**BIM Adoption Integration with Sustainability**

**in the Egyptian AEC Industry**

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**Abstract**

Construction industry is an important sector of the economy of any nation. Yet this industry is liable to numerous issues amid the different phases of the project: for example, delay in the execution-wrong stock of amounts-increase project cost- delay of delivery-and low quality. These issues and in addition of waste, because of the over the top misuse of materials in the construction phase, have extraordinary harm to society and the earth and attempts to break down the economy of the state. From these points the innovation of the BIM (Building Information Modeling) has been developed to advance this industry and past the entirety of its issues. The objective of this research is to accomplish two primary destinations in the Egyptian AEC industry: 1) Assess the awareness of engineers about BIM and sustainability in the construction industry. 2) The extent of companies’ reliance on outsourcing to implement BIM projects. Notwithstanding the information from the study, which included 140 individuals of engineers, there is a comprehension and reception of the BIM by the organizations, and few organizations are not at present utilizing BIM because of Lack of the awareness of BIM by stakeholders and lack of demand from clients regarding with using BIM technology, but plans like create in-house abilities via preparing current staff in BIM. Few organizations depend on outsourcing for the usage of BIM when needed. This study discusses the significant outcomes identified with BIM technology, its incorporation in economic structure, and the enthusiasm of Egyptian organizations in this innovation**.**

**Keywords:** Building Information Modeling, BIM, BIM Outsource, Project, Construction Industry, Sustainability

1. **Introduction**

The Egyptian construction sector is considered as one of the sectors with strategic economic impact. According to the Central Agency for Public Mobilization and Statistics of Egypt, the revenues of the construction industry during the second quarter of 2018-2019 amounted to 58.9 billion pounds and this vital sector provides about 3.7 million job opportunities. Although this sector benefits the economy of the country, it also suffers from many problems during the project execution.With the development and technological progress in all industries to achieve high-quality producer, the share of the construction industry was the best luck with the emergence of BIM technology. From the mid-2000s, the first movement of BIM adoption entered the construction industry as a to address and overcome the problems and provide an integrated model containing all the characteristics and information (Won, et al, 2013). BIM concept is the current expression of innovation in the construction industry through which the teamwork is encouraged during the project period that will increase the efficiency and quality of the construction. BIM is a process that increases the full exchange of information during the project life cycle. Building Information Modelling (BIM) can be claim as a procedural and technological shift in the AEC industry.

On the other hand, construction industry is among the heaviest consumers of natural resources and a big contributor the emission of CO2 that contributes to global climate change (Wang & Kuan, 2014). Where, sustainable buildings increase the quality of life, the performance of jobs, and the development of a safe environment. Sustainable construction and green buildings have therefore been described as the response of the construction industry to the challenge of sustainable development (Safinia et al., 2017).

This paper confirms the growing interest in BIM and sustainability within the construction industry and offers clarification to maximize its uptake

1. **Problem Statement**

Egypt, like any other developing country in which the construction industry is one of the important pillars of the economy. This industry is subject to many problems from the design stage because of the lack of good planning until the post construction phase. Management practitioners and academics have attempted to bridge the AEC industry's recognized holes such as fragmentation of collaboration, inadequate coordination, weak communications, low performance buildings, energy overconsumption, unsustainable buildings, project overrun, low efficiency, low building quality, poor stakeholder / client / user satisfaction and lack or unauthenticated facility management (FM) data during the maintenance process, in addition to design errors and conflicts.

The results of several studies and researches showed that the BIM technology achieves all the objectives of the project from reducing the cost, time and improvement of the quality of the project. Problems are usually revealed before the construction phase that limits the waste of materials.

Stanford University Center for Integrated Facilities Engineering (CIFE) found the following benefits of using BIM-based upon 32 large projects (CIFE, 2007): the cut of unbudgeted change up to 40% - increase the accuracy of cost estimation by 3% up until 80% - reduction in cost estimating time - savings of contract price up to 10% due to clash detections – Up to 7% of project time is deducted - a growth in field efficiency in the range of 20-30%. The advantages of BIM for users who have used a building model to implement BIM technology have been demonstrated by an increasing number of case studies around the world. In spite of that, BIM, like many other regions of the planet, was not adopted by the AEC firms in Egypt. This stimulates the need for research to identify how BIM can be embraced and applied by AEC companies in Egypt in their activities and initiatives to be able to address all the difficult problems in the AEC industry.

