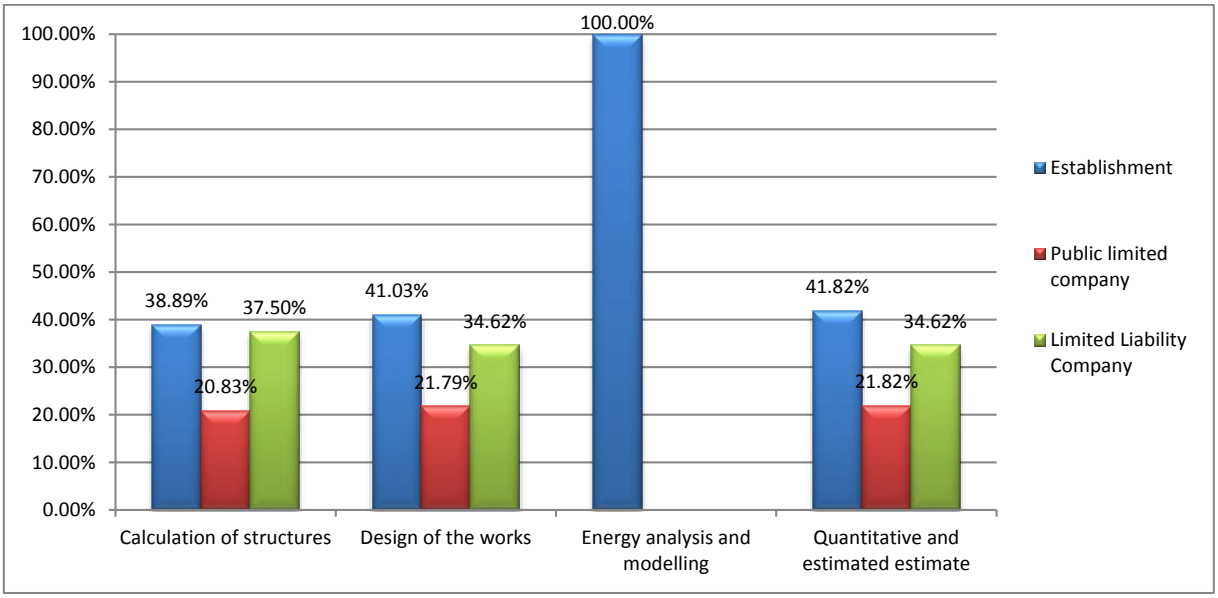

Figure 7 : The application of the BIM

Structural design, structural analysis, energy modelling and quantity removal applications are carried out by private unlimited liability companies, public limited liability companies and private limited liability companies.

✓ **Motivation for the use of BIM**

In Figure 8, there is a clear level of comparability in all incentives for the use of BIM, which is estimated at more than one-third for limited liability companies. Public limited companies and private institutions have a frequency of around 40% at ¼ and around 40% respectively for the following reasons: speed of project processing, improvement in the quality of work (high quality), high performance and reliability of results. For structural design, public limited companies dominate with 40% and private institutions with only 25%.

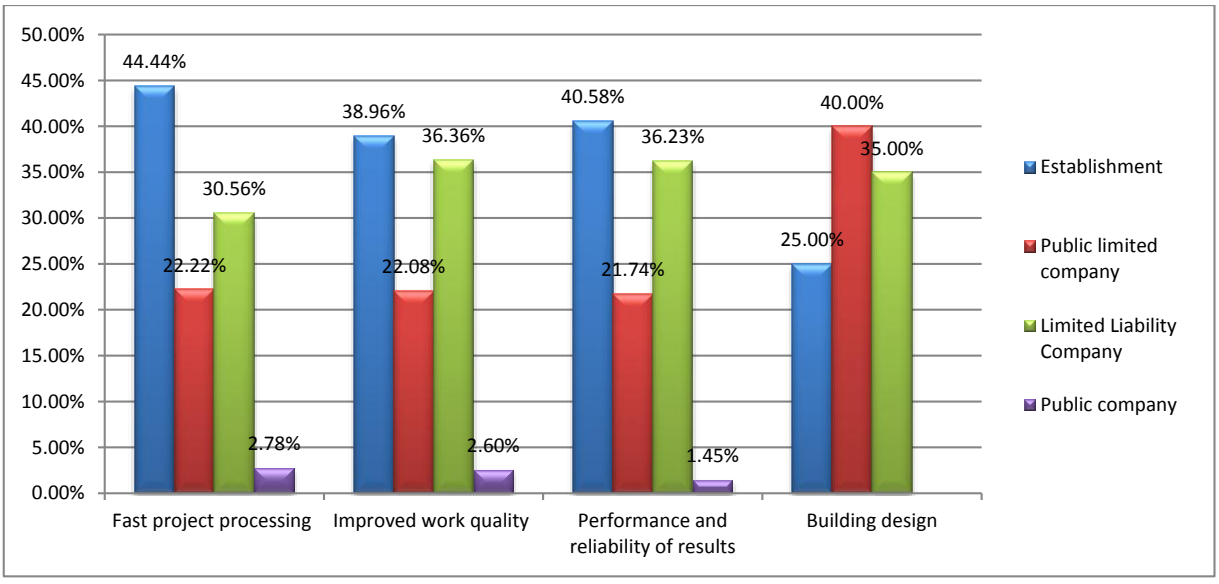

Figure 8 : Motivation for the use of BIM

Figure 9 shows the impact of the use of BIM in the company. We see regular proportions in each of the three impact effects for each type of business. After the "None" monochrome impact for two unlimited private liability companies, three other bars indicate more than 3% for public companies, 35% for private limited liability companies, 21% for public limited liability companies and 40% for unlimited private liability companies.

