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Barriers and Motivators for BIM adoption to achieve Sustainable Construction in Egypt

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الملخص العربى:

أصبحت مبادئ الاستدامة واسعة الانتشار في صناعة البناء والتشييد خلال العقود الماضية. و قد واكبت الجهات البحثية فى مصر هذا الاتجاه من خلال إصدار نظام تصنيف الاستدامة للمباني المسمى بنظام تصنيف الهرم الأخضر(GPRS) منذ عام 2010. يحتوي هذا النظام على سبع فئات لتقييم الاستدامة (المواقع المستدامة [SS] ، وكفاءة الطاقة [EE] ، وكفاءة المياه [WE] ، والمواد والموارد [MR] ، وجودة البيئة الداخلية [IEQ] ، وبروتوكولات الإدارة [MP] والابتكار و القيمة المضافة [VA]. تتطلب فئة بروتوكولات الإدارة تطبيق نمذجة معلومات المباني (BIM) أثناء مراحل التصميم والبناء. و قد امتد دور BIM من مجرد التنسيق بين تخصصات التصميم إلى إدارة مرحلة البناء (الوقت والتكلفة) ثم مرحلة التشغيل لتتبع الصيانة والاستدامة. تتمثل دور BIM في ضمان "توفير بيئة واحدة لتخزين بيانات الأصول المشتركة والمعلومات ، بحيث يكون الوصول إليها متاحًا لجميع الأطراف "

لا تزال صناعة التشييد المصرية في مرحلة مبكرة للغاية فى اعتماد نظم نمذجة معلومات البناء (BIM) لتحسين التصميم والبناء وتتبع الاستدامة وإدارة منشآت مشاريع البناء. تهدف هذه الورقة البحثية إلى استكشاف دور BIM في تحقيق الاستدامة ، والتحديات التي تواجه تطبيق BIM في صناعة التشييد في مصر وأخيراً اقتراح توصيات وحلول لهذه التحديات لتسهيل اعتماد BIM في مصر. تم تنفيذ دراسة استقصائية موجهة إلى المتخصصين في صناعة التشييد لتقييم مساهمة BIM في تحقيق الاستدامة وكشف المتطلبات والتحديات التي تواجه اعتماد BIM. و من ثم أمكن اقتراح التوصيات والحلول لتخطى هذه التحديات.

ABSTRACT

Sustainability principles have had widespread in the construction industry during the last decades. Egypt has responded to this trend by issuing a sustainability rating system for buildings since 2010. This rating system is called Green Pyramid Rating System (GPRS). The rating system has seven categories for sustainability evaluation (Sustainable Sites [SS], Energy Efficiency [EE], Water Efficiency [WE], Materials and Resources [MR], Indoor Environment Quality [IEQ], Management Protocols [MP] and Innovation and added value [IN]). The Management Protocols Category demands the application of Building Information Modeling (BIM) during design and construction phases. BIM role has expanded from mere co-ordination of design disciplines to the management of construction phase (Time & Cost) and to the operation phase for maintenance and sustainability tracking. The implicit philosophy of BIM is to ensure the “provision of a single environment to store shared asset data and information, accessible to all individuals who are required to produce, use and maintain it” [1].

The Egyptian Construction industry is still at the very early stage with the adoption of Building Information Modeling (BIM) to improve the design, construction, sustainability tracking, and facility management of construction projects. This paper aims to investigate the role of BIM in achieving sustainability, the challenges facing BIM application within the construction industry in Egypt and finally propose recommendations and solutions to the addressed challenges to facilitate rapid BIM adoption in Egypt. A survey study directed to construction industry professionals and developers was implemented to evaluate BIM contribution towards achieving sustainability and reveal the requirements and challenges facing BIM adoption. Recommendations and solutions are proposed to address challenges and facilitate rapid BIM adoption in Egypt.

Keywords: Building Information Modeling; Sustainability; Construction Industry; Management; Egypt.

1. INTRODUCTION

Construction is a key and dynamic sector in the Egyptian economy [2]. major construction projects generate, process and store considerable quantities of real-time information prior to, during, and post on-site construction. The construction activities are shrouded in information and management of the construction project requires appropriate systems which facilitate bi-directional data input, information processing, dissemination and functional access. An Information Management System (IMS) should have the capability to engage with performance management and reporting systems to aid management of the project, and the management of the construction organization. In today's complex construction environment, the use of an appropriate IMS has the potential to bring about team integrity and enable increased collaboration and integration among project members. [3]

BIM is a good example of IMS. Many researchers have unanimous agreed definition of BIM as an improved process and a tool that involves applying and maintaining an integrated digital representation of different information across various phases of a building construction project [4] [5] [6]. This technology, covering the entire life cycle of the building can create, coordinate, document, manage/operate and update information about a particular facility. This is a major change in the process of transforming the construction industry worldwide [7]

Bataw, A. et, al. stated that BIM technology has been in existence, in somehow, for about half a century. Within the AEC industry, it began with (AutoCAD). But, it was known to be expensive, fragile and complex. Then, from the early 1990s, many other software tools have been developed to assist the other stakeholders within the industry; such as project management software, programming software, planning software, and excel software for pricing. These software tools have enhanced the control of time, cost and quality but it was still a fragmented way of working as each member of the team was working on a separate software. Therefore, the creation of a collaborative virtual building model such as BIM was required to achieve the required consistency in data circulation [8] It is worth mentioning that the key to BIM is not only the visual model, but also the information database that sits behind it. This enables different members working on the same project to store and retrieve information in a consistent, shareable format [9].