While BIM is a recent development, an abundance of research has been conducted in order to further improve the design and construction capabilities of BIM. However, a substantial amount of work has not been carried out on the effect BIM on sustainable building practices. This study aims to define the possible capabilities of BIM software in relation to sustainable development practices of building.

1. **Research Objectives**

The research aims at a clear understanding of the BIM technology and highlighting its most important benefits to overcome the issues of construction industry and to what extent it has been adopted by the companies and what is their future in Egypt. The research also aims to connect the building database in the BIM tool to help users to design sustainable buildings. The researcher also mentioned in the research the extent of outsourcing to implement the projects of the BIM. This research may be from the rare researches on the outsourcing of the implementation of the BIM in Egypt. The main objectives of this research can be identified as follows: - 1- Assess the awareness of engineers and professionals in the field of construction and the extent of their use of the BIM technology in Egypt. 2- Extent of outsourcing of BIM projects in Egypt. 3- Assess the awareness of engineers and specialists in the field of construction on sustainability and green buildings.

1. **Research Methodology**

The research commenced by carrying out literature reviews on the BIM technology, perceptions about BIM outsourcing, as well as the section on sustainability with BIM. The researcher contacted, by phone, 59 engineering consultants’ offices in Egypt who are related to large consulting firm that strive to apply BIM technology. The first step taken with them was self-introduction and clarifying the subject of the message, then specifying the tool in the research would be the questionnaire as a device to collect sufficient information to achieve the goals of the research. Fifty offices out of fifty-nine welcomed the idea that the questionnaire should be sent to the e-mail and answered electronically due to the lack of time of engineers and the abundance of their work.

The questionnaire was processed by working on a link for easy access, since a large number of specialists were in the field, and also for easy collection for date during short period of time and at the lowest cost. The engineers were searched for all their specialties in LinkedIn and the engineering forums in Facebook. The electronic questionnaire was sent to 200 engineers related to the construction industry within two months, 140 interrogations were collected. The questionnaire consists of five parts: the first part is for personal information, the second part is about the company information, the third part is about the technology of the BIM, the fourth part is about the sustainability of the buildings, and the fifth and final part is about the integration of BIM and sustainability.

1. **Literature Review**

**5.1 Building Information Modeling**

The Committee for National Building Information Modeling Standards (NBIMS) defines BIM as a digital representation of a facility's physical and functional features. The industry of Architecture, Engineering and Construction (AEC) began using BIM in construction projects from mid-2000 onwards (Latiffi et al., 2014). According to (Latiffi et al., 2014) BIM described in 2006 as a new methodology for the management and enhancement of AEC quality in project completion and management. BIM developed in 2008 as a design simulation consisting of a project component's 3-Dimensional (3D) model. It linked and integrated throughout the project phases with the information required. After 2008 until 2013, BIM had been enlarged as a technology revolution that helped to transform the way buildings were conceived, designed, constructed as well as operated.  
Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering, and construction (AEC) industries. With BIM technology, one or more accurate virtual models of a building are constructed digitally (Estman et al., 2011). (Lee & Yu, 2016), stated that the activities in the AEC industry that can use BIM are 3D modeling (architecture / structure / MEP); clash detection; feasibility studies; model-based take-off and calculation of quantities; visualized scheduling (4D) management; environmental assessment, shop drawing development and schedule management.

Global trend has shown over the past few years that BIM concepts have already shifted in architecture, which has progressed from three-dimensional to multi-dimensional (Yang & Li, 2015). In comparison, BIM is turning the AEC industry into a high-tech, high-productivity market.

**5.2 Outsource of BIM**

BIM outsourcing is described as' contracting the development and/or use by an entity of a BIM template for a project to a third party specializing in the BIM system (Fountain & Langar, 2018), but still developing. Multiple challenges hamper the systematic application of BIM. A few general contractors outsource the production and use of BIM models to organizations with advanced information software (IT) because of these obstacles (Fountain & Langar, 2018). Considering that BIM outsourcing can resolve challenges associated with its implementation among general contractors, this implies that businesses are implementing BIM outsourcing services offered by specialized IT firms rather than using BIM workers in-house to develop and implement their BIM models.

