# Studying the Impact of Using Building Information Modeling BIM in mitigating Risks for Construction Projects

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## ABSTRACT

The construction industry faces significant risks because of decline in its production and performance compared to other industries. This is mainly due to lack of realistic planning, coordination and communication among project' parties. Introducing Building Information Modeling (BIM) as a new technique in Project Management (PM) can promise improvement to the construction planning and its performance. This paper is focusing on studying the impact of BIM implementation to mitigate risks in construction projects. The objective of this paper is extending to include design stage to study the role of implementing BIM in reducing the project risks. The study is supported by carrying out structured questionnaire survey from construction industry' experts. In addition, case studies are included for verification purpose. Four case studies are investigated to study the impact of applying BIM systems. The main finding of this study was that a remarkable increase in the rate of construction products was recorded by implementing BIM technology due to the reduction of the re-work and the time wasted. Moreover, adopting BIM systems helps in avoiding a significant number of problems caused by the lack of information required during the implementation phase. Finally, BIM systems have a major role in resolving conflicts and clashes. The results showed that the BIM systems enhancement in the work performance was obtained due to communication improvement among project' stockholders especially in early stages. Finally, BIM threats and future difficulties in business development are examined.

## INTRODUCTION

The construction business has constantly earned reputation for being an exceedingly unpredictable industry because of its high extent of organization disappointments. This circumstance had been related to various elements, not only because of the dangers in embraced the more perplexing and capricious procedures of development instead of the straight, automated and unsurprising tasks of, state, a vehicle or gadgets creation line (Harvey and Ashworth,1997). In the period of dynamic globalization, it is difficult to stay away from the hazard, which has turned into a basic piece of regular daily existence is available all over, in each part of our life. One of such perspective is the development business, where the hazard is an innate component. From the financial perspective this choice is of no use since what is possibly beneficial is by definition dangerous and movement that does not represent a hazard isn't monetarily intriguing. Also, along this choice does not bring unmistakable advantages (Pawel Szymański, 2017). Thus, the execution of structured data displaying (BIM) is viewed as basic to limit hazards in the development ventures. Hand-drafted print, outlining and hand demonstrating were the standard for structure plans before the coming of PC supported plan (CAD) frameworks. These days CAD frameworks are better comprehended, their reception expanded until the 2D, 3D CAD framework and the computer-generated experience turned into the standard. Their common advancement has offered to ascend to another and increasingly complex age of structured configuration devices known as structure data displaying, or BIM. There is lacking lucidity about what BIM is, despite the fact that this is improving, and there is highly shared comprehension. There is an understanding that BIM isn't simply programming. BIM isn't simply CAD or geometric information. BIM is a cooperatively created and kept up, information-rich, data hotspot for the life of the structure procedure and past (Boukara and Naamane, 2015). The importance of BIM for architects, engineers, and construction industry has been taken into consideration. In other words ,BIM can be used by engineers, architects, project managers, etc. in order to achieve these goals: decrease design errors, reduce clash detection, boost the integration of cost and time, improve the integration of design and construction phase, increase the collaboration between different construction sections and finally to improve recycling (Mohandes and Omrany,2013). In the beginning times of BIM, constructors worked from engineering plans since computerized models were not shared by planners with contractual workers. The development modelers unavoidably found blunders and irregularities in the plans as they made the BIM. This realized a characteristic repetition as the development model put the plan to this virtual structure test. With an increasingly trustful sharing of building illustrations, which can be effectively be imported and fill in as the reason for the BIM model, there might be lost this basic checking stage. As it were the point at which all players see themselves on a similar group they may stop to search for and discover botches in one another's work. Previously, an absence of basic audit has been no less than one of the part elements of structure disappointment (Azhar, Hein and Sketo, 2011).

## RESEARCH OBJECTIVES

The problems which face the construction projects are divided into two sectors; the first one is during the design phase and the second is during the implementation phase.The purpose of this paper is to study the impact of implementing Building Information Modeling BIM on the mitigation of construction project risks during all phases of the project. The novelty of this study is two-fold. First, an empirical study was conducted based on the data collected using a survey distributed on two different types of companies, i.e., engineering contractors' firms and engineering consulting firms via emails and face to face interviews. This survey represents two parties. The first part is the risks in the construction industry (when risks are addressed, how to deal with them and who is responsible of dealing with these risks). The second part investigates BIM (Implementation, Cost of applying, benefits, and effects on project risks). In addition, four case studies were investigated with and without BIM.

# 3- LITERATURE REVIEW

The construction projects face many constraints where the risk is one of them. These risks have a negative effect on cost, time and the other constraints. The building information modeling BIM is a system that controls the constraints and is also describes an assortment of ways developers and temporary workers are right now applying BIM apparatuses during the development procedure. Regarding this part, the paper distinguishes a large group of legitimate issues, dangers, and boundaries raised by the utilization of BIM in these settings which the business has not tended to appropriately, and the benefits of the implementation of BIM in construction projects. This part sheds some light on BIM 4-Dimensions. Also, this part states the factors behind approving or rejecting BIM implementation.

## 3.1 Risk Management

As a project manager, you must juggle many things on a project, including project constraints like time, cost, risk, scope, quality ,resources, customer satisfaction, and any other factors that limit options. For example, the data a milestone deliverable is due, the date by which the project must be completed, and the maximum allowable risk a project is allowed to have all constraints.The usage of constraints to help evaluate competing demands, management directly or indirectly sets the priority of each constraint. It is important to realize that you need to evaluate the effect a change to one constraint has on the other constraints, you probably cannot shorten the schedule without causing a negative impact to cost, risk, and another constraint**(PMBOOK 6th edition). Alireza Atin (2016)**.Analyzed the risk propagation among engineering, procurement, and construction phases of construction projects by conducted survey and analyzed the result it found that: “Late design decision and drawings” is the most critical risk of an engineering phase and one which has the greatest impact on other phases (procurement and construction phases). In addition, “Availability of resources for subcontractors” has the greatest impact on other phases (engineering and construction phases). Also, “Delay in decision making and approval” has the greatest effect on other phases (engineering and procurement phases). Finally, according to this sensitive analysis, “late design decisions and drawings” is the most important risk event among a total of forty risk events covered in this study, in terms of risk propagation to other phases. Additionally, the results show us that P-C is the strongest risk event propagation relationship in construction projects. In other words, procurement risk events have the greatest impact on the construction phase. **Amani S A S Bu-Qammaz (2015)** introduced another dimension related to public construction projects: risk related to the public construction industry. Based on the experts’ judgments with respect to bidding phase risk, the results indicated that the joint venture risk category is the most critical risk related to the bidding phase. The experts gave the risks related to joint venture relationships and local partners the highest importance compared to other joint venture risks. Additionally, financial proposal risk was found to be more important than technical proposal risk. Under the financial proposal category, the bid value and accuracy factors were found to be the most critical. Management skills and resources were rated by the experts as being the most critical factors under the technical proposal risk category. Construction phase risk was divided into two main categories: external and the internal risk. The experts believed that external risk is moderately more important than internal risk. This may be because external risk factors are uncontrollable and because a project team cannot eliminate its expected consequences. The external risk was divided into country-specific and inter-country risk. The internal risk was divided into the construction environment and project-specific risk. The most important factors under the project-specific risk category were found to be the delivery system, contract type, and design-related risk.