In North America BIM adoption by contractors escalated from 28% in 2007 to 71% in 2012. In Norway, the civil state client Statsbygg has promoted the use of BIM in the last few years. The Norwegian Homebuilders Association has encouraged the industry to adopt BIM and IFC (a standard for data exchange). A number of Norwegian contractors have spent in and implemented BIM systems for integrating ICT support for their production of apartments and houses. Moreover, Statsbygg has decided to use BIM for the whole lifecycle of their buildings. In 2007, 5 projects had used BIM. By 2010, all the projects will use IFC/IFD based BIM. In Denmark about 50% of the architects, 29% of clients and 40% of engineers in Denmark were using BIM for some parts of their projects in 2006. It is observed from the previous few examples that the support of the central government towards BIM implementation can be regarded as the driving force towards higher utilization of BIM in those countries. If the support is strong it would create a uniform environment for nationwide acceptance of BIM[11].

2. LITERATURE REVIEW

2.1. Management Category in GPRS versus BREEAM and LEED

Most of sustainability rating system have some sort of "Management Tools" to enable and track sustainability features during the design, construction, and operation phases. In this research, the authors focused on comparing the requirements of the Egyptian rating system (GPRS-2017) with two international systems: 1) BREEAM (BREEAM-UK 2018), and 2) LEED (v4 for BUILDING DESIGN AND CONSTRUCTION). The comparison has addressed the main credits / points of management category, and the requirements to obtain credits within this category. [12] [13] [14].

2.2. BIM ADOPTION AND IMPLEMENTATION BENEFITS

Construction projects pass through three major Project Lifecycle Phases (PLP)s: Design [D], Construction [C] and Operations [O]. Caroline T. W. Chan has mentioned that BIM provides a platform which facilitates the creation and sharing of information relevant to design, construction and maintenance of buildings over their entire lifecycle[13]. It acts as an information backbone that supports collaboration between various stakeholders[15]. So, it can be said BIM adoption presents many advantages and opportunities to every project participant. It is used mostly for clash detection, visualization and creation of as-built models[16] [17]. Also, it helps in controlling important variables such as cost, time and quality in a more efficient and timely manner from early stages which leads to make more value creating decisions[18] [19] [20]

Table (1): Common Management Aspects in GPRS, BREEAM, and LEED

Comparison Aspects	GPRS (2017)	BREEAM (UK 2018)	LEED (v4)
1. Management Category	A definite category with 10% of the total credits	A definite category with 10% of environmental credits	No consolidated category but it appears within different categories.
2. Life Cycle Analysis	A definite category with specified requirements	A definite category with specified requirements	It is included in Materials and Resources (MR) category.
3. Building User Guide manual	It has four components: 1. Building Service Information, 2. Monitoring and maintenance plan. 3. Waste management strategy. 4. Emergency Information.	Aftercare in BREEAM is similar to Building User Guide manual.	Sustainable Sites (SS) in LEED is similar to Building User Guide manual but it has extra requirement named 'Site Improvement Plan".
4. Project brief and design implementation	Not included	Will defined requirement to ensure early involvement of all interested parties	The same content of BREEAM requirement, but is named Tenant Design and Construction Guidelines
5. Responsible construction practices	Not included	is unique requirement in BREEAM to ensure accurate monitoring & controlling	Not included
6. Commissioning & handover	Not included	Defines the procedures schedule and responsibility of this phase, it is also unique	Not included
7. Solid Waste Management Report	It contains a detailed construction waste management plan		is included in Materials and Resources (MR).
8. BIM Implementation	3D, 6D or 7D BIM Model is required.	not required	It helps in integrative project planning and design.
9. Building Management System (BMS) plan	It shows all schematic and graphic of all building functions.		

The comparison presented in table (1) has revealed the following notes:

- BIM is only required in GPRS, but there are other credits that could be easily obtained by using BIM; such as INTEGRATIVE PROJECT PLANNING AND DESIGN, INTEGRATIVE PROCESS, Life Cycle Analysis.
- There are many similarities between these GPRS categories even if they have different names as mentioned below:

1) Building User Guide manual in GPRS is similar to “Aftercare” in BREEAM,
2) Project brief and design implementation in BREEAM & INTEGRATIVE PROJECT PLANNING AND DESIGN, INTEGRATIVE PROCESS in LEED,
3) Responsible construction practices in BREEAM & Sustainable Sites (SS) in LEED
4) Solid Waste Management Report in GPRS & Materials and Resources (MR) in LEED.
5) Responsible Construction Practices and Commissioning & Handover are involved in BREEAM only.

It is important to mention that the differences among sustainability rating systems in different countries is a reflection of each country’s specific conditions and limitations related to vital resources (energy, water, materials), standards and laws, social considerations, and climatic conditions.

The conceptual model presented in Fig. (1) depicts the effects of BIM on project lifecycle phases. It illustrates how BIM plays an important role in achieving integration and using Fast Track technique.

