International Journal of Engineering, Science and Mathematics
Vol. 10 Issue 12, December 2021,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Level of details in a BIM model and project cost estimate accuracy

Ayman Adel[*]
Emad Elbeltagi[**]
Ahmed Elhakeem [***]

Abstract

Cost estimate accuracy has a severe effect on the expected profit of a construction contractor. Although Building Information Modelling (BIM) had a significant impact in that domain, it needs some time to create and finish a model. Creating a BIM model with the required Level of Details (LOD) can give accurate cost estimates and save time. This paper tries to find the minor details of a BIM model, which offers a sufficient cost estimate accuracy through residential buildings projects stages. Reaching the appropriate level of details is done by revising literature and conducting a questionnaire survey that was distributed among a sample of expert BIM engineers in Egypt. Finally, a case study for a residential building project in Egypt is introduced. Two BIM models were implemented to find the appropriate level of details that give needed accuracy with the least effort during the design project stages.

Keywords:

Cost estimate accuracy;
Building Information Modelling ;
Level of Details;

Author correspondence:

Ayman Adel,
Master of Science Program, College of Engineering and Technology
Arab Academy for Science, Technology and Maritime TransporT (AASTMT)
Sheraton, Heliopleis, Cairo- Egypt
Email: eng_ayman_adel@yahoo.com

1. Introduction

BIM is developing and using a computer-generated model to simulate a building facility's planning, design, construction, and operation. A computer-generated model is a multidimensional object database containing all the necessary information to simulate, analyze and visualize the design, construction, and operation [1]. Despite its great importance, developing a BIM model can be an ongoing process of adding information - that might not be needed - to the model, increasing its time and cost. If the cost of the model increases, it will not be a profitable investment to use BIM. Construction projects then will lose all benefits of BIM because it takes much time and costs much money. From the point of view of project's stakeholders, they spent time and money developing BIM models. They will prefer to use traditional CAD (Computer Aided Drafting) systems instead of using BIM. Even though 3D CAD systems can represent how the design will be

[*]Master of Science Program, College of Engineering and Technology, AASTMT, Cairo- Egypt
[**]Prof. of Construction Management, Dept. of Structural Eng., Mansoura University, Aldaqahlia - Egypt
[***]Prof. of Construction Management, Construction & Building Eng. Dept., AASTMT, Cairo- Egypt

constructed in the field, they fail to cover the data information (e.g., cost information, material information, and schedule information) for each element in the project, which can be done by BIM models quickly.

Developing a BIM model with the appropriate LOD to satisfy its intended use may help overcome this problem. According to Pareto principle, roughly 80% of the effects come from 20% of the causes for many events. By applying this rule, a small percent of the project details significantly affects its cost. Estimating takes time, which is expensive, and one should spend it only on the details relevant to decisions. If BIM users apply the relevant details on a BIM model, they will save time and money. Therefore, the presented work focuses on saving time and costs while developing a BIM model by finding the appropriate level of detail. As such, this research aims to find a relationship between the level of details in a BIM model and project cost estimate accuracy for residential buildings construction projects.

2. Literature Review

Over the years, cost estimate has gained many definitions. It is the method of estimating or calculating different quantities and expected expenses incurred on a particular work or project[2]. Cost estimate for construction projects starts with quantification[3]. Quantification is a time-consuming task; it consumes 50% to 80% of the cost estimator time on a project [4]. Accurate quantity take-off is the only way to thoroughly analyze a construction project's productivity and various costs, and it is vital to a contractor's financial performance [5].

BIM is an aggregation for a project data during all its stages, starting from planning until operation and maintenance. This is because of creating a model for each discipline, which contains all information created or gathered about this discipline in a format useable throughout its life cycle [6]. An integrated BIM-based approach is proposed to accurately evaluating the cost of different scenarios in the design process [7] . The proposed approach enables owners to easily trace the changes in the project cost according to the changes in the BIM design. Unlike the conventional cost estimation approaches, the BIM-based approach is not highly dependent on the knowledge of an experienced estimator since the process of cost estimation is mainly automated. This fact facilitates its implementation and decreases the required time for cost estimation compared to traditional approaches.

