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Automat Bill of Quantities for School Buildings Projects Using BIM

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Keywords:
Automation Bill of Quantities; Building Information Modelling; School Building Projects; Traditional Bill of Quantities; 3D BIM.

Highlights:

- *The study found that 3D BIM-based calculations of Bill of quantities achieved 93.059% accuracy in design, highlighting its importance for decision-making and avoiding errors in implementation.*
- *BIM improves interdisciplinary coordination in engineering work, preventing conflicts and uncoordinated designs between specialty models.*
- *BIM provides a centralized database for information exchange throughout the project's life cycle.*

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Abstract: The Bill of Quantities (B.O.Q.) is a crucial document in construction projects, analyzing materials, labor, and expenses. Traditional methods involve manual measurement and interpretation, while 3D Building Information Modeling (BIM) offers a novel technique. This research compares the accuracy, efficiency, and industry implications of traditional and 3D BIM methods for estimating B.O.Q., highlighting the labor-intensive and error-prone nature of the conventional method. The second section introduces 3D BIM, which offers a virtual project representation, seamlessly integrating geometry, material data, and quantities to automate measurement and reduce errors. To provide empirical evidence, the paper includes a case study comparing estimated quantities by the (traditional method Tender), BIM, and site) in an actual construction project. The case study analyzes the project's accuracy, consistency, and overall impact. The results showed the accuracy of BIM vs. as-Tender (83.911) and the accuracy of BIM vs. as-Actual (93.059), which is more than the accuracy of Tender vs. as-Actual (65.512).

اتمتة جداول الكميات لمشاريع البناء المدرسي بإستخدام نمذجة معلومات البناء الثلاثية الابعاد (١٨ صف) كدراسة حالة

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الخلاصة

تعتبرجداول الكميات وثيقة حاسمة في مشاريع البناء، وتوفر تفصيلاً مفصلاً للمواد والعمالة والتكاليف اللازمة لتنفيذ المشروع. كانت الطرق التقليدية لتقديرها سائدة منذ عقود، بالاعتماد على القياس اليدوي والتفسير. شهدت السنوات الأخيرة إدخال طريقة جديدة لتقدير جداول الكميات ناتجة عن نمذجة معلومات البناء ثلاثية الأبعاد. تقارن هذه الورقة طريقة نمذجة معلومات البناء الثلاثية الابعاد والطريقة التقليدية لتقدير B.O.Q، مع التركيز على منهجياتها ودقتها وكفاءتها وآثارها الصناعية. يعتمد النهج التقليدي، الموضح في القسم الأول، على القياس اليدوي من الرسومات المعمارية والهندسية، مما يجعله عرضة للأخطاء ويستغرق وقتًا طويلاً. يقدم القسم الثاني نمذجة معلومات البناء الثلاثية الابعاد والذي يقدم تمثيلًا افتراضيًا للمشروع، ويدمج بسلاسة الهندسة وبيانات المواد والكميات لأتمتة القياس وتقليل الأخطاء. لتقديم أدلة تجريبية، تتضمن الورقة دراسة حالة تقارن الكميات المقدرة حسب (الطريقة التقليدية (العطاء) و BIM والموقع) في مشروع بناء فعلي. وتحلل دراسة الحالة الدقة والاتساق والتأثير العام على المشروع، حيث أظهرت النتائج أن دقة نمذجة معلومات البناء مقابل العطاء (٨٣,٩١١) ودقة نمذجة معلومات مقابل الفعلي (٩٣,٠٥٩)، وهي أكثر من دقة العطاء مقابل الفعلي (٦٥,٥١٢).

الكلمات الدالة: أتمتة جداول الكميات، نمذجة معلومات البناء، مشاريع بناء المدارس، جداول الكميات التقليدية، نماذج معلومات البناء ثلاثية الابعاد.

1.INTRODUCTION

Project management in the construction industry requires utilizing quantity take-off, a process that spans various phases of construction project management, including feasibility studies, investment decision-making, development, construction, and completion. Quantity take-off provides crucial data for calculating, controlling, supervising, and monitoring construction costs [1]. However, the conventional approach to quantity take-off is labor-intensive and prone to errors, posing a significant challenge in the architecture, engineering, and construction (A.E.C.) sector. Building Information Modeling (BIM) is a three-dimensional digital technology [2], based method that has proven more effective than conventional techniques for quantity estimations in construction-related fields such as risk management, long-term sustainability, facility management, and energy simulation [3]. BIM data can be directly extracted from the 3D BIM-based design model, enabling autonomous quantity take-off [4]. BIM software outperforms conventional approaches in terms of efficiency and dependability, as it automatically calculates quantities by obtaining geometric data and semantic attributes of architectural components [5]. The research highlights Iraq's progress in engineering and construction industries, particularly in embracing new technologies like BIM. Modern BIM is used in Iraqi school construction projects to automate bill of quantities, reduce project duration and expenses, and provide valuable insights for academic institutions and project teams in ideation, planning, design, and implementation.