It has been proven that by using BIM monetary savings can be obtained by minimizing the cost of retrieving project information and lowering life cycle costs of the facility [22] [20] [23]. The concept of making design decisions earlier has also been called the Integrated Project Delivery (IPD) approach. The idea in IPD is to integrate knowledge, systems, business structures and practices of different stakeholders into a collaborative process. The “MacLeamy Curve” Fig.(2) shows the design decisions that were made earlier in the project are more cost effective since in this stage the opportunity to influence positive outcomes is highest and the cost of changes is minimal. Also; Hui-Yu Chou and Pei-Yu Chen [24] try to prove the efficiency of BIM uses by calculating four benefit indices as shown in Fig. (3), by applying their indices on a case study they found that rework costs were reduced by 0.16%, schedule delay was reduced by 6.49% and consequently delay penalty was reduced by 5%. Another research team from Stanford University Center for Integrated Facilities Engineering (CIFE) tried to evaluate the benefits of using BIM based on 32 major projects using BIM and they concluded that use of BIM can achieve the following: [25]

1. Up to 40% elimination of unbudgeted change.
2. Cost estimation accuracy within 3%.
3. Up to 80% reduction in time taken to generate a cost estimate.
4. A savings of up to 10% of the contract value through clash detections.
5. Up to 7% reduction in project time.

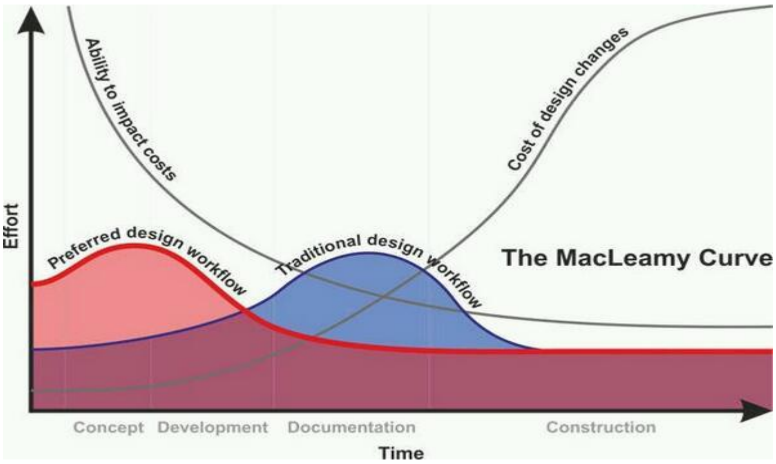

Fig. (2): The MacLeamy Curve [20]