**5.3 BIM with Sustainability**

With the rising cost of energy and growing environmental concerns, the demand for sustainable building facilities with minimal environmental impact is increasing (Azhar, et al., 2009). Green materials are environmentally responsible because the impacts of the product are considered over its life cycle. BIM execution has numerous advantages for the construction rehearses that emphatically impact the sustainability of the industry. As BIM selection improves the administration of the construction project data, enhances the quality of deliverables, offers better collaboration between the project team, facilitates and improves environmental building analysis, and adds to materials squander decrease (Mohamed, 2018). The future of BIM‟s use within the industry will continue to grow at a gradual pace. This includes utilizing BIM as a mechanism for sustainable design and construction practices (BYNUM, 2010).

Green BIM is defined as, the ability to assess sustainability aspects including near zero carbon in construction, optimizing energy usage, optimizing the environmental performance, efficiency in managing waste, improvement on indoor climate, in the building lifecycle (Ampratwum, 2017). BIM Technology can affect green building in the project lifecycle (Ampratwum), where, linking the building information model to energy analysis tools allows for evaluation of energy use during the early design phase. This is not possible using traditional 2D tools, which require a separate energy analysis be performed at the end of the design process, thus reducing the opportunities for the early modifications that could improve the building’s energy performance (Azhar, et al., 2009).

1. **Analysis of results**

**Part One: Demographic information**

In this section, the respondents' personal data will be analyzed to show the random selection of samples. The diversity of respondents in terms of educational level showed that the majority was with those holding the Bachelor's degree with a rate of 76.4%, and came in second level with a master's degree of 17.8%, and the lowest number of respondents who got a doctorate by 5.8%. The engineers who participated in the questionnaire were from various engineering sectors according to the answers provided, so the answers contained rang of opinions reflect departments to which they belong. Among the individuals and companies surveyed, the majority (44.3%) of the respondents had less than 5 years of construction experience, which is a good indication that there is a conception for newly graduated engineers who are well involved and contributed in new research in construction techniques. The percentage of the respondents that has professional certificate (PMP, LEED) was 29.3%, 7.1% of respondents chose another that included (PRMG, ACP, CEM, FE Civil). Since one of the objectives of the research is to identify the awareness of the engineers in the Egyptian construction industry about the BIM, collected data showed that 92.1% of participants have knowledge about BIM.

Table: 1 Participants demographic information

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **Characteristics** | **Freq.** | **Percent %** | **Total** |
| Education Level | Bachelor  Master  PhD | 107  25  8 | 76.4  17.8  5.8 | 140 |
| specializations | Architect  Engineer  MEP  Other | 57  59  11  13 | 40.7  42.1  7.8  9.4 | 140 |
| Years experiences | 0- 5 years  6 - 10 years  11 - 20 years  < 20 | 62  45  25  8 | 44.3  32.1  17.9  5.7 | 140 |
| know of BIM | Yes  No | 129  11 | 92.1  7.9 | 140 |
| Years of experience in BIM | No experience  0-5 years  6-10 experience  <10 | 41  77  18  4 | 29.3  55  12.9  2.8 | 140 |

**Part Two: Building Information Modeling**

**- Using of BIM**

This section explains the responses of respondents on two most important points of the research, the first is about their knowledge of the technology of the BIM and to what extent it can be used in the construction industry and the second point is about relying on outsources for the implementation of the BIM. Within the context of the use of BIM over the last five years, the chart below (Fig.1) shows that the percentage of the participants that worked on BIM before were 51.4% of the total participants, while the remaining (48.6%) of the participants did not work on BIM before.

Figure: 1 Participants experience in using BIM.

