

## Improvement estimating of project cost and design for a hospital project by using (3D&5D) simulation

Saja Abd Alrazak Khamees<sup>1</sup>, Hatim A. Rashid<sup>2</sup>, Reem Hatem Ahmed<sup>3</sup>

<sup>1</sup> Civil Engineering with Specialization in Construction Engineering & Management.

<sup>2</sup> Department of Civil Engineering, AL-Nahrain University

<sup>3</sup> Ministry of Higher Education and Scientific Research /Reconstruction and projects Directorate / Baghdad.Iraq

---

### ABSTRACT

Building Information Modeling (BIM) is an approach of managing and generating building data during its life cycle, dimensional (2D) drawings and later developed to (3D). The scope of BIM 3D, 4D, 5D, in this research 3D model to understand the process project special for beginner's engineers and give idea about all steps the project. 5D the cost component helps create estimates.

Estimator is consuming 70% of a cost estimator's time which required to a project. BIM can provide the capability to create takeoffs the materials, measurements and counts immediately from a model. Building Information models are also more and more used by Owners, Designers, Contractors and Engineer during the project lifecycle.

Planning and cost estimation used in design phases for huge project to detect errors before start in the work, through account the time required to set up a hospital and reduce the time needed to build the project through overlapping relationships and getting shorter period to build the project utilizing MS Project software and to detect estimated 5D costing of total construction project, BIM can support cost estimating, the period spent by the estimator on quantification differ by project, using BIM for take-off or cost estimating, the removal of manual take-offs saves cost, time and minimize potential for human error.

---

**Keywords:** Two dimensions (2D), visualization model (3D), Building Information Model (BIM), Cost Estimation (5D), Quantity Take-Offs (QTO).

---

### *Corresponding Author:*

Saja Abd Alrazak Khamees

Wasit Education Directorate - Department of School Buildings,

E-mail: [swwe8065@gmail.com](mailto:swwe8065@gmail.com)

---

### 1. Introduction

Building Information Modeling is very important for owner and engineer, to deliver the projects without mistake, BIM is consisting from three-dimensional (3D) model is automatically created from the two-dimensional (2D) and quantity take off for project (5D). BIM is entity used by many in the construction projects to make efficiency, savings and to enhance the accuracy and coordination of documentations.

The aim of the study is design virtual prototype and cost estimation used BIM technology basic steps and principles of cost estimation based on elements, and in this study automate the elements of building, cost estimation process and make comparison between traditional method and use software. The model is drafting by AutoCAD and developing 3D visualization, Cost estimation by Revit Architecture.

Use Rivet in construction industry it is perfect solution to understand the process of project, ceiling for example what is and how effect to the remnant of buildings, it can be scheduled like ceiling. Building information model supports construction activities and specification management, estimators when preparing their cost without (BIM) and use takeoffs material (manual) that mean traditional method or through digitizing the drawings will increase potential for human error [1]

Construction industry is traditionally delayed in take on new technology and BIM will have great effects on how the work processes in the construction projects. BIM used to enhance productivity that needed to change work processes. BIM will support, collaborate and innovate connected with large changes in the construction industry [2].

Through BIM, proven benefits of using this computer-aided technology. this benefit allowing for a more coordinated to the documents in (2D&3D), it provides a real visualization of the design that it is help the owner to confirm if the final building would meet requirements, BIM is considered of information and data resource, would make the communication among projects much easier. Other benefits of BIM are quicker and dynamic processes, in life costs and best for customers [3].

Use 5D through building information model by engineers give best feedback about the cost of a projects, and give the designer best way to modify the project design to suitable the budget, 5D can provide to the designer better seeing the contractor's budget through building confidence and use software technology will save time and effort estimating the cost and the budget of the project by the preparation of an estimate without errors through at the touch of a button [4].

