TOWARDS A SUSTAINABLE APPROACH FOR EFFECTIVE SOLUTIONS TO INTEGRATE BUILDING PROJECTS FROM DESIGN TO CONSTRUCTION

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ABSTRACT

The traditional construction industry is facing a low rate in productivity during the construction phase when compared to other industries, mainly due to poor planning, coordination and poor communication between project parties.The research aims to study the impact of using building Information Modeling (BIM) as an effective solution to integrate the design, construction and post-operation phases by examining three measurable Key performance indicators (Request for Information-Change Order - Cost Estimating) applied on Residential Compound as a case study and determining the intended benefit of using BIM. An increase in the rate of construction productivity has been found with the implementation of the BIM systems due to the reduction of re-work cases that cause time and avoid a large number of lacks of information required in the implementation phase and resolving conflicts before the start of construction phase. So, the implantation of BIM led to reduce the cost and avoid operational problems before the start of the project. The research also has included an assessment of the use of building information at a low rate in productivity during the construction phase when compared to other industries. This research aims to study the impact of using Information Modeling systems in design and implementation stages through the dissemination of a questionnaire with a response rate of 75 respondents. The results show that while BIM systems are modern, many have adopted them due to their ability to improve work efficiency, enhance communication among project teams, and reduce environmental waste. Despite some barriers, such as a lack of qualified professionals, BIM is expected to be widely used in the construction industry in the near future.

Keywords: Sustainability, Integrated Building projects, Key performance indicators, Construction projects, BIM.

INTRODUCTION

Building Information Modeling (BIM) is a collaborative approach to storing, sharing, and managing information across the entire life cycle of a building project, including the planning, design, construction, operation, maintenance, and demolition phases Ganbat et al., (2019); Samy، A F.M et al., (2024). BIM tools enable architects to create more accurate and varied construction drawings in less time, whether during the preliminary design phase or the design development phase. Additionally, site engineers and contractors benefit from BIM by better managing material usage and construction processes. Project owners and developers also leverage BIM to optimize the operation and maintenance phases Kamel et al., (2022). While BIM adoption is growing globally, its use in Egypt remains relatively limited. Robin et al., (2022) study in Egypt revealed that only 48% of local professionals used BIM for 2D and 3D modeling. Nonetheless, it is encouraging that 85% of the firms expressed interest in investigating ways to use BIM, and that BIM awareness in Egypt and Africa is estimated to be around 50% Marzouk et al., (2022). This paper recommends the use of BIM technology for design integration and enhances the implementation process. By cutting down on the time needed to coordinate plans within and across specialties and the potential to calculate the cost to achieve the best possible sustainability Kapogiannis et al., (2015), it enables the design team to devote more time to creativity and innovation.

The research aims to study the impact of using Building Information Modeling to improve the performance of the facilities and integrate the design, construction and post-operation phases. This was done through two Practical studies; Case Study (Residential Building) and Questionnaire.

MATERIALS AND METHODS

This paper exploring The impact of using BIM systems on construction building by examining three measurable Key performance indicators (Request For Information- Change Order - Cost Estimating) through Case study (residential building) and evaluation of the extent of use of BIM systems in the design and construction stages by an online questionnaire survey 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.

Applied Case Study for Measuring Performance Indicators:

A Residential Compound in **Fig. 1** has been Selected for a project under construction in October 6, Egypt as a case study for this research using Request for information, Change order indicator to determine the impact of cost and time and one Residential Building from the compound have been Selected to be modeled using Revit to measure its performance indicators .

Fig. 2. General layout plan for the compound

Analyzing the Information Required for the Residential Compound (RFI):

The collected and analyzed information required (RFI) of the current Case study, mentioning the element, location and the RFI body estimating the effect of this RFI whether to change the design, cost or time in term of the number of delay time of the project. After Analysis the impact of the mentioned RFI it can be concluded that only 76 RFI have been recorded by the research and the calculated number of delayed days of the project timeline was 307 days There is RFI happened after construction that caused change order and its impact on both delayed time and cost as shown in **Table 1**.

Table 1. The impact of changing orders on both delayed times and cost.

RESPONSE	ADDITIONAL COST	TIME OF RESPONSE
The mentioned RW is required to be RW2 instead of RW1 Please find the attached drawing that showing the detail for converting the existing RW1 footing to be RW2	150000 LE	10 days
The stair starter location has been updated to match the Arch by Growing Ashire Steel in new place, as IFC plans.	10000 LE	10 days
Due to an error occurred in the direction of reducing some columns dimensions (as clouded area in DWG) during their implementation on the site. so, we need to cut bars and drill new bars in the right places according to the approved shop drawing	20000 LE	10 days

Appling Revit Model for One Building (Model I) from the Residential Compound

One of the buildings in the residential compound was chosen, consisting of six floors as shown in figure (4-6), to apply the Revit tool to it to obtain an accurate and clear view of the building elements as shown in **Fig. 3** such as columns, beams, and Slabs , and to calculate the concrete quantities for these elements and calculate the cost for these elements.

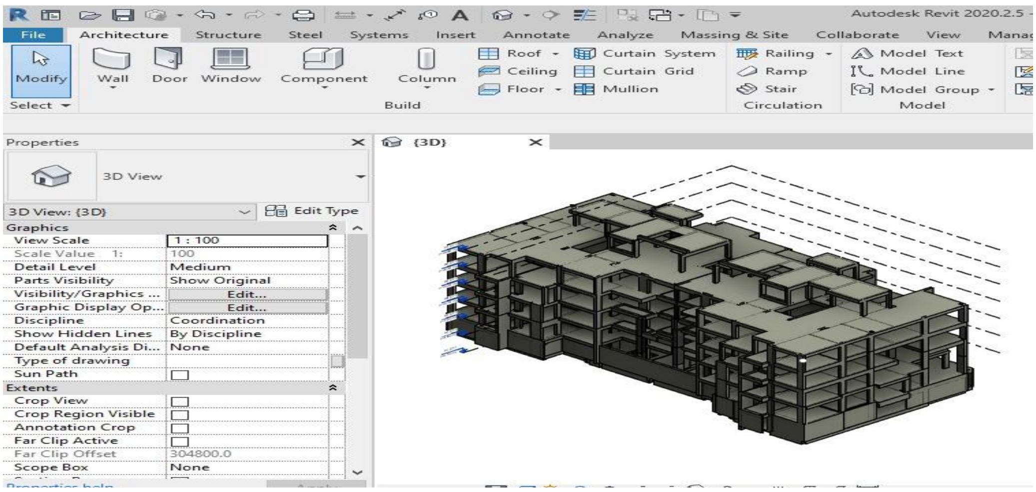
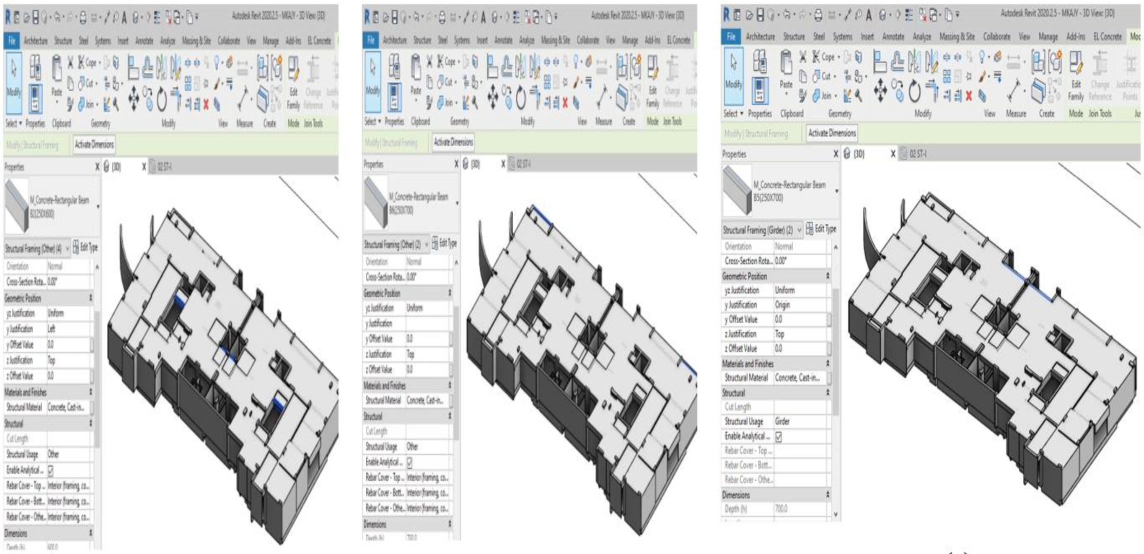


Fig. 3. Building I isometric view

Analyzing the Information Required (RFI) for the building (I):

- By reviewing the clouded areas in **Fig. 4** there are (Conflict Between (Structure & Arch) at FIRST Floor BL TYPE I&I` (10&11) at level +3.60 Please check drawing.