### 3.2 Building Information Modeling (BIM)

**National Institute of Building Sciences (2012**) characterized BIM as an advanced portrayal of the physical and practical attributes of an office. Accordingly, it fills in as a mutual learning asset for data about an office shaping a solid reason for choices amid its life cycle from initiation onwards. **Arundhati Ghosh (2015)** examined that the normal incentive from BIM for the five partner bunches relies upon the esteem BIM adds to their business procedure and their extent of work in the undertaking. There are covering choice elements for which the partner bunches are capable. Basic leadership is in this manner communitarian and must consider the necessities of the partners who are utilizing BIM. The BIM-viewpoints (for example geometrical data, clear data and work processes) **are esteemed correspondingly b**y partners inside their gatherings (for example Proprietor, An/E, CM and Modeler), yet may vary when they are considered between the gatherings (for example Proprietor versus Modeler, CM versus, An/E**,** CM versus Modeler). **William Michael Duke (2013)** examined that BIM benefits usually result in decreased cost, decreased time, increased quality, or a combination of the three. The main benefit BIM offers any project is increased collaboration. By using BIM, project teams can more effectively communicate with one another and create innovative and optimized solutions. While creativity is encouraged in construction, BIM also offers increased safety on the project site. Site conditions can be monitored and future safety hazards identified to ensure the safety of workers and future occupants alike. Upon project completion, BIM can then be used for managing the building during its useful life cycle. BIM adds great benefit to the lifetime management of the facility. By possessing the record model created during construction, the owner has a real-time as-built representation of the facility at their fingertips. **Saeed KIA (2013)** made a review of BIM software. There are various programming accessible that have the ability to change over 2D structure information into a 3D model. BIM programming does not plan investigation programming and is not proposed to assess the structure uprightness of the structure yet rather are planned to examine potential blunders or oversights and clashes inside the different plan components. The industries recognized software's are as following: Revit by Autodesk, Bentley Systems and Graphic soft. **McGraw-Hill** (**2013**) in the National BIM Standard – United States decided that Building Data Model Standard Project Committee has the accompanying definition: Building Information Modeling (BIM) is a computerized portrayal of physical and practical qualities of an office. A BIM is a common learning asset for data about an office shapinga solid basis for choices amid its life-cycle; characterized as existing from most punctual origination to demolition. Conventional structure configuration was to a great extent dependent upon two-dimensional specialized illustrations (plans, heights, ssegments, and so on.). Building data modeling broadens this past 3D, increasing the three essential spatial measurements (width, tallness, and profundity) with time as the fourth measurement (4D) and cost as the fifth measurement 5D). BIM in this way covers something beyond geometry. It likewise covers spatial connections, light examination, geographic data, and amounts and properties of structure components (for instance, manufacturers' details).

### 3.3 BIM and Risk

**Hammad, Rishi, and Yahaya (2012)** conducted research about relieving development venture chance utilizing Building Information Modeling (BIM).

Relieving hazard in development ventures has been considered as a significant endeavor so as to accomplish a task's target regarding time, cost, quality, wellbeing, and supportability. The paper has recognized some inner components that may cause a hazard in development venture; these may incorporate flawed structured, misty detail and ill-advised documentation of changes in the illustration. At long last, BIM has been distinguished as sophisticated stage that will help in diminishing danger in the development venture, especially in the end of the regular blunders in the structure the board.**(Rosenburg, 2007)** considered that the incorporated idea of BIM obscures the dimension of obligation so much that hazard and risk will probably be improved. Consider the situation where the proprietor of the structure documents suits over an apparent plan mistake. The modeler, engineers and different benefactors of the BIM procedure look to one another with an end goal to endeavor to figure out who obligation regarding the issue had raised. On the off chance that contradiction results, the lead proficient won't just be dependable as an issue of law to the petitioner yet may experience issues demonstrating an issue with others, for example, the designers.

## 4. Research Methodology

BIM (Building Information Modeling) is quickly becoming the standard amongst major countries. In fact, many now have BIM standards mandating that certain BIM levels are achieved in projects. The reason of this paper is to explain how to deal with risks facing construction projects and to expand a clear understanding of the returned benefits and constraints of using BIM in the construction industry. The methodology used for this research approach depends on a detailed literature review; a field survey on the risks and problems facing construction projects and the building information modeling in the Egyptian construction industry. As it is intended to use the questionnaire answers of a group of experienced engineers using the technology or have good knowledge about it and then followed by statistical analysis of the collected responses to the questionnaire. Also, the research depends on a created 4D and 5D model to a selected four case studies to preview some of the risks and problems and to explain the effect of using BIM in construction projects and comparing between using this technology or using the conventional method in construction projects.

## 5. Questionnaire Survey

Based on the view of the past inquiries and with reference to the examination of the insight about the diverse parts of development dangers and Building Information Modeling (BIM) innovation, a poll was created. The planned survey evaded any perplexing or rehashed questions and was organized as shut finished inquiries, where respondents needed to choose an answer from a progression of decisions for each inquiry. The distinctively created questions intended to fulfill the goals of the examination, by gathering all the required information and data to help the exploration of results. Before distributing the questionnaires, some interviews with engineers in different companies were conducted. The purpose of these interviews was to verify the completeness of the questionnaire in capturing the target of the paper.

The developed questionnaire is divided into three parts as follows:

**Part 1: questions about Risks such as:**

a- How you can deal with risks in construction projects?

b- Management administration or team to manage the problems and risks which face the projects.

c- When the risks are addressed?
d- Risk record for previous projects.

**Part 2: questions for engineers who implemented BIM in their construction projects such as:**

a- Implementation of BIM in construction projects.
b- BIM tools (Revit Architecture, Revit Structure, Revit MEP, Site planning). c- The most important benefit of using BIM.
d- Effect of BIM in decreasing risk during the project life cycle.
e- BIM and clash detection during the design phase.
f- BIM and delay mitigation.
g- BIM and cost estimation.

**Part 3: questions for engineers who don't use BIM asking them about their opinion regarding the benefits of implementing BIM technology in construction projects.**

**Survey Population Selection and Sample Size Calculation**

The sample is of a limited extent that goes about as a representation of the absolute focused on the population. The focus of this research is to examine how incorporated organizations' classes (1&2) as indicated by the Egyptian Federation of Construction and Building Contractors consider the use of BIM.

<u>Equation 1 – Cochran Formula</u>

$$N = (P * Q * Z^2) / C^2$$

Where: N = the first estimate of sample size, Z = 1.96 for 95% confidence level, P = 0.5% selecting a choice, C = 0.09 margin of error 9%, Q = 1-p

<u>Equation 2 – Solv in's Formula</u>

$$N0 = N / ((1+N(C^2))$$

Where: N = Total population

- According to The Egyptian Federation of Construction and Building Contractors which located in Nasr City in Cairo. The number of building contractor category 1 is 218 contractor companies, the number of building contractor category 2 is 187 contractor companies and the number of building contractor category 3 is 286 contractor companies.

A survey is developed for category 1 and category 2 from the building contractors so,
N = 218 + 187 = 405 contractor companies.
NO = 405 / ((1+405(0.09) ^2)) = 94.615 contractor companies.
Take sample size of 95 contractor companies.
100 companies are selected as a sample.

There were 140 copies of questionnaires distributed to the potential respondents in the organizations within the construction industry. Different ways used to distribute questionnaire: (Delivered for number of companies directly through a meeting with their engineers-Delivered to different companies by email. Questionnaire was created in a survey website to be easier to reach different companies-a copy of the survey and its link was put in public media outlets like groups for BIM engineers at different pages to collect random responses). Of the 140 questionnaires, 100 copies (70 percent) returned and there were 86 copies (86 percent) from the contractor and 14 copies (14 percent) from consultants. The collected questionnaires were reviewed and analyzed by the SPSS (Statistical Package for Social Sciences) program.
Cronbach's α coefficient. This technique is utilized to gauge the unwavering quality of the poll between each segment and the mean of the considerable number of

classifications of the survey. The ordinary scope of Cronbach's α coefficient is somewhere in the range of 0.0 and +1.0, and the higher qualities mirror a higher level of interior consistency. The general dependability of all gatherings approaches 0.897. This range is viewed as high, and more noteworthy than 0.70. Along these lines, the unwavering quality of the survey is guaranteed.

**Table1. Reliability coefficient**

**Reliability Statistics**

| Cronbach's Alpha | N of Items |
|---|---|
| .897 | 100 |

## 5.2 RESULTS AND DATA ANALYSIS

### 5.2.1 Risk in Construction Projects

The following table presents the opinion about Risks based on the survey results (part1).