the connection of cost to a model is referred to as the fifth dimension (5D) of CAD. The vision is that quantities from model or prototype must be connected to (cost database), which then automatically will be generated cost calculations for all components of project, the model should be dynamic, that meaning when delete or add for elements in the model or the cost database, result from that the cost estimations will change directly, that are giving the managers the opportunity to control on cost developments during projects [5]. The time spent by estimator on account of quantity to project, may be 40-80% of the time required to create a cost estimate, is spent on quantification [6]. estimators will typically start with cost estimating by digitizing the drawings, which human errors will be insert and inaccuracies in the original drawings for project will be spread in such traditional process with the BIM model can be create imaginary estimates[7] . The new life cycle approach to projects, in order to BIM strong, require an extra integrated collaboration approach [8] . The application of BIM in projects has increased the quality and brought efficiency of construction projects such as Autodesk Revit, and Vico System. all capable of managing construction projects[9]. The best way for the project cost management professional to adopt the (5D) and become major players in BIM environment [10]. North America and the Scandinavian area are generally considered as a head in BIM implementation and development [11]. BIM, computer technologies allows GSA to more effectiveness to meet customers, designer, asset of management, and program needs [12] . cost estimation and how can be developed automatically from the 3D model and focused on the design stages of a construction projects that provide cost estimates matching with design of project develops [13] . BIM allows integrated staff to get good understanding that encourage requirements for staff, reduce cost and develop innovative of decisions [14] . BIM also is assign as an open standards depend on information warehouse for the lifecycle of project [15] .

### 1.2 invention in building information modeling

BIM is a powerful tool technology in construction projects. It provides project manager more accurate and stronger project information and data, many major innovations in BIM. Here are a few examples:

- 2D drawings display, from drawings are the established design and drafting format and used in all engineering and architectural industries
- 3D Design real visualizations allow users to see new project before implementation, also permit for 3D coordination to minimize, omissions and errors.
- 5D cost estimation automated quantity take-offs (QTO) and cost estimating, including the relationships between locations, quantities and costs and, as shown in Figure 1.

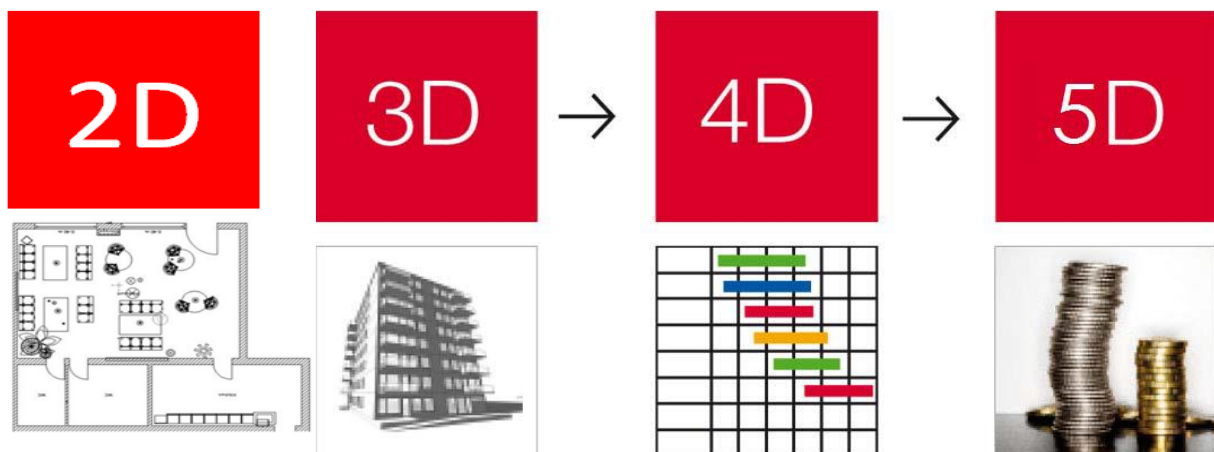


Figure 1. Innovations in BIM

## 2. Methodology and model development

### 2.1. General

The BIM used for this research Autodesk(Revit) because this technology provided for construction industry facilitate dealing with complex projects, which displays cost estimation and checking the life cycle analysis, with building information modeling (BIM) can be seen as a virtual processes include all system of a facilities for project include virtual model giving all team (engineers, owners and contractors) to cooperate more accurately rather than traditional method.

