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THE IMPLEMENTATION OF BUILDING INFORMATION MODELING (BIM) TOWARDS SUSTAINABLE CONSTRUCTION INDUSTRY

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Abstract: Global environmental changes, energy consumption, and the scarcity of water have all imposed the need to implement sustainable development strategies worldwide. The construction industry is not exception, as it should take more strides to alleviate harmful impacts of unsustainable construction practices on the built environment. The construction industry is a multi-disciplinary industry that includes all the built environment elements that has a high economic impact and serious environmental and social concerns. The significant contribution of the industry on the built environment is urging the Architecture, Engineering, and Construction (AEC) professionals to convert current conventional construction approaches into more sustainable ones. One of the useful in this regard is to capitalize on an innovative technological means to narrow the gap and advance the sustainable green construction mission. Building Information Modeling (BIM) is a relatively recent technology within the construction industry that, when properly introduced, can help in providing adequate project quality, accurate time and quantity take-offs schedules, and project costs reduction. This study aims at analyzing the impact of BIM implementation on the sustainable construction practices and assessing current BIM implementation trends during the design process phase in the AEC industry. In principle, the study describes the BIM implementation obstacles, and success factors of adopting BIM for achieving sustainable construction. In addition, interviews were conducted with BIM experts to investigate the BIM implementation situation in the Egyptian consultancy firms and the needed actions for successful BIM adoption strategies that can be applicable for the Egyptian construction market and other markets worldwide.

1 INTRODUCTION

A fact that cannot be denied, human activities have a substantial impact on climate change such as ice melting, increasing sea level, changing weather conditions, water scarcity, and the damages of the tropical forests causing the greenhouse effect and greenhouse gas emissions (Bampou, 2016). Moreover, with the rapid construction industry development, buildings are estimated to double by the year 2030 creating a greater energy demand. In addition, the International Energy Agency (IEA) forecasts the growth in energy

demand 30% by the year 2030 which will cause an increase in the energy consumption rates, especially in the developing countries (Bampou, 2016).

The construction industry is a significant industry that contributes to the socio-economic growth, especially in the developing countries. Furthermore, the construction industry is the main contributor to the unsustainable development worldwide. For instance, the industry consumes 40% of the total energy production, 40% of the raw materials, and 25% of all the timber production worldwide. In addition, the construction industry is responsible for 16% of the total water consumption and 35% of the CO_2 emissions (Son, Kim, Chong, & Chou, 2011).

Since the construction industry has a significant economic, social, and environmental impact, the relationship between sustainable development and construction industry vital for saving the environment. As improving the construction practices become essential to minimize the construction industry detrimental effects on the natural environment (Sev, 2009).

Sustainability can be achieved only through the efforts of everyone involved in the construction industry. Furthermore, sustainability must be incorporated into the entire lifecycle of a construction project to make a significant impact starting from the concept phase up to the operation phase where different environmental, social, and economic considerations appear (Son, Kim, Chong, & Chou, 2011).

In 2004, the National Research Council (NRC) that focuses on providing the strategy for advancing the competitiveness, efficiency, and the productivity of the U.S. construction industry conducted a study to investigate the gap between the building industry and IT. This study found that the interoperable technology applications or Building Information Modeling (BIM) is not only a solution but also the most promising technology to improve the quality, timeliness, cost-effectiveness, and the sustainability of the construction projects. BIM is a process to improve and maintain an integrated digital representation of information through the different phases of the building lifecycle. In addition, BIM can create, document, coordinate, update, and manage information about each particular facility and components in the building through powerful data modeling capabilities forming a major change in the construction industry worldwide (Matarneh & Hamed, 2017).

As many other countries, Egypt is suffering from serious environmental pollution problems like air pollution, solid and liquid waste, hazardous materials, high noise level, and harmful chemicals and pesticides. These problems cause diseases like schistosomiasis and microbiological diseases (Hopkins & Mehanna, 2003) that makes offering a safe and healthy environment for the people a vital issue that should be considered by the construction decision makers.

2 RESEARCH METHODOLOGY

The research followed the social science research technique. The literature review and interviews were found to be the most appropriate approach for the research nature. The inductive “down-up” approach is

adopted for this research as the kind of the research is a learning process research that encourages the progress of the research from specific to general.