Furthermore, automated extraction of Quantity-Take-Off (QTO) and the required calculations in the BIM-based plug-in increase the accuracy of the cost estimation process and decrease the probability of human errors or omissions occurrence. A questionnaire survey is conducted among BIM engineers and managers in Egypt to explore the real benefits of implementing BIM applications in project management [8]. The benefits are varied and include many aspects, which include data flow, cost control, schedule, project information, stakeholders with different backgrounds, efficient use of resources, enhancing communication, improving, decision making, reduction of risks, model-based quantity take-off, and maintenance process. Also, the results showed that risk management could be significantly improved, if BIM applications are used and communication management.

Having an exact digital 3D model of a building is very hard to achieve due to time and effort considerations. Therefore, a certain level of details of the actual building or facility is needed. The level of detail in the model will vary depending on the project phase and costing exercises that can be conducted throughout the project lifecycle with BIM to

reach a final estimate [9].Five different levels of development are introduced to define the detailing levels in a BIM model. They were as follows: LOD 100, LOD 200, LOD 300, LOD 400, and LOD 500.LOD is used as the level of details or the level of development. The LOD means how detailed the BIM model elements for each step are. In other words, the input concept focuses on how detailed the shape and property information are represented in the BIM model and how many details it contains [10].

3. Methodology

To achieve the objective mentioned above and find the relationship between the level of details in a BIM model and project cost estimate accuracy, authors established a three-step research methodology: (1) Review related literature to the research subject; (2) Performing a questionnaire survey among BIM users in construction companies; (3) Introducing a case study for a residential building project in Egypt, two BIM models were implemented to find the appropriate level of details that give needed accuracy with least effort during the design project stages.

4. Questionnaire Survey

This survey aims to stand on items in a residential building project with the highest LOD in a BIM model to achieve a desired cost estimate accuracy. The number of construction engineers in Egypt who are using BIM are not known. However, the number of construction companies and consultant offices using BIM in Egypt is 44 [11]. Consequently, 44 is considered to be the sample size needed for the survey. Although, 64 respondents answered the questionnaire.The survey consisted of 2 parts. The first part was to stand on the respondents and their companies' experience with BIM. The second part was to find the items in a residential building project that must have the highest LOD in a BIM model to achieve a desired cost estimate accuracy.

The questions of the second division were:

- What is the accepted percentage of accuracy for the project cost estimate in the following stages (concept, schematic design, detailed design, construction, operation, and maintenance)?
- What is the minimum level of details needed in the previous project stages?
- What is the effect of thefollowing elements (foundations, columns, beams, slabs, slab on grade, stairs, masonry works, windows, doors, plastering, painting, suspended ceilings, and floors) on the project cost estimate?
- How much time (concerning the overall model time) do you take to input the previous elements on the BIM model?

Data analysis and observations driven from the questionnaire survey are explained in Figures (1-5). As it shown in Figure (1), (15.6%) of the respondent's companies used BIM in more than thirty projects, while (18.8%) of them used BIM from 21 to 30 projects, (25%) of the companies used BIM in a range from 11 to 20 of their projects. Also, the survey showsthat (18.8%) of respondent's companies used BIM in about 6 to 10 projects, similarly, (18.8%) of the respondent's companies used BIM from one to five projects. Finally, only (3%) of the respondent's companies did not use BIM in any of their projects yet.

