Building Information Modelling (BIM): Benefits for Small Scale Construction Industry

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**ABSTRACT**

While time passes and life changes, the development of technology is taking place in every part of our life quickly, also it affects daily life. It creates new tools, procedures, and methods for all sectors, and simplifies many operations. Nowadays, design tools that depend on computers have been used in the construction industry, it has a direct effect on the whole project life, and it has made a revolution in the construction sector. Building information modeling (BIM) simply refers to the development of a building model generated by using the computer, that model is rich of data, object-oriented, smart and also a parametric digital representation of the building.

This paper discusses the advantages of implementation of BIM technology for the small scale construction industry, it will mainly focus on quantity takeoff and accuracy of projects, firstly it presents the definition and the main concept of BIM. Then, a case study of a 3-storey building project in Baghdad is done to evaluate the effect of BIM quantity takeoff, tendering, and other effects on the project. At the end, results and challenges will be discussed.

**Keywords**— Building Information Modeling (BIM), Quantity Takeoff, Cost Management

**I. INTRODUCTION**

Building information modeling (BIM) simply refers to the development of a building model generated by using the computer, that model is rich of data, object-oriented, smart and also a parametric digital representation of the building, which provides views, plans, and data convenient for different needs of users, it can be obtained easily and analyzed to get information that can help with making decisions and improving the operation of delivering the project.

One of the main differences between BIM 3D and 2D CAD is that 2D CAD represents the project by separated and independent drafts, such as plans, elevations and sections. When it is required to edit one of those drafts, all other drafts in the project must be checked to see the effect of editing on them, that process usually causes many faults and interactions between drafts, and quantities must be also checked. In addition, in 2D drafts, data are graphical elements only, such as lines, rectangles, arcs and circles, while in 3D BIM models, objects are smart elements and defined as walls, beams, columns, and slabs. The Associated General Contractors of America (AGC) defined BIM as the following: “Building Information Modelling (BIM) is the development and use of a computer software model to simulate the construction and operation of a facility”.

USA National Building Information Model Standard Project Committee (NBIM) provides the following definition: "Building Information Modeling (BIM) is a digital representative of the physical and functional properties of a plant. BIM is a common information source which creates a reliable basic for the decisions being taken for a plant during its lifecycle; is valid starting from the decision for the construction until the end of the demolition (NBIMS, 2016)".

**II. BENEFITS OF BUILDING INFORMATION MODELING (BIM)**

- 3-D visualization: Architectural 3-D rendering can be easily made with BIM.
- Shop drawings generating: shop drawings can be quickly and easily generated for different plans, sections and other parameters.
- Maintenance of buildings: BIM can be applied for renovation and maintenance of buildings.
- Material and cost estimating: Materials and cost estimating can be done with BIM softwares automatically and very quickly. In addition, when changing any part of the model, materials extracted and changed immediately.
- Interference detection: It is one of the most useful features of BIM. To make certain that no elements intersect with each other, all main systems and elements can be visually checked for interference.
- Structural Analytical model: Since BIM-based model has intelligent objects, it can be exported to other analytical softwares, for example, Autodesk Revit has analytical model feature.
• Reducing the time of project delivery: Stanford University center for integrated facilities engineering (CIFE) indicates that BIM can reduce project time up to 7%.

• Team work-friendly: Some BIM softwares like Autodesk Revit have the feature of “work set” which allows different users to have the access to the same model and also edit it if they have been given the authority to. however, every edit is recorded according to the user who has made it. This can help architects, structural, mechanical, and electrical designers to work in one platform, and that can save time and minimize the conflicts.