2.JUSTIFICATION FOR THE RESEARCH

This study focused on the engineering and building industries in Iraq, which are crucial for urban and developing settings. These sectors are key indicators of a nation's progress, especially in adopting modern technologies. A prime example is the automation of the bill of quantities in school building projects using cutting-edge BIM technology. This approach reduces project time and costs while maintaining technical standards. The study's findings will offer valuable insights and tools for creation, planning, design, and implementation for academic scholars and real-world project teams.

3.METHODOLOGY

This study was conducted using the following methodology:

1- Theoretical part: The theoretical part of this study was built on performing a comprehensive review of 3D BIM Quantity take-off literature, which included books, theses, dissertations, websites, and papers from as far back as the middle of the 1970s, published in the digital databases ScienceDirect, Springer, Google Scholar, and Iraqi Scientific Journal.
2- Practical part: To achieve study goals, the practical portion was separated into two phases:
   a. The evaluation phase: The aim of conducting the assessment is to pinpoint the underlying factors leading to differences between three approaches (Quantity take-off estimated by BIM, Quantity take-off estimated by Tender, and Quantity take-off estimated by site work) through interviews and field visits, as the researcher interviewed the officials, including engineers and contractors involved in the project to collected project documents.
   b. The recovery plan phase: This approach assists in identifying design flaws and determining the underlying causes behind inaccurate and insufficient calculations of work

quantities, through creating a 3D visual model using BIM.

4.BACKGROUND RESEARCH

The basis for the viability of quantity computation using BIM technology is the BIM model, built on 3D digital software and includes details regarding the building itself [6]. A model created using BIM can make revisions, reduce the need for alterations, and react to changes in the design. Using BIM can raise a project's quality. Construction can also be expedited and expenses reduced. Another benefit of BIM is the decrease in design conflict. A computer may divide the various parts of the model's information and learn more about its geometrical and physical characteristics to finish the calculation and generate statistics for the necessary volume, area, length, and other variables. Following that, the current code's rules produce those quantities. Traditional approaches may not be as accurate, versatile, or efficient as BIM-based quantity calculation [7]. Also, BIM-based quantity computation lessens information loss and distortion from the design phase to the cost-calculating stage. Due to the excellent efficiency, it is easier to keep project costs under control because the engineer can receive cost information throughout the design phase. Lastly, BIM-based quantity calculations can more effectively respond to design changes and more quickly complete the work prompted by such modifications. BIM encompasses task-specific applications, producing various outcomes like model generation, drawing production, cost estimation, and more. These tools can generate standalone outputs or interface with other applications, like QTO for cost estimation or connection-detailing apps for structural analysis [8]. BIM QTO tools extract information from models to produce counts, area, volume, and material quantity schedules, suggesting the potential for full QTO automation using BIM tools, indicating a potential shift towards complete automation in quantity take-off due to the BIM revolution [9]. Based on research and systematic reviews conducted in various digital databases, four studies examined the automation bill of quantity and its impact on construction projects. These results are shown in Table 1.

Table 1 Summary of Similar Previous Studies.

1	**Title of Study**	**Researchers Name**	**Year**	**Country**	**Paper Type**
	The efficient generation of 4D BIM construction schedules: A case study of the Nanterre 2 CESI project in France [10].	Omar Doukari Boubacar Seck David Greenwood	2022	France	Research Article
Tools & Techniques	Historical data and BIM software.				
Methods used	The methodology used in the paper was based on a preliminary survey and historical data.				
Results	The study suggested a practical method to reduce the workload of producing 4D BIM building schedules. This procedure intends to assist project participants in fully utilizing 4D BIM's capabilities. However, the study does not mention any specific findings or results.				
Conclusions	The paper concluded that Building Information Modelling (BIM) offers a chance to improve planning practices in the construction sector. By effectively implementing 4D BIM, project teams may eliminate planning errors, foster stakeholder collaboration, and make better decisions. Ensuring that time and budgetary restrictions are met can make progress tracking easier.				
2	**Title of Study**	**Researchers Name**	**Year**	**Country**	**Paper Type**
	BIM adoption and its impact on planning and scheduling influencing mega plan projects-(CPEC-) quantitative approach [11].	Ahsan Nawaz Xing Su Ibrahim Muhammad Nasir	2021	China	Research Article
Tools & Techniques	Interviews and observation.				
Methods used	Field visits and Field analysis.				
Results	The survey indicated that 3D technology, such as BIM, replaced 2D CAD drawings. According to the study, BIM is a valuable tool for scheduling and planning that will help ensure perfect planning and raise project success rates.				
Conclusions	The paper concluded that Building Information Modeling (BIM) has an advantageous impact on efficient scheduling and planning in Pakistan's building sector.				
3	**Title of Study**	**Researchers Name**	**Year**	**Country**	**Paper Type**
	Using 4D dimension for BIM system to improve project implementation schedule[12].	Dhuha.Kazz Mwafaq Ibraheem	2021	Iraq	Research Article
Tools & Techniques	Historical data and BIM software.				
Methods used	The methodology used in the paper was historical data and case study analysis.				
Results	The paper did not explicitly mention any results. However, it provided insights into the requirements for applying BIM 4D in architectural projects in Iraq, improving the project execution schedule.				
Conclusions	The paper highlighted the benefits of using BIM 4D for project scheduling in architectural projects in Iraq. It emphasized the need for specific prerequisites in the public sector, such as using Iraqi codes for component libraries, considering local market factors, promoting cooperation between government agencies and design teams, and involving the contractor early in the design process to prevent conflicts later. BIM 4D implementation can lead to more accurate project scheduling in Iraq's architectural projects.				
4	**Title of Study**	**Researchers Name**	**Year**	**Country**	**Paper Type**
	Time and cost planning of a housing construction project using building information modeling. [13].	Amit Shriwas	2020	India	Research Article