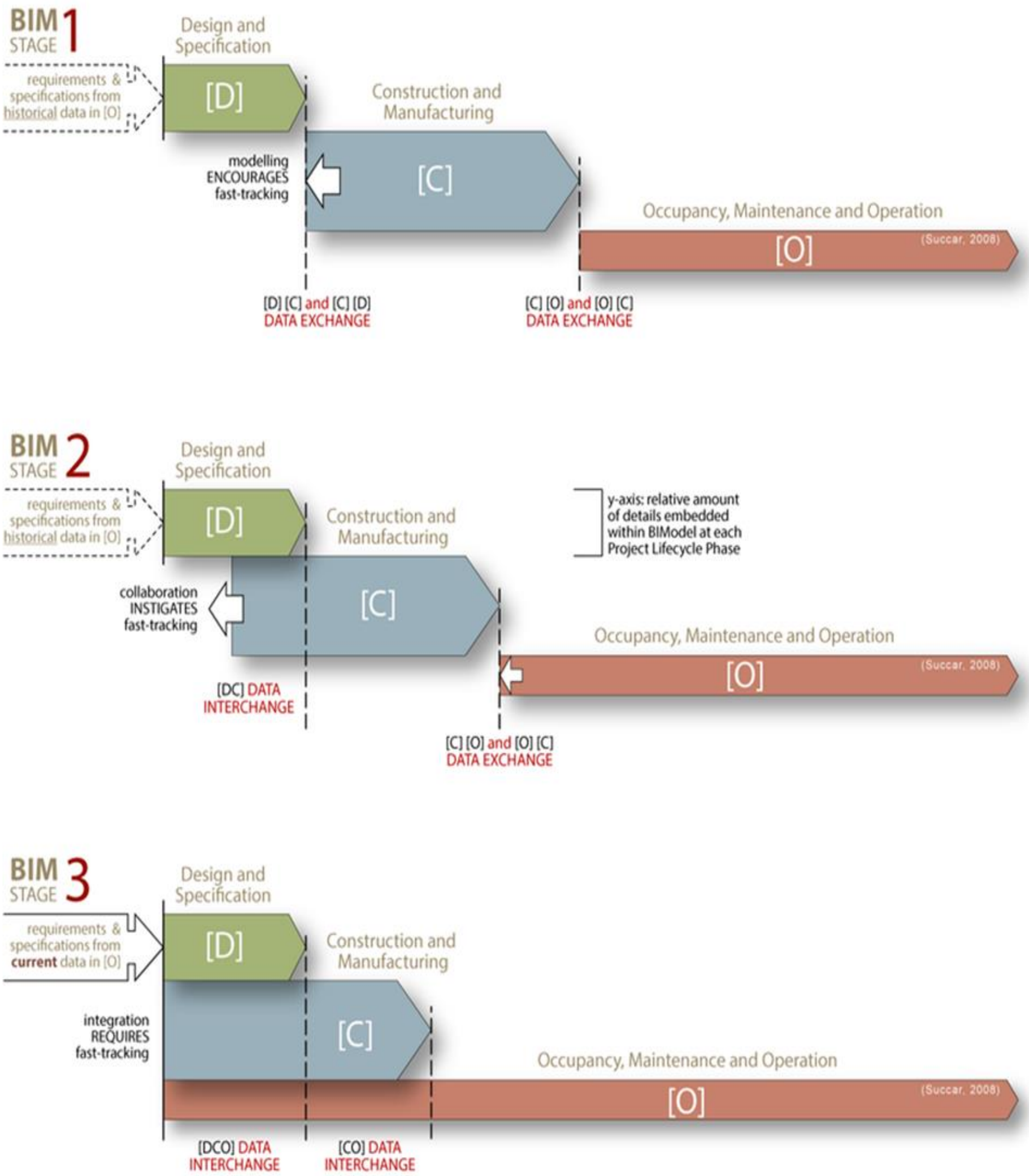

Fig.(1): Effect of BIM on Project Lifecycle Phases
Source: The BIM Framework blog [part of the BIMe Initiative]

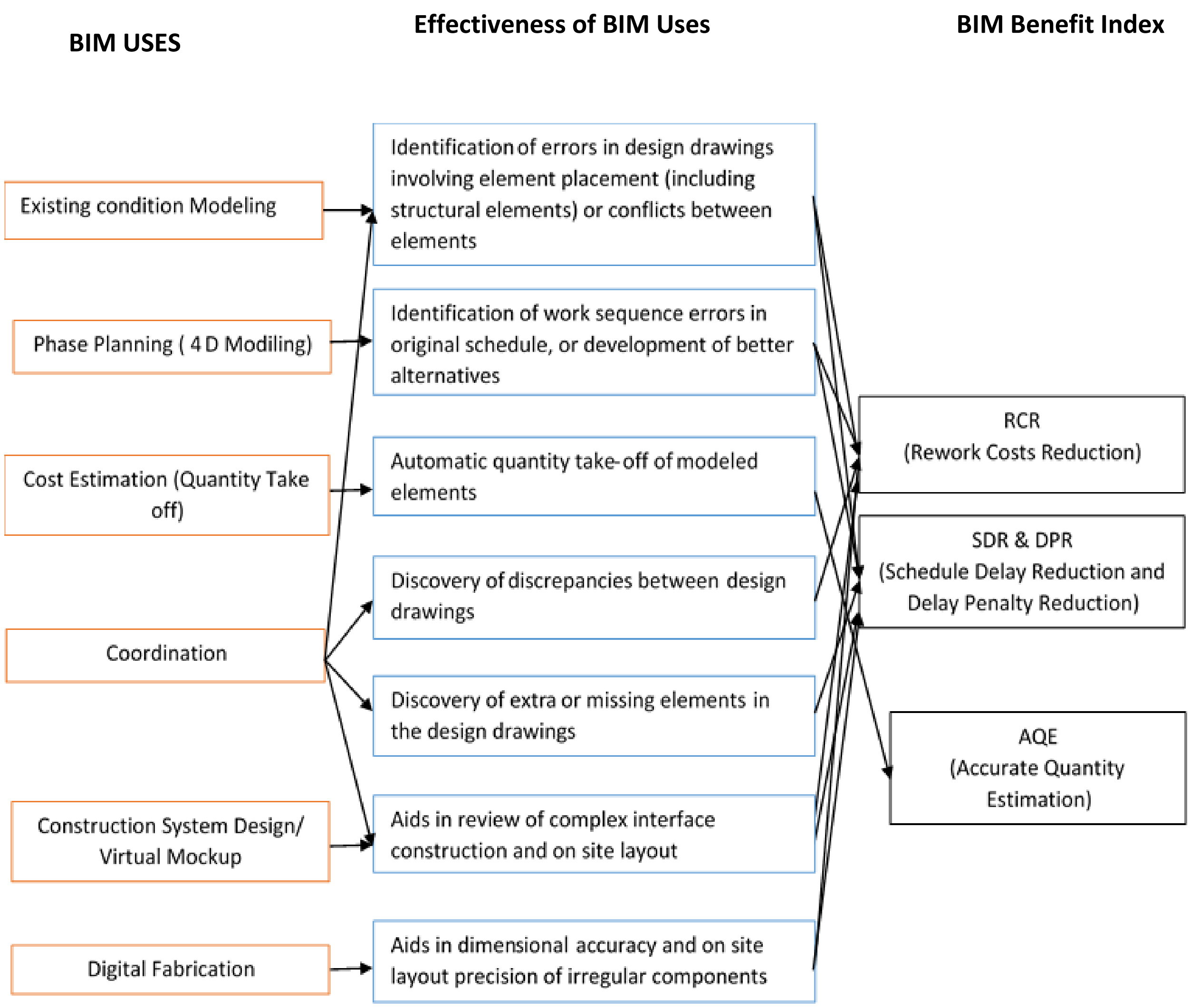

Fig. (3): Relationship between the functions of BIM Uses and Benefit Indices [24]

2.3. BIM IMPLEMENTATION CHALLENGES

Many researchers have addressed the challenges facing BIM implementation. As mentioned by Dainty et al., advantageous outcome of BIM can be obtained only if possible pitfalls in both organization and project level comprehensively are taken into account [26]. Challenges classifications have little differences in categories' names but they can finally give the same meanings. The following tables (table 2-A, table 2-B, table 2-C) provides main challenges according to results of previous research.

