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Quantitative Analyses Towards Prioritising the Challenges Facing Wider Utilisation of BIM Applications in the Construction Industry in Egypt

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Abstract The applications of Building Information Modelling BIM can benefit different phases of a project's life cycle. It contributes to design, construction, operation and maintenance of a building. Despite the expanding use of BIM worldwide, the problem is that its application in Egyptian Architecture, Engineering and Construction (AEC) firms is still at a relatively early stage. The present study first analyses the relevant literature to identify the major challenges facing BIM applications worldwide. It then examines empirically the extent, to which these challenges influence the Egyptian context, to prioritise their significance for future improvement in the field. Towards this objective, the study undertakes quantitative analyses to a purpose-designed questionnaire survey, which was answered by 123 participants in the construction industry in Egypt, to provide diverse perspectives on what may challenge the expansion of using BIM applications in the local market. Descriptive analyses (frequencies, mean values and standard deviations) were applied to the answers. The findings showed that 'institutional challenges' came on the top of the list, while 'economic challenges' showed to be the least influential to participants. It is hoped that these findings may help all stakeholders in the Egyptian construction industry to take more enlightened decisions towards wider utilisation of BIM applications in the local context.

Keywords Building Information Modelling (BIM), Construction Industry, Quantitative Analyses, Institutional Challenges, Egypt

1. Introduction

Building Information Modelling (BIM) is a collaborative way for multidisciplinary information storing, sharing, exchanging, and managing throughout the entire building project lifecycle including planning, design, construction, operation, maintenance, and demolition phases [1].

BIM applications can help architects produce more precise and diverse construction drawings in a shorter time, be it in the preliminary design phase or the execution design/ design development phase. It also helps site engineers and contractors to maintain control over material consumption and construction management. On the other hand, project owners / developers are known to make the best out of BIM in the phases of operation and maintenance [2].

Despite the wide expansion of using BIM applications worldwide, the figures in Egypt seem to lie far behind. A recent study that took place in Egypt in the year 2022 highlighted that only 48% of the local practitioners used

BIM for 2D and 3D modelling, and that 80% of which had less than two years of experience in working with BIM [3]. Another study in the same year indicated that only 20% of the local firms use or intend to use BIM. However, it is optimistic that the BIM awareness in Egypt and Africa is estimated to be around 50%, and that 85% of the AEC firms showed interest in exploring means of using BIM [4].

Therefore, the present study aims at identifying the challenges that influence AEC practice in the Egyptian context, to prioritise their significance for future improvement and wider utilisation in the field.

2. Backgrounds

The early introduction of the concepts of computer-assisted drafting started by two-dimensional CAD drawings. This was then developed towards three-dimensional models in the late 1970's. The concepts of BIM started to crystallise in the 1980's when Simon Ruffle and Robert Ash introduced the term 'building model'. This 'model' aimed at merging comprehensive data-sets about the building together with its three-dimensional graphic representation. It was not until the year 1992 when Van Nederveen and Tolman first tagged the term 'Building Information Modelling – BIM', which became widely known and used in the early years of the present century [5, 6, 7, 8].

Just as in many other disciplines, the introduction of 'time' as a fourth dimension became inevitable for BIM. This was realised by projecting the construction duration, planning its activities and monitoring their progress [9, 10].

This was taken a step further by the introduction of 5D BIM by involving 'cost'. This fifth dimension was meant with calculating physical quantities and cost estimate instantly with the development of the model [11].

In response to the world environmental crises, and the global emphases on developing more environmentally-appropriate construction solutions, 6D BIM addressed the development of 'sustainable life cycle management', on top of the previous modules. Under this module, the final model submitted by the conclusion of the construction activities, is expected to provide complete information about as-built drawings, used materials, technical specs, quantities, suppliers, contact information and the like [12, 13].

Maintenance and operation were introduced more recently as 7D BIM. This dimension addresses maintenance plans, facility management, operation manuals, building-elements condition, and the terms of guarantee for different components [14, 15, 16].