**- Reasons using of BIM**

Since the basis of the research is about the evaluation of engineers about the BIM, the questions of the questionnaire in this section were divided into those who stated that they had already used the BIM (51.4%) and those who had not yet used the BIM in their companies. It was found from the explanations for the questions ahead of those who have used the BIM, that 33% of the sample think that BIM is faster way to capture/resolve quality issues and eliminate clashes (design quality),16.4% stated that the market/client/government offices requires BIM usage. It was found that 15.5% of the participants believe that BIM improve competitive position while 11.3 % stated that application of the technology was demand by the customers. The remaining groups of participants concluded the following statements: reduce design and constructions costs, handover information, collaborative project environment between stakeholder from project inception to completion and finally reduce operating costs and full access to asset information in operation and maintenance. Findings collected from this remaining groups for the above statement are: 8.2%, 6.2%, 5.2% and 2.1 %, respectively. Table 2, summarize the reasons of using BIM by the companies.

Table: 2 Reasons Company use BIM.

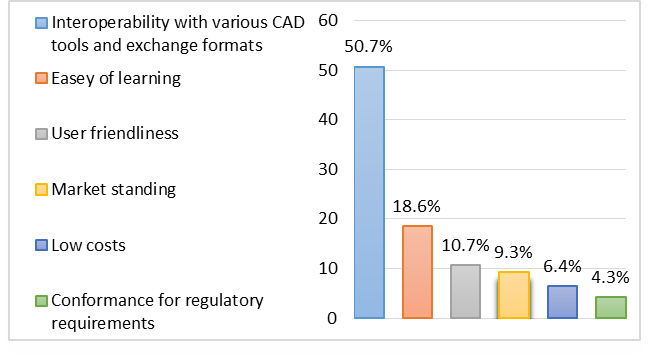
|  |  |  |  |
| --- | --- | --- | --- |
| Rank | Statement | Responses | Percent |
| 1 | Faster way to capture/resolve quality issues and eliminate clashes (design quality) | 32 | 33% |
| 2 | The market/client/government requires BIM usage | 16 | 16.4% |
| 3 | Improved competitive position | 15 | 15.5% |
| 4 | Forced to by customers | 11 | 11.3% |
| 5 | Reduced design and construction costs | 8 | 8.2% |
| 6 | Completeness and accuracy of construction handover information | 6 | 6.2% |
| 7 | Facilitate a collaborative project environment between all stakeholders from project inception to completion (Single source of information) | 5 | 5.2% |
| 8 | Full access to asset information in operation & maintenance | 2 | 2.1% |
| 9 | Reduced operating and maintenance costs | 2 | 2.1% |
|  | Total of Responses | **97** | **100** |

**- Software Used**

Respondents were asked in another question to pick the BIM tool they used in design purposes to see the most dominant one. As seen in figure (2), the study revealed that (75%) were using Autodesk Revit, (11.1%) used Autodesk Navisworks, (5.6%) of the respondents mentioned Graphisoft ArchiCAD and Primavera. Some software such as Bently architecture, Innova and Vico Constructor were not used by respondents. The main reason for choosing Revit is that it is fully compatible with the different specialties (architectural - structural - electrical - sanitary - mechanical).

Figure: 2 most common BIM tool used.

Figure (3) represent the most significant criteria for implementing software tools compatible with BIM. The results of the questionnaire revealed that (50.7%) of the respondents, accepted the interoperability with various CAD tools and exchange format. Comparatively, the criteria of easy for learning tool come next with (18.6 %) of respondent. Respondents commented in close proportions for using criteria of friendliness, market and low costs tools with the findings of (10.7%, 9.3 % and 6.4%), respectively. It is important to note that a minority of respondents have chosen Conformance for regulatory requirements as the main criterion for the adoption of BIM compatible software tools.

  
Figure: 3 important criterion for purchasing BIM software.

Four evolving BIM model categories are thoroughly implemented in existing practices according to Taylor et al. (2009), they are Visualization, Coordination, Analysis and Supply/Chain Integration in order to understand the sample population use of BIM. The researcher conducted a survey for the role of the BIM in operations shown in figure (4) below, which indicate that the majority of the survey respondents (87.5%) do use BIM as project coordination. Comparatively, (38.9%) of the participants use BIM as project Visualization, and (33.3%) of respondents use as Project Analysis, while (16.7%) of them use BIM as product for supply/vendor integration.

BIM integrates different disciplines by effective communication, analyzes the project systems for constructability, and estimates the cost and time of projects at any time. All of this will be done only with the effective BIM coordination role during the project phase.