Tools Techniques	The paper did not mention any specific tools used in the research. However, the study team used a preliminary survey and historical data.
Methods used	-Historical data (Desk research to collect data, Online sources). -An industry-wide survey. - Semi-structured interviews using an online survey. - Field analysis.
Results	The results showed that using 4D and 5D BIM improved the scheduling of tasks, planning, monitoring, and clash conflicts for all building construction stages.
Conclusions	The paper concluded that applying Building Information Modeling (BIM) can greatly advance the construction process and enhance execution in the multidisciplinary and multiorganizational field. 5D BIM, which provides visualizing, timetables, planning, monitoring, and clash of conflicts of a structure's pre-construction, construction, and post-construction activities, was created by integrating 3D aspects of a building model with its planned time and cost parameters.

5.BENEFITS OF QUANTITY TAKE-OFF USING 3D BIM

Quantity take-off by 3D BIM (Building Information Modeling) offers several significant benefits that can significantly improve the construction process and project outcomes. Some of the key advantages include:

1- Accurate and Reliable Measurements: 3D BIM models provide a high level of accuracy in quantity take-off, as the measurements are based on the actual 3D representation of the building elements, reducing errors and discrepancies in traditional 2D take-off methods, leading to more reliable cost estimates and construction planning [14].
2- Time Efficiency: BIM software tools streamline the quantity take-off process by allowing for automated or semi-automated extraction of quantities from the 3D model, saving time compared to manual take-off methods and enabling quicker response to project changes and tighter schedules [15].
3- Better Design Optimization: The 3D BIM model provides a comprehensive overview of the entire project, making it easier to identify potential design inefficiencies and clashes before construction begins, optimizing the design, reducing material wastage, and saving costs [16].
4- Change Management: Construction projects often change during their lifecycle. With 3D BIM, quantity take-off and cost estimation can be quickly adjusted to reflect design changes, ensuring the project stays on track and within budget [16].
5- Sustainability and Green Building: BIM can analyze material quantities and their environmental impact, supporting sustainable design decisions and promoting green building practices [17].

6.EVALUATING STAGE

The aim of conducting the assessment is to recognize and comprehend the current state of the project and to pinpoint the key indicators. Underlying factors leading to differences between the three approaches: Quantity take-off estimated by BIM, Quantity take-off estimated by Tender, and Quantity take-off estimated by site work, offering a foundation for implementing corrective measures and a more equitable evaluation of the project to prevent encountering the same problem during recovery. The assessment is composed of two stages**:**

6.1.Documents Examine

Initiating an evaluation requires reviewing the pertinent project documents, as they serve as the starting point to gain insight, perspective, and understanding into why the project is facing challenges. A practical case study was employed to attain the research objective and comprehend the evaluation stage and its fundamental steps. The researcher interviewed the officials, including engineers and contractors involved in the project, and collected project documents, such as:

1- AutoCAD 2D drawings.
2- Bill of quantities (Estimated quantities and Actual quantities).

6.1.1.Case Study for the Model School Buildings Project (18 class)

A building is situated in a location of land with dimensions of (70×50) meters estimated (at 3500) square meters, where the project consisted of four components:

1- Main school building: located on the eastern side of the project and consisting of two floors, including classrooms, a bathroom, laboratory rooms, administration rooms, electric rooms, and service rooms with (1350) square meters.
2- Guard building: located on the eastern side of the project, 10 meters from the main school building, consisting of one room and one bathroom, with an area of (24) square meters.
3- W.C. Building: located on the western side of the project, 15 meters from the main school building, consisting of three entrances, one room, and ten bathrooms, with an area of (135) square meters.
4- landscape (site layout): with an area of (450) square meters, footpaths, and the entrance and gardens. Table 2. summarizes details of the structural Main School building as a case study.

Table 2 Main School Building Information (Case Study).