Azhar (2011) suggests that adopting BIM can cut down the unexpected implementation changes by 40% [17]. It realises 97% precision in Bill of Quantities (BOQ) calculations, and saves 80% of the time needed for this task. The same source argues that using BIM can reduce a project's overall cost by 10% and duration by 7%. Most importantly, it sets an effective medium for facilitating the communication and coordination between different stakeholders involved in a project.

Therefore, the use of BIM applications in the construction industry is being widely adopted in different parts of the world. For example, utilising BIM has increased significantly in Northern America. It used to be 28% in 2007, then reached 71% in 2012. Likewise, in Malaysia, it increased from 13% in 2010 to 31% in 2012. Similar trends were documented in many other countries around the world [18].

However, despite the presence of some sporadic endeavours by a few firms, the overall situation in Egypt is somehow left behind. There is no statistical record for the use of BIM in Egypt. The vast majority of the local construction market depends, to a far extend, on more conventional two-dimensional/ three-dimensional drawings. The present research is meant to investigate the challenges facing the use of BIM, and how they apply to the Egyptian construction industry.

3. Methodology

The paper aims at exploring the challenges facing the wider use of BIM applications in the Egyptian construction industry, as perceived by its different stakeholders. It first reviews the relevant literature to conclude to the challenges facing the application of BIM in different parts of the world. The concluded set of challenges is then used to design an online questionnaire survey, to test the applicability of the theoretical findings to the Egyptian context. After the personal information section, participants were required to identify their degree of agreement to each of the 21 variables concluded from the literature on a five-point Likert scale. A pilot test which involved 9 random participants suggested minor re-phrasing to a few questions for the sake of clarity. The online survey was answered by 131 architects, site engineers, contractors and real estate developers. After eliminating the incomplete answers, the final sample ended up to 123 participants of different genders, age-groups, disciplines, firm sizes and years of experience. The answers were compiled in a Microsoft Excel sheet that was then imported to SPSS ver. 22 – Statistical Package for Social Sciences. Cronbach's Alpha test, frequencies, mean values, standard deviations and cross-tabulations were tested in the compiled answers.

4. Sampling

The study adopted a stratified random sampling strategy. Stratified random sampling is a method of sampling that involves the division of a population into smaller subgroups known as strata. In stratified random sampling, the strata are formed based on members' shared attributes or characteristics [19]. In the present study, the strata definition was set to involve participants who are currently working in architectural firms, and that these firms had to be located in Cairo, Egypt. The sample was further extended via snowball sampling, where participants who have already answered the survey were asked to recruit further participants from among their acquaintances.

The actual number of included participants was 123. They were mainly grouped in relation to gender, academic degree, years of experience, institutional scale and the use of BIM in their institutions. 67.5% of the involved sample were male participants and 32.5% were female participants. The largest segment represented Bachelor degree holders at 69.9%, and the least were Ph.D. degree holders at 4.1%. This seems to resemble their natural occurrence in the studied field. However, it is interesting that the number of Master degree holders (16.3%) has outnumbered the number of Postgraduate Diploma holders (9.8%). The following table 1 outlines the participants' profile in relation to their years of experience.

Table 1. Sample profile in relation to years of experience

Years of Experience	Count	Percentage
Less than 5 years	34	27.6%
5-9 years	32	26.0%
10-19 years	44	35.8%
20-29 years	7	5.7%
30 years and more	6	4.9%

Institutional classification followed the European Commission model, which classifies scale in relation to the number of staff head count. It suggests four main categories, namely: less than 10 members, 10 to 49 members, 50 to 250 members and more than 250 members [20]. The following table 2 shows their distribution within the studied sample.

Table 2. Sample profile in relation to institutional scale

Institutional scale	Count	Percentage
less than 10 staff members	22	17.9%
10 to 49 staff members	32	26.0%
50 to 250 staff members	19	15.4%
more than 250 staff members	50	40.7%

The prevailing percentage of participants working in large scale institutions can be seen as directly proportional to the number of members in these firms.