**Table2. Conclusion from the risks part1 from the survey**

| Risk | Majority Percentage |
|---|---|
| Management team to manage risks | 47% |
| Risks addressed during project periodically | 67% |
| Risks addressed only when problems occur | 32% |
| Deal with risk by an official team | 49% |
| Deal with risk by a specific mechanism | 44% |
| Deal with risk by call outside part | 6% |
| Risk record | 69% |
| Specific risk software | 8% |



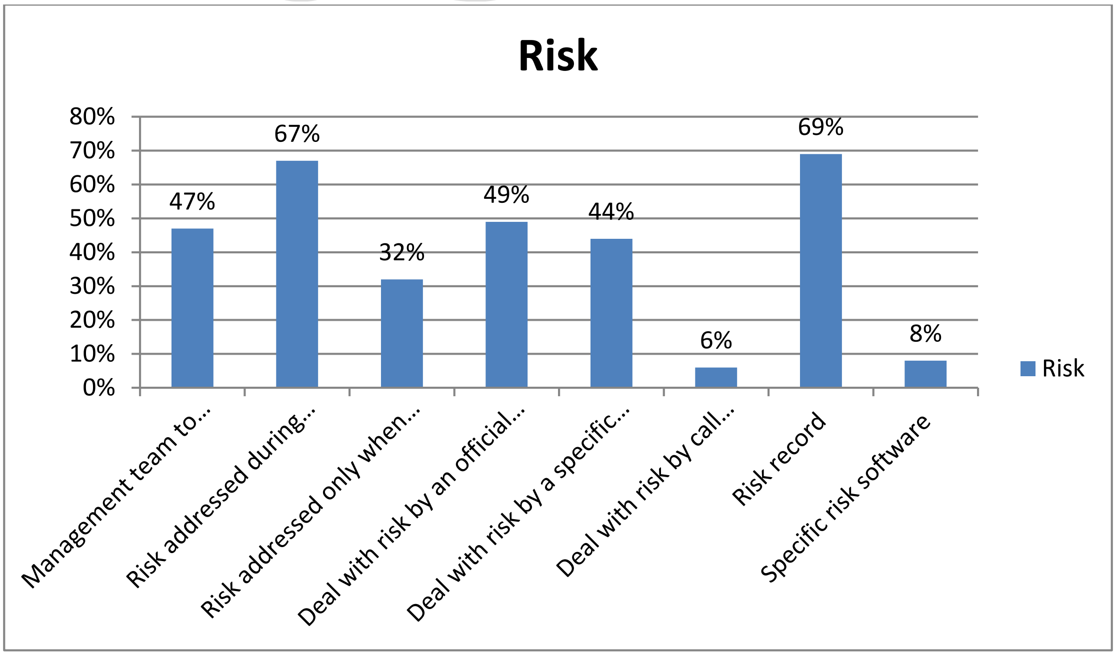



**Figure1. Conclusion of the survey about risk (part1)**

### 5.2.2 BIM in Construction Projects

The following table presents the opinion about BIM implementation based on the survey results (part2 and part3).

**Table3. Conclusion from BIM part2 and part3 from the survey**

| BIM Implementation | Major Percentage |
|---|---|
| BIM user | 23% |
| Recommended BIM in large projects (more than 100 million EG.P) | 90% |
| Recommended BIM in small projects (less than 100 million EG.P) | 10% |
| Easy to learn and use BIM software | 45% |
| Cost of training BIM is high | 69% |
| Execution plan for BIM technology | 80% |
| Constraints in using BIM | 60% |
| Companies will left behind without BIM | 13% |
| Long time to spread BIM in EGYPT | 75% |
| **BIM benefits** | **Major percentage** |
| Decrease the percentage of risk in the project | 87% |
| Extract more accurate data during the project | 77% |
| Increase safety | 84% |
| Save time | 92% |
| Cost control | 90% |
| Fast and more accurate quantity survey | 98% |
| Reduce the project's overall cost | 90% |
| Delay mitigation | 68% |
| Facility management | 82% |
| Preparation of tender and contract documents | 53% |
| Analyzed proposed outcomes | 56% |
| Valuing completed works and arranged payments | 53% |
| Clash detection during design phase | 78% |



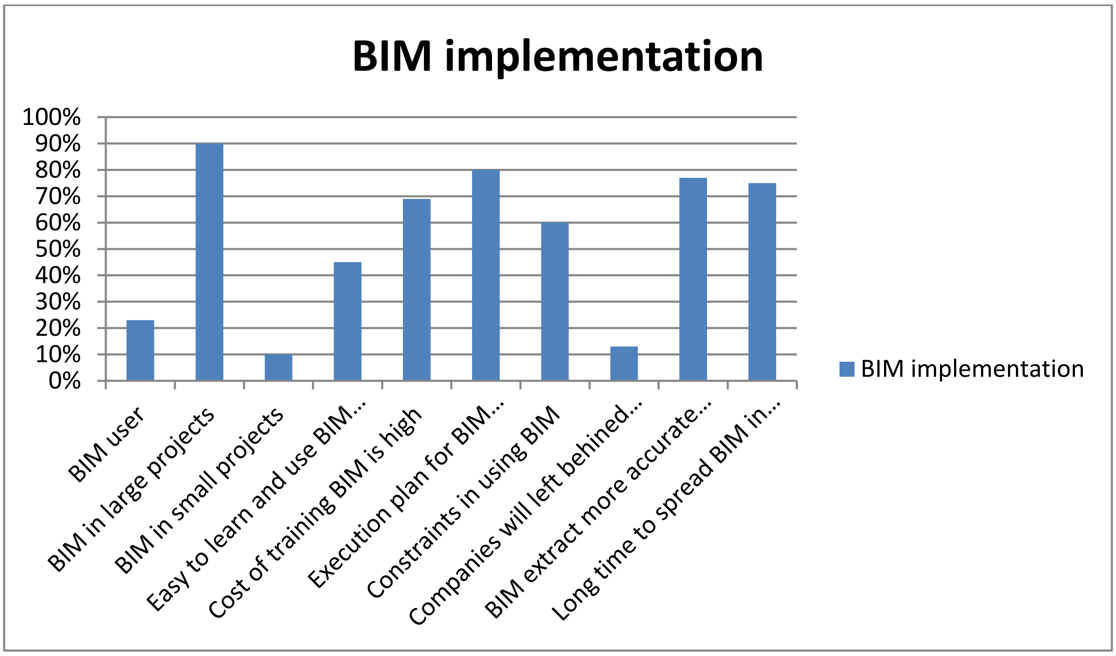



**Figure2. Implementation BIM**

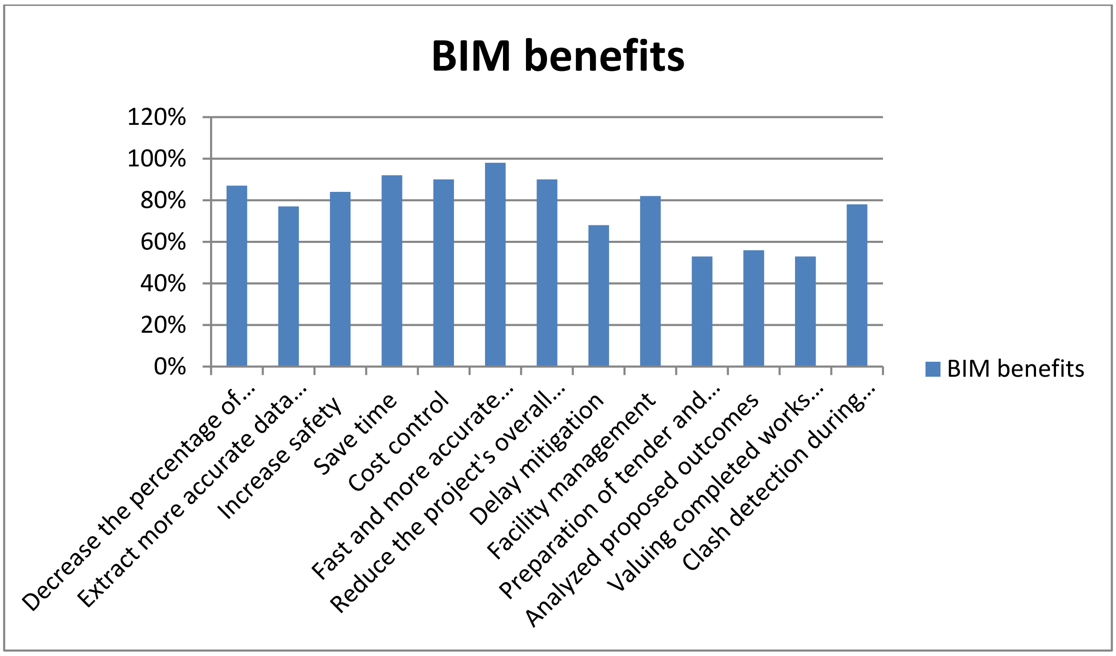



**Figure3. BIM benefits**



## 6. Model Verification

This paper included four case studies with one of them explained in details.
The following case study exposes the difference between executed the project with the traditional method and with implemented BIM technology on it and showed the effect of applying BIM to mitigating risk in construction projects.