Table (2-A): Technical, Managerial, and Financial challenges for BIM Adoption

Challenges' Category	Sub-Category	Reference
Technical	Lack of software compatibility. In other words, Lack of technology alignment leads to a digital divide between the design and other stages.	[27], [20], [28]
	Inefficient data interoperability between the used types of software.	[27], [20], [28]
	Some concerns regarding the quality of the data used to construct some intelligent approaches such as Virtual Project Development that utilized for the first time.	[29]
Managerial	Management process change difficulties, such as re-engineering all impacted processes, creating new business processes and strategies and creating clear plan for BIM implementation	[27], [20], [28]
	Inadequate top level management commitment	[27], [20], [28]
	The difficulty of foreseen the consequences of BIM implementation due to the immature level of the users	[20]
Financial	The need for redistribution of fees due to the new project development system.	[20],

Table (2-B): Environmental challenges to BIM Implementation

Sub-Category	Reference
Lack of available skilled personnel	[27], [20], [28]
Reluctance to train staff or initiate new work flows.	[29], [28],
increase in short-term workload	[27]
The need for new roles to expand knowledge and awareness of BIM within the organization to assure effective implementation.	[20], [28],
Alignment of the social nature of construction projects with the functionality of technology is necessary.	[30], [20],
The social issues in the implementation stage could lead to failure or misaligned usage.	[20],
Benefits of BIM are directly correlated to the ability to maximize collaboration in project. Piecemeal adoption across the project team leads to problems.	[29]
Lack of proof for tangible benefits of using BIM	[28],
Lack of clients demand for BIM in their projects	[28],

Table (2-c): Legal challenges to BIM Implementation

Sub-Category	Reference
lack of BIM standards	[27], [29], [28],
Unclear of the legal liabilities. In other words, who will be responsible for the accuracy of data entry into the model	[27], [20],
The issue of information Ownership	[20],
Responsibility for maintaining and updating the information in the collaborative designed model.	[20],
Distribution of economic benefits gained by BIM implementation between project participants.	[20],
The determination of the contract type suitable for the projects using BIM.	[20], [28],

3. RESEARCH METHODOLOGY AND STRATEGY

3.1. The Outline

Sustainability and other benefits obtained by using BIM and Challenges facing BIM application have been collected from previous studies and then evaluated to define the perceived value of BIM in achieving sustainability and the most significant factors that hinder BIM adoption in Egypt. The evaluation process aims to rank benefits (Drivers) and the causes (Challenges) that hinder the adoption of BIM in Egypt through a survey of construction professionals. An exploratory study has been conducted using a structured, on-line survey that was designed based on the literature reviews to identify the current level of BIM experience, and to define the perceived value, benefits and challenges facing BIM implementation in Egypt. The survey also covered the perceived contribution of BIM adoption on achieving sustainability. Finally, suggested solutions to overcome the challenges will be evaluated and ranked.

The steps used to reach the objective of this study include:

1. Identify the research problem, the study area, and the objectives. This survey has been conducted with experts in the fields of sustainability and BIM application in Egypt to analyze the current case of using BIM and how to increase usage rate and to maximize its benefits,
2. Define the required data to reach the study objectives, the sample size, the methods of data collection and analysis,
3. Investigate the current state of BIM usage, the main challenges of BIM adoption and how to overcome them
4. Identify factors affecting BIM adoption collected from literature and evaluate them through the questionnaire according to Egyptian practitioners' experience.
5. Perform data analysis and conclusions.

3.2. Survey and data collection

This study used two different surveys to collect, evaluate, and analyze data related to BIM adoption in construction projects in Egypt.
1. A "literature survey" performed on previous studies to collect benefits, challenges, and suggested solutions.
2. A field survey to evaluate the data extracted in the first step to rank them and define the significant drivers and effective solutions to challenges that hinder BIM adoption in Egypt and BIM contribution to sustainability.

3.3. The Questionnaire Form Design

This study has designed a questionnaire which was divided into six sections; these are:
1. Participant's general information related to experience, company classification and work type.
2. Ranking the effectiveness of each BIM adoption decision driver.
3. Ranking the impact of identified obstacles on BIM adoption decision.
4. An evaluation of the added value of using BIM in each phase of construction project life cycle.
5. An evaluation of the added value of using BIM to achieve sustainability during different project phases.
6. Ranking the effectiveness of the suggested solutions to facilitate BIM adoption in Egypt.

Respondents were asked to answer with a rank from 1 to 5; (1) is the minimum value and (5) is the maximum value.

4. Data ANALYSIS

The questionnaire was distributed online through a research platform (qualtrics.net). The respondents vary as follows: 4% were “Contracting companies”, 20% are Design Consultancies, 12% are “Owner-Governorate”, 8% of Owner (Private Sector) and 56% are Academics. Response rate shows that most efforts paid to BIM application are still limited mainly to academics. The respondents experience in construction industry ranges between (2) to more than (20) years. Respondents’ years of experience working with BIM; the results shows that more than 50% of the sample have experience within (2) years and 26% have years of experience varies between (2) and (5) years.