At last, for that the present study is exploratory in nature, and for that it is meant with finding out the different perspectives on why to use / not to use BIM – the involved sample included 26 participants (21.1%) whose firms do not apply BIM, 49 participants whose firms use BIM in limited activities like preliminary design and working drawings (39.8%) and 48 participants whose firms rely mainly on BIM. The last category comprised 39% of the overall sample.

5. Challenges Facing Wider Utilisation of BIM Applications

This paper is part of an extended research, which has reviewed a wide range of resources. These different references have classified the challenges facing wider utilisation of BIM under various models of grouping / categorisation. These models have sometimes overlapped, shared similarities in main categories, demonstrated some variables / categories which may be absent in other models, or sometimes addressed similar variables under different categories. The present study has developed a synthesis of the most common models, after removing repeated variables and re-placing others under different categories in some cases to better respond to the context of the present study.

After reviewing the relevant literature, the challenges facing the application of BIM showed to be grouped under five main categories – namely, 'human challenges', 'economic challenges', 'technical challenges', 'institutional challenges' and 'market challenges'.

'Human challenges' included the lack of training for all/some project stakeholders, lack of awareness of the BIM advantages, shortage in skilled BIM operators and the resistance to any changes in the ongoing work-flow. 'Economic challenges' referred to the time and cost needed for training, the high expenses of hardware and software purchases, the limited short-term revenues in comparison to high initial costs (Return of Investments ROI), the running cost of maintaining and upgrading the software and hardware in use and the novelty of the experience that does not allow sufficient time for financial evaluation. 'Technical challenges' were about the huge file sizes, the weak communication infrastructures, the incompatibility between programs and the technical difficulty in maintaining continuous updates to BIM models/files. On the other hand, 'institutional challenges' addressed the absence of governmental support, the lack of contractual regulations, the lack of standardised procedures, coordination difficulties between different stakeholders and the difficulty in switching from conventional systems to BIM application – particularly in large-scale firms. At last, 'market challenges' highlighted the short demand from clients and state executive authorities, as well as the limited solutions/packages offered by software developers [21, 22, 23, 24, 25, 26].

Table 3 below shows the synthesis of the challenges and categories facing the wider utilisation of BIM, as concluded from the literature.

Table 3. Synthesis of the challenges and categories facing the wider utilisation of BIM

No.	Categories	Challenges
1	'Human challenges'	• lack of training for all / some project stakeholders • lack of awareness of the BIM advantages • shortage in skilled BIM operators • resistance to any changes in the ongoing work-flow
2	'Economic challenges'	• time and cost needed for training • high expenses of hardware and software purchases • limited short-term revenues in comparison to high initial costs (Return of Investments ROI) • running cost of maintaining and upgrading the software and hardware • novelty of the experience does not allow sufficient time for financial evaluation
3	'Technical challenges'	• huge file sizes • weak communication infrastructures • incompatibility between programs • technical difficulty in maintaining continuous updates to BIM models/files
4	'Institutional challenges'	• absence of governmental support • lack of contractual regulations • lack of standardised procedures • coordination difficulties between different stakeholders • difficulty in switching from conventional systems to BIM
5	'Market challenges'	• short demand from clients and state executive authorities • limited solutions/packages offered by software developers

6. Findings and Discussion

First, the Cronbach Alpha test was applied to the collected date to examine its reliability and internal consistency. It concluded that $\alpha = 0.765$. It is confirmed by the literature that $0.7 > \alpha \geq 0.8$ is acceptable [19].

The 'institutional challenges' seemed to have received wide agreement amongst participants, with a standard deviation of 0.786 and a mean value of 3.77 that is closest to 'Strong Effect' on the five-point Likert scale. This is confirmed by figure 1 hereunder, which shows that 43.9% of the involved sample chose 'strong effect' and 29.3% chose 'very strong effect'.

The most significant 'institutional' elements were 'coordination between different stakeholders' at a mean value of 3.99, 'the lack of standardisation' at a mean value of 3.70 and the lack of 'contractual regulations' at 3.50 mean value.