(a) (b) (c)

Fig. 5. Revit Model at level +3.60

Table 2. The time response for RFI at level +3.60.

RESPONSE	TIME OF RESPONSE
(a) Four beams modified from B2 (250*500) to B2 (250*600)	4 day
(b)Two beams modified from B5 (250*500) to B5 (250*700)	4 day
(c)Two beams modified from B5 (250*500) to B5 (250*700)	4 day

The time response for RFI at level +3.60 as shown in **Table 3. is 12 days .**

- There is a conflict between Arch & Civil Due to the conflict between beams depth and the windows BL TYPE I&I` at level +7.00 as shown in **Fig. 6** Please check drawing.

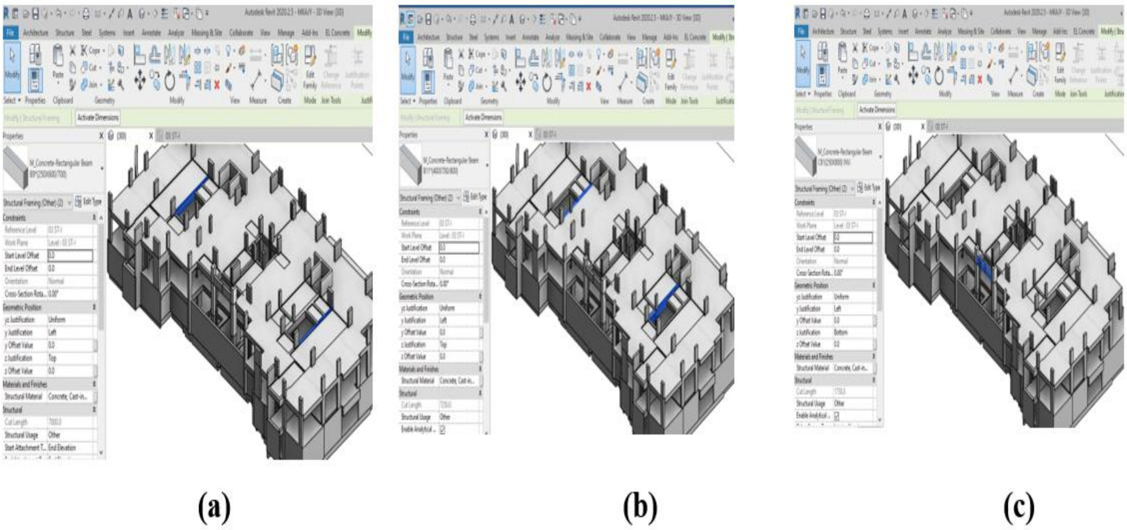


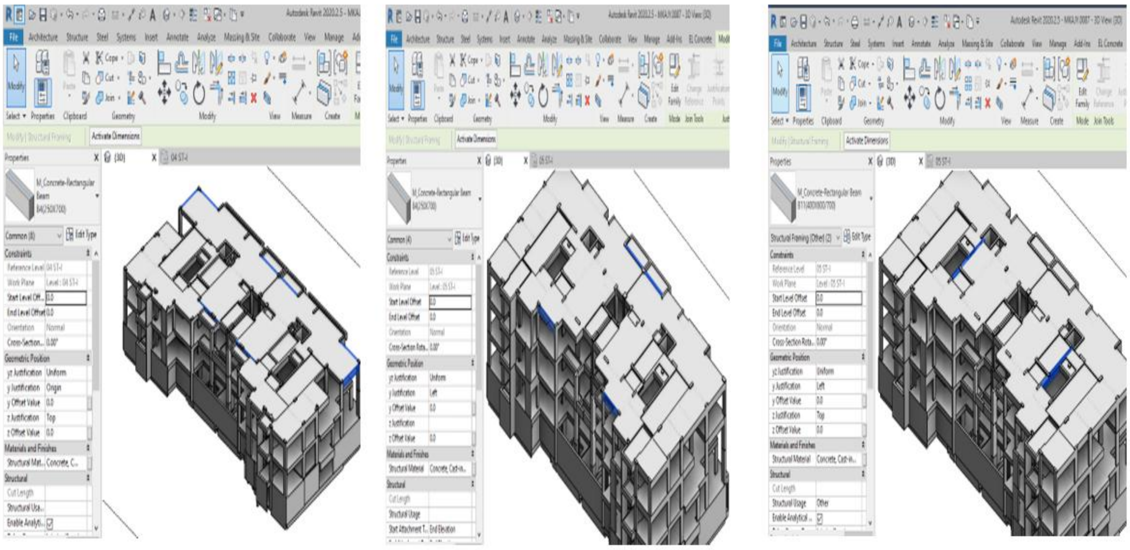
Fig. 7. Revit Model at level +7.70

Table 4. The time response for RFI at level +7.70.

RESPONSE	TIME OF RESPONSE
(a) Two beams modified from B9* (250*700) to B9*(250*600/700)	4 day
(b) Two beams modified from B11 (400*700/800) to B11(400*600/700)	4 day
(c) Two beams modified from CB1(250*900) INV to B2(250*800) INV	4 day

The time response for RFI at level +7.70 as shown in **Table 3. is 12 days .**

- Another RFI as shown in **Fig. 5** stated that review the clouded areas is need for Conflict Between (Structure & Arch) at THIRD Floor as Figure (4-16) BLTYPE I&I` (15&I6) at level +10.10 Please check drawing.



(a) (b) (c)

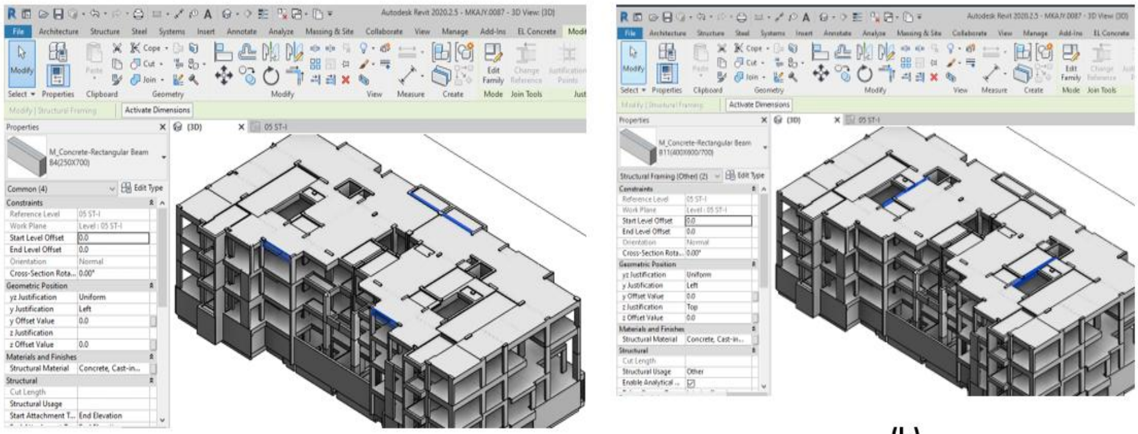
Fig. 8. Revit Model at level +10.10

Table 5. The time response for RFI at level +10.10.

RESPONSE	TIME OF RESPONSE
(a)Eight beams modified from B4 (250*500) to B4 (250*700)	10 days
(b)Four beams modified from B2 (250*500) to B2 (250*600)	6 days
(c)Two beams modified from CB1(250*900)INV to B2(250*800) INV	4 days

The time response for RFI at level +1.10 as shown in **Table 4. is 20 days .**

- Information Requested About the Depth of Beams as shown in **Fig. 6**. According to Arch Requirements, Missing RFT We need your review the clouded areas (Depth of Beams According to Arch Requirements, Missing RFT) at Forth Floor BL TYPE I at level +13.20 Please check drawing.



(a) (b)

Fig. 9. Revit Model at level +13.20

Table 6. The time response for RFI at level +13.20.