Figure: 4 Roles of BIM.

Throughout its implementation, BIM is far from being one-dimensional, that is expressed in the vast number of different fields where software is used. The capabilities of BIM extend over the entire lifecycle of the network, potentially be used in several processes. Survey participants could select multiple answers. Based on the data from figure (5), the majority of the survey participants have used visualization [3D model] by (69.4%), use in Constructability [clash detection] by (55.6%), and BIM use in Model-based estimating and Cost control equally by 29.2%.

This explains the relationship between the field utilize BIM and the best use of the tool, whereas, Revit and Navisworks are used for the purpose of modeling, coordination, and clash detection. These are the three most important areas agreed upon by the respondents and the following figure (5), shows the rest of the ratios for each area.

Figure: 5 fields for company utilize BIM.

**- Outsource of BIM**

Out of the companies who reported BIM utilization in the last five years, the majority of respondents (76.4%) , reported unconcerned to use outsourced some aspects of the BIM process to a specialized Information Technology firm. Figure (6) show this information and reveal that 23.6% of the companies had outsourced aspect of BIM implementation to a specialized information technology firm.

Figure: 6 Outsourcing of BIM.

Another important aspect of BIM outsourcing is the duration for which a firm’s services are engaged per project. The majority of the respondents (29.4%) indicated that it’s throughout a project’s entire duration, while the second group of respondents (23.5%) stated that its 1-3 months, and the third group of respondents (17.6%), decided that the duration varies from project to project. As a researcher, I agree with the third group that BIM outsourcing duration varies from project to project because it depends on the type, size and scope of the project, as well as other matters related to the project. Figure (7) shows findings of the rest of the respondents.

Figure: 7 Time Spent Outsourcing for Each Project.

* **Reasons for outsource of BIM in future**

The relative importance index ‘RII, was computed for each reason to identify the most significant reasons for outsourcing in the future. The reasons were ranked based on ‘RII’ values. From the ranking assigned to each reason for outsourcing, it is possible to identify the most important reasons for outsourcing in Egyptian construction industry as per this survey. Findings show that the lowest RII is 72.93% while the highest is 77.55%. As indicated in table (3) the five most significant reasons for outsourcing, as perceived by respondents in construction Egyptian industry, were: (1) Lack of trained in house employees experienced with BIM (RII=77.55%), (2) Lower costs (RII=76.56%), (3) Lack of qualified BIM professionals seeking employment (RII=73.93), (4) Specialized IT firms provide a high quality of service (RII=72.93), (5) Ability to use BIM services only when needed (RII=72.93).

Table: 3 Importance of the Motives to Outsource BIM.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Rank | statements | Mean | S. D | RII (%) |
| 1 | Lack of trained in house employees experienced with BIM. | 2.35 | 0.6 | 77.55 |
| 2 | Lower costs. | 2.32 | 0.62 | 76.56 |
| 3 | Lack of qualified BIM professionals Seeking employment. | 2.24 | 0.56 | 73.92 |
| 4 | Specialized IT firms provide a high quality of service. | 2.21 | 0.63 | 72.93 |
| 5 | Ability to use BIM services only when needed. | 2.21 | 0.63 | 72.93 |

**Non-BIM users**

Through the study, it became clear from the respondents that there are number of them who have not used BIM yet. There are two main reasons why survey participants choose not .to use BIM: 1- they are not in a position to make demand, 2 - they have to follow their client’s instruction regarding use of BIM in their projects. BIM only makes sense if all partners in the project use it. As far as internal reasons are concerned, the introduction of BIM fails either due to a lack of know-how or because the benefits of BIM are not yet generally understood. Where 50% of the participants believe that the lack of the awareness of BIM by stakeholders is considered, the remaining participants responded with even distribution (38.2 % - 35.2%, 35.3% and 35.3%) for the other four reasons, while lack of government regulations and lack of effective collaboration among project stakeholder gave indication of 26.5% and 20.6%, respectively, as indicated in table (4).