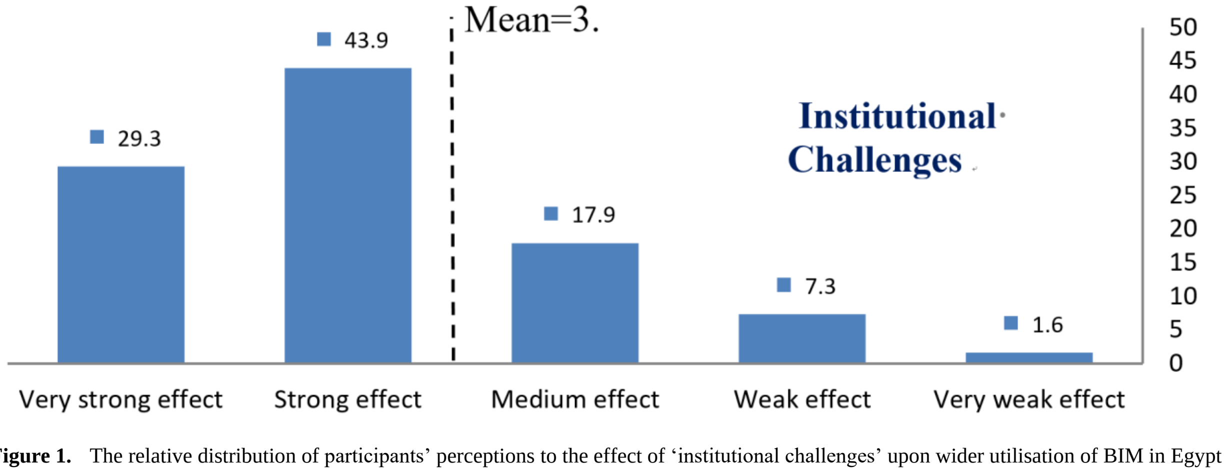

Figure 1. The relative distribution of participants' perceptions to the effect of 'institutional challenges' upon wider utilisation of BIM in Egypt

Based on the preceding literature, institutional challenges can be mainly attributed to issues that can be dealt with internally within a firm, and those regulated by the state. As per the state's role, it is important that official bodies mandate the submission of a complete BIM model together with the licensing documents for any project. It is also important that the specifications of the submitted model are standardised and announced to all practitioners. This shall significantly promote the use of BIM with appropriate qualities. Similar experiences have been documented in the UK, Malaysia, India, Iceland and many other countries [2, 18, 21, 22]. On the other hand, firms are encouraged to assign their R & D departments to set gradual plans for the transition from conventional systems to more comprehensive BIM applications.

'Human challenges' came second, with a standard deviation of 0.764 and a mean value of 3.74 that is closest to 'strong effect' on the five-point Likert scale. This is confirmed by figure 2 below, which shows that 31.7% of the involved sample chose 'very strong effect', 30.9% chose 'strong effect' and 32.5% believed it had a 'medium effect'. On the contrary, 4.1% thought its effect was weak and 0.8% thought it has no effect.

Out of the human challenges propounded above, the 'shortage of experienced BIM operators' came first at 3.83 mean value, followed by 'The lack of training programs' at 3.75 mean value, then the resistance to any changes in the ongoing work-flow at 3.72 mean value, then the lack of awareness of BIM advantages at 3.68 mean value. All three challenges seemed to lie between 'strongly agree' and 'agree' on the five-point scale.

This challenge requires collaborative efforts between schools of architecture, local community organisations and the AEC firms. While the schools of architecture make sure their graduates are ready to use BIM effectively, local community organisations may play a role in extending the awareness of middle-age engineers with the needed training to familiarise them with the best means of utilising BIM in their practice. Yet, AEC firms can structure specialised training programs for their staff to keep them acquainted with the latest technologies in BIM applications. Similar endeavours showed to have a significant positive effect on the expansion of using BIM in many countries around the world [6, 18, 21, 22, 24, 26].