### 2.2. Conversion of AutoCAD data in to Revit 3D

To achieve the CAD plan or detail in Revit, follow these steps

- Go to **insert**.
- Import the file into the model.
- Under **Positioning**, select **auto - origin to origin**.
- Go to **visibility graphics overrides**.
- **Select open**

All times going to difficult features and ignores the basics. So, I am going to go through how to place your drawing into (Revit) and start working with this software.

### 2.3. Quantity take-offs and cost estimating

Building information model solution like (Revit Architecture) can understand by a computer as a building, designing the building is the responsibility of designer, but estimate the cost for project fall into the responsibility of estimator, the designer work doesn't provide to cost estimation, Through the inter of data for construction projects using the (Revit) software and completion of the design work of the construction project and identify the basic components of the project, for example (walls - doors - windows ....). Revit software calculates all the internal materials of the project at the click of a button and the result to obtain an estimate of the most accurate and without error as known, the evaluators may be subject to error in the case of the preparation of the speculative detection.

## 3. Result and discussions

### 3.1 Project collaboration with building information modeling

Utilizing building information modeling (BIM) can simplify construction project and facilitate the thinking of the stakeholders through the integration of information elements in one place, BIM is considered as right pathway a decision-making makes all partners are encouraged in work with this feature in making decisions and to reach the best decisions regarding the design and budget of the project.

Design decisions for designer able to optimize the design building at a stage less expensive to analyze, instead of the traditional method that should be minimized the need to produce changes later the design or during the construction process, even tiny changes can impact on both the cost of project and life-cycle cost of the building this illustrates in Figure 2.

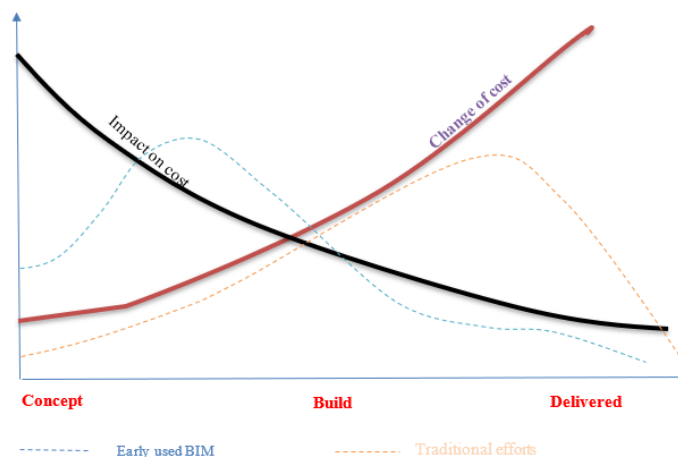


Figure 2. Life-cycle cost of the building with BIM

### 3.2 Creating 3D modeling in Revit architectural

to create of building levels are to be identified for each storey . These levels are given in the elevation then are created. Next move based on details in beams, columns, windows and doors, next step is creating the families and levels, is shown from Figure 3.

- Structure framing
- Foundations
- Doors and windows
- Roof
- Furniture



Figure 3. 3D model of final view for HHS Hospital

### 3.3 Creation 5D model and quantity takeoffs schedule

Creating the cost estimates, estimators is beginning by digitizing the design 2D, or shifting drawings into a cost estimating 5D. All of these ways increase the potential for human error, but within building information modeling (BIM), the takeoffs the materials and measurements can be created from model. Then the information is always coordinate with the design. When any change is made in the details of drawing or design for example, dimension of window is changed, the change automatically ripples to all documentation of project

The time spent by the estimator on quantity takeoffs materials (QTM) depend on type of project, but 40-70% of the time needed to generate cost estimate .by using building information model (BIM) for cost estimating, and minimize manual takeoffs, will save time, cost, and minimize the potential for human error, are shown in table 1. to table 8.