**Case study Compound_Palm Hills Katameya (PK2) in New Cairo.**

A case study is presented to demonstrate the relationship between the model and the proposed methodology of handling risks in a proactive manner. A residential compound located in Egypt is considered for this purpose. The project has a total land area of 434,000 square meters and includes 441 units. Zone 1 cost approximately = 420,000,000 EGP.

**2D model from AutoCAD (Traditional way)**

In the traditional way, the plans showed by AutoCAD programs it is a 2-dimensional model. Not all stakeholders can understand it.

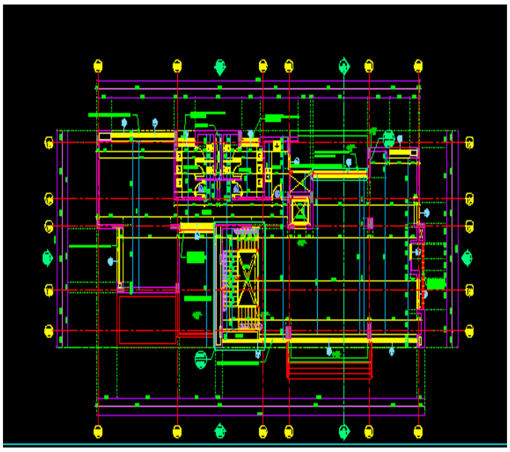


**Fig.4. 2D model architecture of facility building**

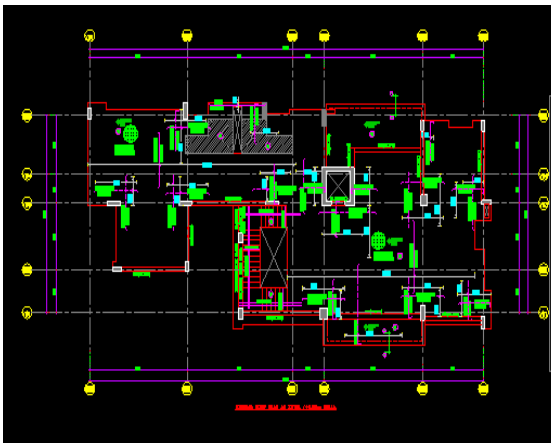


**Fig.5.2D model structure of facility building**

## 3D model from Revit (BIM)

In BIM technology the plans showed by Revit program in 3-D models. It's very clear and easy to be understood from all the stakeholders.

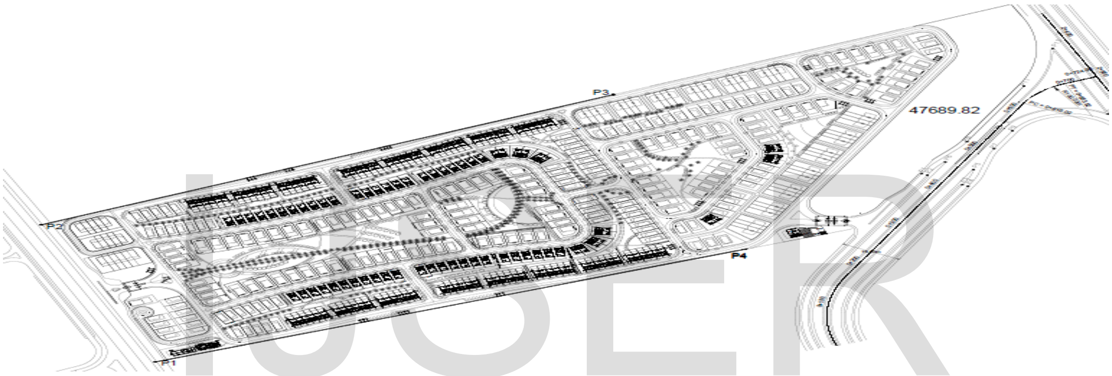





**Fig.6.PK2 3D model from Revit**

From 3D model extract details for the construction component such as roof slab and columns of the facility building in the compound shown in figures below.

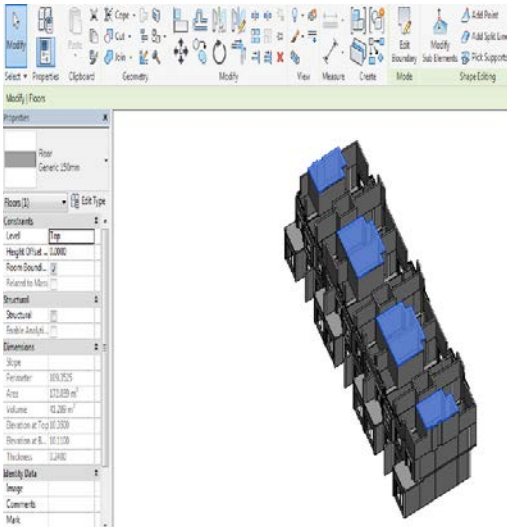


**Fig.7.3D model Facility building's Roof slab**

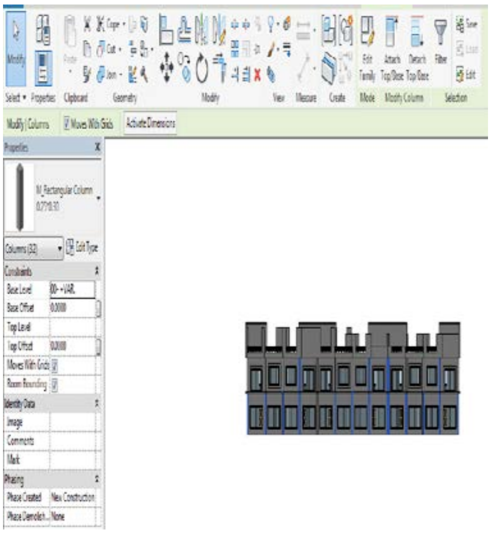


**Fig.8. 3D model Facility building's columns**

From the received 3D model, the contractor starts to extract some needed data about each element of the project. For example, column data will be available in the model and can be extracted quickly. The column exported data from the BIM model can be material, volume, and unit of measure, so these data are collected in a table extracted from the BIM model.

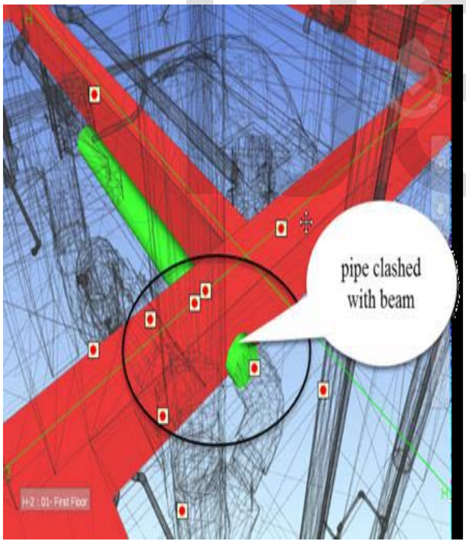
## Clash Zone

### The 3D model most benefit is Clash Detection such as:

1) Eliminate defects and conflicts during design and modeling.
2) Eliminate defects and conflicts during the overlap between systems of the project like (civil, architect, electrical, mechanical, etc.).
3) Reduce cost and time consumed in correcting the defects appeared in the construction phase and instead correct it early in the design phase.
4) Increase the overall productivity of the project.
5) Have a trusted one model for the project to transfer it to the parties of the project, (Bloomberg, (2012)).
6) Fire Protection Systems vs. Electronics Systems, (Bloomberg, (2012), Campbell, D.A., (2007).
7) Different sorts of conflict may include the booking of contractual workers, the conveyance of hardware and materials, and the general course of events clashes. These are frequently alluded to as 'Work process or 4D conflicts'.