The 'market challenges' also seemed to have received some agreement amongst participants, with a standard deviation of 0.813 and a mean value of 3.72 that is closest to 'strong effect' on the five-point Likert scale. This is confirmed by figure 3 hereunder, which shows that 40.7% of the involved sample chose 'agree' and 30.9% chose 'very strong effect'.

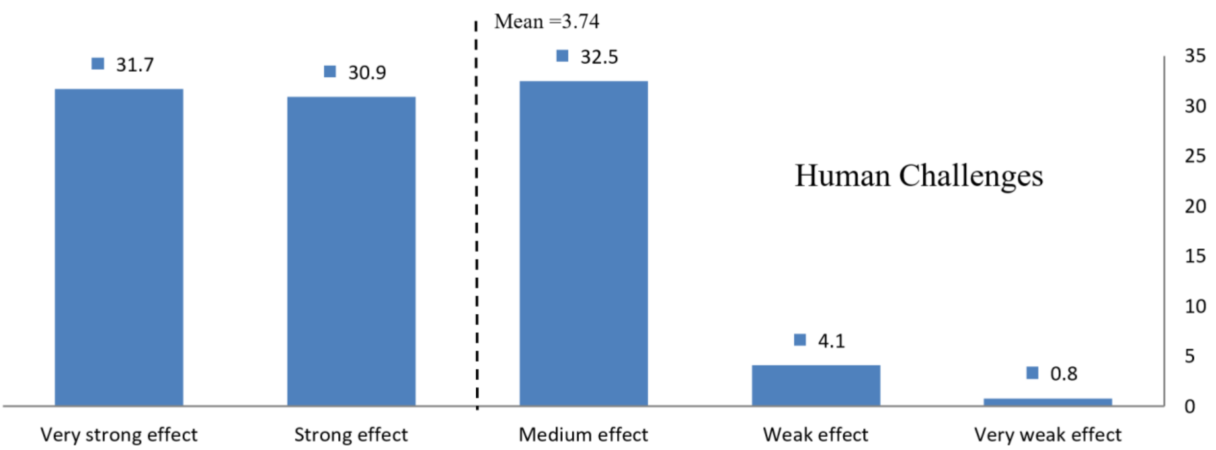

Figure 2. The relative distribution of participants' perceptions to the effect of 'human challenges' upon wider utilisation of BIM in Egypt

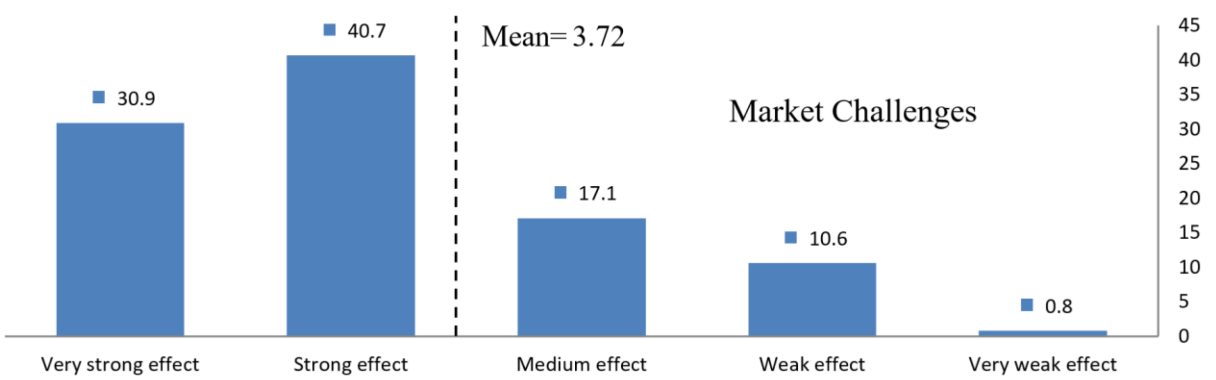

Figure 3. The relative distribution of participants' perceptions to the effect of 'market challenges' upon wider utilisation of BIM in Egypt

In this context, participants' expectations to the 'demand for BIM applications in the Egyptian market in the near future' seemed to be pretty high, with a 4.29 mean value. This is probably explained with their assessment of 'extent to which BIM applications are currently adopted in the Egyptian market' at a mean value of 3.15 – shifting closer to 'medium effect' on the Likert scale.