RESPONSE	TIME OF RESPONSE
(a) Four beams modified from B4 (250*500) to B4 (250*700)	6 day
(b) Four beams modified from B2 (250*500) to B2 (250*600)	6 day

The time response for RFI at level +13.20 as shown in **Table 5. is 12 days .**

- At Block 2-building-15&16 type-I&I` Upper roof floor +19.40 all beam will be projected B (250*540) except B6(250X550) INV At axis 8-11 & BETWEEN AXIS (C&D)as shown in **Fig. 7**. please check.

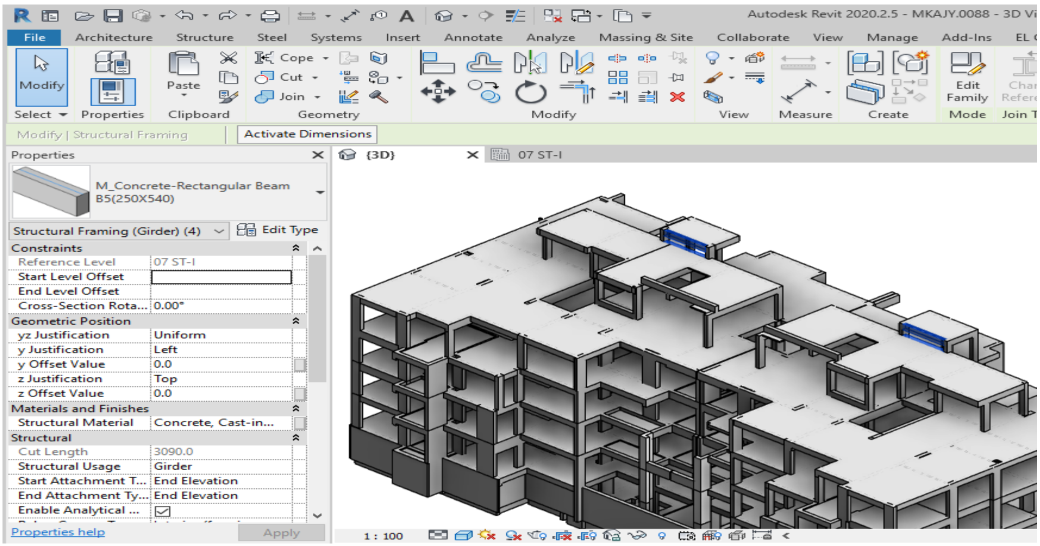


Fig. 10. Revit Model at level +19.40

Table 7. The time response for RFI at level +19.40.

RESPONSE	TIME OF RESPONSE
Four beams modified from B4 (250*500) to B4 (250*700)	10 day

The time response for RFI at level +19.40 as shown in **Table 6. is 10 days .**

Questionnaire survey

The frequencies and percentage of Personal data expressing the study sample of **75** individuals were calculated, in order to explore the characteristics of the study sample as shown in table (7):

Table (7): illustrate the number and percent of Survey participants

COMPANIES	NO	%
Designer	13	17.3
Consultant	21	28.0
Contracting	34	45.3
Project Owner	7	9.3
Total	**75**	100.0

From the Table (7) illustrate the number and percent of survey participants obtained find that the greatest number of samples was (Contracting) with No (34) with percent (45.3%), after that the number of (Consultant) were (21) with percent (28.0%), and the number of (Designer) were (13) with percent (17.3%), finally (Project Owner) with No (7) with percent (9.3%).

The Aim of Questionnaire :

The aim questionnaire is measuring the effect of Using Building Information Modeling (BIM) Technology on construction projects as a Solution to Integrate Building Projects in the design and implementation stages .

Questionnaire Structure:

The questionnaire has been prepared for the employees; The questions are of Open Ended and multiple choices. The questionnaire contains different questions covering the variables. It was divided into 4 sections aligned with the objectives of the research.

Section one: The first section includes personal data such as "type of Companies, End Degree obtained, nature Work and years of experience.

Section two: The second section of the questionnaire comprises 13 questions to measure the Institution Data.

Section three: The third section of the questionnaire comprises 5 items to measure the effectiveness of using (BIM) using a five-point Likert scale format with the descriptive phrases for the scale ranged from 1 ' Very weak' to 5 ' Very good'.

Section four: The last section of the questionnaire comprises 15 items to measure the Obstacles Using BIM using a five-point Likert scale format with the descriptive phrases for the scale ranged from 1 'Ineffective' to 5 'Its effect is very strong'.

Coding of the questionnaire data:

The data on the questionnaire lists was reviewed to ensure suitability and completeness for data entry and statistical analysis. The answers of the study sample were coded by a set of weights, each of which expresses the different opinions of the study sample according to the criteria for approval and disapproval in the framework of Likert five-scale as shown in Table (8).

Table 8: Coding study sample answers

OPINIONS	OPINIONS	WEIGHTS
Ineffective	Very Weak	1
Its effect is weak	weak	2
Its effect is medium	medium	3
Its effect powers	good	4
Its effect is very strong	Very good	5

Reliability and Validity tests

The Cronbach's 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 (Taber, 2018).

$$Alpha = \frac{n}{n-1}\left(1 - \frac{\sum_{i=1}^{n} Vi}{Vt}\right)$$

Where:
Alpha stands for Cronbach's alpha coefficient.
n stands for the number of statements in the survey list.
Vi stands for one-statement variance.
Vt stands for the variance of all statements in the poll list.

The validity coefficient is measured by taking the square root of the reliability coefficient as shown in equation:

$$Validity = \sqrt{\text{Alpha}}$$

Table 9. Results of Reliability and Validity coefficient for this Study.

DIMENSIONS	RELIABILITY COEFFICIENT	VALIDITY COEFFICIENTS
Institution Data	0.719	0.848
The effectiveness of using (BIM)	0.766	0.875
Obstacles Using BIM	0.732	0.856
The variable as a whole	0.799	0.894

Table 9. illustrates the number and percent of survey participants obtained find that the greatest number of samples was (Contracting) with No (34) with percent (45.3%), after that the number of (Consultant) were (21) with percent (28.0%), and the number of (Designer) were (13) with percent (17.3%), finally (Project Owner) with No (7) with percent (9.3%).

Table 10. The number and percentage of experience years.

years of experience / Companies	Designer		Consultant		Contracting		Project Owner	
	No	%	No	%	No	%	No	%
less than 5 year	6	46.2	8	38.1	11	32.4	4	57.1
9 - 5 Years	1	7.7	5	23.8	11	32.4	2	28.6
19 - 10 Years	5	38.5	6	28.6	11	32.4	1	14.3
29 - 20 Years	1	7.7	1	4.8	1	2.9	0	0
39 - 30 Years	0	0	1	4.8	0	0	0	0
Total	13	100.0	21	100.0	34	100.0	7	100.0

χ^2 **= 7.819 & P-value = 0.8**

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Table 10. illustrates the number and percentage of years of experience find the following:

- **<u>Designer:</u>** the greatest number was (Less than 5 years) with No (6) and percent (46.2%), after that (19 - 10 Years) (5) with percent (38.5%), finally (9 - 5 Years) and (29 - 20 Years) with No (1) and percent (7.7%).
- **<u>Consultant:</u>** the greatest number was (Less than 5 years) with No (8) and percent (38.1%), after that (19 - 10 Years) (6) with percentage (28.6%), (9 - 5 Years) with No (5) and percent (23.8%), finally (29 - 20 Years) and (39 - 30 Years) with (1) and percent (4.8%).
- **<u>Contracting:</u>** both numbers were (Less than 5 years), (9 - 5 Years) and (19 - 10 Years) with No (11) and percent (32.4%) the greatest, after that (29 - 20 Years) with (1) and percent (2.9%).
- **<u>Project Owner:</u>** the greatest number was (Less than 5 years) with No (4) and percent (57.1%), after that (9 - 5 Years) (2) with percentage (28.6%), finally (19 - 10 Years) with No (1) and percent (14.3%).