In order to rank results; the mean values will be used. Related to the mean score (MS) in Likert's scale should be ($1 \leq MS \leq 5$) for each item and computed using the formula [31]:

$$MS = \sum_{i=1}^{i=n} \frac{(F_i \times S_i)}{N} \qquad (1)$$

Where:
S: is the score given to each answer by the respondents, ranging from 1 to 5
F: is the frequency of responses; and
N is the respondent’s number for the same item.

The ranking technique used is the “Relative Importance Index”; RII values ranging from 0 to 1 ($0 \leq RII \leq 1$) computed by the following formula [32]:

$$RII = \frac{\text{e the summation of the } total\ point\ score}{5 \times N} \qquad (2)$$

The results of the questionnaire show that “Construction Documentation Phase” is the most phase that benefit from using BIM followed by “Construction Phase”, “Design Development”, “Operation & Maintenance” then “Schematic Design” and finally the “Pre-Design” phase as shown in Fig. (4).
Firstly, to identify the stakeholder that has the highest influence on BIM adoption rate in construction industry. The respondents decided that “the owner” is the party most able to enforce BIM usage followed by Designer. Contractor and PM Team have weak effect as results show in Fig. (5).

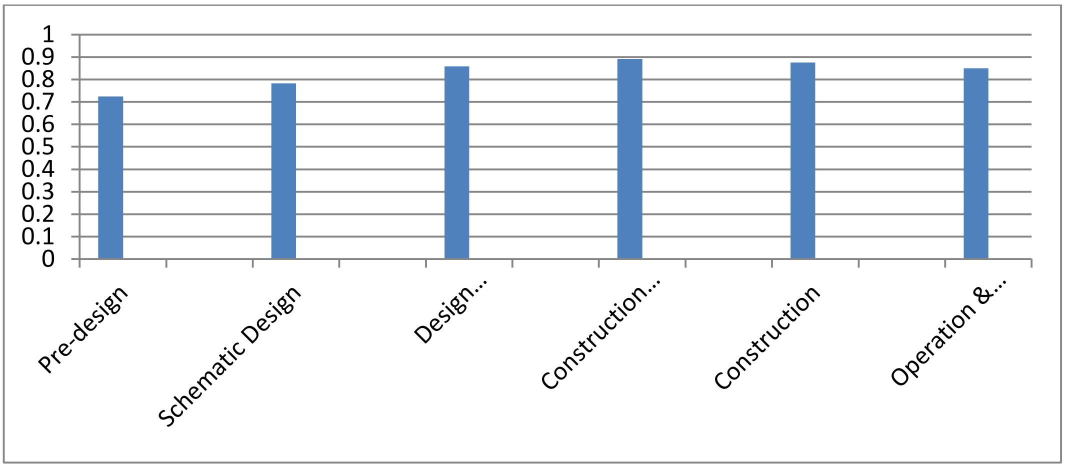

Fig.(4): The added value of using BIM by each phase in the project life cycle

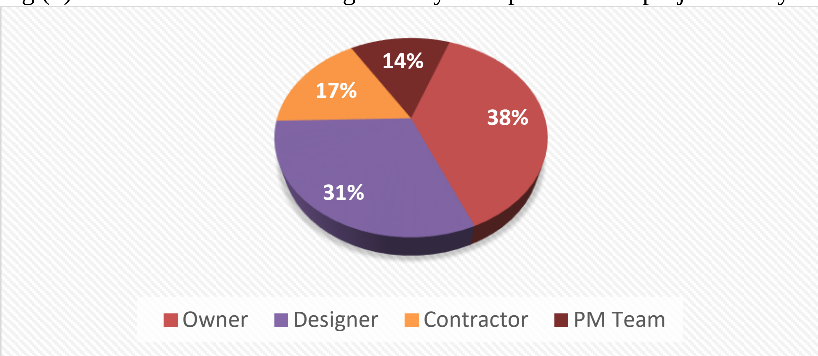

Fig. (5). The contribution of each stakeholder in BIM adoption leadership as expected by respondents

In order to achieve one of the study objectives; to identify the role of BIM in achieving sustainability the respondents were asked to determine the added value of using BIM during “Construction Phase” and “Operation & Maintenance” Phases. The results are analyzed and the RII for each usage is as shown in tables [3], [4]. From the results, it is concluded that BIM plays important role in solving the problems of fragmentation and miscommunication in construction projects and it helps effectively in achieving sustainability through its high capabilities in the field of data collection, processing and retrieving.

Table [3]: RII of BIM uses to achieve sustainability during construction phase.

#	Added value of using BIM to achieve sustainability during construction phase.	RII
1	BIM as a tool for collaboration and coordination during construction.	0.776923
2	BIM as a tool for faster and accurate project drawings (2D and 3D) that improve the ability of prefabrication which lead to Materials savings.	0.769231
3	BIM as a tool for reduction of materials waste during construction.	0.761538
4	BIM as a tool for reduction in design errors, revisions, litigation, claims and conflicts through Visualization of the project & clash detection.	0.746154
5	BIM as a tool for monitoring, reporting and creating accurate construction documents.	0.7
6	BIM as a tool to Improve budgeting and cost estimating capabilities and reduction of project costs.	0.7
7	BIM as a tool to improve scheduling capabilities and possibility to shorten the project duration.	0.7

Table [4]: RII of BIM uses to achieve sustainability during operation& maintenance phase.