Table 1 Quantity takeoffs - column schedule

Column schedule				
Actual Cost (ID)	Item Description	Area(m <sup>2</sup> )	Height(m)	Simulated Cost (ID)
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
5150	Rectangular Column	0.186	3.2	3065.28
Grand total 263	Total cost for column			726012

Table 2. Quantity takeoffs structural framing schedule

Structural framing schedule						
Actual Cost (ID)	Item Description	Length(m)	Type	Volume(m <sup>3</sup> )	Simulated Cost (ID)	Reference Level
5150	Concrete- Beam	5.135	beam9	0.751	3867.65	08fourthfloor
5150	Concrete- Beam	5.427	beam9	0.794	4089.1	08fourthfloor
5150	Concrete- Beam	5.122	beam9	0.75	3862.5	08fourthfloor
5150	Concrete- Beam	5.734	beam9	0.839	4320.85	08fourthfloor
5150	Concrete- Beam	5.74	beam9	0.84	4326	08fourthfloor
5150	Concrete- Beam	5.734	beam9	0.839	4320.85	08fourthfloor
5150	Concrete- Beam	5.849	beam9	0.856	4408.4	08fourthfloor
5150	Concrete- Beam	5.734	beam9	0.839	4320.85	08fourthfloor
5150	Concrete- Beam	5.734	beam9	0.839	4320.85	08fourthfloor
5150	Concrete- Beam	4.75	beam9	0.695	3579.25	08fourthfloor
5150	Concrete- Beam	3.519	beam9	0.515	2652.25	08fourthfloor
5150	Concrete- Beam	2.45	beam9	0.359	1848.85	08fourthfloor
5150	Concrete- Beam	2.767	beam9	0.388	1998.2	08fourthfloor
5150	Concrete- Beam	3.519	beam9	0.515	2652.25	08fourthfloor
5150	Concrete- Beam	4.435	beam9	0.649	3342.35	04secondfloor
5150	Concrete- Beam	4.437	beam9	0.649	3342.35	04secondfloor
5150	Concrete- Beam	4.438	beam9	0.649	3342.35	04secondfloor
5150	Concrete- Beam	5.925	beam9	0.867	4465.05	06thirdfloor
Grand total	198	Total cost Structure Framing		1237351.51		

Table 3. Quantity takeoffs stair schedule

Stair schedule				
Item Description	Width (m)	Top Level	Base Level	Simulated Cost (ID)
Stair	1.52	0.01stilthieght	0.00stilt	32000
Stair	1.52	01groundceiling	00groundfloor	32000
Stair	1.52	03firstceiling	02firstfloor	32000
Stair	1.52	05secondceiling	04secondfloor	32000
Stair	1.52	07thirdceiling	06thirdfloor	32000
Stair	1.52	02firstfloor	00groundfloor	32000
Grand total	6	Total cost for stair		192000

Table 4. Quantity takeoffs wall schedule

Wall schedule							
Item Description	Area (m <sup>2</sup> )	Length(m)	Width(m)	Volume(m <sup>3</sup> )	Structural Material	Actual Cost (ID)	Simulated Cost (ID)
Basic Wall	9.808	3.823	0.233	2.289	brick	145	1422.139
Basic Wall	11.383	4.437	0.233	2.656	brick	145	1650.524
Basic Wall	11.377	4.435	0.233	2.655	brick	145	1649.732
Basic Wall	11.384	4.438	0.233	2.657	brick	145	1650.723
Basic Wall	14.714	5.736	0.233	3.434	brick	145	2133.598
Basic Wall	6.483	2.806	0.116	0.752	brick	77	499.219
Basic Wall	11.476	3.925	0.116	1.322	brick	77	883.64
Basic Wall	7.426	3.104	0.116	0.852	brick	77	571.787
Basic Wall	5.936	2.002	0.116	0.688	brick	77	457.058
Basic Wall	14.717	5.737	0.116	1.707	brick	77	1133.171
Basic Wall	6.833	2.242	0.116	0.793	brick	77	526.137
Basic Wall	4.968	2.313	0.116	0.576	brick	77	382.525
Basic Wall	22.729	7.457	0.116	2.636	brick	77	1750.161
Basic Wall	24.49	10.357	0.116	2.841	brick	77	1885.766
Basic Wall	7.685	3.189	0.116	0.882	brick	77	591.731
Basic Wall	4.522	1.701	0.116	0.524	brick	77	348.166