Table 11. The number and percent of kind of projects.

kind of projects / Companies	Designer		Consultant		Contracting		Project Owner	
	No	%	No	%	No	%	No	%
Residential	12	44.4	15	35.7	27	36.5	3	42.9
Commercial	8	29.6	13	31.0	21	28.4	2	28.6
Roads & Infrastructure	3	11.1	7	16.7	10	13.5	2	28.6
Industrial	4	14.8	7	16.7	16	21.6	0	0
Total	27	100.0	42	100.0	74	100.0	7	100.0

Table 11. illustrates the number and percentage of kind of projects find the following:

- **Designer:** the greatest number was (Residential) (12) with percent (44.4%), (Commercial) (8) with percent (29.6%), (Industrial) (4) with percent (14.8%), finally (Roads & Infrastructure) with No (3) and percent (11.1%).
- **Consultant:** the greatest number was (Commercial) (13) with percentage (31.0%), finally (Roads & Infrastructure) and (Industrial) with No (7) and percentage (16.7%).
- **Contracting:** the greatest number was (Residential) (27) with percent (36.5%), (Commercial) (21) with percent (28.4%), (Roads & Infrastructure) (16) with percent (21.6%), finally (Industrial) with No (16) and percent (21.6%).
- **Project Owner:** the greatest number was (Residential) (3) with percent (42.9%), (Commercial) and (Industrial) (2) with percent (28.6%).

RESULTS

The case study explore the impact of using building Information Modeling to improve the performance of the facilities and integrate the design, construction phases by examining three measurable performance indicators on a case study and determining the intended benefits, standard performance indicators based on the scientific review of previous research are Request for Information(RFI) which applied and analyzed on the Residential Compound only 76 RFI have been recorded by the researches and the calculated number of delayed days of the project time line was 307 days.

After analysis the impact of the mentioned RFI on the Residential Compound there was three change order have been recorded by the researches and the calculated number of delayed days of the project time line was 30 days and additional cost 180000 LE .

From Appling Revit Model for One Building elements (Building I) from the Residential Compound BIM systems help in visual communication of building information, allowing the user to navigate through three-dimensional facilities, discover the building as a whole in terms of spaces, elements and materials used, and generate the necessary perspectives to understand the project. Providing materials representing building elements, which contributes to reducing the need for questions about elements in terms of specifications and materials that make them up, without the need to generate more detailed plans for clarification. By reviewing the project timeline studied with the construction agency and studying the tasks that included inquiries and change orders resulting from errors, oversights, and the contractor's lack of vision, and calculating the increase in time associated with inquiries for the contractor, it was found that it was 66 days.

The quantities of Concrete volume result from Appling on (Building I) from the Residential Compound accurately automatically as shown in table 7

Table 8. Quantity of Concrete for Building I elements**.**

THE ELEMENT	THE VOLUME OF CONCRETE
Total volume OF Column	361.23 m^3
Total Volume of Beams	351.54 m^3
Total Volume OF Slabs	672.12 m^3
The Total Volume of Concrete for Building Element	1493.62 m^3

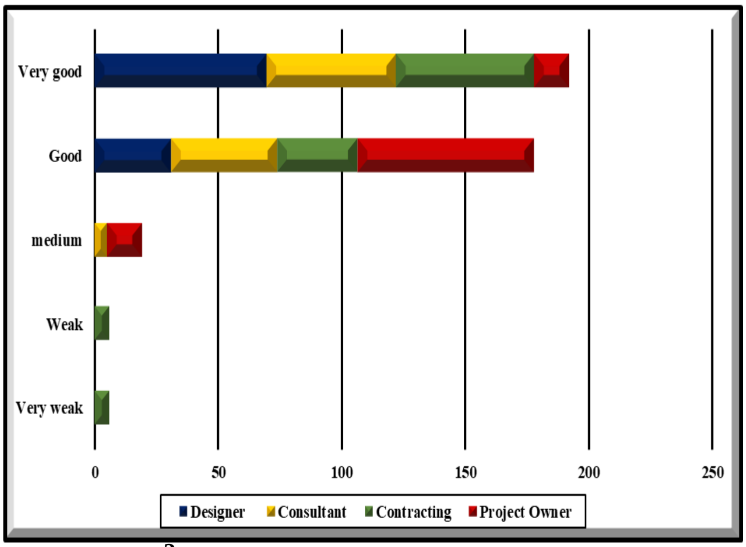
- The Total Volume of concrete for building element is 1493.62 m^3 as shown in Table 7 with cost 11948960 LE.
- The recorded RFI determining the extent to which the 3D Parametric building Model is used by reducing change orders and avoiding lack of information for construction and raising the efficiency of building cost estimation.

Questionnaire survey results present The effectiveness of using building Information modeling systems and the challenges of its use in design and Construction stages as the statistical tools utilized in the study The questionnaire participants of (75) have been selected from Designer, Consultant, Contracting, Project Owners from Egypt .

-The Effectiveness of using (BIM)

BIM has many benefits, including the quality of the design, improving the site construction productivity, forecasting, optimal control of costs, reducing conflicts, raising the change management efficiency and reducing the re-work caused by the change, in general, these changes lead to reduce the time and cost of the Project, improve its quality which led to sustainable approach.

- Usefulness of BIM systems at the stage of design



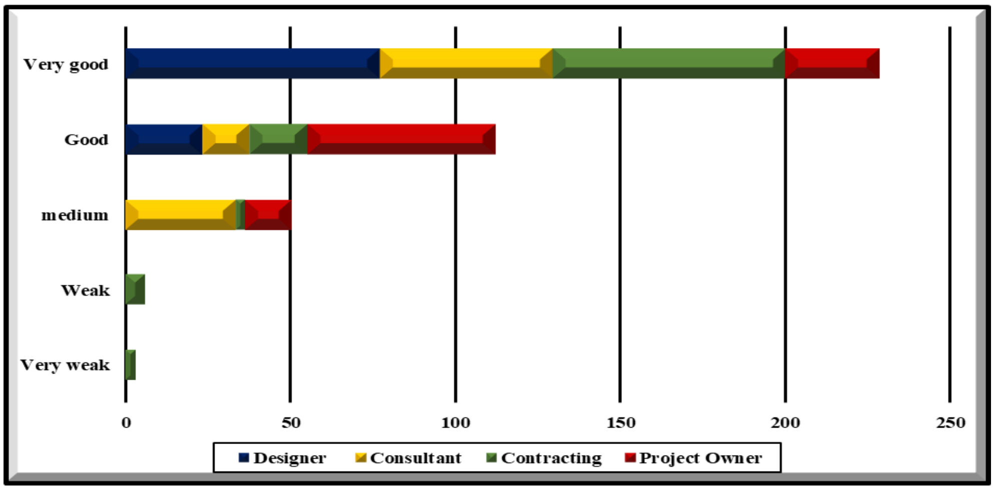
χ^2 **= 15.227 & P-value = 0.2**

Fig. 11. The percentage of answering of The Usefulness of BIM systems in the project design stage

Fig. 12. illustrates the number and percent of Usefulness of BIM systems in the project design stage find the following:

- **Designer:** the greatest number was (Very Good) with percent (69.2%), (Good) with percent (30.8%) with mean±SD (4.69±0.48) and Weight Percentile (93.85).
- **Consultant:** the greatest number was (Very Good) with percent (52.4%), (Good) with percent (42.9%), finally (medium) with percent (4.8%) with mean ± SD (4.48±0.60) and Weight Percentile (89.52).
- **Contracting:** the greatest number was (Very Good) with percent (55.9%), (Good) with percent (32.4%) with mean ± SD (4.26±1.14) and Weight Percentile (85.29).
- **Project Owner:** the greatest number was (Good) with percent (71.4%), (Very Good) and (medium) with percent (14.3%) with mean ± SD (4.00±0.58) and Weight Percentile (80.0).

- The Usefulness of BIM systems at the stage of Implementation



χ^2 **= 22.844 & P-value = 0.03**

Fig. 9. The percentage of answering of The Usefulness of BIM systems at the stage of Implementation

Fig. 9. illustrates the number and percent of Usefulness of BIM at the stage of Implementation find the following:

- **Designer:** the greatest number was (Very Good) with percent (76.9%), (Good) with percent (23.1%) with mean ± SD (4.77±0.44) and Weight Percentile (95.38).
- **Consultant:** the greatest number was (Very Good) with percent (52.4%), (medium) with percent (33.3%), finally (Good) with percent (14.3%) with mean ± SD (4.19±0.93) and Weight Percentile (83.81).
- **Contracting:** the greatest number was (Very Good) with percent (70.6%), (Good) with percent (17.6%), (weak) with percent (5.9%), finally (Very weak) and (medium) with percent (2.9%) with mean ± SD (4.44±1.11) and Weight Percentile (88.82).
- **Project Owner:** the greatest number was (Good) with percent (57.1%), (Very Good) with percent (28.6%), finally (medium) with percent (14.3%) with mean ± SD (4.14±0.69) and Weight Percentile (82.86).