Handling market challenges can be coupled with institutional counterparts. When state bodies mandate the submission of BIM models for official permits, it shall become better known to large and medium scale developers – as well as large and medium scale practitioners, until it becomes a common market practice, even at the level of small-scale projects / firms. On the other hand, local software companies may undertake the role of developing more affordable programs and tailored solutions for the local practitioners to contribute to a wider use of such important technologies [27].

The 'technical challenges' came fourth in order with a mean value of 3.46 between the 'strong effect' and 'medium effect' scale points, as shown in figure 4 below. Its most effective parameter was the 'weak communication infra-structure' at a mean value of 3.14.

Table 4 hereunder shows the findings of the relationship between the perceived influence of technical challenges in relation to the years of experience. It suggests that 19.5% of those who agreed to medium effect had 10-19 years of experience. Likewise, 11.4% of those who suggested medium effect had less than 5 years of experience. On the other hand, none of the 5-9 years experienced participants thought it was of very weak effect, probably for belonging to the group that is most acquainted with modern technologies. All in all, the results showed a significant correlation between the perceived influence of technical challenges and the participants' years of experience at 0.000 significance.

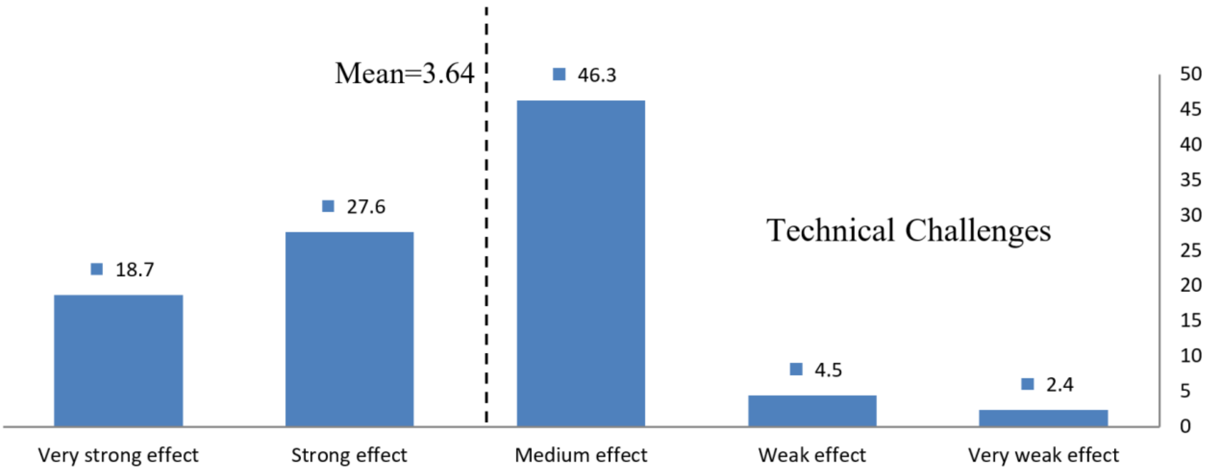

Figure 4. The relative distribution of participants' perceptions to the effect of 'technical challenges' upon wider utilisation of BIM in Egypt

Table 4. Findings for 'technical challenges' in relation to years of experience.