Wall schedule							
Item Description	Area (m <sup>2</sup> )	Length(m)	Width(m)	Volume(m <sup>3</sup> )	Structural Material	Actual Cost (ID)	Simulated Cost (ID)
Basic Wall	6.516	2.313	0.116	0.756	brick	77	501.751
Basic Wall	0.684	0.56	0.006	0.004	Tile, Porcelain, 4in	80	54.721
Grand total		230			Total cost for Wall	5818417	

Table 5. Quantity takeoffs floor schedule

Floor Schedule						
Item Description	Type	Level	Structural Material	Area(m <sup>2</sup> )	Actual Cost (ID)	Simulated Cost (ID)
Floor	floorbase1	0.00stilt	Analytical Floor Surface	832	750	624000
Floor	floorbaseground6"	00groundfloor	Analytical Floor Surface	742	750	556500
Floor	floorbaseground6"	02firstfloor	Analytical Floor Surface	745	750	558750
Floor	tile floor	00groundfloor	Tile, Mosaic, Gray	741	750	555750
Floor	tile floor	02firstfloor	Tile, Mosaic, Gray	744	750	558000
Floor	floorbaseground6"	04secondfloor	Analytical Floor Surface	735	750	551250
Floor	tile floor	04secondfloor	Tile, Mosaic, Gray	735	750	551250
Floor	floorbaseground6"	06thirdfloor	Analytical Floor Surface	735	750	551250
Floor	tile floor	06thirdfloor	Tile, Mosaic, Gray	735	750	551250
Floor	floorbaseground6"	08fourthfloor	Analytical Floor Surface	735	750	551250
Floor	tile floor	08fourthfloor	Tile, Mosaic, Gray	735	750	551250
Floor	floorbaseground6"	010fifthfloor	Analytical Floor Surface	43	750	32250
Grand total		12	Total cost for Floor		6152185	

Table 6. Quantity takeoffs furniture schedule

Furniture schedule				
Item Description	Type	Level	Count	Simulated Cost (ID)
Bed-Hospital	32" x 82"	02firstfloor	1	12500
Bed-Hospital	32" x 82"	02firstfloor	1	12500
Bed-Hospital	32" x 82"	02firstfloor	1	12500
Bed-Hospital	32" x 82"	02firstfloor	1	12500
Chair	Chair	02firstfloor	1	3500
Chair	Chair	02firstfloor	1	3500
Chair	Chair	02firstfloor	1	3500
Chair	Chair	02firstfloor	1	3500
Cabinet-File 2 Drawer	36" x 18" Lat.	02firstfloor	1	7500
Sofa	72"	04secondfloor	1	12000
Sofa	72"	04secondfloor	1	12000
Table-Coffee	36" x 72" x 18"	04secondfloor	1	2500
Grand total	51	Total Cost for Furniture		877000

Table 7. Quantity takeoffs door schedule

Door schedule					
Item Description	Level	Height(m)	Width(m)	Actual Cost (ID)	Simulated Cost (ID)
Single-Flush	02firstfloor	2	1	4500	9000
Single-Flush	02firstfloor	2	1	4500	9000
Single-Flush	02firstfloor	2	1	4500	9000
Single-Flush	02firstfloor	2	1	4500	9000

Door schedule					
Item Description	Level	Height(m)	Width(m)	Actual Cost (ID)	Simulated Cost (ID)
Single-Flush	02firstfloor	2	1	4500	9000
Single-Flush	02firstfloor	2	1	3000	6000
Single-Flush	02firstfloor	2	1	3000	6000
Single-Flush	02firstfloor	2	1	4500	9000
Double-Uneven	02firstfloor	2	1	4500	9000
Double-Uneven	02firstfloor	2	1	4500	9000
Double-Uneven	02firstfloor	2	1	4500	9000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Double-Flush	04secondfloor	2	2	4500	18000
Curtain Wall	02firstfloor	2	2	3000	12000
Grand total	80	Total Cost for Door		1050815	