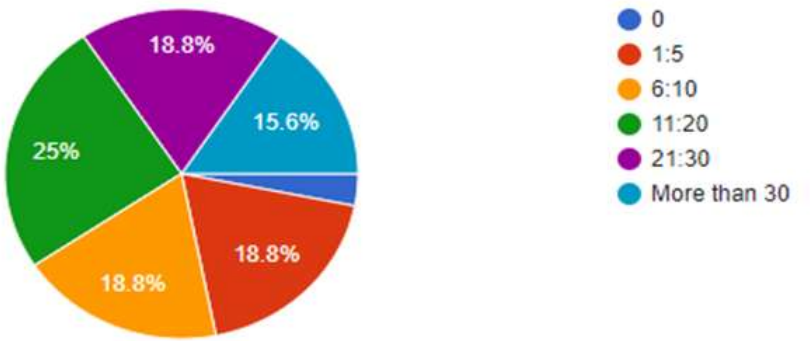


Figure (1): Number of projects where the companies used BIM

Figure (2) shows that thirty of the respondents (46.2%) acknowledged that 20% is an accepted accuracy for the project cost estimate during concept design stage. While thirty-five (53.8%) of them acknowledged that it is between 21% and 40% during schematic design stage. Thirty-four of the respondents (53%) see that it should be between 41% and 60 % during detailed design stage. On the other hand, during construction phase, thirty of the respondents (46.2%) considered that the accepted accuracy for the project cost estimate is between 61 % and 80 %. Finally, forty-eight (73.8%) of the respondents considered that the project cost estimate accuracy shall not be less than 81% for operation stage of a project.

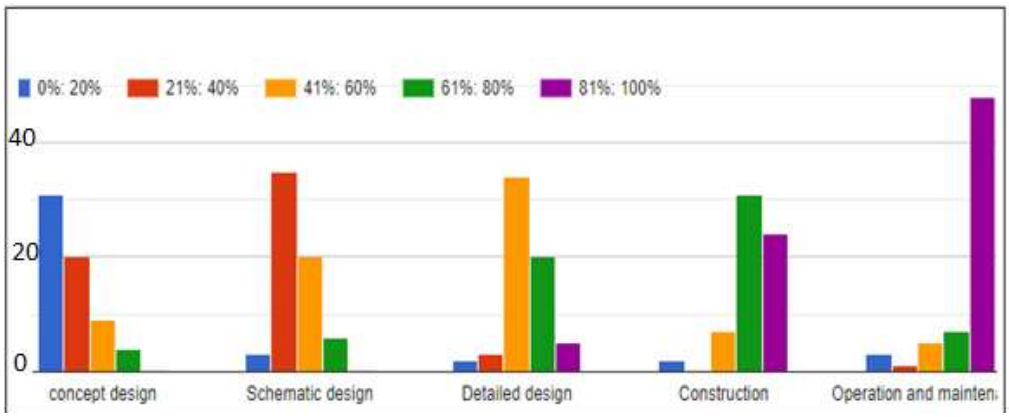


Figure (2): Accepted project cost estimate accuracy during its different stages

As it shown in Figure (3), forty-eight of the respondents (75%) see that level of details "100" can be the minimum level of details needed during the concept design stage. While fifty-one (79.7%) of them choose level 200 for the schematic design stage. Fifty-three (82.8%) of the respondents see that level 300 will be efficient for detailed design stage. In addition, forty-one (64%) of the respondents selected level 400 to be the minimum level of details needed for construction stage. Finally, for operation and maintenance stage, level 500 is the minimum level of details from the point of view of forty-six (71.9%) of the respondents.