III. CASE STUDY

A case study of 3-storey building was applied using Autodesk Revit 2020, the model was created depending on the documents and drawings given by the contractor company. The project brief is as following:

- Project name: Salim Khdair - N95
- Project’s budget: 679,942,000IQD
- Main Structure: reinforced concrete
- Owner: private sector investor
- Contractor: Al-Khaled design and contracting Limited
- Design method: AutoCAD drawings
- Quantity takeoff: Traditional method (using AutoCAD, excel and hand calculations)

In this paper, the project was re modeled with Autodesk Revit 2020 depending on the drawings and information of the project. While creating the model with Autodesk Revit, all drawing objects were defined as intelligent objects, for example while creating the Raft foundation, it hasn’t been drawn as merely cube, but as a structural/foundation/Raft foundation. And by entering all the information and determining the orientations, the object was created. This can give many benefits, like quantity takeoff, rebars placement, member connections, and helps to detect any interference.

Figure 1 shows some parts of creating the model:

![Grids and levels](https://ssrn.com/abstract=3908390)
Figure 1: Some parts of creating the model
Figure 2: Placement of Rebars for columns

Figure 3: Placement of Rebars for beams.
IV. RESULTS AND DISCUSSION

By using Autodesk Revit, by selecting view/schedule/material takeoff, Quantity takeoff of different objects can be obtained automatically, it also provides many information and details that the designer or contractor might need. In this part, schedules will be created for the items mentioned in the BOQ that was made by the company, later, the results can be exported to an excel file and arranged and compared with the tender Quantities and prices.

Here are samples of the schedules obtained by Autodesk Revit:

| Structural Foundation Schedule |
|-------------------------------|
| Volume | Cost IQD | Perimeter | Area | Foundation Thickness | Comments |
| 255.76 | 28133300 | 82600 | 426 m² | 600 | raft foundation |
| 64.22  | 7064600 | 92600 | 536 m² | 120 | blinding |

| Structural Column Schedule Ground Floor |
|----------------------------------------|
| Volume | Cost IQD | Type | Count | Base Level | Top Level |
| 26.57 m³ | 2524000 | 300 x 600 mm | 41 | Level 0 | Level 1 |

| G.F column Rebar Schedule |
|---------------------------|
| weight | cost | Bar Diameter | Reinforcement Vol | Spacing | Comments |
| 1.926187 | 1772100 | 10 mm | 0.245374 m³ | 120 mm | G.F col. |
| 0.16469 | 151500 | 10 mm | 0.020980 m³ | 248 mm | G.F col. |
| 4.529825 | 4167400 | 16 mm | 0.577048 m³ | | G.F col. |
| 6.620701 | 6091000 | | 0.843401 m³ | | |

| 2nd. Floor Concrete & Formwork Schedule |
|-----------------------------------------|
| Volume | Area | Perimeter | Elevation at Top | Default Thickness | Formwork Area | Cost IQD | formwork Cost IQD |
| 89.59 m² | 448 m² | 131685 | 16600 | 200 | 474.3 | 8511100 | 4742900 |

| Stairs Material Takeoff |
|-------------------------|
| Top Level | Material Volume | Cost | Actual Number of | Actual Rise Height | Actual Tread Depth | formwork area | formwork cost |
| Level 1 | 3.07 m³ | 291800 | 20 | 210 | 300 | 15.01 | 150100 |
| Level 2 | 2.71 m³ | 257580 | 17 | 100 | 300 | 13.01 | 130100 |
| Level 3 | 2.71 m³ | 257580 | 17 | 100 | 300 | 13.81 | 138100 |