Table: 4 Reasons to don’t use BIM.

|  |  |  |  |
| --- | --- | --- | --- |
| Rank | Reasons | NO. of responses | percent |
| 1 | Lack of the awareness of BIM by stakeholders | 34 | 50% |
| 2 | Lack of demand and disinterest from clients regarding with using BIM technology in design and construction of the project. | 26 | 38.2% |
| 3 | Lack of knowledge of how to apply BIM software | 24 | 35.3% |
| 4 | Lack of the awareness of the benefits that BIM can bring to Engineering offices, companies, and projects | 24 | 35.3% |
| 5 | Lack of Architects/ Engineers skilled in the use of BIM Programs | 24 | 35.3% |
| 6 | Lack of the governmental regulations to fully support the implementation of BIM | 18 | 26.5% |
| 7 | Lack of effective collaboration among project stakeholders to exchange necessary information for BIM application | 14 | 20.6% |

Approximately 48.6% of respondents reported that they had not implemented BIM at the moment but were "likely" to implement BIM in the near future. When they were asked how planned to implement BIM, a majority of respondents reported that they would like to develop in-house capabilities by training current staff in BIM, while some refer to develop in-house capabilities by hiring people trained in BIM. 30.4% of the respondent reported being unsure of the strategy that they would utilize to implement BIM. Table (5) shows all above results.

Table: 5 BIM Implementations for Future Adopters.

|  |  |  |  |
| --- | --- | --- | --- |
| Rank | Plans | NO. of responses | percent |
| 1 | Develop in-house capabilities by training current staff in BIM | 25 | 54.3% |
| 2 | Develop in-house capabilities by hiring people trained in BIM | 16 | 34.8% |
| 3 | Unsure | 14 | 30.4% |
| 4 | Hire an outside consultant to implement BIM within the company | 7 | 15.2% |
| 5 | Outsource all or parts of the model creation to an outside information technology firm | 5 | 10.9% |
| 6 | Other | 1 | 2.2% |

**Part Three: BIM and Sustainable Building Practice**

This part of the study is concerned with understanding of the survey participants about the importance of sustainable building practices and their relationship with Building Information Modeling within the Egyptian construction industry. Familiarity with Sustainable Design Construction (SDC) has been seen as a key to the understanding of stakeholder meanings determining whether respondents are aware of the SDC definition is one step used in this study to capture the perception of SDC by stakeholders.

The questionnaire survey findings revealed that 77.9% of respondents are aware of the term SDC, while 22.1% did not seek it before. When participants were asked about the optimal definition of sustainable design construction, the majority referred to environmental, cultural and economic responsive design and construction, while few (2.8%) confirmed that traditional design and construction is the sustainable design, according to their view. The meaning of environmental, cultural and economic responsive design and construction was stated by 55% of the respondent, while environment friendly design and construction meaning was stated by 29.4%. Figure (8) show the histogram of these findings and other findings related to meaning of SDC from respondent’s views with lower percentage of participants (2.8% - 8.3%).

Figure: 8 Understanding of participants for SDC.

As for the term, Green Design Construction (GDC), it was found that 91% of respondents had heard about it. This is a clear indication that there is knowledge, even if it is superficial, about green construction. Figure (9) show that by 68% “green design and construction” mean that Environmentally friendly design and construction, while understanding of Environmental, cultural and economic responsive design responded by 28.1%. Minor sector of participants (3.9%) stated other meanings about GDC. The following figure (9), shows these results.

Figure: 9 Understanding of Green Design Construction GDC.

A list of essential sustainable practices (e.g. USGBC LEED, Green Globes) has been already developed by many different green building evaluation organizations. In this study, it’s essential to understand how respondents perceived these features within sustainable practices. Table (6) contains the results generated from the survey questionnaire, in addition to understanding the participants viewpoints.

Table: 6 Importance of common sustainable features and their impact on construction.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| statements | Strongly disagree % | Neutral % | Strongly agree % | Mean | Standard Deviations |
| Sustainable Site Development | 12.1 | 23.6 | 63.6 | 2.51 | 0.71 |
| Water Efficiency | 10.7 | 21.4 | 67.9 | 2.6 | 0.68 |
| Energy Efficiency | 8.6 | 15.0 | 76.4 | 2.7 | 0.63 |
| Sustainable Materials | 11.4 | 20.7 | 67.9 | 2.6 | 0.69 |
| Indoor Air Quality | 10.0 | 22.9 | 67.1 | 2.6 | 0.67 |
| Project Management | 4.3 | 25.7 | 70.0 | 2.59 | 0.452 |

From the above table, the following points can be summarized: -

1- Of the survey respondents, 63.6% believed that sustainable site development is of high importance. Having applied a weighted score to each of the selection options, an average rating score of 2.51 was attained.