The gathered data from the literature review used to develop qualitative interview questions for data collection from the field. The linear snowball sampling technique was used to reach the targeted population, as it was difficult to reach samples. The data was collected by over phone interviews with BIM and sustainable design experts from the Egyptian design consultancy firms to identify the BIM practices in their firms and the difficulties they faced in the implementation process. In addition to the benefits, they have gained from the implementation. These interviews added in-depth understanding of the current BIM implementation practices in Egypt and the future actions needed for a successful implementation and encourage the use of the BIM technology for achieving sustainable buildings. SWOT analysis was developed to identify strengths and weaknesses, as well as opportunities and threats regarding the BIM implementation situation in Egypt. Figure *1*

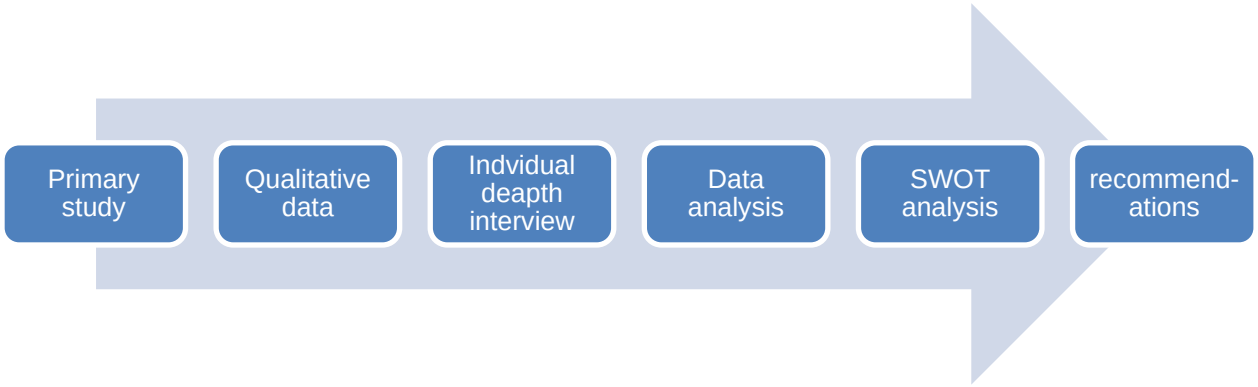

Figure 1: Research methodology

3 LITREATURE

3.1 Sustainability in construction and the pre-construction phase

The term sustainable construction is used to define the sustainable development principles in the construction industry. In 1994, the Conseil International du Batiment (CIB) defined sustainable construction as "…creating and operating a healthy built environment based on resources efficient and ecological principles" (Al-Yami & Price , 2006). (Du Plessis, 2002) defines sustainable construction as "a holistic process aiming to restore and maintain harmony between the natural and built environments and create settlements that affirm human dignity and encourage economic equity". Since the construction industry generates environmental damages over the entire course of a project, sustainability measures should be undertaken throughout the whole construction process from the planning to the deconstruction phase and all the project's parties should be involved.

Nemours people involved in any construction project to fulfill the client's requirements where the project construction process can be divided into three main stages: pre-construction, construction, and post-construction (Kazi, 2005). In this phase decisions related to the project's activities and performance are taken, the design process is divided into four phases pre-design and feasibility studies, conceptual design, design development, final design, and procurement (Thabet, 2000). Several stakeholders involved in managing the preconstruction stage (client, architect, structural engineer, MEP engineers, controls engineer, facilities manager, and the construction manager). They are also known as the design team (Laitinen, 1998). The cooperation between the stakeholders is essential to avoid the design problems like design changes, design clashes, poor design constructability, and poor 2D drawings that are the main factors that contribute in several construction problems like project delay, cost overrun, disputes, and low productivity. (Ahmed & Yusuff, 2016); (Kikwasi, 2012). Figure 2 shows the pre-construction problems effect on construction stage.