Fig (4) samples of the schedules obtained by Autodesk Revit

After getting those schedules, it has been arranged in one brief schedule comparing with the tender schedule as following:
| No. | Description                                                                 | Unit | Revit Quantity | Tender Quantity | Difference | Revit price | Tender price | Difference |
|-----|------------------------------------------------------------------------------|------|----------------|-----------------|------------|-------------|--------------|------------|
| 1   | Excavation 0.6m from the surface                                              | m3   | 417            | 417             | 0.000      | 3753000     | 3753000      | 0          |
| 2   | filling with subbase and compacting                                          | m3   | 278            | 278             | 0.000      | 4865000     | 4865000      | 0          |
| 3   | Blinding 12cm                                                                | m3   | 64.22          | 67              | -2.780     | 7064200     | 7370000      | -305800    |
| 4   | sanitaries                                                                   | -    | -              | -              |            | 2000000     | 2000000      | 0          |
| 5   | Raft foundation's rebar,                                                      | Ton  | 11.06          | 12              | -0.939     | 14379807    | 15600000     | -1220193   |
| 6   | raft foundation's formwork                                                   | -    | -              | -              |            | 1500000     | 1500000      | 0          |
| 7   | raft foundation concrete 60 cm                                                | m3   | 255.76         | 275             | -19.240    | 24297200    | 26125000     | -1827800   |
| 8   | Ground floor's column concrete                                               | m3   | 26.57          | 30              | -3.430     | 2524150     | 2850000      | -325850    |
| 9   | Ground floor's column formwork & Rebar works                                 | Count| 41             | 41              | 0.000      | 6150000     | 6150000      | 0          |
| 10  | rebar for G.F columns 10mm and 16mm                                          | Ton  | 6.62           | 7               | -0.379     | 6091045     | 6440000      | -348955    |
| 11  | concrete for slab and beams of G.F                                           | m3   | 123.75         | 133             | -9.250     | 11756250    | 12635000     | -878750    |
| 12  | rebar for G.F slab-beams and stair 10mm, 12mm and 16mm                       | Ton  | 11.96          | 12              | -0.038     | 15550714    | 15600000     | -49286     |
| 13  | G.F formwork for slab-beam and stairs                                        | m2   | 781.79         | 690             | 91.790     | 7817900     | 6900000      | 917900     |
| 14  | rebar for 1st. Floor columns 10mm and 16mm                                  | Ton  | 4.75           | 5.00            | -0.251     | 4482124     | 4600000      | -117876    |
| 15  | First floor's column formwork & Rebar works                                  | Count| 39             | 39.00           | 0.000      | 5850000     | 5850000      | 0          |
| 16  | First floor's column concrete                                                | m3   | 18.02          | 21.00           | -2.980     | 1756550     | 1995000      | -238450    |
| 17  | 1st. floor formwork for slab-beam and stairs                                 | m2   | 762.11         | 690             | 72.110     | 7621100     | 6900000      | 721100     |
| 18  | rebar for 1st. slab-beams and stair 10mm, 12mm and 16mm                      | Ton  | 11.47          | 12.00           | -0.534     | 14905289    | 15600000     | -694711    |
| 19  | concrete for slab and beams of 1st. Floor                                    | m3   | 121.56         | 133             | -11.440    | 11548200    | 12635000     | -1086800   |
| 20  | rebar for 2nd. Floor columns 10mm and 16mm                                  | Ton  | 4.16           | 5.00            | -0.836     | 3944486     | 4600000      | -655514    |