Items	Descriptions
Location	Iraq/Baghdad
Type of Contract	Bill of Quantities Contract
Height of Buildings	8.15m
Construction area	1350 m²
Number of Floors	2
Number of laboratory rooms	2 lab rooms (First Floor)
Number of classroom rooms	Eight (Ground Floor) Ten (First Floor)
Number of Administration rooms	Four (Ground Floor)
Number of Electric rooms	One (Ground Floor) One (First Floor)
Facilities	Six rooms for different purposes
Deep of Excavation	1.65 m
Foundation, Slabs, Beams, Columns	Concrete Materials

6.1.1.1.Justifications for Choosing the Case Study

Selecting this particular building as a case study was motivated by the following factors:

1- The building is part of the model school buildings project.
2- As these prototype structures are not fully completed, utilizing BIM for visualization, document creation, updates, quantity take-off, and cost estimation will aid in their completion and operation.
3- Multiple change orders were issued due to design errors, omissions, inadequate understanding, and inadequate coordination among major disciplines or the project.

6.2.Interviews and Site Visits

The researcher examined the final designs in AutoCAD and PDF formats, then interviewed the building implementers and visited the building to capture photographs from various perspectives, as depicted in Fig. 1. The purpose of these activities was to address the issue of inconsistencies between some architectural and construction drawings. Additionally, the researcher made several modifications to the 3D model in the Revit program to represent the real-life situation accurately. The researcher also discussed the concept of insufficient documentation and explained how BIM tools could be utilized to generate these documents. Through field visits and interviews, the researcher identified the missing data and other details necessary for quantity take-off (QTO) and prioritized the problems causing difficulties.

Fig. 1 Pictures of the Project.

7.THE PHASE OF DEVELOPING A RECOVERY PLAN UTILIZING 3D BIM

It is seen as a contemporary approach that aids in analyzing a case study project. It assists in identifying design flaws and determining the underlying causes behind inaccurate and insufficient calculations of work quantities. It also helps identify the reasons for inaccurate predictions of activity durations. These insights serve as valuable inputs for future corrective actions to mitigate deviations in project durations, particularly in school building projects.

7.1.The Software Used in this Study

BIM was implemented using Revit 2021. The results were presented and compared using Excel 2019. To convert construction drawings from PDF to AutoCAD format, AutoCAD 2021 was employed.

1- AutoCAD Software: Engineers and technicians have relied on AutoCAD in two-dimensional engineering and graphics programs and converted it to PDF files, a documentation extension to facilitate their storage and movement; therefore, flipping it back to an AutoCAD application before initiating the modeling process was essential. However, BIM software would be much easier in the design process. Project drawings were obtained and exported to Revit.

2- Revit Software: Revit is a design and documentation system that enables BIM for construction project design, drawings, and schedules. BIM provides project design, scope, quantities, and phases as needed. BIM relies on Revit software for its essential operations. Drawing sheets, 2D and 3D views, and a quantity schedule comprise Revit's 3D model, containing information from the building model database. Revit's parametric change engine synchronizes changes to drawing sheets, schedules, sections, and plans. High-quality graphics and enhanced visual representations are possible using Revit, which allows multidisciplinary collaboration. The software interface has various components that emerge immediately after a project starts. These components work together to enable users to create building information models.

3- MS Excel Software: Due to the many paragraphs of the project and its complexity, the tool utilized by the researcher was Excel 2019 to divide the project into regular sequences and, according to the table of quantities for the building, to be entered into the Revit program to model the model correctly and consistently, creating a central database where all the building components are stored. On this basis, the bills of quantities are calculated and exported to Excel to picture Take-off Quantity Reports.

7.2.Creating a 3D Visual Model Using BIM for the Main School Building

Revit offers robust visualization capabilities that allow users to create compelling visual representations of building designs. These visualizations help stakeholders, such as architects, engineers, and clients, to better understand and communicate the project. The researcher employed Revit, a BIM technology tool, to create a distinct structural model as part of the research. During this phase, the researcher analyzed the primary causes of implementation-related issues, which include the lack of modern techniques and inadequate perception and visibility of the designer. Disparities between design documentation, including specifications and drawings, and the actual implementation were also identified as contributing factors. Furthermore, inaccuracies and lack of detail in calculating work quantities were recognized as challenges. The following is an overview of the design phases for the three-dimensional buildings, explicitly focusing on the structural model.

7.2.1.Create Levels

Revit levels are essential for establishing a building model's vertical dimension and organization. They help define the heights of various building elements, ensure consistency throughout the project, and facilitate efficient collaboration and coordination among project stakeholders—the levels of a case study made in Revit, as shown in Fig. 2.