2- 67.9% of the survey respondents believed that water efficiency is of high importance. Having applied a weighted score to each of the selection options, a total rating score of 2.6 was attained

3- Out of the survey respondents, 76.4% believed that energy efficiency is of high importance. Having applied a weighted score to each of the selection options, an average rating score of 2.7 was attained.

4- 67.9% of the survey respondents believed that use of sustainable materials is of high importance. Having applied a weighted score to each of the selection options, an average rating score of 2.6 was attained.

5- Out of the survey respondents, 67.1% believed that indoor air quality is of high importance. Having applied a weighted score to each of the selection options, an average rating score of 2.6 was attained.

6- 70% of the survey respondents believed that incorporated project management is of high importance. Having applied a weighted score to each of the selection options, an average rating score of 2.59 was attained.

A large number of 2D/3D CAD and BIM analytical tools are currently available; thus, it is important to decide what types of analyzes are being applied in typical business practices. Figure (10) shows types of computer aided analysis. The highest percentage of the population sample used some form of structures analysis at 77.1% of the entire sample. Additionally, Energy analysis, MPE analysis, and lighting analysis were selected by a large number of participants responses at 26.4%, 20%, and 13.6%, respectively. This result is due to the fact that multiple BIM software platforms are trying to integrate different forms of analysis, most typically found are the analysis programs for structures, energy, and MEP.

Figure: 10 Types of computer aided analysis performed by respondents’ company

From respondent’s view of project delivery methods as it relates to BIM and sustainable design and construction practices, the intent here is to determine which delivery method provides the best environment for BIM to act as a mechanism for sustainability. The data in figure (11) shows that Integrated Project Delivery method is regarded by the respondents as the most effective methods at 50% to bridge together both BIM and sustainable practices within a company in the AEC industry. Construction Management also provides the best environment for the utilization of BIM software as a mechanism for sustainable design and building practices by 19.3%, and Design-Build provides by 18.6%. It is clear that The Building Information Modelling (BIM) is transforming the way building delivered traditionally.

Figure: 11 project delivery method

Another part of the research focuses on the effectiveness of BIM within the AEC industry in terms of common sustainable practices. Since this study is primarily concerned with understanding BIM's capabilities as a catalyst for sustainable practices in the AEC industry, this question is imperative when it comes to the understanding to how respondents view BIM as an effective tool. The following points show the details of analysis of results: -

1- Of the survey respondents, 85% believed that BIM‟s effectiveness with respect to sustainable site development is neutral to highly effective. Having applied a weighted score to each of the selection options, an average rating score of 2.95 was attained.

2- Of the survey respondents, 85% believed that BIM‟s effectiveness with respect to water efficiency is neutral to highly effective. Having applied a weighted score to each of the selection options, an average rating score of 2.91 was attained.

3- Of the survey respondents, 90% believed that BIM‟s effectiveness with respect to energy efficiency is neutral to highly effective. Having applied a weighted score to each of the selection options, an average rating score of 3.42 was attained.

4- Of the survey respondents, 85% believed that BIM‟s effectiveness with respect to use of sustainable materials is neutral to highly effective. Having applied a weighted score to each of the selection options, an average rating score of 2.98 was attained.

5- Of the survey respondents, 91% believed that BIM‟s effectiveness with respect to indoor air quality is neutral to highly effective. Having applied a weighted score to each of the selection options, an average rating score of 2.86 was attained.

6- Of the survey respondents, 87% believed that BIM‟s effectiveness with respect to incorporated project management is neutral to highly effective. Having applied a weighted score to each of the selection options, an average rating score of 3.46 was attained.

7- Of the survey respondents, 88% believed that BIM‟s effectiveness with respect to post-construction facility operations is neutral to highly effective. Having applied a weighted score to each of the selection options, an average rating score of 3.11 was attained.