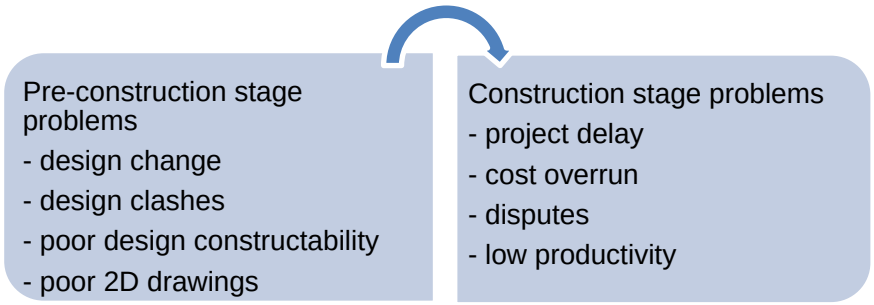

Figure 2: Pre-construction stage problems influence on construction stag

3.2 Building Information Modeling (BIM)

Computerization has improved the speed and accuracy in the construction industry. BIM is the process where a digital representation of the construction elements is built, analyzed, documented, evaluated virtually, and developed until the final model documented. BIM is a giant database for the project that contains all the information for construction management like cost estimation, schedules, change orders, and construction documents before the construction stage (Yalcinkaya & Arditi, 2013). Applying BIM in the early stage of the project assists in efficient design review for different scenarios analysis, this facilitates the decision for the selection of the best construction method, elements prefabrication, generating schedules, and providing drawing with free errors for construction. This input of BIM in the construction industry leads to cost and time reduction and high-quality deliverables which are the three main objectives of the construction industry. In addition, using BIM contributes in the reduction of materials waste, and effective construction management throughout the project lifecycle. Figure 3 illustrates the benefits of BIM for construction industry.