Table 8. Quantity takeoffs window schedule

Window schedule						
Item Description	Level	Height(m)	Width(m)	Area(m <sup>2</sup> )	Actual Cost (ID)	Simulated Cost (ID)
Casement with Trim	02firstfloor	0.91	1.83	1.67	5000	8327
Casement with Trim	02firstfloor	0.91	1.83	1.67	5000	8327
Casement with Trim	02firstfloor	0.91	1.83	1.67	5000	8327
Casement with Trim	02firstfloor	0.91	1.83	1.67	5000	8327
Casement with Trim	02firstfloor	0.91	1.83	1.67	5000	8327
Casement with Trim	02firstfloor	1.22	1.22	1.49	5000	7442
Casement with Trim	04secondfloor	1.22	3.06	3.73	5000	18666
Casement with Trim	04secondfloor	1.22	3.06	3.73	5000	18666
Casement with Trim	04secondfloor	0.91	1.83	1.67	5000	8327
Casement with Trim	04secondfloor	1.22	3.06	3.73	5000	18666
Casement with Trim	04secondfloor	0.91	1.83	1.67	5000	8327
Casement with Trim	04secondfloor	1.22	3.06	3.73	5000	18666
Casement with Trim	04secondfloor	1.22	3.06	3.73	5000	18666
Transom with Trim	06thirdfloor	0.5	0.91	0.46	5000	2275
Grand total	66	Total cost for Window			989653	

Table 9. Comparison of cost estimate between traditional method and BIM

Cost Estimate by traditional method (manual) and Estimate Cost by BIM (with Revit architectural) of each item				
S.No	Item	Cost Estimate by traditional method (manual)	Cost Estimate by BIM (with Revit architectural)	Percentage Reduced (%)
1	Column	768300	726012	8
2	Structural Framing	1342763	1237351.517	11
3	Stair	198400	192000	6
4	Wall	6822100	5818417	15
5	Floor	6476600	6152185	7
6	Door	1103455	1050815	6
7	Window	1077600	989653	10
8	Furniture	877000	877000	0



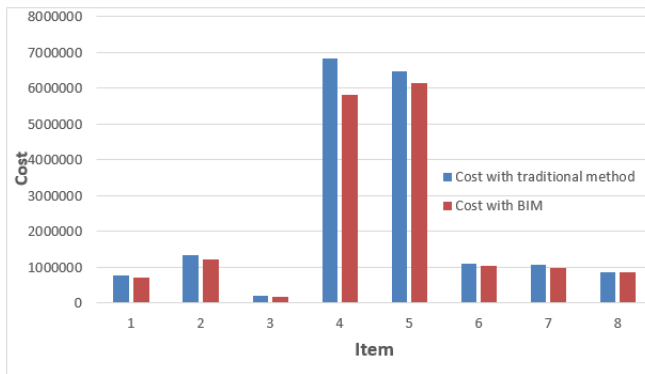


Figure 4. Estimated cost by traditional method comparison with BIM

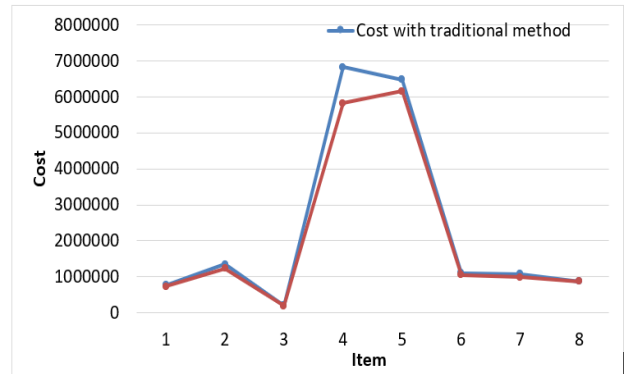


Figure 4. Line graph showing of estimated cost by traditional method comparison with BIM

#### 4. Conclusion

H.H.S hospital is case study to find the advantage and actual uses of building information model and to select a site for building a new hospital in Samawah, Al Muthanna, Iraq, this study includes formation of 3D model by using building information modeling, using Revit software and 5D (cost estimating) modeling is also.

The best developments in construction industry it is Building Information Modeling (BIM), it is used to generate virtual models for building digitalizing, use computer to generate models include accurate data of the building components to support the innovation and construction projects. This model can be used for planning, design, construction, and facility of the construction project. This case study illustrate BIM used to enhance the traditional scheduling and cost estimating methods within a more reliable.