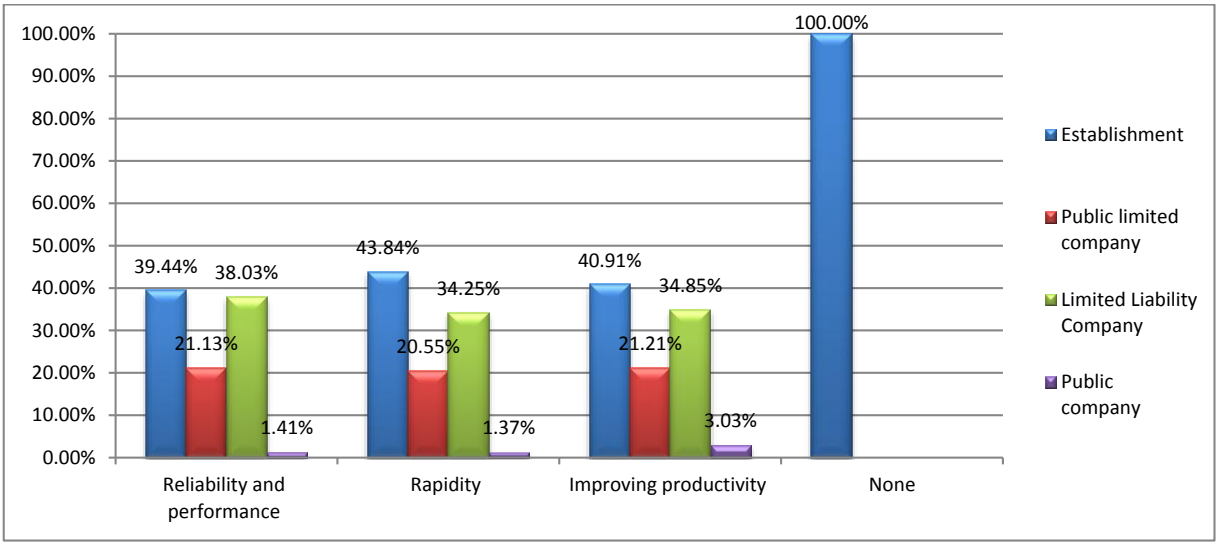

Figure 9 : Impact of the use of BIM

✓ **Some obstacles to the use of BIM**

As for the reasons for not using BIM tools, there is almost always a need for capacity advocacy, followed by financial constraints at par or 50%. The absence of major projects subject to BIM cost reduction represents 33%. High license fees are no longer a major constraint with 16%. However, it is alarming and curious to note that almost all of the 89 companies did not answer the relevant question "if the obstacles and constraints mentioned in the questionnaire are removed to better use BIM?

Indeed, 82 companies do not respond with only 7 responses from 5 private unlimited liability companies, the limited liability company. 5 companies gave reasons for the lack of motivation to use BIM (Figure 10).

With regard to the type of activity of the company, it appears that 4 companies have the status of Unlimited Private Liability and one company the status of Limited Private Liability, which explains the lack of knowledge of the BIM. Most of the barriers have also been examined in the literature that has been solicited and include high costs [37], lack of BIM experts, limited interoperability between BIM systems [35], liability, model copyright and cultural issues [17].