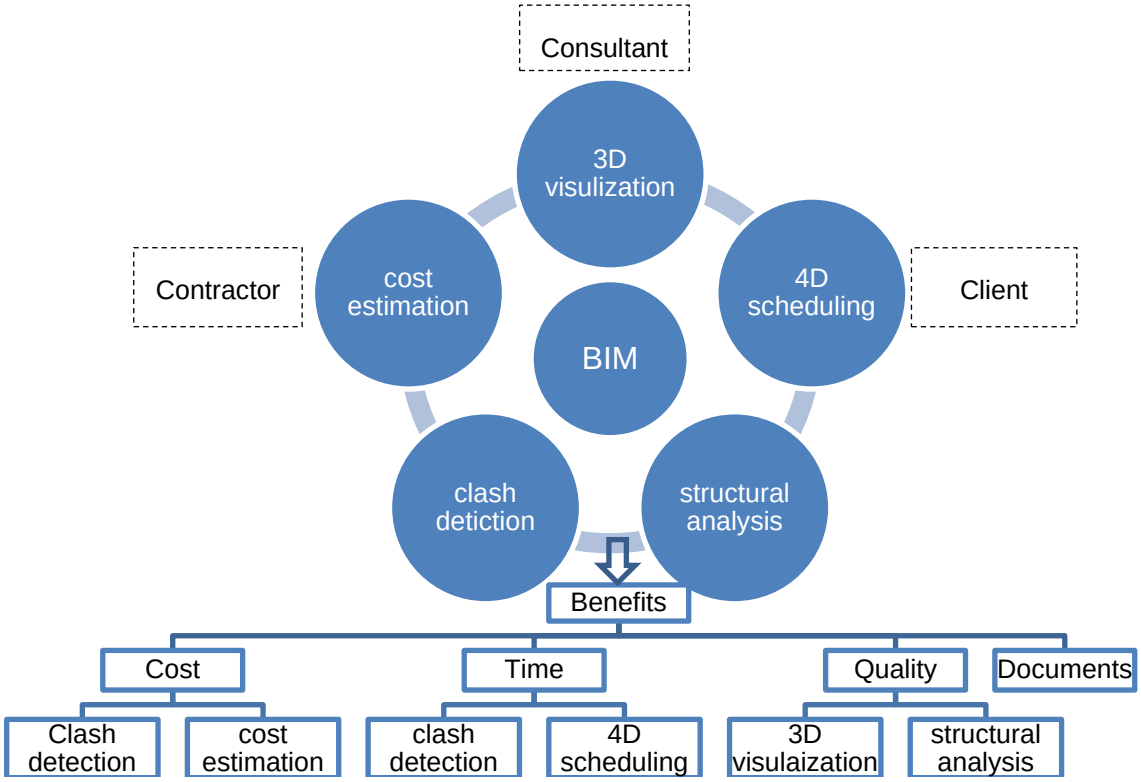

Figure 3: BIM benefits for construction industry

3.3 BIM and sustainable design

One of the barriers to sustainable construction is the notoriously low rate of Information Communication Technology (ICT) adoption. As the most of the adopted information systems are single entry oriented where the software is used for a specific activity in the building and not supporting the collaboration between the AEC players. In addition, most of the software lacked working interoperability. For example, Cad and any project management software work with geometries, quantities, time management, and budget management but none of them can read information directly from the other and updates the project data. The proper use of ICT in the construction industry during the design and pre-construction phases can significantly facilities the sustainable construction process through enabling applications interoperability, information access, intelligent documents, and integrated data exchange (Matar, Georgy, & Abou-Zeid, 2010). BIM can contribute in providing sustainable construction. As a technology, BIM simulates building projects in its virtual environment and integrates all associated data include geometry, geographic information, quantities, relationships, and all the buildings elements properties. In addition, it provides simulation for the building performance in different fields helping the designers to select the optimal proposal for construction (Oduyemi & Okoroh, 2016).

3.4 Best practices and approaches to BIM adoption

From reviewing different adoption approaches it was concluded the following: Governments and public authorities are playing the key role in BIM adoption. As discussed, the BIM adoption leading countries (USA, UK, and Singapore) have an active governmental and public sector efforts in implementing and improving the BIM practices. The main driver for these countries is the ambitious construction strategies plans to improve the efficiency, productivity, and sustainability of the construction industry. Unlike the other countries, the UK government was the first to mandate BIM in the country through its public projects (Up-Down diffusion). Other countries like USA, Singapore, Hong Kong, and UAE, the BIM was first mandated by the public authorities and then adopted within the governmental strategies (Middle-Out diffusion). Other drivers like the complexity of the construction projects and catching the new trends in the construction industry technologies are influencing countries like Qatar through the AEC firms (Bottom-UP diffusion). The successful BIM implementation requirements are recognized in the following: The collaboration between the government, industry leaders, and public authorities, Proper implementation scheduling, Pilot projects (business case) to measure the success, Education and training, Increasing of the level of maturity gradually, National standards, guides, and protocols, Project delivery system like (IPD), National and international object library, Change in the construction business environment.

It can be also concluded that to achieve sustainable construction, many actions are needed. First, a governmental vision to develop policies and regulations. Then the industry professionals and academic institutes are establishing supportive standards to support the national vision. Finally, a broad base of projects, teams, professionals, and enterprises needed to evaluate, track, and maintain the adoption plans.

4 BIM IN EGYPT

The literatures that are discussing the BIM implementation practices in Egypt are limited. However, three researches are found in the topic or near to it. First, (Elyamany, 2016) discussed the current BIM practices within the Egyptian construction industry. Second, (Khodeir & Nessim, 2017) discusses BIM and energy modeling in the Egyptian architectural firms, and finally, (Gerges, et al., 2017) investigated the BIM implementation in the Middle East and Egypt was mentioned in the study. A quantitative approach was used in the three studies, as questionnaires were developed and spread to a large number of participants to collect data. The gap in the three studies was that there was no face-to-face interview conducted with the interviewees in order to get a closer view on the BIM implementation in the Egyptian design firms.

Gerges, 2017 sent online questionnaires to 297 participants all over the Middle East countries 200 of them are valid with 67.34% response rate. 19% of the respondents who are using BIM in their companies are from Egypt. The study claimed that Egypt comes after the UAE in using BIM in the infrastructure projects. However, 37% of the Egyptian respondents stated that this is due to the international projects they are working in through their companies (Gerges, et al., 2017).

Elyamany has conducted an online survey and sent it to120 contracting companies and 10 consultancy firms, the rate of respond was 17.2% and the author explained that the low response rate may be related to the lack of the BIM understanding in the Egyptian firms. As a result of the survey, the participants think that BIM is a helping tool towards sustainable buildings and it is expanding in the construction firms (Elyamany, 2016).