Table 1: Material and Cost comparison
|   | Description                                      | Unit | Count | Price  | Revit Total Price (IQD) | Tender Total Price (IQD) | Difference (IQD) |
|---|--------------------------------------------------|------|-------|--------|--------------------------|--------------------------|-----------------|
| 21| second floor's column formwork & Rebar works     |      | 39    | 39.00  | 0.000                    | 5850000                  | 5850000         |
| 22| Second floor's column concrete                   | m3   | 18.02 | 21.00  | -2.980                   | 1756550                  | 1995000         |
| 23| 2nd. floor formwork for slab-beam and stairs     | m2   | 798.92| 710    | 88.915                   | 7989151                  | 710000          |
| 24| rebar for 2nd. floor slab-beams and stair 10mm, 12mm and 16mm | Ton  | 11.49 | 12.50  | -1.005                   | 14943078                 | 1625000         |
| 25| concrete for slab and beams of 2nd. Floor        | m3   | 127.49| 136    | -8.510                   | 12111550                 | 1292000         |
| 26| rebar for 3rd. Floor columns 10mm and 16mm      | Ton  | 0.89  | 1.20   | -0.309                   | 820056                   | 1104000         |
| 27| Third floor's column formwork & Rebar works      |      | 10    | 10.00  | 0.000                    | 1500000                  | 1500000         |
| 28| Third floor's column concrete                    | m3   | 4.39  | 5.00   | -0.610                   | 417050                   | 475000          |
| 29| 3rd. floor formwork for slab & beam              | m2   | 128.07| 95.00  | 33.070                   | 1280700                  | 950000          |
| 30| rebar for 3rd. floor slab & beams, 10mm, 12mm and 16mm | Ton  | 1.92  | 2.00   | -0.076                   | 2501296                  | 2600000         |
| 31| concrete for slab and beams of 3rd. Floor        | m3   | 19.16 | 17.00  | 2.160                    | 1820200                  | 1615000         |
| 32| DPC                                             | M    | 215.85| 170    | 45.845                   | 1942605                  | 1530000         |
| 33| Ground floor's Brickwall works                   | M3   | 162.44| 155    | 7.440                    | 26802600                 | 25575000        |
| 34| First floor's Brickwall works                    | M3   | 120.44| 108    | 12.440                   | 19872600                 | 17820000        |
| 35| Second floor's Brickwall works                   | M3   | 120.44| 108    | 12.440                   | 19872600                 | 17820000        |
| 36| Third floor's Brickwall works                    | M3   | 44.07 | 48.00  | -3.930                   | 7271550                  | 7920000         |

**Table 2: Price difference**

| Description                  | Cost Comparison (IQD) |
|------------------------------|-----------------------|
| Revit Total price            | 284292461             |
| Tender Total price           | 286992000             |
| Difference                   | -2699539              |

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Schedules obtained by Autodesk Revit are full of very detailed information, however, only necessary information listed. Those schedules can be used individually or collected in one schedule, in this work, data collected individually and listed in one table in the same style of the tender and also it was linked so that any change in Revit data will be reflected to the table. In addition, tender quantities and prices was listed in the same table to be compared.

The total price of the tender was 286,992,000 IQD while Revit-based price was 284,608,602 IQD with difference of -2,383,398, changing in price is less than 1%, so it is not a big difference especially in small scale projects.

Although the total price is nearly the same, the quantity takeoff shows a big difference, increasing and decreasing. Fig(5)(a) shows that Revit quantity is less than tender quantity in all concrete casting except the last floor’s slab and beams where 18% more than tender quantity. (B) shows that steel rebar quantity is less than tender quantity by different ratios. (c) shows that Revit-based formwork area is higher than tender formwork area with big gap. (d) shows that the bar chart is wiggling again, Revit-based brick wall quantity is more that tender quantity in 3 floors, while in the last floor it is less. This wiggling in quantities might be a serious problem, in case of any change order in during the construction phase, if the change was affecting the quantity of one material, it may change the price sharply and causing a big loss. Another option is that if the price of one material goes up the total difference in price will be more than 1% and it could also cause a big loss.

V. CONCLUSION

While bills of quantities are being calculated, the most common error occurring is that the quantities of some items tend to be more or less than they should be. This might be occurring because of forgetting some parts or repeating the calculation of some parts of the item(s).
small scale projects, this kind of problem can be obviated, it can decrease the expected profit or cause a little loss, but in large scale projects this issue cannot be avoided. if the errors of bills of quantities are too much, then the contractor will face many problems in proceeding and the work might reach a point that the project should be stopped. By using BIM softwares, quantities are being calculated automatically depending on the model created, which makes the designer engineers responsible of the accuracy of quantities takeoff.

According to investigations and information carried out in this study, it has been revealed that traditional quantities takeoff calculation method contains many serious errors that might cause big problems, losses, and delaying for projects, BIM-based quantities takeoff gives more accurate results, in addition to the benefits like quick design, 3-D rendering, interference detection, time controlling, team work platform, and other features. Finally, the researcher concludes that BIM technology should be implemented for small scale construction projects, also the level of awareness to implement this technology by stakeholders should be raised.

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