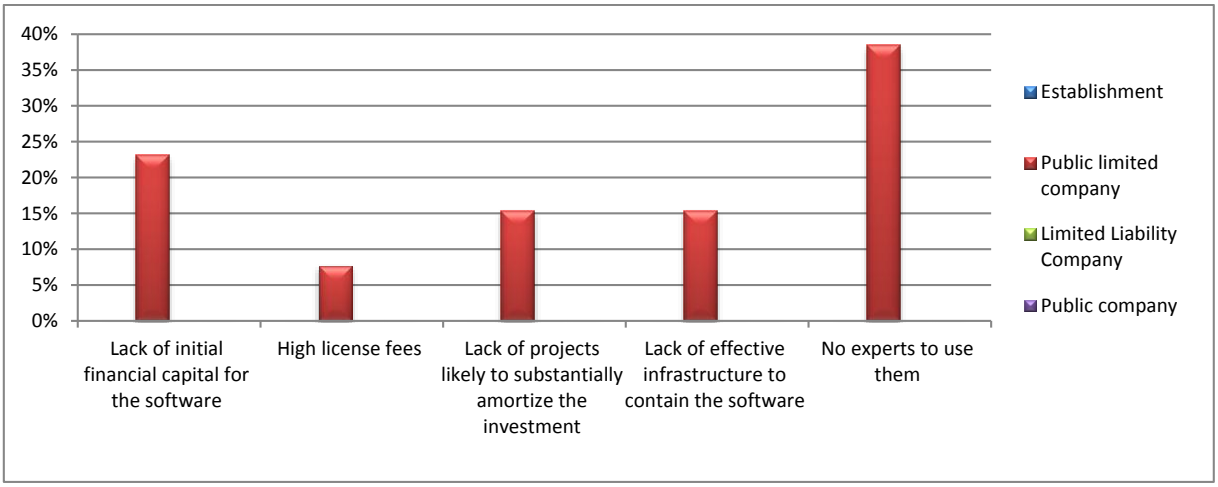

Figure 10 : Some obstacles to the use of BIM

DISCUSSIONS

Several studies have been conducted on the use of BIM in cost estimation **[15; 16; 32; 33]**. Although these different BIM applications appear to be common in most developed countries, their quantitative advantages differ. In a recent study, surveyors reported time savings of a few weeks to a few days in 4D and 5D simulations **[34]**. A study conducted in 2014 reported an overall positive return on investment (ROI) on BIM of 76% in North America, 80% in some European countries, 78% in Australia and New Zealand **[35]**. Without providing quantitative estimates, the same report revealed the benefits of BIM in China and India (although with slow adoption) and a BIM ROI of 85% in Brazil. It is likely that more companies will adopt BIM if the real benefits can be demonstrated. One example is North America, where the adoption of BIM has increased from 28% to 71% **[35]**. While much has been done in Western countries, very little has been done in Africa. A study on the use of BIM to optimize the total life-cycle cost of a building in Egypt was conducted **[36]**. The use of BIM in the calculation of intrinsic energy and carbon dioxide in residential buildings in Cameroon has been studied **[19]**. The importance of using BIM to improve sustainability in the South African construction industry was discussed **[12]**. An online system (eBuilding) for the integration of a set of functions, consisting of one or more software packages for the management of all graphic and alphanumeric information on Luxembourg real estate using a BIM approach, has been developed and the suitability and applicability of such a system for construction projects in Africa has been studied **[13]**. A recent study on the use of BIM in construction in different regions of the world revealed nothing about Africa except a very insignificant publication on Egypt, although not mentioned [37].

In order to identify the problem and knowledge gaps, a literature review was conducted. Although this study did not focus on ICT, it was a holistic approach where ICT in general was undertaken to appreciate a broader picture of ICT and BIM applications in the construction industry in Congo. In order to optimize the chances of finding peer-reviewed literature, systematic searches were conducted using established peer-reviewed databases. Those considered include EBSCO, Science Direct, Ingenta connect, Ei-Compendex, Emerald, Google and Google Scholar. The three main search terms used are "Information and Communication Technologies in Congo", "Information Modeling on Construction in Congo", "Information Modeling on Construction in Congo". Since ICT and BIM are very common acronyms used to represent these search terms, "TIC au Congo" and "BIM au Congo" were also used. Based on this literature research, most ICT studies tend to focus on certain activities as impacts on poverty reduction and development issues, types of ICTs, the diffusion or expansion of ICTs in Africa, ICTs in education, telemedicine, climate change, etc [38]. Since the results of the renowned repositories provided very little information on the use of BIM in Congo, the research was diverted to conferences and institutions dealing with ICT in Congo. The sampling plan chosen was the quota draw, whose variables were the location and legal status of the company or firm. Since statistical utility is the enterprise, this survey considered a sample of 89 structures in Brazzaville and Pointe-Noire.

CONCLUSION

In most developing countries, including the Republic of the Congo, there are many cost and time overrun problems in the management of the construction industry and public works, or building construction projects in particular. Many studies have been conducted on the causes or concerns. Other researchers have focused on the overview of some methods on time control. BIM as a process is one of the decision support systems applied in construction to improve performance, productivity and predictability of results, with many advantages.

The two most important benefits of BIM for sustainable building design are: integrated project delivery and design optimization. While BIM is gradually gaining ground in developed countries, little is known about its use in most developing countries. The purpose of this study was to study the adoption of BIM in Congo and to explore its impacts on the environmental performance of buildings. Eighty-nine (89) companies participated in this study. These companies were selected by type of activity (status) and their field of activity. Most of them have become aware of the importance of our study and have accepted their voluntary participation and wished for the anonymity of the data collected. The reluctance was noted with regard to issues related to annual turnover. The main conclusions of this study are as follows: the cost as a major obstacle to the adoption of BIM in Congo; the low level of involvement of government departments in the use of BIM; the low level of involvement of large companies in the use of BIM and its limited use in sustainable construction. Despite some difficulties due to the objective of covering a larger sample, everything was statistically compensated. This ensures the credibility of the results of our study.

ACKNOWLEDGEMENTS

We would like to thank the Construction Department of the Ministry of Construction, Urban Planning and Housing for providing us with data on the various companies involved in the Civil Engineering sector.

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