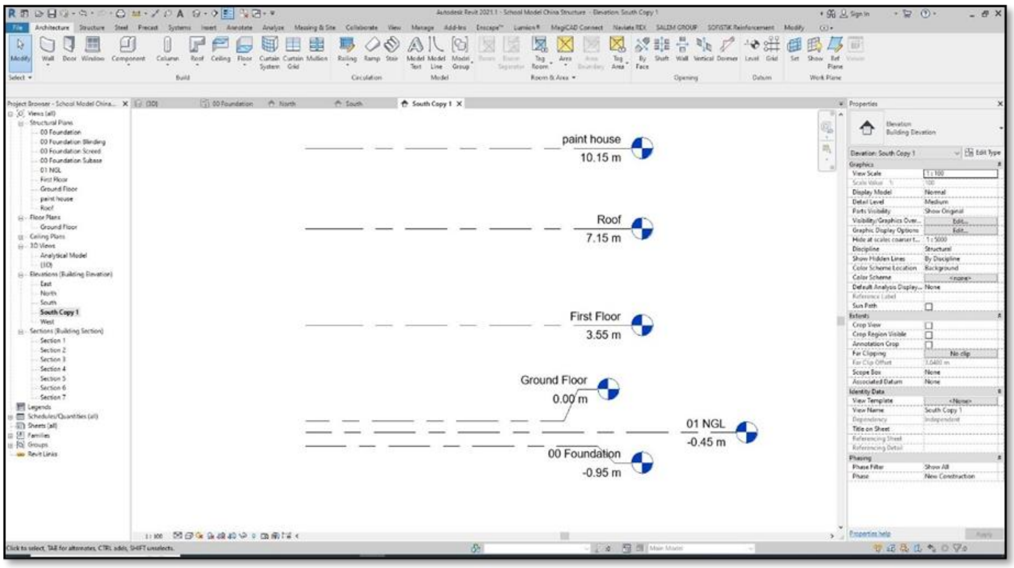

Fig. 2 Main School Building Levels.

7.2.2.Create Grids

Grids are essential for establishing a visual reference system for and aligning building components. They provide horizontal and vertical guidelines that help accurately place and align elements within the model. Grids are typically placed at the intersection points of columns, walls, and other critical structural components. They act as a reference for positioning and aligning these elements accurately. The grid lines of the case study were made in Revit, as shown in Fig. 3.

7.2.3.Site Work

Excavation refers to removing earth, soil, or rock from a site to create a cavity, trench, or hole for various purposes. Excavation work can encompass a wide range of activities, depending on the specific project and its requirements, and includes the following:

1- Excavation work for (Strip and Separated) foundation, depth between (1.5 -3 m), as shown in Fig. 4.

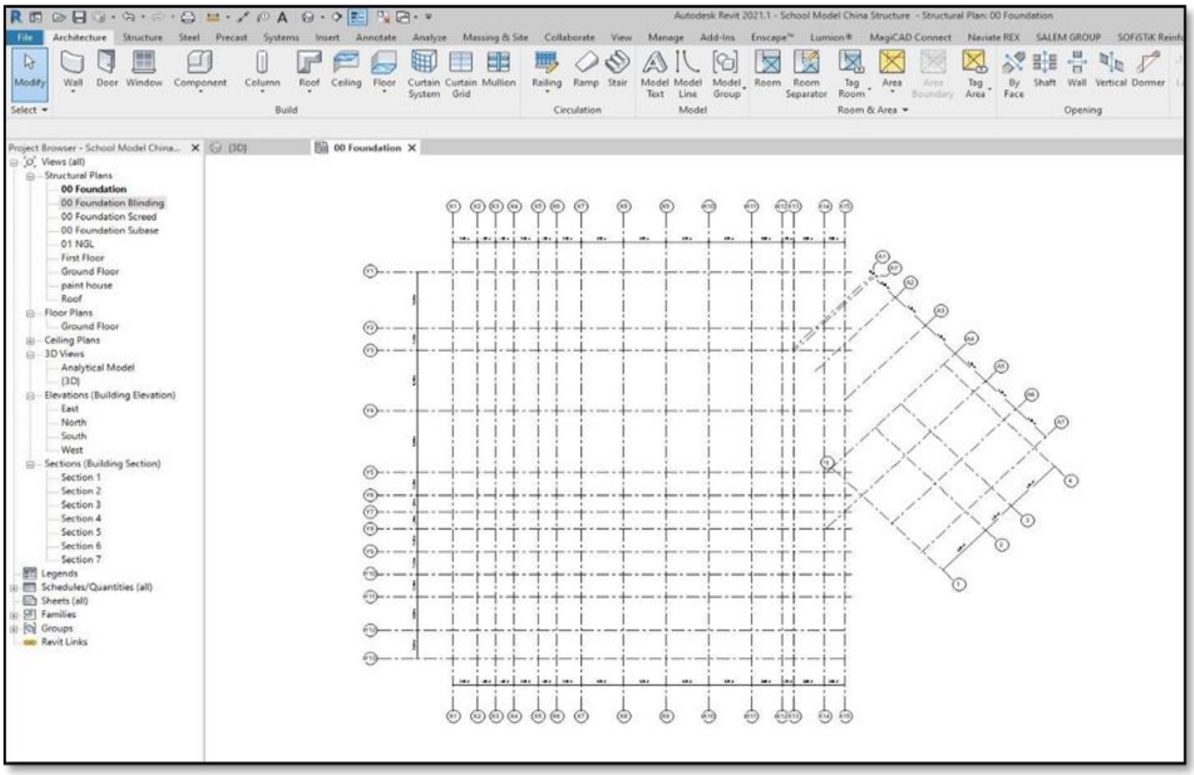

Fig. 3 Main School Building Gridlines.