#	Added value of using BIM to achieve sustainability during operation& maintenance phase.	RII
1	BIM as a tool to achieve efficient project management during the project life-cycle through improved operations, maintenance and facility management.	0.88
2	BIM as a tool to model water and wastewater networks in the building to detect water leakage and increase water efficiency.	0.85
3	BIM a tool to calculate energy savings resulting from improved building envelope design	0.81
4	BIM as a tool to track occupancy level in different building spaces in order to control HVAC system operation.	0.81
5	BIM as a tool to track occupancy level in different building spaces in order to control Artificial Lighting operation?	0.81
6	BIM as a tool to track sound and thermal insulation materials used in the building to prevent toxic emissions?	0.78
7	BIM as a tool to monitor thermal, visual, acoustic comfort in different building spaces.	0.78
8	BIM as a basis to enable efficient creation and operation of the building management system (BMS).	0.78

Drivers that encourage the adoption of BIM were investigated. The literature review revealed several drivers, the major drivers were determined, then respondents were asked about the efficiency of these drivers in Egypt. The results are shown in Fig. (6). It is concluded that the need for communication and interoperability between stakeholders, especially in case of international projects is the most effective motivation that leads to BIM use.

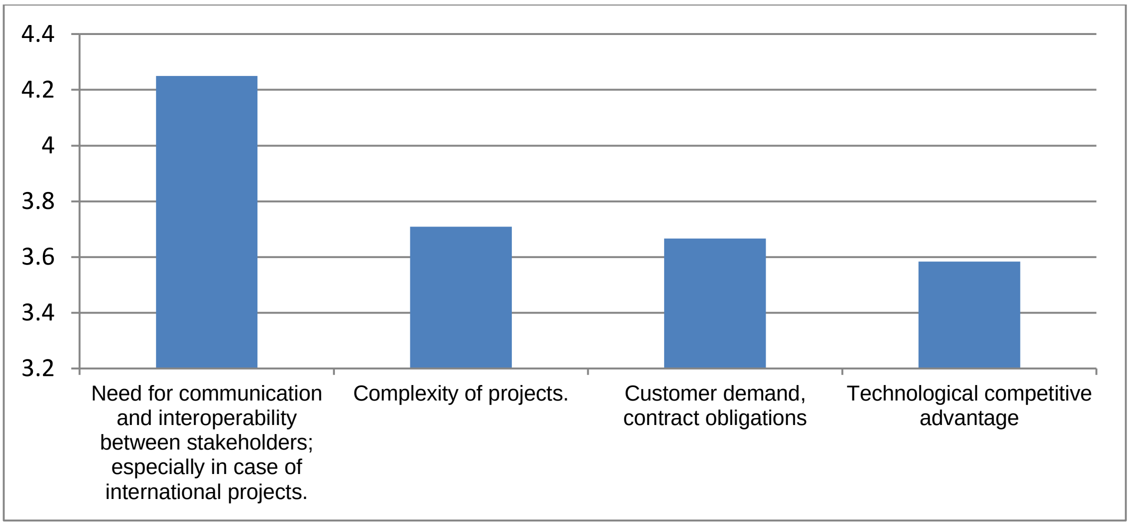

Fig. (6): Mean values for the effect of most important drivers on BIM adoption decision

As shown in Fig. (7); lack of owners' demand is the most significant obstacle to BIM adoption and this conclusion is in line with the opinion of the respondents about the most effective stakeholder in the BIM adoption decision.

Finally, the survey has suggested solutions to overcome obstacles hindering the expansion of BIM application in construction industry, and respondents were asked to answer with ranking. Government& Industry Leadership comes as the most effective solution followed by BIM education, training& research programs (As shown in Fig.8)