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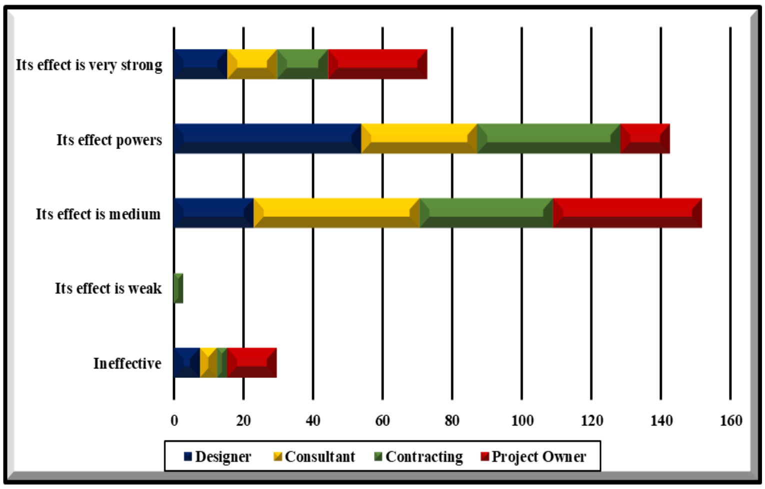
- The impact of avoiding missing information and change orders affected on the time of project during implementation phase



χ^2 **= 9.771 & P-value = 0.6**

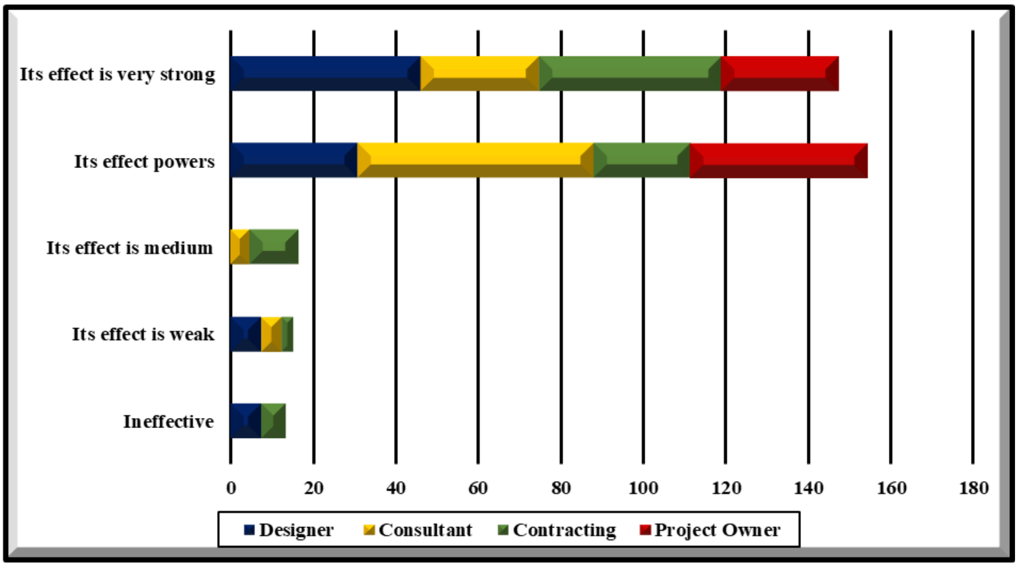
Fig. 11. The percentage of the impact of avoiding missing information and changing orders affected on the time project during the implementation phase

Fig. 11. illustrates the number and percentage to answer the question What is the impact of avoiding lack of information and changing orders at the time of the project during the implementation phase? find the following:

- **Designer:** the greatest number was (Its effect is powers) with percent (38.5%), (Its effect is medium) with percent (30.8%), (Its effect is very strong) with percent (23.1%), finally (Ineffective) with percent (7.7%) with mean ± SD (3.69±1.11) and Weight Percentile (73.85).
- **Consultant:** the greatest number was (Its effect is powers) with percent (42.9%), (Its effect is medium) with percent (33.3%), (Its effect is very strong) with percent (14.3%), finally (Ineffective) (Its effect is weak) with percent (4.8%) with mean ± SD (3.57±0.98) and Weight Percentile (71.43).
- **Contracting:** the greatest number was (Its effect is powers) with percent (58.8%), (Its effect is medium) with percent (26.5%), (Its effect is very strong) with percent (8.8%), finally (Ineffective) with percent (5.9%) with mean ± SD (3.65±0.86) and Weight Percentile (72.94).

- **Project Owner:** the greatest number was (Its effect is very strong) with percent (42.9%), (Its effect is medium) and (Its effect is powers) with percent (28.6%), (with mean ± SD (4.14±0.90) and Weight Percentile (82.86).

- The impact of avoiding missing information and change orders affect the cost of project during the implementation phase



χ^2 **= 12.475 & P-value = 0.4**

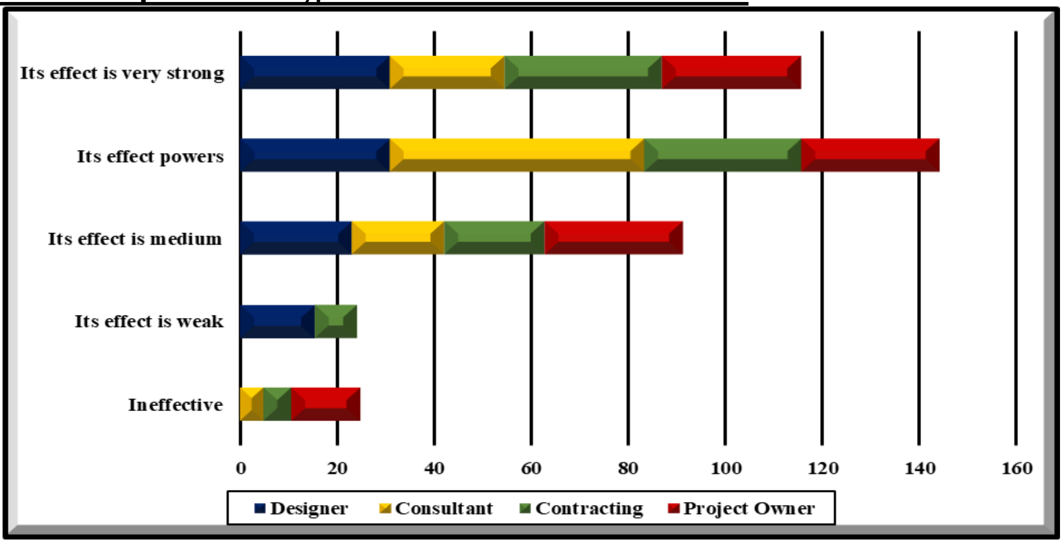
Fig. 13. The percentage of the impact of avoiding missing information and change orders on the project cost during the implementation phase

Fig. 13. illustrates the number and percent to answering the question How much does avoiding lack of information and change orders affect the cost of the project during the implementation phase? find the following:

- **Designer:** the greatest number was (Its effect is very strong) with percent (46.2%), (Its effect is powers) with percent (30.8%), finally (Ineffective) and (Its effect is weak) with percent (7.7%) with mean±SD (3.62±1.12) and Weight Percentile (72.31).
- **Consultant:** the greatest number was (Its effect is powers) with percent (57.1%), (Its effect is very strong) with percent (28.6%), finally (Its effect is weak) and (Its effect is medium) with percent (4.8%) with mean ± SD (3.38±0.87) and Weight Percentile (67.62).

- **Contracting:** the greatest number was (Its effect is very strong) with percent (44.1%), (Its effect is powers) with percent (23.5%), (Its effect is medium) with percent (11.8%), (Ineffective) with percent (5.9%), finally (Its effect is weak) with percent (2.9%) with mean ± SD (3.62±0.37) and Weight Percentile (72.5).
- **Project Owner:** the greatest number was (Its effect is powers) with percent (42.9%), (Its effect is very strong) with percent (28.6%), with mean ± SD (4.14±0.90) and Weight Percentile (82.86).