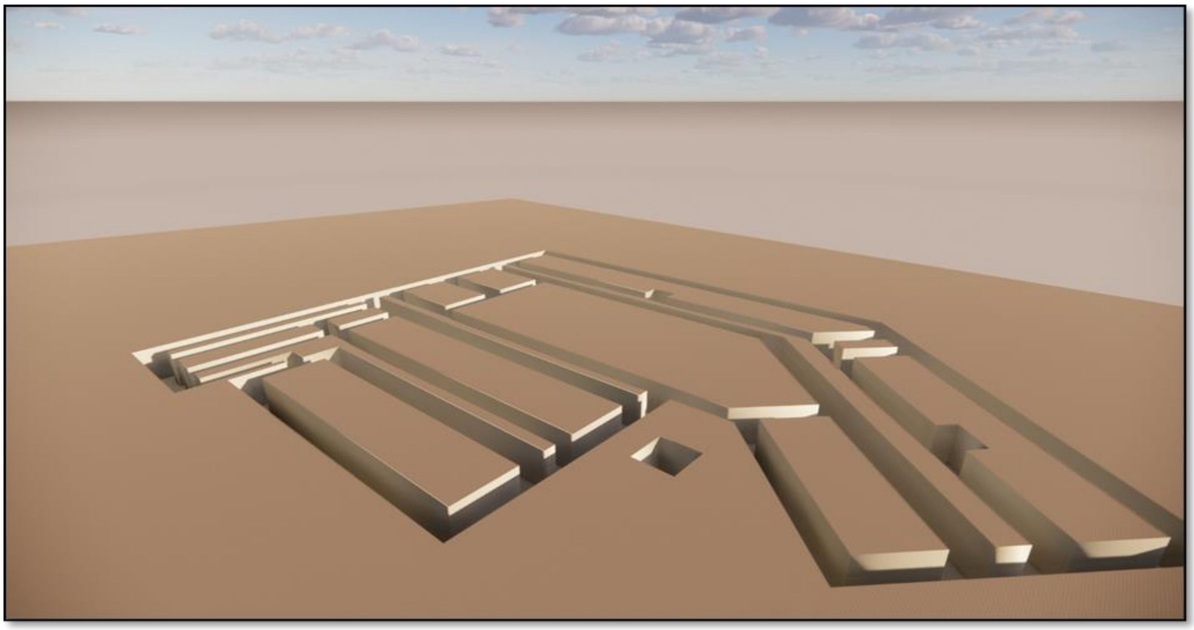

Fig. 4 Excavation Work for Main School Building.

2- Backfilling with sub-base materials refers to filling excavated areas or trenches with a layer of compacted material that serves as a foundation for subsequent construction or to restore the ground to its original level. It helps distribute loads, improves the overall structural integrity, and minimizes settlement issues. Proper compaction and adherence to engineering standards are crucial to ensure the long-term performance of the backfilled area. Figure 5 shows backfilling with sub-base for (Strip and Separated) foundation; thickness (500 mm).

7.2.4.Concrete Structure (Under D.P.C)

The concrete structure under the foundation refers to the construction of a concrete footing or foundation slab that supports and transfers the load of a structure to the underlying soil. It is a critical component of the construction process and provides a solid base for the entire building. It includes the following:

1- Blinding concrete: It is known as a blinding layer or blinding coat, refers to a thin layer of low-strength concrete placed on the prepared surface before the construction of foundations or slabs. The primary purpose of blinding concrete is to create a clean and level surface that acts as a barrier between the foundation or slab and the underlying soil or substrate. Figure 6 shows a blinding concrete layer for (Strip and Separated) foundation; thickness (100 mm).