Therefore, according to the results, the respondents were found to be neutral on their viewpoints of BIM and its effectiveness on sustainable practices. This was typical of all categories; however, Indoor air quality and Energy efficiency were found to have the highest weighted scores. Figure (12), shows the rating of BIM in terms of effectiveness in achieving sustainability.

Figure: 12 Rating of BIM in terms of effectiveness in achieving sustainability

1. **Conclusions**

The specific conclusions which can be concluded from the current research work, can be summarized below:

* **The first objective was:** Assess the awareness of engineers and professionals in the field of construction and the extent of their use of the BIM technology in Egypt.

Findings showed that 92% of the respondents had heard of BIM, while 8% of them had not. This finding concurs with (Elyamany, 2017). With regards to the context of the use of BIM over the last five years, the results showed that the percentage of the participants that worked on BIM prior to the survey was 51.4% and the percentage of the participants that didn’t work on BIM was (48.6%).

From the research analysis, the justifications for companies’ applications of BIM showed the following results: 1- 33% think that using BIM is a faster way to capture /resolve quality issue 2- 16.5%, believe that market / client/government require BIM applications. 3- 15.5 % think that BIM improve competitive position. 4- 11.3%, stated that using BIM is required (forced) by the customers. 5- 8.2%, think that BIM reduced design and construction costs.

It was found from results that the more commonly program used by the respondents to carry out projects in the AEC industry is Autodesk Revit. Respondents suggested that the reason was due to interoperability with different CAD tools and to exchange formats and easy of learning. The study findings indicated that there is a significant need for BIM functions. For the professionals, some of BIM's functions were more important than others. The BIM functions which according to the overall respondents have top five ranking are as follows: (1) visualization (2) Constructability [clash detection] (3) Scheduling (4) Model- based estimating (5) site planning.

Through the study, it became clear from the respondents that there are a number of them who have not used BIM yet, where 50% of the participants believe that the lack of the awareness of BIM by stakeholders is considered the most important reason for not using BIM. Approximately 48.6% of respondents reported that they were "likely" to implement BIM in the near future. When asked how they planned to implement BIM, a majority of respondents reported that they would like to develop in-house capabilities by training current staff in BIM, while some refer to Develop in-house capabilities by hiring people trained in BIM. Findings in this study reveal clearly that there is a growing BIM awareness in construction sector in Egypt.

* **The second objective was:** Extent of outsourcing of BIM projects in Egypt.

When the respondents were asked about Outsourcing of BIM, the vast majority chose not to outsource BIM tasks to other companies. 60% who currently utilized BIM, but do not outsource reported being likely to outsource in the foreseeable future. A majority of respondents indicated that outsourcing is from inside Egypt.

The relative importance index ‘RII’, was computed for each reason to identify the most significant reasons for outsourcing in the future. The reasons were ranked based on ‘RII’ values, as indicated in table (7).

Table: 7 Importance of the Motives to Outsource BIM

|  |  |
| --- | --- |
| Rank | statements |
| 1 | Lack of trained in house employees experienced with BIM. |
| 2 | Lower costs. |
| 3 | Lack of qualified BIM professionals Seeking employment. |
| 4 | Specialized IT firms provide a high quality of service. |
| 5 | Ability to use BIM services only when needed. |

* **The third objective was:** Assess the awareness of engineers and specialists in the field of construction on sustainability and green buildings.

As indicated throughout the research, the targeted purpose for this analysis was to understand trends within BIM and sustainability, both as dependent and independent entities within design and construction. The results showed that respondents are aware of two concepts sustainable design and construction, and green design and construction. BIM has been at the cutting edge of design / build technology for a long time, so it makes sense to be able to play a significant role in achieving sustainable construction objectives. From the results, 54.3% of the respondents suggested that the optimal phase for BIM applications to be utilized within sustainable practices was within the pre-design or program phase, while the schematic design phase and Pre-construction Phase was (15.7%) for each stage respectively.

Currently, BIM is sought after primarily for its project coordination and visualization capabilities. Although certain available BIM software provides access to allow the user to perform environmental analysis, the industry does view.

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