- How BIM help in reducing the waste of the environmental



χ^2 **= 7.742 & P-value = 0.8**

Fig. 14. The percentage How BIM help in reducing the waste of environmental resources

Fig. 14. illustrates the number and percent to answering the question Does BIM help? in reducing the waste of environmental resources find the following:

- **Designer:** the greatest number was (Its effect is powers) and (Its effect is very strong) with percent (30.8%), (Its effect is medium) with percent (23.1%), finally (Its effect is weak) with percent (15.4%) with mean ± SD (3.77±1.09) and Weight Percentile (75.38).
- **Consultant:** the greatest number was (Its effect is powers) with percent (52.4%), (Its effect is very strong) with percent (23.8%), (Its effect is medium) with percent (19.0%),

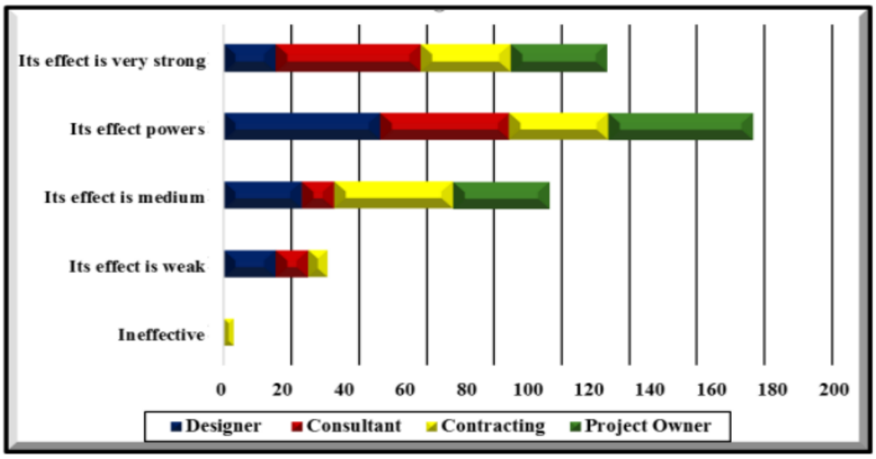
finally (Ineffective) with percent (4.8%) with mean ± SD (3.90±0.94) and Weight Percentile (78.1).

- **Contracting:** the greatest number was (Its effect is very strong) and (Its effect is powers) with percent (32.4%), (Its effect is medium) with percent (20.6%), (Its effect is weak) with percent (8.8%), finally (Ineffective) with percent (5.9%) with mean ± SD (3.76±1.16) and Weight Percentile (75.29).
- **Project Owner:** the greatest number was (Its effect is very strong), (Its effect is powers) and (Its effect is medium) with percent (28.6%), (Ineffective) with percent (14.3%), with mean ± SD (3.57±1.40) and Weight Percentile (71.43).

-The Challenges of Using (BIM)

The remarkable developments in BIM systems carry many obstacles (Samy، A F.M et al., 2024) that construction manufacturers must address by allowing the project team to test the electronic model of the building before implementing it. Among the challenges facing BIM systems are the difficulty of switching from the traditional system, high initial cost (low productivity), lack of awareness and knowledge, demand from clients and companies to use application, complex modeling process and software, lack of experience, lack of training, high cost of software required to operate.

- Difficulty switching from the traditional system



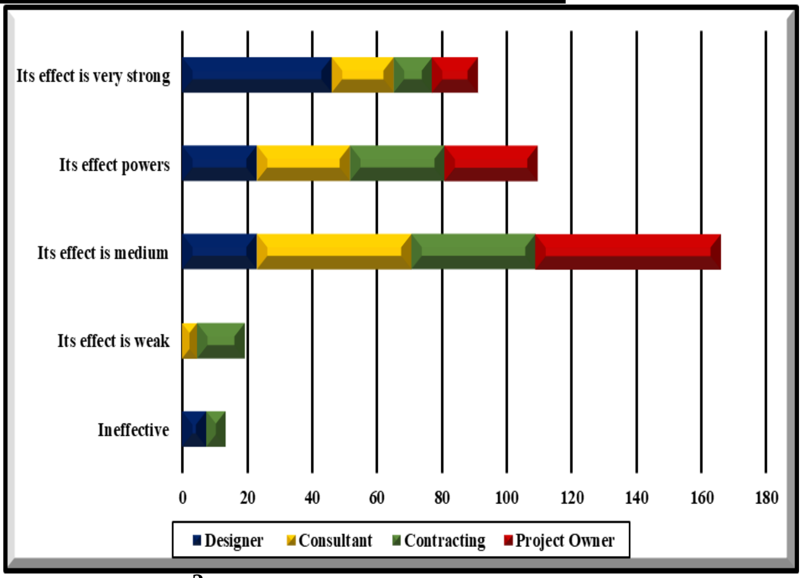
χ^2 = 12.535 & P-value = 0.4

Fig. 15. The percentage of the difficulty of switching from the traditional work system to the use of Applications (BIM)

Fig. 15. illustrates the number and percentage of the difficulty of switching from the traditional work system to the use of Applications (BIM) find the following:

- **<u>Designer:</u>** the greatest number was (Its effect is medium) with percent (38.5%), (Its effect is powers) with percent (30.8%), finally (Its effect is weak) with percent (23.1%), finally (Its effect is very strong) with percent (7.7%) with mean ± SD (3.23±0.96) and Weight Percentile (64.62).
- **<u>Consultant:</u>** the greatest number was (Its effect is powers) with percent (28.6%), (Its effect is weak) and (Its effect is medium) with percent (23.8%), finally (Its effect is very strong) with percent (19.0%) with mean±SD (3.33±1.20) and Weight Percentile (66.67).
- **<u>Contracting:</u>** the greatest number was (Its effect is medium) with percent (47.1%), (Its effect is very strong) with percent (26.5%), (Its effect is powers) with percent (20.6%), finally (Ineffective) and (Its effect is weak) with percent (2.9 %) with mean±SD (3.65±1.01) and Weight Percentile (72.94).
- **<u>Project Owner:</u>** the greatest number was (Its effect is medium) with percent (57.1%), (Its effect is powers) with percent (28.6%), (Its effect is very strong) with percent (14.3%) with mean±SD (3.57±0.79) and Weight Percentile (71.34).

<u>- Low productivity of (BIM) in the first period of Use</u>



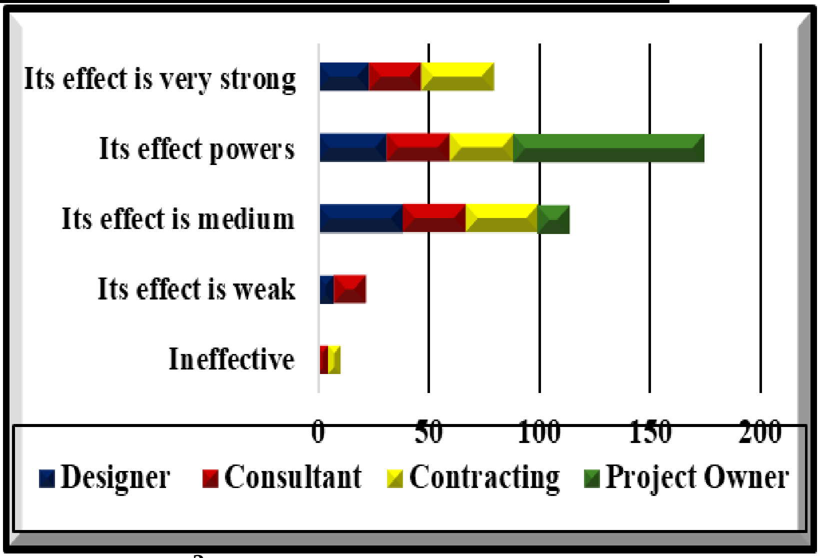
χ^2 = 3.380 & P-value = 0.99

Fig. 16. The percentage of Low productivity of (BIM) in the first period of Use

Fig. 16. illustrates the number and percentage of Low productivity of (BIM) in the first period of Use find the following:

- **Designer:** the greatest number was (Its effect is very strong) with percent (46.2%), (Its effect is medium) and (Its effect is powers) with percent (23.1%), finally (Ineffective) with percent (7.7%) with mean ± SD (3.23±0.93) and Weight Percentile (64.62).
- **Consultant:** the greatest number was (Its effect is medium) with percent (47.6%), (Its effect is powers) with percent (28.6%), (Its effect is very strong) with percent (19.0%), finally (Its effect is weak) with percent (4.8%) with mean ± SD (2.95±0.97) and Weight Percentile (59.05).
- **Contracting:** the greatest number was (Its effect is medium) with percent (38.2%), (Its effect is powers) with percent (29.4%), (Its effect is weak) with percent (14.7%), (Its effect is very strong) with percent (11.8%), finally (Ineffective) with percent (5.9%) with mean ± SD (3.18±1.03) and Weight Percentile (63.53).
- **Project Owner:** the greatest number was (Its effect is medium) with percent (57.1%), (Its effect is powers) with percent (28.6%), (Its effect is very strong) with percent (14.3%), with mean ± SD (3.57±0.98) and Weight Percentile (71.43).