### Clash zone and Clash detection:

According to the poor communications between the stakeholders, there are a lot of clashes happened between their works like the clash shown in figure 9 and figure 10 showed how to resolve it.



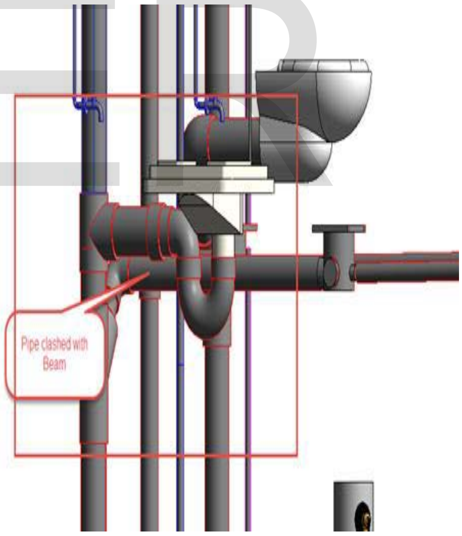




**Fig.9.Clash bet. Pipe (green) & Str. beam(red)** **Fig.10.Resolving clash bet. pipe and beam by Changing slope of pipe**

### Clash detection steps:

1-Import 3D Revit files into Naviswork.
2- Press the Clash Detective tool to test conflict performing in Naviswork programming
3- Snap-on the 'Select' tab that is situated inside a conflict analyst device in Naviswork programming as observed in fig.11.
4- -Autodesk Naviswork consequently gives status to each conflict for sometimes later. So, after that the Clash Detective apparatus that continues refreshing the status of the conflicts after they are distinguished and is recorded inside the Results tab as observed in fig.12.

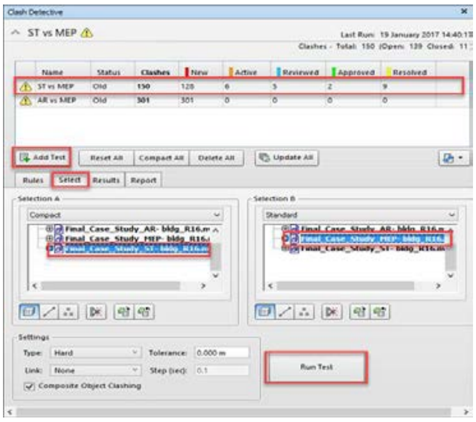



**Fig.11. Clash report generated by Naviswork**

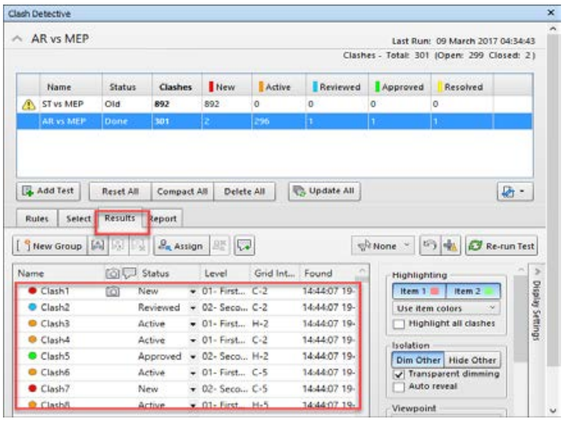



**Fig.12.Clash Detective showing the results**

## 2D Time schedule with primavera (traditional way)

The time schedule of the project made with primavera software which shows the start and end date of every activity in the project.

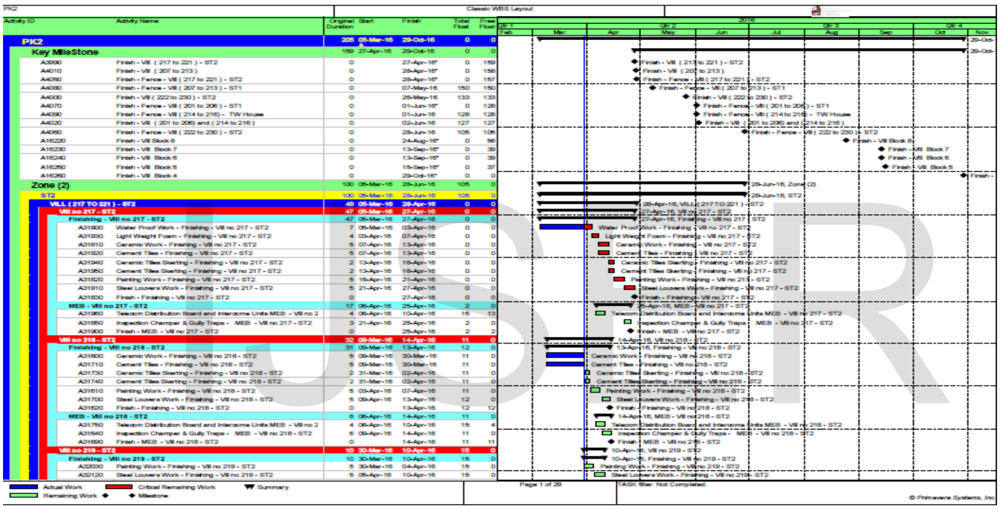


**Fig.13. 2D Time schedule from Primavera (traditional method)**

## 4D BIM model with Navies work program (Time schedule)

The 4D model is the combination of the 3D model and the Time in the project.
Achieved benefits from combining of 3D model and time in PK2 Project:

1- Coordinated timelines of construction operation between all systems.

2- What-If-Scenarios/hosting of alternatives.

3- Availability of materials of each activity before the start date.

Developing a time schedule model with the Navies work program by connecting with the Revit model that model is more accurate and solves a lot of problems.

The following images show the steps of some weeks of the project in details and showing the overlap of the works that happen at the same time in the different zone in the project. Daily activities taking place during the project is reflected as shown below with previews of works done in the project.