4.1 BIM adoption efforts in Egypt

- BIM Egypt day (BIM Egypt Day, 2018)

The first Egypt BIM day took place in January 2018. Speakers; who are BIM experts from different AEC firms shared their personal experiences with implementing BIM and the benefits they gained in increasing the quality and reducing cost and time. Autodesk as one of the technology providers showed its marketing strategies and different sale plans to help medium and small firms to purchase the licensed software. The conference to be held annually to show the progress and discuss the BIM adoption situation in the Egyptian market. This was followed by the BIM Egypt day 2019 with the same criteria.

- TEMPUS project (Erasmus, 2018)

TEMPUS IV “Building Information Modeling: Integrated Design Environment for Engineering Education”, with participation of 4 European (Northumbria University, Leeds Metropolitan University, University of Twente and Chalmers tekniska högskola AB) and 6 Egyptian Universities (Cairo University, Mansoura University, El Shrouk Academy, The German University in Cairo, Beni Suef University, Sohag University), 2 industry partners (Kemet Corporation, Orascom Construction Industries) and the Egyptian Ministry of Housing. The project was a fund from the European Commission that started in 2013 and ended in 2017.

“The project aims at promoting Digital Engineering for Construction (DE4C) and the related BIM concept of Integrated Project Delivery (IPD) to professionals from different disciplines within the Built Environment in Egypt in order to develop skills and create better value through smarter and more sustainable processes.” Although the project’s results did not publish yet on the website, one of its objectives was to establish MSc degree in (DE4C) technologies and IPD, this master’s degree have started at Cairo University from 2015 with fund from the TEMPUS. The fund was stopped by 2017 by the end of the project period and still available at the University till know (Lab, n.d.). In addition, the program aimed to establish training centers in each of the six joined Egyptian Universities and that is the case know the six Universities (Erasmus, 2018).

- BIM in Universities

Admed, 2016 investigated BIM education in some of the Egyptian universities both governmental and privet universities. The author also stated that 60% of architecture students in Cairo University, and from 60 to 70% of Ain Shams University use BIM in their projects and it is a part of their curriculums. In Al Azhar University, 35% of the students are using BIM in their projects although it is not a part of their study in the university (Admed, 2016). Private universities like the American University in Cairo (AUC), British University in Egypt (BUE), and the Canadian University in Cairo (CIC) are teaching BIM in their curriculums and it is planned to develop their curriculums to involve BIM in all the study years. Also, the German University in Cairo (GUC) is teaching BIM in the engineering curriculums and has a BIM unit that has conducted BIM forum in 2017. The forum was a cooperation between the GUC and NourthUmbria University & BIM Academy and discussed the latest development of the BIM practices in the built environment (Unit, 2017).

- . Governmental efforts

In September 2018, the Egyptian Housing and Building National Research Center (HBNR) released the first Egyptian code for BIM for discussion for engineers. The code is still a draft and the final edition is not published yet. The Egyptian government aims with this step to improve the construction industry practices.

4.2 Interview data analysis and discussion

The interview questions objectives were to complete the gap with the previous studies concerning the BIM implementation in Egypt. 75% of the interviewees are architects and 25% are mechanical engineers who are responsible for MEP management and coordination within their companies. All the participants have experience in BIM implementation with their current companies in addition to previous experience with other firms. Four of the participants companies' scope is BIM implementation and they are managing BIM implementation in different Egyptian consultancy and construction firms. Two of the participants are carrying the "Certificate in Building Information Modelling (BIM): Project Management" from the Royal Institution of Chartered Surveyors (RICS). Three of the participants their main study is interest in BIM and its application in sustainable building in Egypt whether in their master's degree, teaching experience, or work experience. The questions were to investigate the drivers and barriers, factors of success, maturity level, used protocols, impacts, and the need of government for adopting BIM in the country.

4.3 SWOT ANALYSIS

Combining the data received from the literature review, the interviews, and current BIM implementation practices and awareness efforts in Egypt, a SWOT analysis was used to illustrates the situation of BIM implementation in Egypt that can be also applicable for other countries, Table *1*.