- Lack of Awareness of the Benefits of Using BIM Applications



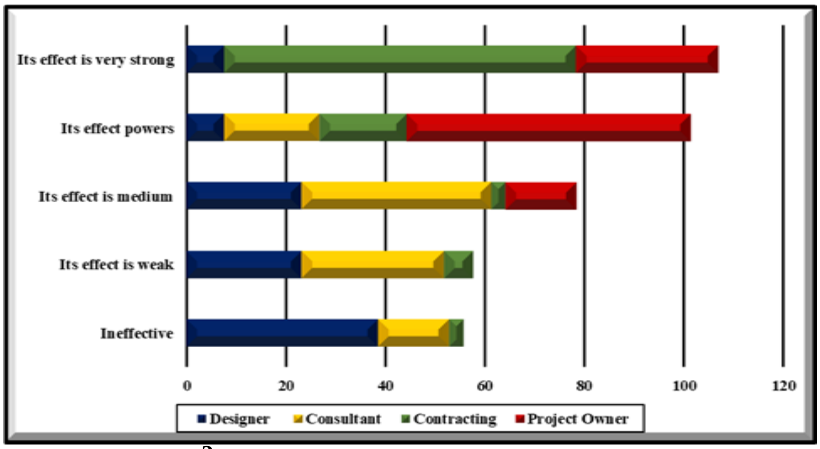
χ^2 = 15.836 & P-value = 0.2

Fig. 17. The percentage of Lack of awareness of the benefits of using BIM applications

Fig. 17. illustrates the number and percent of Lack of awareness of the benefits of using BIM applications find the following:

- **Designer:** the greatest number was (Its effect is medium) with percent (38.5%), (Its effect is powers) with percent (30.8%), (Its effect is very strong) with percent (23.1%), finally (Its effect is weak) with percent (7.7%) with mean±SD (3.69±0.95) and Weight Percentile (73.8).
- **Consultant:** the greatest number was (Its effect is medium) and (Its effect is powers) with percent (28.6%), (Its effect is very strong) with percent (23.8%), (Its effect is weak) with percent (14.3%), finally (Ineffective) with percent (4.8%) with mean ± SD (3.52±1.17) and Weight Percentile (70.48).
- **Contracting:** the greatest number was (Its effect is medium) and (Its effect is very strong) with percent (32.4%), (Its effect is powers) with percent (29.4%), finally (Ineffective) with percent (5.9%) with mean ± SD (3.82±1.09) and Weight Percentile (76.47).
- **Project Owner:** the greatest number was (Its effect is powers) with percent (85.7%), (Its effect is medium) with percent (13.4%), with mean±SD (3.86±0.38) and Weight Percentile (77.14).

- Complex modelling process and tricky software



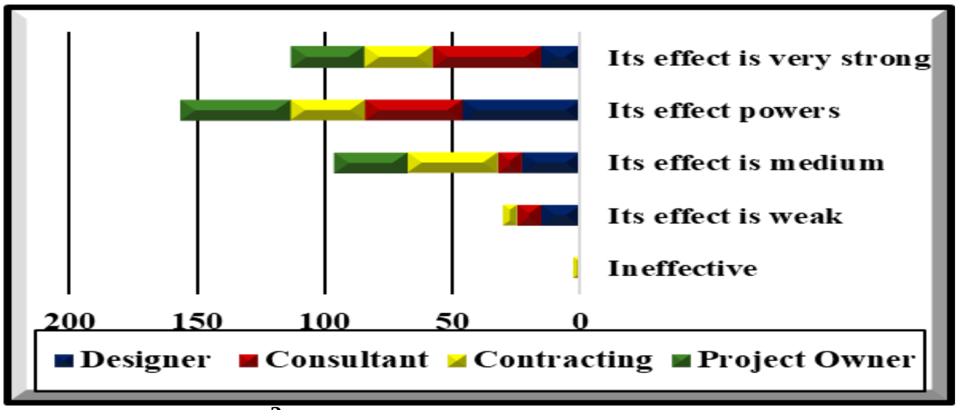
χ^2 = 15.625 & P-value = 0.2

Fig. 19. The percentage of answering of The Complex modelling process and tricky software

Fig. 19. illustrates the number and percentage of Complex modelling process and tricky software find the following:

- **Designer:** the greatest number was (Ineffective) with percent (38.5%), (Its effect is weak) and (Its effect is medium) with percent (23.1%), finally (Its effect is powers) and (Its effect is very strong) with percent (7.7%) with mean ± SD (3.23±1.30) and Weight Percentile (64.6).
- **Consultant:** the greatest number was (Its effect is medium) with percent (38.1%), (Its effect is weak) with percent (28.6%), (Its effect is powers) with percent (19.0%), finally (Ineffective) with percent (14.3%) with mean ± SD (2.62±0.97) and Weight Percentile (52.38).
- **Contracting:** the greatest number was (Its effect is medium) with percent (38.2%), (Its effect is weak) with percent (20.6%), (Its effect is powers) with percent (17.6%), (Its effect is very strong) with percent (14.7%), finally (Ineffective) with percent (8.8%) with mean ± SD (3.09±1.16) and Weight Percentile (61.76).
- **Project Owner:** the greatest number was (Its effect is medium) with percent (71.4%), (Its effect is powers) and (Its effect is very strong) with percent (14.3%) with mean ± SD (3.43±0.79) and Weight Percentile (68.57).

- Absence of training programs for employees of construction institutions On the use of (BIM) applications



χ^2 **= 9.529 & P-value = 0.7**

Fig. 20. The percentage of answering of the Absence of training programs for employees of construction institutions on the use of (BIM) applications

Fig. 20. illustrates the number and percentage of Absence of training programs for employees of construction institutions on the use of (BIM) applications finds the following:

- **Designer:** the greatest number was (Its effect is powers) with percent (46.2%), (Its effect is medium) with percent (23.1%), finally (Its effect is weak) and (Its effect is very strong) with percent (15.4%), with mean ± SD (3.62±0.96) and Weight Percentile (73.31).
- **Consultant:** the greatest number was (Its effect is very strong) with percent (42.9%), (Its effect is powers) with percent (38.1%), finally (Its effect is weak) and (Its effect is medium) with percent (9.5%) with mean ± SD (4.14±0.96) and Weight Percentile (82.86).
- **Contracting:** the greatest number was (Its effect is medium) with percent (35.3%), (Its effect is powers) with percent (29.4%), (Its effect is very strong) with percent (26.5%), (Its effect is weak) with percent (5.9%), finally (Ineffective) with percent (2.9%) with mean ± SD (3.71±1.03) and Weight Percentile (74.12).
- **Project Owner:** the greatest number was (Its effect is powers) with percent (42.9%), (Its effect is medium) and (Its effect is very strong) with percent (28.6%), with mean ± SD (4.00±0.82) and Weight Percentile (80.0).

This challenge requires collaborative efforts between schools of architecture, local community organizations and the AEC firms. While the schools of architecture make sure their graduates are ready to use BIM effectively, local community organizations may play a role in extending the awareness of middle-aged engineers with the needed training to familiarize them with the best means of utilizing BIM in their practice. Yet, AEC firms can structure specialized training programs for their staff to keep them acquainted with the latest technologies in BIM applications. Similar endeavors showed to have a significant positive effect on the expansion of BIM in many countries around the world (CIDB, 2013; Navendren et al., 2014; Tulenheimo, 2015).

DISCUSSION

The traditional construction industry is facing a low rate in productivity during the construction phase when compared to other industries, mainly due to poor planning, coordination and poor communication between project parties (Ganbat et al., 2019; Samy, 2024). Problems experienced by construction projects such as lack of information, missing elements, missing Data (loss of time from 20% to 25% in the search) and requirements and modifications of the owner ; The ease of adjustment in the work before execution, as a result of the owner or decision holder not imagining the form of the project, because the fallout and the sectors are not often studied and the amendment was requested after the completion of the building as a result the modification was at a higher cost. The adjustment before the start of the project is estimated at five (20%) the value of the modification after the completion of the project (Robin et al., 2022).