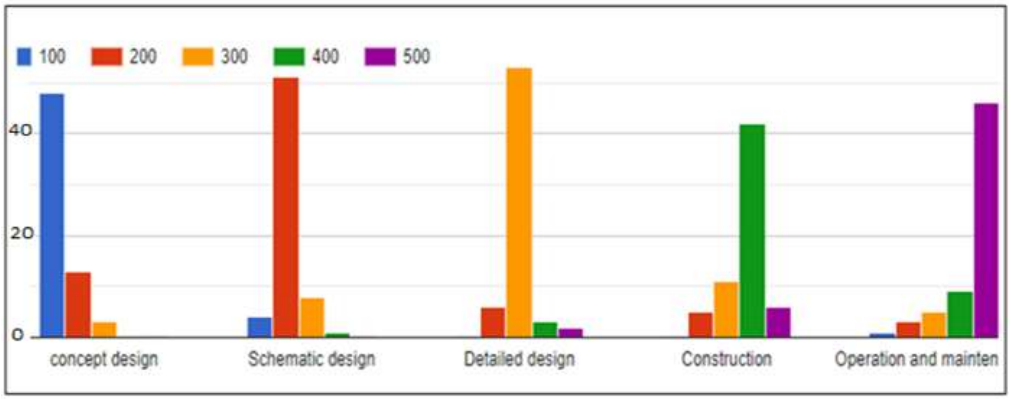


Figure (3): Level of details needed during project stages

Figure (4) shows that thirty-eight (59%) and thirty-two (50%) of the respondents respectively considered that foundations and stairs items have a very high effect on residential projects cost. While forty (63%), thirty-four (53%), thirty-four (53%), forty (63%) and thirty-three (52%) of the respondents respectively acknowledged that columns, beams, slabs, masonry works, and plastering items have a high effect. On the other hand, twenty-nine (45%), thirty-five (55%), forty (63%) and also thirty-five (55%) of the respondents respectively acknowledged that windows, doors, painting and floors items have a normal effect on cost estimate. Finally, twenty-five (39%) and thirty (47%) of the respondents respectively considered slab on grade and suspended ceiling items have a low effect on residential projects cost.

	Foundations	Columns	Beams	Slabs	Slab On Grade	Stairs	Masonry Works
Very High	38	5	4	18	3	32	2
High	15	40	34	34	7	17	40
Normal	10	19	24	11	19	13	17
Low	1	0	2	1	25	2	4
Very Low	0	0	0	0	10	0	1

	Windows	Doors	Plastering	Painting	Suspended Ceiling	Floors
Very High	11	2	3	3	3	5
High	21	17	33	10	14	24
Normal	29	35	23	40	15	35
Low	2	9	5	11	30	0
Very Low	1	1	0	0	2	0

Figure (4): Items' contribution on project cost

As it shown in Figure (5), thirty-two of the respondents (50%) acknowledged that stairs item takes a very high time to be created on a BIM model. While thirty-four (53%), forty (63%), twenty-seven (42%), twenty-five (39%) and also twenty-seven (42%) of the respondents respectively acknowledged that beams, masonry works, doors, suspended ceiling and floors items take a high time. On the other hand, thirty (47%), also thirty (47%), thirty-eight (59%), twenty-nine (45%), thirty-three (52%) and also thirty (47%) of the respondents respectively acknowledged that foundations, columns, slabs, windows, plastering and painting items take a normal time. Finally, twenty-five (39%) of the respondents considered that slab on grade item takes a low time to be created on a BIM model with respect to the overall time of the model.

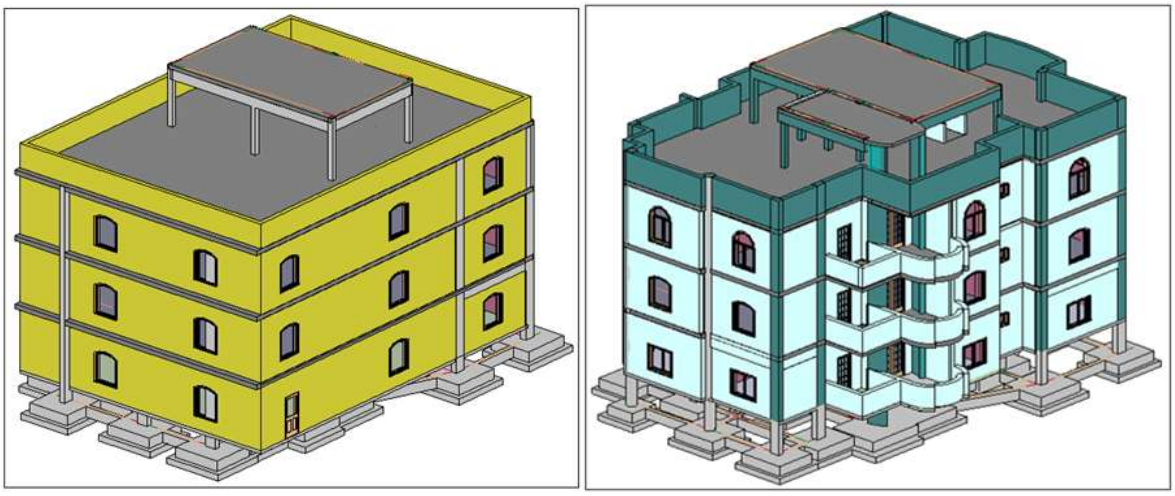
	Foundations	Columns	Beams	Slabs	Slab On Grade	Stairs	Masonry Works
Very High	5	5	7	5	3	32	2
High	7	24	34	10	7	17	40
Normal	30	30	22	38	19	13	17
Low	21	3	1	10	25	2	4
Very Low	1	2	0	1	10	0	1