Years of Experience		Technical Challenges: Very weak effect	Weak effect	Medium effect	Strong effect	Very strong effect	Total	Chi-Square test	Asymptotic Significance (2-sided)
Less than 5 years	Count	0	1	14	12	7	34	48.842	0.000
	% of Total	0.0%	0.8%	11.4%	9.8%	5.7%	27.6%		
From 5 - 9 years	Count	0	1	11	8	12	32		
	% of Total	0.0%	0.8%	8.9%	6.5%	9.8%	26.0%		
From 10 - 19 years	Count	1	4	24	12	3	44		
	% of Total	0.8%	3.3%	19.5%	9.8%	2.4%	35.8%		
From 20 - 29 years	Count	0	0	7	0	0	7		
	% of Total	0.0%	0.0%	5.7%	0.0%	0.0%	5.7%		
From 30 - 39 years	Count	2	0	1	2	1	6		
	% of Total	1.6%	0.0%	0.8%	1.6%	0.8%	4.9%		
Total	Count	3	6	57	34	23	123		
	% of Total	2.4%	4.9%	46.3%	27.6%	18.7%	100%		

A great deal of the technical challenges can be resolved by the state and the software companies. Despite the vast improvements of communication infrastructure in Egypt over the past few years, where the Egyptian government improved the average internet speed from 6.5 Mbps in 2019 to 39.6 Mbps in 2021, together with an investment of around 1 billion Egyptian pounds ($63 million) to update mobile networks, it appears to be still lagging behind the local aspirations. More investments in developing communication infrastructure need to be considered. Parallel with that, software specialists are required to focus their programming skills on providing easier means of exchanging files – be it in terms of lessening file sizes or in terms of more universal compatibility between output file formats [27, 28].

At last, the ‘economic challenges’ appeared to be the least of challenges perceived influential for the participants. The mean value was 2.99, which lies between ‘medium effect’ and ‘weak effect’ on the proposed Likert scale, as shown in figure 5 below.

The statistical findings also suggest a significant correlation between the economic challenges and the scale of the institution. 14.6% of those who suggested a medium effect worked in large scale firms (250+ employees). On the other hand, 10.6% of the participants who thought that the economic challenges had a very weak effect belonged to small-scale institutions, with less than 10 staff members. This comes at a high significance of 0.006, as shown in Table 5.

The most influential factor was, ‘knowledge of the potential ROI’ from adopting BIM with 3.83 mean value, followed by ‘software cost’ at a mean value of 3.33, then the ‘time consumption’ came third at 2.5 mean value.

It is interesting that economic challenges came last in Egypt, despite the general perception of economy-related issues as a major force in developing countries. It is more interesting that many of these economic challenges can be dealt with at a micro / macro scale. The majority of these problems seemed to emerge from adopting fast-profit strategies. It only takes confident awareness of the long-term revenues associated with adopting BIM technologies. It can reflect on the overall efficiency of design, implementation and operation phases – timewise and cost-wise, rather than the misleading speed of providing two-dimensional drawings that might entail undesirable implementation and operation delays and expenses [12, 13, 26].