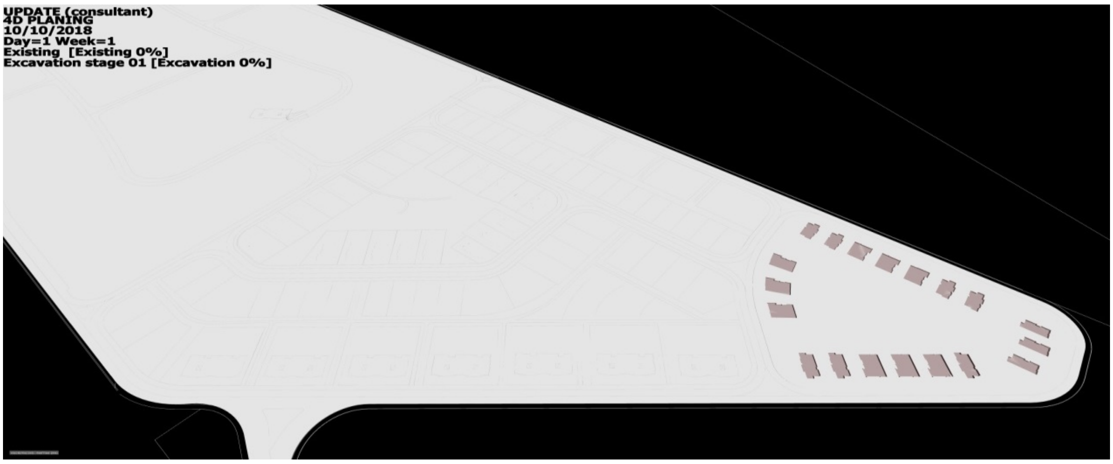



**Fig.14. Day 1 in week 1 → just starts excavation.**
**→ No construction work begin**

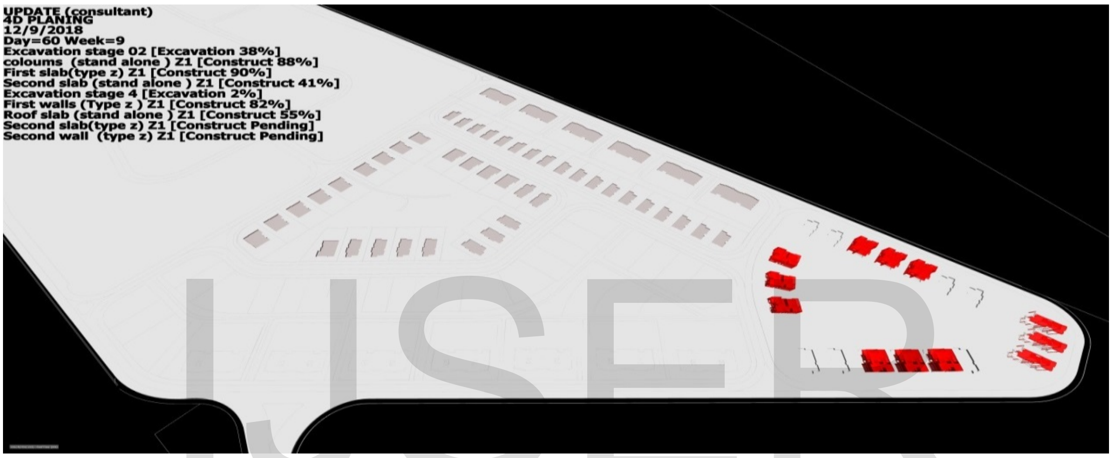





**Fig.15. Day 60 in week 9 → excavation (38% stage 2 & 2% stage 4).**
**→construction(88% Columns standalone Z1 ).**
**→construction (90% first slab type z zone 1)&(41% second slab)**
**→construction (82% first wall type z zone 1)&(55% roof slab)**

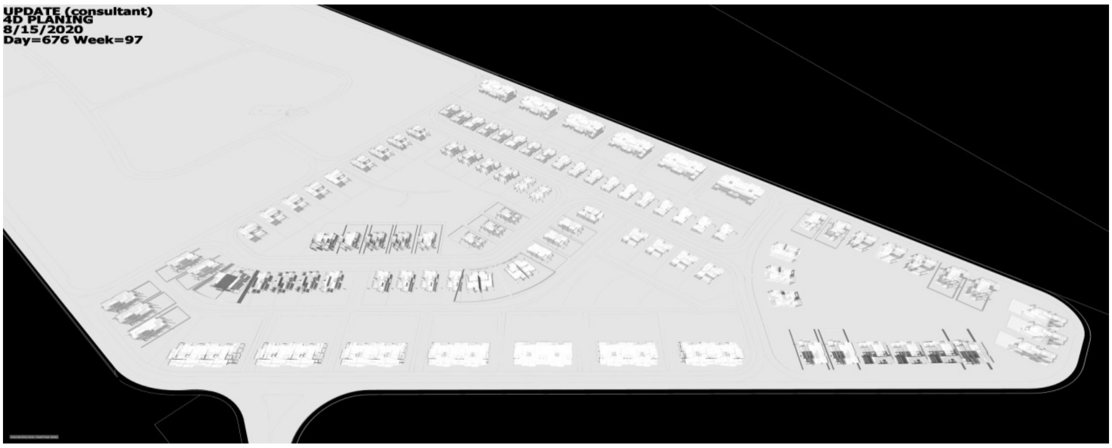



**Fig.16. Day 676 in week 97→construction (100%)**

The BIM 4-dimensional model shows every day in the project life cycle and the percentage done in every activity every day.

The 4D model shows that the construction of all units without finishing took 97 weeks approximately 2 years and the finishing for all types took 64 weeks so the total time for this project is 161 week which equals approximately 3 year and 4 months.

### Bill of Quantities (BOQ)

The traditional method calculated of the Bill of Quantities (BOQ) shown in Table 4 and defining alternatives on the application and exported quantities from Revit files as shown in Table 5.

**Table.4.Case study (1) BOQ by traditional method**

| | | | | | |
|---|---|---|---|---|---|
| | PROJECT : KATAMIA EXTENSION - PK2 | | | | |
| | BUILDING : FACILITY BUILDING | | | | |
| ITEM No | DESCRIPTION | UNIT | QTY. | RATE | AMOUNT |
| 1 | DIVISION 4 - MASONRY WORK | | | | |
| | Notes: | | | | |
| | Prices of block works shall include supply of hollow clay block or solid cement blocks from good and approved factory in perfect dimension and build it in good manner , cement sand mortar ( 1:3 ), concrete fillet (B250) between columns & block walls (15 cm wide ), compressive strength 35kg/cm2, works shall includes all materials, testing, scaffolds, placing of approval blocks, work man ship, all ducts, sleeves, opening areas, fiber board , protection concrete (B-200) around sleeves and pipes (for electrical, sanitary & mechanical), tools and anywhere else , needed, all according to drawings , specifications, conditions and directed instructions by the Engineer or his representative. | | | | |
| 1.1 | Supply and build hollow clay block 25cm thickness with dimension 25x12x10 cm | | | | |
| 1.1.1 | For Basment floor | M3 | 32 | | |
| 1.1.2 | For Ground floor | M3 | 46 | | |
| 1.1.3 | For First Floor | M3 | 38 | | |
| 1.1.4 | For Second Floor | M3 | 34 | | |
| 1.1.5 | For Prthouse & roof | M3 | 24 | | |

**Table.5.Case study (1) BOQ by BIM**

<Structural Framing Schedule>

| A | B | C | D |
|---|---|---|---|
| Type | Count | Length | Volume |
| 12X60 | | | |
| 12X60 | 1 | 1670 | 0.12 m³ |
| 12X60: 1 | 1 | | 0.12 m³ |
| 12X70 | | | |
| 12X70 | 1 | 1235 | 0.10 m³ |
| 12X70 | 1 | 1235 | 0.10 m³ |
| 12X70: 2 | 2 | | 0.21 m³ |
| 12X80 | | | |
| 12X80 | 1 | 1780 | 0.17 m³ |
| 12X80: 1 | 1 | | 0.17 m³ |
| 20X92 | | | |
| 20X92 | 1 | 4425 | 0.81 m³ |
| 20X92: 1 | 1 | | 0.81 m³ |
| 24X60 | | | |
| 24X60 | 1 | 450 | |
| 24X60: 1 | 1 | | 0.00 m³ |
| 25X60 | | | |
| 25X60 | 1 | 675 | 0.10 m³ |
| 25X60: 1 | 1 | | 0.10 m³ |
| 25X70 | | | |
| 25X70 | 1 | 3775 | 0.66 m³ |
| 25X70 | 1 | 3778 | 0.66 m³ |
| 25X70 | 1 | 3445 | 0.60 m³ |
| 25X70 | 1 | 3445 | 0.60 m³ |
| 25X70 | 1 | 4000 | 0.65 m³ |
| 25X70 | 1 | 4000 | 0.65 m³ |



## Activities classifications

### Duration Index (DI) = Actual Duration/Original Planned Duration

Duration Index (DI) for the project = Actual Duration/Original Planned Duration = 1326/1237= 1.07

**Cost Impact % = (New cost-Previous cost)/Previous cost**

**New cost= (**420,000,000+2,562,000) =422,562,000 EG.P

**Cost Impact %**=( (422,562,000-420,000,000)/420,000,000))*100= 0.61%

According to the contract: The amount of liquidated damages for delay in completion of sections is calculated as the following:

1- (EGP 42,000 per day shall be applied for each day of delay up to ten days).

2- (EGP 63,000 per day shall be applied for each day of delay after ten days up to 20 days).

3- (EGP 84,000 per day shall be applied for each day of delay after 20 days).

4- Liquidated damages not to exceed 10% of the contract price.