	Windows	Doors	Plastering	Painting	Suspended Ceiling	Floors
Very High	11	10	5	6	22	9
High	21	27	13	24	25	27
Normal	29	23	33	30	14	26
Low	2	3	13	4	2	1
Very Low	1	1	0	0	1	1

Figure (5): Items contribution on BIM model preparation time

5. Model Implementation

This research aims to find the minimum level of details needed for establishing a BIM model, giving accepted accuracy for the cost estimates of a residential building project during its different stages. According to the survey analysis, the minimum LOD needed in a BIM model created for project cost estimate through schematic design stage is 200, and that for the detailed design stage is 300.A comparison will be made between the two levels, 200 and 300, for the design stages of a project.



a. LOD 200 b. LOD 300

Figure (6): Case Study Project

This comparison will be madeby introducing a case study for a residential building project in Egypt (Figure 6). It is a part of a large residential building project with a total cost of one billion EGP.This building is built on an area equals to about 500-meter square.Two BIM models are introduced for the project. The first one with LOD 200, and the second one with LOD 300.The time needed to create the model, project cost estimate and its accuracy are calculated for each model. A comparison is performed between both models. As such, BIM engineers may choose the LOD for their models to save time and money according to the needed project cost estimate accuracy.

As it shown in Figure (6), a BIM model with LOD 200 is a general model, where elements are modeled with approximate quantities, size, shape, location, and orientation. Non-geometric information could be attached to the model elements. While a BIM model with LOD 300 is an accurate model where elements are defined with specific assemblies, precise quantity, size, shape, location, and orientation. Here also non-geometric information could be attached to the model elements (10).

For comparison purposes, the time taken by each item in both models is recorded. Since the ability of working on a BIM application differs from an individual to another, therefore the input times of items will be represented in the form of percentages where the time taken for each item in the 300-LOD model is assumed to be 100%.As such, the time calculated for the same item in the 200-LOD model will take a percentage with reference to the time of the 300-LOD model. These calculations are shown in (Table 1). The time saved during creating the LOD 200 model equals 63.75 %.

Table (1): Comparison between BIM models of the case study project

	Input time		Cost			Cost Estimate Accuracy %	
Items	LOD 300 model	LOD 200 model	LOD 300 model	LOD 200 model	Actual cost	LOD 300 model	LOD 200 model
Foundations	100%	45%	345,636	358,720	467,673	73.91%	76.70%
Columns	100%	30%	178,936	149,315	285,779	62.61%	52.25%
Beams	100%	35%	73,918	67,166	1,229,703.30	81.47%	69.46%
Slabs	100%	20%	927,910	787,047			
Masonary works	100%	35%	320,877	238,522	301,792	93.68%	79.04%
Windows	100%	35%	154,031	135,110	163,011	94.49%	82.88%
Doors	100%	40%	226,000	150,553	214,300	94.54%	70.25%
Outer finishing	100%	50%	250,738	152,600	235,605	93.58%	64.77%
Total	**Time Saving**	**63.75%**	2,478,046	2,039,033	2,897,863	**85.51%**	**70.36%**