Table 1: SWOT analysis

Strengths	International project's experience Young trained employers Increasing implementation rate Increasing client's demand BIM education increases in universities
Weaknesses	Absence of governmental support or implementation Education do not support integration between disciplines Expensive technological infrastructure Change resistance from top management Lack of BIM experts
Opportunities	Some Egyptian companies have international experience Increasing awareness in BIM benefits Egyptian companies to lead the construction market practices in middle east Technology providers design new sales strategies to support medium and small companies.
Threats	Competition from the surrounding markets

	High initial implementation cost
	Lack of sharing best practices
	Un professional implementation process

5 CONCLUSIONS

The study shows that BIM implementation has many benefits for the construction practices that positively influence the sustainability of the industry. As BIM adoption improves the management of the construction project information, enhances the quality of deliverables, offers better collaboration between the project team, facilitates and improves environmental building analysis, and contributes to materials waste reduction.

Barriers towards a successful BIM implementation are many for companies and countries. Barriers like top management resistance to change, technology cost, insufficient implementation, and lack of training and experts, are the main obstacles in the adoption process.

Implementing BIM is not the goal by itself; the technology is a part of a main goal towards improving the construction industry practices and sustainability of the sector to achieve the sustainable development strategies.

The main driver that influences BIM implementation in the Egyptian consultancy firms is mandating BIM in some of the GULF countries, as the Gulf Cooperation Council (GCC) countries area construction market is a vital market for Egyptian firms.

The Egyptian client requires BIM for developing their project's construction documents, especially in the large and complex projects. Their main goals are to reduce construction conflicts and disputes, getting accurate materials take-offs, and time schedules.

Experts believe that BIM has the ability to facilitate and support sustainable building in Egypt; however, the problem is the lack of demand on sustainable buildings and it is not supported by the country.

Regardless the slow implementation rate, the research revealed that there are some promising initiatives from the universities and the private sector towards improving the BIM practices in Egypt.

Experts also stressed on the role of the government in expanding the use of BIM to achieve sustainability in the construction industry and the design of sustainable buildings. In addition, the literature also supported this vision, as the governments and public authorities' role in BIM adoption is vital, as they can form a pressure towards implementing BIM throughout countries.

6 RECOMMENDATIONS

Building on the literature review and the interviews the study recommended some actions that should be taken by Government, construction industry stakeholders for adopting BIM towards sustainable construction industry.

Government and public authorities

Adopt BIM in the countries sustainable development strategies in the area of sustaining the built environment towards improving the construction industry practices.

Set broad goals for the BIM adoption with the cooperation with the industry stockholders and set a time frame for reaching these goals.

Release a roadmap for mandating BIM in the construction industry.

Provide professional BIM education.

Implement BIM in the building license authorities.

Collaborate with the private sector to develop BIM standards and guidance based on their experience.

Form a benchmark and best practices platform in order to help more firms in the implementation process.

Make a partnership with the international organizations that support BIM adoption through countries like the BIM task group or buildingSMART organizations.

Encourage the AEC firms to implement BIM and sustainable buildings by providing training, reducing taxes, and provide loans to update the companies' technological infrastructure.

Universities and educational centers

The rapid development in the construction technologies and practices towards more sustainable practices need adaptive curriculum that can follow and update the students' knowledge and skills.

Use BIM applications in the environmental courses to train the students on using simulation to measure the building performance.

Encourage the collaboration and communication between the engineering departments through shared projects.

AEC companies and manufactures

Set goals, form a BIM implementation plan, and inform the company's staff with the plan to support the implementation process.

Monitor the plan gradually and update it when needed.

Measure the implementation maturity level and evaluate the performance of the implementation process.

Celebrate each goal achievement and support the staff by giving rewards and accepting errors at the beginning.

Inform the top management with the BIM benefits through providing training in the BIM management tools and its ability to enhance the quality and improve the productivity on the long run, in addition to showing them successful implementation and projects cases.

Invest in the staff training and upgrading the firm's technological infrastructure.

Make any required change in the company's business or disciplines structure to support collaboration and communication between the project team.

Manufacturers and suppliers should provide the design team with BIM objects for their products to be used in the building analysis and simulation.

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