## Risk analysis summary report

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project Information** | | | | | | | |
| Project Name | Palm Hills Katameya | Baseline start date | 9-June-13 | Baseline finish date | | 29-June-16 | |
| Project Budget | 420,000,000 EG.P | | | Completion% | | 100 | |
| **Schedule Update Results** | | | | | | | |
| Update Cut-Off Date | 9-Jun-13 | Project Finish Date | 29-Jun-16 | Total Float | | -38 | |
| **Report Summary** | | | | | | | |
| Number of delayed activities | 160 | Project finish date | | 6 Aug.-16 | | | |
| | | Expected delay(days) | | 38 | | | |
| | | Cost Impact | | 2,562,000EG.P | | | |
| | | Cost Impact% | | 0.61% | | | |
| **Report Details** | | | | | | | |
| Activity Name | Cause of Delay | Delay(Days) | | Cost Impact | | BIM | % |
| Clash | Clash bet. Sanitary electrical | -6 | | **252,000**(6*42,000) | | 3D | 19 |
| Clash | Clash bet. Structure MEP | -4 | | **168,000**(4*42,000) | | 3D | 12 |
| Shop drawings | Lack in shop drawings | -5 | | **315,000**(5*63,000) | | 3D | 15 |
| Columns late | Wrong in calculate | -10 | -5 BIM | **735,000**(5*63,000 5*84,000)+ | **315,000**(5*63,000) | 4D | 15 |
| Slabs late | Due to columns late | | | | | | |
| FRP | Change order from traditional to FRP | -5 | | **420,000**(5*84,000) | | 3D &5D | 15 |
| Finishing | Change interfaces from traditional to stone | -4 | | **336,000**(4*84,000) | | 3D &5D | 12 |

| | | | | | |
|---|---|---|---|---|---|
| Rework due to errors during construction | Order to execute 2nd floor column in the same time of demolition under slab | -4 | **336,000**(4*84,000) | 4D | 12 |
| **Total without BIM** | | **-38** | **2,562,000** | | |
| **Total with BIM** | | **-5** | **210,000**(5*42,000) | | |

**Table6. Palm Hills PK2 Risk summary report**

The previous table discussed in details of the project's risks and how to control the cost and the time with implemented BIM and from the table extracted relation between the effect of 3D, 4D and 5D Models as shown in figure 17.

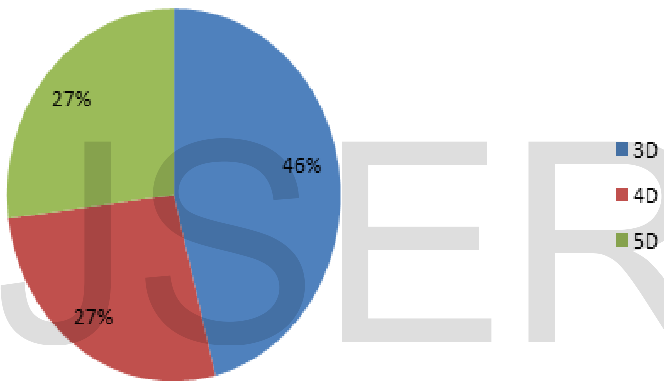





**Fig.17.Comparison between 3D&4D&5D model**

## The difference between the traditional method and applied BIM technology achieved from the result of Implemented BIM in the case study

| | **Traditional method** | **BIM** |
|---|---|---|
| **Programs** | AutoCAD 2D<br>Primavera | Revit<br>Naviswork |
| **Data** | Not accurate | Extract more accurate data |
| **Drawings** | Traditional drawings | Enhancing the coordination and integration between the drawings |
| **Cost Estimate** | Take long time | More accurate |
| **Stakeholders** | Difficult to connect | Enhancing the collaboration between the stakeholders |

| | | |
|---|---|---|
| **BOQ** | Take long time and not accurate | Fast and more accurate |
| **Clashes** | Not detected | detected |
| **Cost overrun** | More cost | Save cost |
| **Time overrun** | more time | Save time |

**Table 7.Comparison between traditional method and BIM**

# 7. RESULTS AND DISCUSSIONS.

## 7.1 The Questionnaire results Discussions

The questionnaire consisted of 3 parts (questions about Risks-questions for engineers used BIM-questions for engineers didn't use BIM) and the most important result from it is as follow:

1- Approximately 50% of the total respondents did not have a team to manage risks that faces the projects in their companies.

2- Approximately 67% of the total respondents dealt with problems which face the project during the project periodically in their companies.

3- Approximately 50% of the total respondents according to the official (individual-team-department) about dealing with the risks and 44% of the total respondents have a specific mechanism of the company as part of its risk management policy.

4- Approximately 77% of the total respondents did not use BIM in their companies.

5- Approximately 9% of the total respondents said that most important benefit of using BIM in their projects is cost-saving and quality control, 8% of the total respondents said that most important benefit of using BIM in their projects is quality control, saving time, saving money, and achieving safety(all of them), 6% of the total respondents said that most important benefit of using BIM in their projects is quality control.

From analyzing the data, the following discussion is obtained on checking whether the results are expected or unexpected, comparing these results to the previous work.

### 7.1.1 Risk part

Comparison between the percentages of how to deal with risk now and at the previous studies is listed in Table 8.

| Risk | Previous studies | paper Majority Percentage |
|---|---|---|
| Management team to manage risks | Shahid (2015) 68% | 47% |
| Risks addressed during project | Shahid (2015) 44% | 67% |

| | | |
|---|---|---|
| periodically | | |
| Risks addressed only when problems occur | Shahid (2015) 50% | 32% |
| Deal with risk by an official team | Nerija (2012) 53% | 49% |
| Deal with risk by a specific mechanism | Nerija (2012) 28% | 44% |
| Deal with risk by call outside part | Frank (2013) 9% | 6% |
| Risk record | Nerija (2012) 92% | 69% |
| Specific risk software | Frank (2013)14% | 8% |

**Table8. Comparison between project risks now and at the previous studies**

## 7.1.2 BIM part

Comparison between the percentages of BIM implementation now and at the previous studies is listed in table 9.

**Table9. Comparison between the percentages of BIM implementation now and at the previous studies**

| BIM Implementation | Previous studies | Major Percentage |
|---|---|---|
| BIM user | Peter and Tomas (2017) 24.7% | 23% |
| Recommended BIM in large projects (more than 100 million EG.P) | Rana (2016) 96% | 90% |
| Recommended BIM in small projects (less than 100 million EG.P) | Rana (2016) 53% | 10% |
| Easy to learn and use BIM software | Rana (2016) 62% | 45% |
| Cost of training BIM is high | Rana (2016) 51% | 69% |
| Execution plan for BIM technology | Rana (2016) 80% | 80% |
| Constraints in using BIM | Rana (2016) 41% | 60% |
| Companies will left behind without BIM | Azhar (2011) 28% | 13% |
| Long time to spread BIM in Egypt | Rana (2016) 59% | 75% |
| **BIM benefits** | **Previous studies** | **Major percentage** |
| Decrease the percentage of risk in the project | Rana (2016) 84% | 87% |
| Extract more accurate data during the project | Rana (2016) 95% | 77% |
| Increase safety | Azhar (2011) 80% | 84% |
| Save time | Rana (2016) 76% and Duke(2013) 63% Patrick (2009) 88% | 92% |
| Cost control | Rana (2016) 81% Peter and Tomas (2017) 89% | 90% |
| Fast and more accurate quantity survey | Rana (2016) 95% | 98% |
| Reduce the project's overall cost | Rana (2016) 74% and Duke(2013) 55% | 90% |
| Delay mitigation | Rana (2016) 64% and Goyal (2016) 75% | 68% |
| Facility management | Rana (2016) 69% | 82% |
| Preparation of tender and contract documents | Peter and Tomas (2017) 47.5% | 53% |
| Analyzed proposed outcomes | Peter and Tomas (2017) 75% | 56% |
| Valuing completed works and arranged payments | Peter and Tomas (2017) 75% | 53% |
| Clash detection during design phase | Rana (2016) 92% and Goyal (2016) 85% | 78% |

### 7.2 The Case Studies results Discussions

The results of the case studies discuss the difference between the traditional methods and applying Building Information modeling BIM on controlling the risks that face the construction projects in all stages part of the risks the BIM could deal with it and the others that couldn't as shown in the table below. The spread of BIM in Egypt is still limited and has many restrictions. Some big companies only implemented BIM such as EHAF, Palm Hills and ECG. In the 3-Dimensional model clash detection is the most benefit of used BIM that controlled cost and time. In the 4-Dimensional model the rework and any change in time schedule applied so easy to the model

1- Control the Poor communication and coordination

a- Clashes between Sanitary and electrical in facility building at twelve positions, everyone takes one day to defect.

b- Clash between Structure and MEP in facility building.

c- Lack of shop drawings.