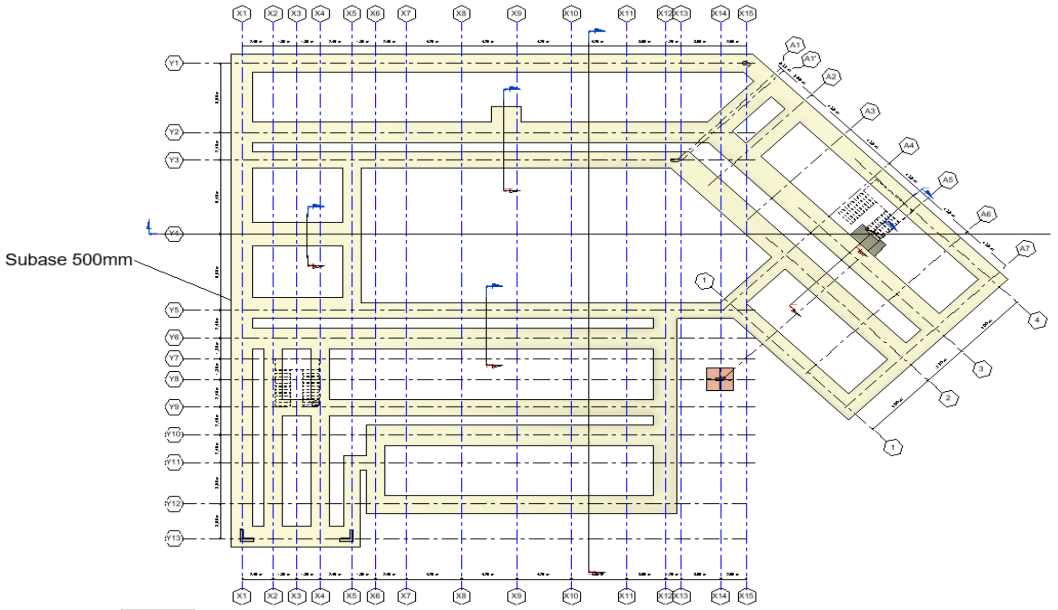

Fig. 5 Backfilling with Sub-Base Materials for Main School Building.

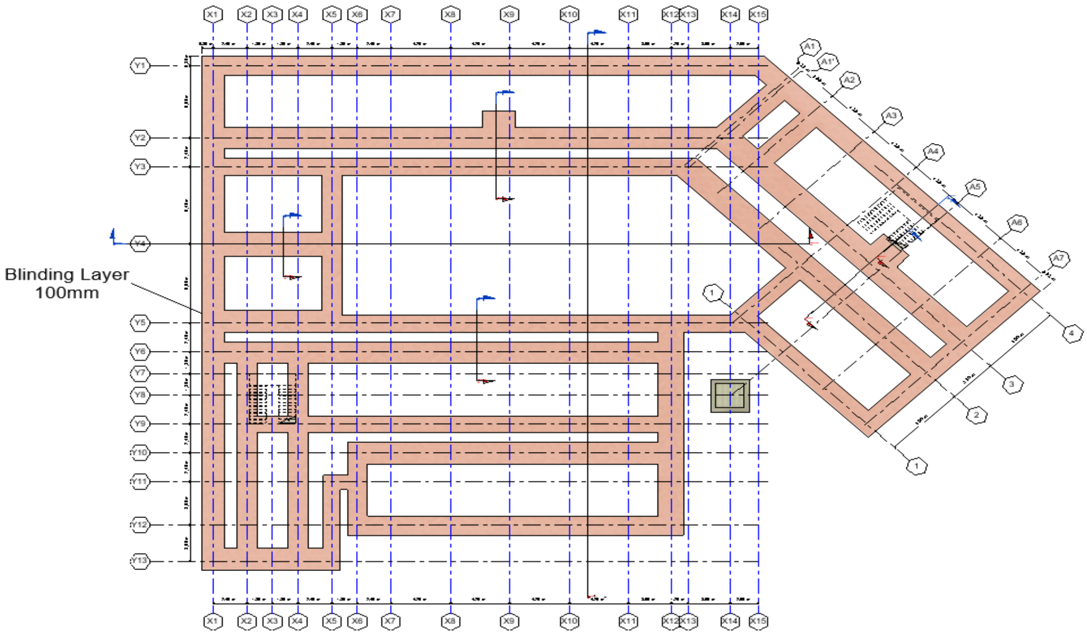

Fig. 6 Blinding Concrete Layer for Main School Building.

2- Screed concrete: It is a technique used to level and smooth the surface of a concrete slab or foundation. It involves using a screed, a straightedge, or a specialized tool to distribute and strike off the excess concrete to achieve a flat and even finish. When screeding is done under a foundation, it helps ensure the concrete base is level, providing a solid and stable surface for the above structure. Figure 7 shows the screed concrete layer for (Strip and Separated) foundation; thickness (50 mm).

3- Foundation: The main school building has two types of foundations, Strip and Separate, with a uniform thickness of 500mm. This information is depicted in Fig. 8, which showcases the top and side views of the structural design.