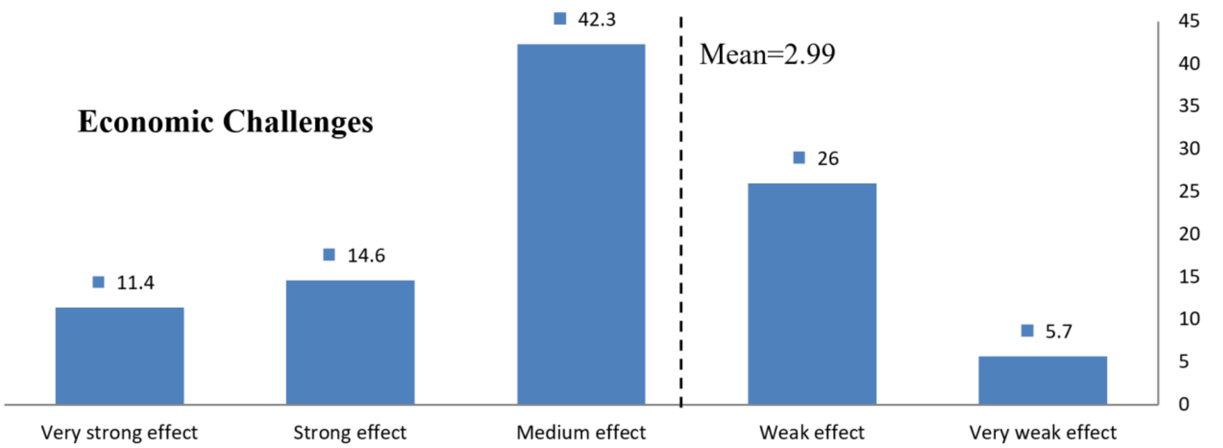

Figure 5. The relative distribution of participants’ perceptions to the effect of ‘economic challenges’ upon wider utilisation of BIM in Egypt

Table 5. Findings for ‘economic challenges’ in relation to institutional scale

Years of Experience		Economic Challenges: Very weak effect	Weak effect	Medium effect	Strong effect	Very strong effect	Total	Chi-Square test	Asymptotic Significance (2-sided)
less than 10 staff members	Count	1	3	9	1	8	22	27.833	0.006
	% of Total	0.8%	2.4%	7.3%	0.8%	6.5%	17.9%		
10 to 49 staff members	Count	3	10	15	3	1	32		
	% of Total	2.4%	8.1%	12.2%	2.4%	0.8%	26.0%		
50 to 250 staff members	Count	0	6	10	1	2	19		
	% of Total	0.0%	4.9%	8.1%	0.8%	1.6%	15.4%		
30 years and more	Count	3	13	18	13	3	50		
	% of Total	2.4%	10.6%	14.6%	10.6%	2.4%	40.7%		
Total	Count	7	32	52	18	14	123		
	% of Total	5.7%	26.0%	42.3%	14.6%	11.4%	100%		

7. Conclusions

The present paper aimed at exploring the challenges facing wider utilisation of BIM in the Egyptian context. The literature identified five main challenges. These were empirically examined through a purpose-designed questionnaire survey. The empirical findings showed that 'institutional challenges' were most influential, particularly those related to coordination between different stakeholders. 'Human challenges' came next, with high emphases on the 'shortage of experienced BIM operators' and the 'lack of training programs. The subsequent group showed to be 'market challenges', where the expectations to the 'demand for BIM applications in the Egyptian market in the near future' seemed to be pretty high. However, 'technical challenges' came forth in order. Its most effective parameter was the 'weak communication infra-structure'. At last, 'economic challenges' appeared to be the least of challenges as perceived by the participants. Its most influential factor was 'knowledge of the potential ROI'.

Therefore, it is recommended that the state together with the local community organisations, all practicing firms, developers and schools of engineering put the efforts towards dealing with these challenges towards a broader adoption of BIM technologies in the construction industry in Egypt. Educational institutions are required to lay extended emphases on teaching BIM applications to future engineers and architects to be capable of using them more broadly and easily. Community organisations may play a role in extending awareness of the values of extended use of BIM, as well as familiarising middle-aged practitioners with the best means of using its technologies. Local AEC firms are encouraged to adopt long-term profit strategies, rather than avoiding the short-term added expenses of software, hardware and staff provision. They are also recommended to develop the required structures for the gradual transition from conventional systems to BIM, and facilitate the coordination/communication between all project stakeholders. These companies shall also pay special attention to the importance of continuous staff training to keep up with the latest technologies in the field. Parallel with that, software companies may provide more affordable and tailored solutions to respond to the local market demands. They may also develop smaller output file sizes in more universally compatible formats, to promote more effective exchange of information amongst the project stakeholders. Developers, owners and clients can promote the use of BIM in design, implementation and operation phases. They may request the designing firms to provide them with the BIM model, to keep track of the work progress and make use of it in the facility management and energy consumption. At last, the role of the state can be exemplified in providing better communication infrastructure, mandating the submission of complete BIM models for any projects to be licensed, and developing structures for standardised the procedures and contractual regulations towards wider utilisation of BIM applications in the construction industry in Egypt – to realise more effective design, construction and operation of the built environment.

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