2- Control the Delay due to design error.

A- Wrong in calculating column initial duration (lack three days in everyone).

B- Lack of slabs due to the columns lack.

3- Control changing material type.

A- Change order from the traditional to FRP.

B- Change interfaces from traditional to stone.

4- Control the Rework due to errors during construction.

a- Order to execute second-floor column at the same time the under a slab is demolition.

**Applying the questions of the questionnaire in Palm Hills katameya project**

| ID | Question | Answer |
|---|---|---|
| **1** | What is the category of your current organization? | Specialized contractor |
| **2** | What is the specialty of your current organization? | Civil |
| **3** | What is the level of your current occupation? | Top management |
| **4** | What are your total years of experience? | 15 |
| **5** | In which geographical locations does your company carry out work? | Egypt only |
| **6** | What is the scale of your current/previous project? | Mega project |
| **7** | In which sector does your company seek construction work? | Private |
| **8** | Is there a management or team to manage the problems and risks which faces the projects? | Yes |
| **9** | Are there any risk situations that have been addressed in the project stages? | Yes |
| **10** | When the risks that the project can face are addressed? | During the project periodically |
| **11** | In how many cases, after the baseline schedule/revised schedule preparation, a unexpected event occurs distributing your schedule and causing portion of it to be incorrect and a waiting a future revision? | Usually happens |
| **12** | In case of dealing with risk is used? | According to the official dealing with risks |
| **13** | Is there a risk record for previous projects in the company? | Yes |
| **14** | Do you think it will be a good solution to have a historical data base to help in prepare your schedule and then pass it to scheduling software? | Yes |
| **15** | Is there specific software used in the analysis and evaluation of problems? If yes, what is it? | No |
| **16** | Does your company currently use BIM, or is it intending to use BIM in the near future? | Yes |

| | | |
|---|---|---|
| **17** | Do you recommend using BIM in large projects (budget more than 100 million L.E)? | Yes |
| **18** | Do you recommend using BIM in small projects (budget less than 100 million L.E)? | Yes |
| **19** | Do you think it will take a long time for BIM to spread in Egypt? | Yes |
| **20** | Do you think your clients in your company pass an adequate knowledge about BIM? | No |
| **21** | Do you think it easy to learn and use BIM software? | No |
| **22** | Do you think we have enough possibilities to spread BIM in Egypt? | Yes |
| **23** | Do you think using the BIM model would increase safety in the projects? | Yes |
| **24** | Do you think BIM save time through the lifecycle of the project? | Yes |
| **25** | Do you think BIM help in cost control through the project lifecycle? | Yes |
| **26** | Do you think BIM help in fast and more accurate quantity surveying? | Yes |
| **27** | Do you think using BIM will reduce the project's overall cost? | Yes |
| **28** | Do you think BIM decrease the percentage of risk in the project? | Yes |
| **29** | Do you think BIM help in delay mitigation for the project? | Yes ( 4D model) |
| **30** | Do you consider the implementation costs associated with BIM (e.g. Hardware , software and staff training) to outweigh the financial gains from BIM? | No |
| **31** | What is the most important benefit of using BIM in your projects? | Cost saving |
| **32** | Do you think With the successful adoption of BIM a new collaborative way of working and sharing of information is expected. From your opinion, will this be achieved? | Yes |
| **33** | Do you think BIM help in facility management for projects? | Yes |
| **34** | Is there any constraints in using BIM in projects? | Yes |
| **35** | Do you forecast companies will be left behind if they don't adopt BIM quickly? | Yes |
| **36** | In what way do you think the implementation of BIM will affect the following key tasks performed? | - |
| **36/1** | Preparation of tender and contract documents | Medium |
| **36/2** | Cost analysis and lifecycle costing | High |
| **36/3** | Identifying and developing responses to risks | High |
| **36/4** | Analyzing proposed outcomes | High |
| **36/5** | Valuing completed work and arranging payments | High |
| **37** | Do you hear about BIM 4D and 5D? | Yes |
| **38** | How many projects did you implement BIM | 2 |
| **39** | From which year your company implement BIM? | 2016 |

**Table10. Applied the questionnaire questions on a case study**

# 8. CONCLUSIONS

- According to the utilized benefits by the contractor and consultant in the presented case studies, BIM proves its useful role in construction management despite being used on a small scale in Egypt and with limited experience.

- From the owners' standpoint, applying BIM has proved its importance in achieving owner needs according to the construction market and in reducing errors and saving energy.

- It was clear from the case studies that any construction project faces many errors during the designing phase that may have an effect on the project time, cost and quality which could lead to inefficiency and disappointing results. However, the project. However, using some of the BIM features in project phases especially from the start of any project helps in avoiding these errors and leading to more efficient project.

- Based on the application of the 3D model, it is evident that it is effective to use a 3D model in all the project stages. In these case studies using the 3D model was very significant in solving the problems caused due to applying the traditional method and the focus on the clash zone which can be limited with using 3D model and build an effective connection with every section in the project( civil, architecture, mechanical, …etc.).

- Based on the application of the 4D model, it is evident that it is effective to use a 4D model in both the design and the construction phases. The simulation of the 4D model makes every day in the project very clear and accurate.

- Based on the application of the 5D model, it is evident that it is effective to use a 5D model in both the design and the construction phases and also after project delivery. It is also proved that some of the BIM benefits in the first case study will positively affect project's overall cost and time.

- It is concluded from the case studied cases that BIM is an integrated process that includes all implementation steps from the start to the delivery of any project. It is also useful in establishing a controlled system that provides follow-up on all steps of the project and help in achieving the owner's goals.

- After applying BIM in the four projects as case studies, it is evident that the large and complex projects such as (large compounds- hospitals) are more affected than small ones such as (mini compounds) as shown in figure 18.

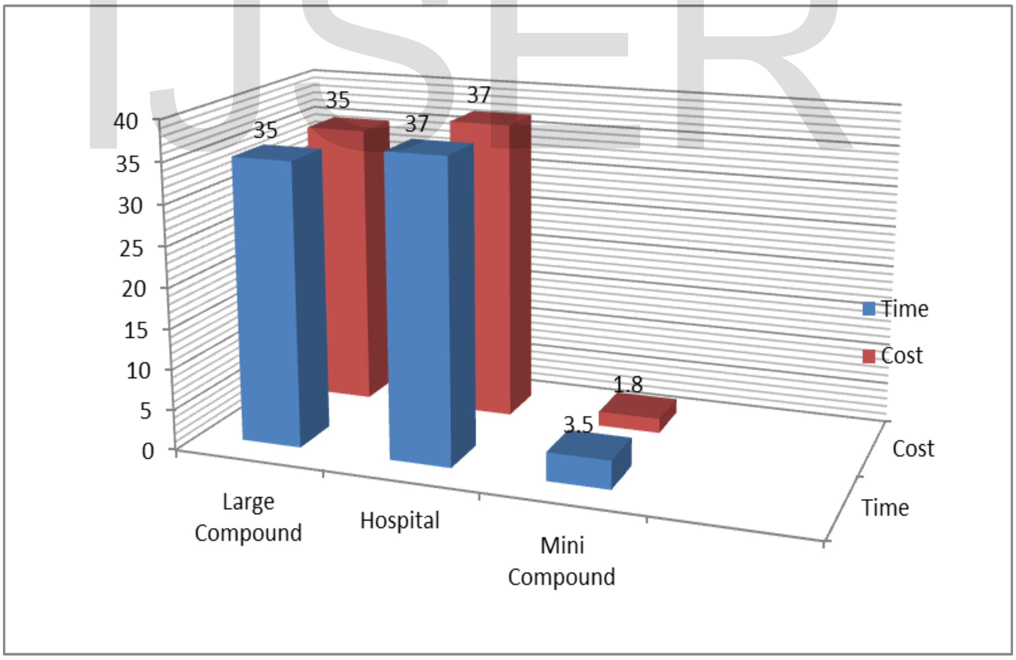



**Fig.18. the Percentage of applying BIM technology on different construction projects**

## Compliance with ethical standards

Conflict of interest on behalf of all authors, the corresponding author states that there is no conflict of interest.

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