This study suggests the use of BIM systems to improve the implementation process. It allows the design team to invest time in innovation and creativity by reducing the coordination time of the schemes by one specialization and between different disciplines. Inefficient with existing systems. In addition to providing a virtual environment for the owner to be able to roam the building and inspect its elements and color systems. The possibility of providing different alternatives is made available and directly linked to their cost impact.

The inclusion of "time" as a fourth dimension in BIM became inevitable, leading to the integration of construction schedules, activity planning, and progress monitoring Ganbat et al., (2019). This concept further evolved into 5D BIM, incorporating "cost" as the fifth dimension, which allowed for real-time calculation of physical quantities and cost estimates as the model developed Vigneault et al., (2020)

In response to global environmental challenges and the growing emphasis on sustainable construction, 6D BIM introduced the concept of "sustainable life cycle management." This module builds on previous dimensions by requiring the final model to include comprehensive information on as-built drawings, materials used, technical specifications, quantities, suppliers, and contact details (Kapogiannis et al., 2015); Wong, 2015). More recently, 7D BIM was introduced to focus on maintenance and operations, encompassing maintenance plans, facility management, operation manuals, building component conditions, and warranty terms for various elements (Becerik-Gerber et al.,2012; McPartland, 2017)

Accurate cost estimates require accurate quantities of building elements. Quantities were evaluated through smart methods of BIM systems. The Revit program was used to calculate the quantities of concrete for three of the main building elements slabs، beams, and columns for the case study) residential building) . The final results were produced for the construction elements, and the defects of traditional methods of calculating quantities were found, as they are based on manual extraction of quantities, whether from electronic or paper plans, which consumes a lot of time. It also requires following up on continuous modifications in the design during implementation to avoid calculating larger quantities or less or frequent, which affects the accuracy of the calculated quantities and thus affects the accuracy of the construction cost.

Data analysis by questionnaire measuring the effect of using Building Information Modeling (BIM) as a solution in the stages of design and implementation in the construction industry. A survey was conducted aiming at the extent to which the BIM systems were used in engineering projects and provided feedback from Egypt construction industry workers. Research information has thus been linked to practical experiments to use these systems. The response rate was ٧٥, and the data collected was statistically analyzed using the SPSS statistical analysis software. The results revealed that real steps have been initiated to adopt the BIM systems, but expertise is still needed and not yet available. One of the most important reasons for the desire to adopt the BIM systems was to reduce the time, prolong the design time and improve communication between the parties of the project by 56%, the most lacking in the current systems because of the lack of a mechanism to ensure the coherence of the information of the project. The greatest number and percent of uusefulness of BIM systems in the project design stage is as the following: (69.2%) from Designer, (52.4%) Consultant, (55.9%) Contracting, and (71.4%) from Project Owner. The greatest number and percent of lack of awareness of the benefits of using BIM is (38.5%) from Designer, (28.6%) Consultant, (32.4%) Contracting and (85.7)% from Project Owner .

Future recommendations:

To study the impact of using the six-dimensional model (6D Model) which is introduced as the concept of sustainable life cycle management .

To ensure a successful transition from the CAD systems to the BIM systems, a set of proposals is recommended as follows:

a) Assessing the BIM software packages and extrapolating around them to choose packages that match the nature of the work and the projects to be implemented.
b) Working within a team that includes all disciplines, involving the owner and the contractor of the project and its early stages, and familiarizing the team with the responsibilities of each of them.
c) Training should be based on a specific plan in terms of selected programs and the time between training and actual application.
d) Determining from the beginning what is required as a final outcome (quantities and cost estimate - three-dimensional model - conflict detection)
e) Optimal planning for all phases of the project and optimal utilization of available resources.

It is highly recommended to conduct questionnaires that include a larger research sample in order to generalize the results on the use of the BIM systems at the project stages and to identify significant differences among the participants in the questionnaire.

The lack of a complete study case as evidence of the financial and technical benefit of the application of the BIM is considered one of the obstacles to the research, it is highly desirable to invest in this context when work is done on an integrated case guide for projects and applied BIM systems.

Integrating the concepts of the BIM systems into university education programs and workshops, ensuring that new people enter the job market in the future with the required skills and covering the skills shortage.

CONCLUSION

1. BIM systems help in visual communication of building information, allowing the user to navigate through three-dimensional facilities, discover the building as a whole in terms of spaces, elements and materials used, and generate the necessary perspectives to understand the project. Providing materials representing building elements, which contributes to reducing the need for questions about elements in terms of specifications and materials that make them up.
2. Using the BIM systems software, quantities are automatically extracted once the building is modeled, which holds the designer responsible for the correct modeling to get the correct quantities. The Revit program features the ability to assemble, sort and filter the quantities of building elements according to any user-defined standard and at any time. Through the Revit program, we can also visually verify the building components calculated by providing direct automated correlation between quantities and elements, which provides optimal management of change in construction and contributes to providing immediate cost for the proposed alternatives at the design stage. However, when assessing the efficiency of the program in terms of effort, the level of effort is greater, and experience and training is needed to reach the correct modeling of elements compared to software based on two-dimensional diagrams, where the main effort is at the quantification stage.
3. The impact of the inquiries of the contractors and the orders of change resulting from errors and omissions and poor perception on the cost and time of the project, and this impact was measured quantitatively in cities during a study case approved in the research (residential building). The researcher concluded that addressing the contractor's inquiries and changing orders resulting from errors, omissions and poor perception before reaching the implementation stage and automated management of changes during the implementation phase would raise the efficiency of the work by avoiding an increase in time.
4. The questionnaire results by group of survey respondents from the designer, consultant, contracting and owner organizational evaluated two axes Firstly :The effectiveness of using (BIM) , the most important Question include: usefulness of BIM systems at the stage of design and implementation, the impact of avoiding missing information and

change orders affected on the time and cost of project during the design phase, the impact of avoiding missing information and change orders affect the time and cost of project during the implementation phase and How BIM help in reducing the waste of the environmental.The second axis The Obstacles of Using (BIM) the most important Question include: Difficulty switching from the traditional system, Low productivity of (BIM) in the first period of Use, Lack of Awareness of the Benefits of Using BIM Applications, The demand from customers and companies to use Applications (BIM), Complex modelling process and tricky software, Absence of training programs for employees of construction institutions on the use of (BIM) applications.

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نحو مدخل مستدام لحلول فعالة لتكامل مشروعات البناء من التصميم إلى التنفيذ

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المستخلص

تواجه صناعة البناء التقليدية انخفاضًا في الإنتاجية خلال مرحلة البناء مقارنة بالصناعات الأخرى .يهدف هذا البحث إلى دراسة أثر استخدام نمذجة معلومات البناء (BIM) كحل فعال لتكامل مراحل التصميم والبناء وما بعد التشغيل من خلال فحص ثلاثة مؤشرات أداء رئيسية قابلة للقياس (طلب الحصول على معلومات – تغيير المعلومات – تقدير التكلفة) المطبقة على المجمع السكني كدراسة حالة وتحديد الفائدة المرجوة من استخدام ال (BIM) ، وقد استنتج زيادة في معدل إنتاجية البناء مع تطبيق أنظمة ال (BIM) بسبب تقليل حالات إعادة العمل التي تسبب هدر الوقت وتجنب عدد كبير من نقص المعلومات المطلوبة في مرحلة التنفيذ وحل التعارضات قبل بدء مرحلة البناء .مما أدى إلى تقليل

التكلفة وتجنب المشاكل التشغيلية قبل بدء المشروع .كما تضمن البحث تقييم استخدام نظم نمذجة معلومات البناء في مراحل التصميم والتنفيذ من خلال نشر استبيان بنسبة استجابة بلغت 75 مستجيباً .تظهر النتائج أنه على الرغم من أن أنظمة ال(BIM) حديثة، فقد اعتمدها الكثيرون بسبب قدرتها على تحسين كفاءة العمل وتعزيز التواصل بين فرق المشروع وتقليل المخلفات البيئية .على الرغم من بعض العوائق، مثل الافتقار إلى المهنيين المؤهلين، فمن المتوقع أن يتم استخدام ال (BIM) على نطاق واسع في صناعة البناء والتشييد في المستقبل القريب.

الكلمات المفتاحية: الاستدامة، مشاريع البناء المتكاملة، مؤشرات الأداء الرئيسية، مشاريع التشييد، نمذجة معلومات البناء.