Using a three-dimensional (3D) can develop the design of the project and find the best alternatives to the components of the project and using this model can solve any question faced by the designer during the design process, the site engineer can imagine all parts of the building and facilitate the process of implementation of activities of the project and increases the process of communication between the engineer and the contractor and reduce conflicts, especially during the implementation of the project, we are currently looking for other real projects to integrate layout planning to optimize the construction planning schedule before start the project.

The resulting from (5D) in construction project to give faster feedback about the budget for construction project, more accurate quantities for materials, accurate cost estimates and minimizing the effort for quantification lead to, saves cost, time and minimize potential for human error.

- It is observed from the Figure 3, 3D model was generated, which give us real visualizations to the project by using Revit software
- From the Table 9. the 5D cost estimating of the model is done and made comparison between the cost estimate by the traditional method and the method of BIM for establishing HHS Hospital .it is seen from the Figure 4. and Figure 5. that, the estimated cost of the Hospital Building is found less in BIM method as compared with traditional method.
- From the Table 1. to Table 9. it is observed that up to 80% reduce the period to quantity takeoffs for the project because the time spent by the estimator to quantity takeoffs material for project, but about 60% to 70% of the time needed to generate a cost estimate, using BIM to eliminate of manual takeoffs, save cost, time and minimize potential for estimator error.
- The best advantage from (BIM) through 5D if any change in the design would be directly reflected in the cost of the project , meaning that change in the dimension will change the account and quantity for the cost of project , for example, in the case that we have a building of 20 floors and in the opinion of the designer to change the dimensions of the windows on the fourth floor and the sixth and make them less dimensions in case of change will reduce the cost of the windows will be adjusted to the total budget of the project.

#### References

- [1] C. M. Eastman, C. Eastman, P. Teicholz, R. Sacks, and K. Liston, *BIM handbook: A guide to*



*building information modeling for owners, managers, designers, engineers and contractors.* John Wiley & Sons, 2011.

- [2] A. Kiviniemi, "Public clients as the driver for open BIM adoption-how and why UK government wants to change the construction industry," 2013.
- [3] S. Azhar, "Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry," *Leadersh. Manag. Eng.*, vol. 11, no. 3, pp. 241–252, 2011.
- [4] H. Kim, C. Benghi, N. Dawood, D. Jung, J. Kim, and Y. Baek, "Developing 5D system connecting cost, schedule and 3D model," in *10th International Conference on Construction Applications of Virtual Reality*, 2010, pp. 123–130.
- [5] A. Lindström, "Model-based Quantity Takeoff in Production. An experimental and interview-based approach on site to develop and implement new work methods." 2013.
- [6] L. Sabol, "Challenges in cost estimating with Building Information Modeling," *IFMA world Work.*, pp. 1–16, 2008.
- [7] M. Estimating, "BIM and Cost Estimating."
- [8] R. Sebastian, "Changing roles of the clients, architects and contractors through BIM," *Eng. Constr. Archit. Manag.*, 2011.
- [9] S. Mohd and A. Ahmad Latiffi, "Building Information Modeling (BIM) application in construction planning," 2013.
- [10] D. Mitchell, "5D: Creating cost certainty and better buildings," in *Proceedings of the European Conference on Product and Process Modelling*, 2012, pp. 253–258.
- [11] A. K. D. Wong, F. K. W. Wong, and A. Nadeem, "Comparative roles of major stakeholders for the implementation of BIM in various countries," in *Proceedings of the International Conference on Changing Roles: New Roles, New Challenges, Noordwijk Aan Zee, The Netherlands*, 2009, vol. 5.
- [12] D. A. Campbell, "Building information modeling: the Web3D application for AEC," in *Proceedings of the twelfth international conference on 3D web technology*, 2007, pp. 173–176.
- [13] F. K. T. Cheung, J. Rihan, J. Tah, D. Duce, and E. Kurul, "Early stage multi-level cost estimation for schematic BIM models," *Autom. Constr.*, vol. 27, pp. 67–77, 2012.
- [14] P. Sell, *BIM and Quantity Surveying*. Routledge, 2016.
- [15] R. Deutsch, *BIM and integrated design: strategies for architectural practice*. John Wiley & Sons, 2011.