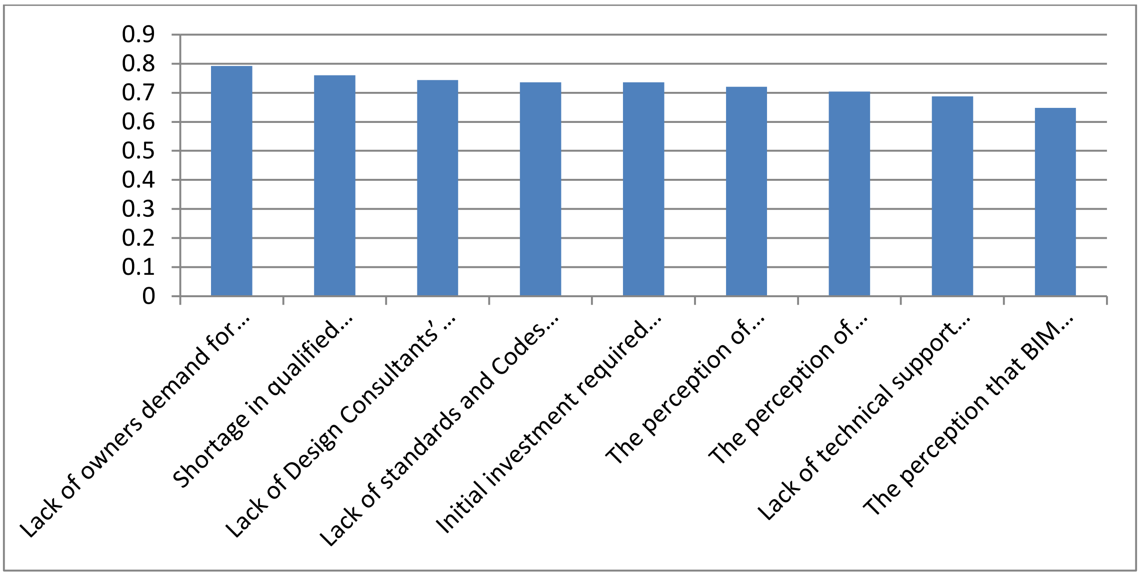

Fig. (7): Obstacles' ranking according to its effect

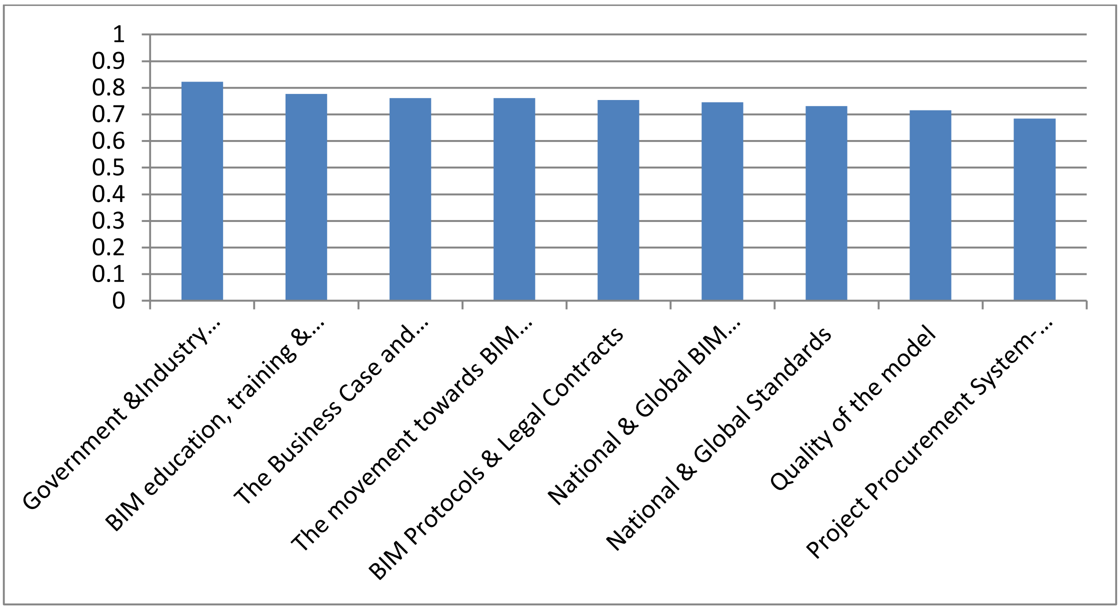

Fig. (8): Order of solutions according to its effectiveness

5. Conclusions

Building Information Modeling (BIM) is the use of multi-Faceted computer software data model to document a building design, to simulate the construction and to operate a new facility. The Egyptian Sustainability Rating System (GPRS) has a "Management Category" Requirement of BIM implementation during design, construction, Operation phases. This study introduced a comparison between LEED, BREEAM as the most famous rating systems for sustainability and GPRS as a tailored system for Egypt.

Through the analysis of respondents' opinion; it can be concluded that the current state of BIM implementation in Egypt is in the very early stages. The study identified the challenges of BIM implementation in Egyptian AEC industry and it includes: "Lack of support and incentives from construction policy makers", "Adoption Costs" (software, hardware upgrade, training, and time), "Lack of standards and codes" and "Lack of awareness about BIM". Similarly; it mentioned drivers that are expected to push AEC industry to adopt BIM, some of those drivers are: "the achievement of sustainability requirements", "the ability to reduce Materials Waste during construction", "the efficient work-site management", "operation and maintenance management", "the reduction of litigation for claims and conflicts" and "the reduction of project duration and cost". Finally, the study suggested some solutions to the barriers and challenges of BIM adoption and implementation that includes: "Government & Industry leadership", "BIM education", "training & research", "re-evaluation and re-engineering of construction firms' business practices", "national & Global BIM Product Databases & Libraries", "the Business Case and competitive advantage and national & global standards".

6. RECOMMENDATIONS FOR FURTHER RESEARCH

This study can be considered as a step on a long way to achieve the goal of adopting and implementing BIM in Egyptian AEC industry and sustainability achievement. It is expected to be beneficial to academics, educational authorities and governmental authorities. The importance of that technology comes from that it solves some of the issues have high impact on the industry; fragmentation and lack of documentation. So, it is very important to conduct future research to define more accurately the drivers and incentives that lead the stakeholders to believe in the importance of BIM. Also, it is necessary to search for solutions to overcome the adoption and implementation challenges and obstacles. Stating the roles and standards organizing and governing the relation between project partners will solve a lot of the problems associated with this technology adoption like the ownership of data as an example.

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