LOD stands for Level of Details or Level of Developments. Level of Details are concerned with accuracy of geometry, orientation and location. Level of Developments is level of details plus level of information (12). As the information increases, cost per cubic meter or squared meter for an item becomes more detailed and accurate. Therefore, cost of an item differs through different levels. In this research, LOD stands for Level of Details. For simplification, the cost of each item is assumed constant and equals the price in the Bill of Quantities (B.O.Q.) of the case study project. Quantities of the items are calculated in both models. Then, cost per cubic meter or squared meter is entered to them. Consequently, the items cost estimate in each model is extracted, and the overall cost estimate of the project in the two models is calculated.

In order to calculate cost estimate accuracy, the actual quantities executed in the case study are driven from the project site. By multiplying these quantities by cost, the cost of the actual quantities executed in the site for each item and the overall project is extracted as shown in Table (1). Finally, the cost estimate accuracy for LOD 200 model is 70.36 %,

and that for LOD 300 model is 85.51 %. According to the questionnaire survey results, these percentages of cost estimate accuracy during design stages are very satisfying results.

6. Conclusions

Finding an appropriate level of detail while creating a BIM model that saves time and gives a sufficient cost estimate accuracy is a great challenge, as no end details can be added to the model. Throughout the entire effort done in this research, the followingconclusions were drawn:

1) By reviewing the previous literature, different levels of details for the BIM model are defined.
2) The questionnaire survey results found that the needed LOD during the concept, schematic, detailed design, construction, and operation stages are 100, 200, 300, 400, and 500, respectively. Also, some elements have a higher effect on project cost and need lower input time to a model than other elements.
3) A case study for a residential building project in Egypt is introduced. Two BIM models with 200-LOD and 300-LOD are developed. The cost estimate accuracy achieved using the 200-LOD model is 70.36%, and it saved time for the user by 63.75%. On the other hand, the cost estimate accuracy achieved using the 300-LOD model is 85.51%.

Further case studies are recommended to ensure that the research results are valid in other project stages like construction and operation.

References

[1] Krezel, A., 2014. Productivity gains by utilization of BIM methodology in the design and construction of large- scale buildings. Materials and Construction Engineering Conference, Istanbul, Turkey, 65- 74.
[2] Khan, M.A, Barrister, T.R. and Haider, Y., 2017. Costing and Estimation. International Journal of Advanced Research and Development, 2 (5), 20-26.
[3] Sabol, 2008, Challenges in Cost Estimating with Building Information Modelling, Available from: http://www.dcstrategies.nrt/files/2_sabol_cost_estim ating.pdf.
[4] Autodesk, 2007. BIM and Cost Estimating. Autodesk, Inc.
[5] Monteiro and Poças, 2013. Automation in Construction, 35, 238-253.
[6] NBIMS, 2007. National Building Information Modeling Standard. United States of America: National Institute of Building Sciences.
[7] Fazeli, A., Dashti, M.S., Jalaei, F. and Khanzadi, M., 2020. An integrated BIM-based approach for cost estimation in construction projects. Engineering, Construction and Architectural Management Journal, ISSN: 0969-9988.
[8] Shaqour, E.N., 2021. The role of implementing BIM applications in enhancing project management knowledge areas in Egypt. Ain Shams Engineering Journal, Available from: https://doi.org/10.1016/j.asej.2021.05.023

[9] Nassar, K., 2012. Assessing Building Information Modeling Estimating Techniques Using Data from the Classroom. Journal of Professional Issues in Engineering Education and Practice, 138 (3), 171-180.

[10] AIA, Document G202™, 2013. Project Building Information Modeling Protocol Form. American Institute of Architects. Available from: https://content.aia.org/sites/default/files/2016-09/AIA-G202-2013-Free-Sample-Preview.pdf

[11] Selim, O., 2020. BIM Arabia magazine (online). Available from: https://draftsman.wordpress.com/2016/06/15/32123/

[12] BIM Egyptian Code, 2020.