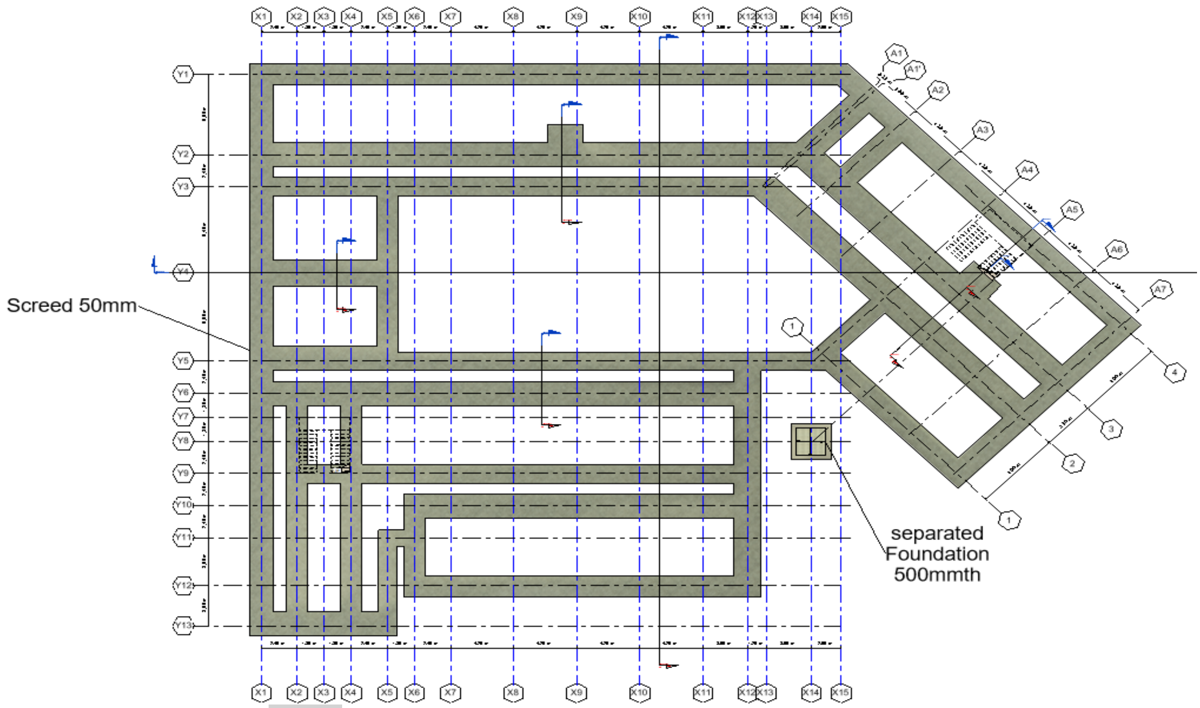

Fig. 7 Screed Concrete Layer for Main School Building.

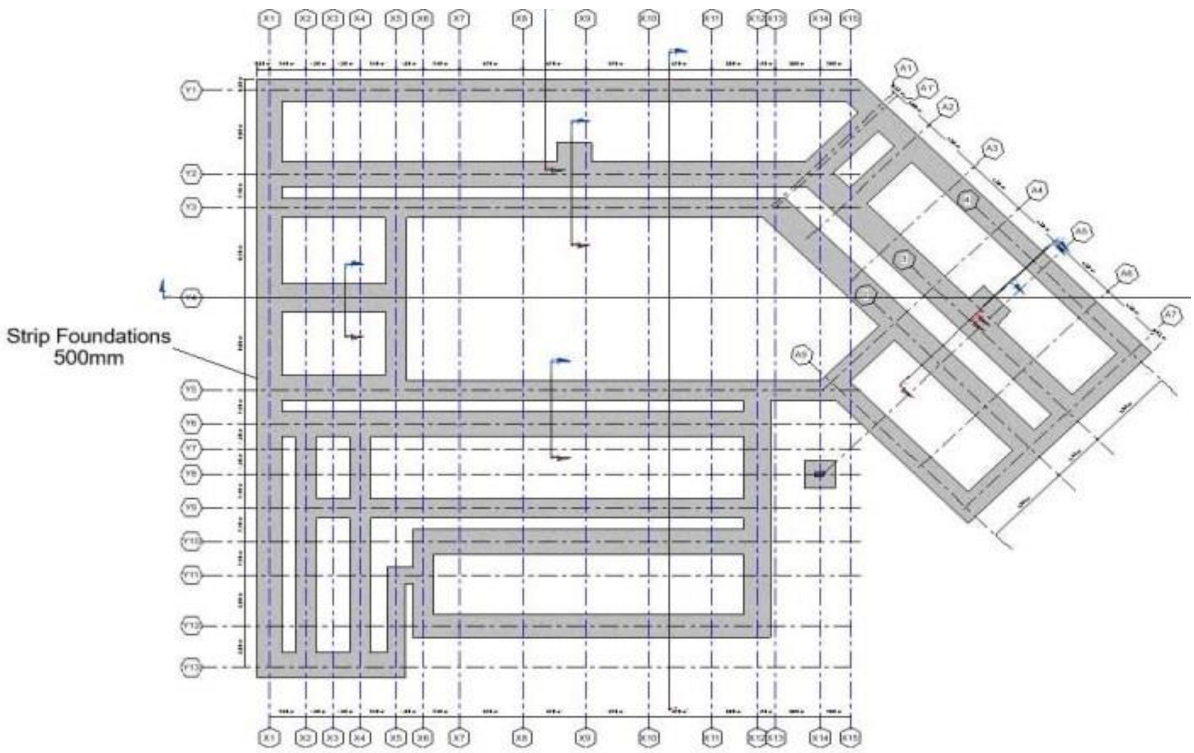

Fig. 8 The foundation of the Main School Building.

7.2.5.Concrete Structure (Above D.P.C)

1- Columns: The researcher models the building's columns after the design of the foundation. The building consists of 262 columns of various types and diameters distributed on the ground, first floors, and penthouse, with 127 columns for each floor and eight columns for a penthouse. The researcher created the columns, as shown in Fig. 9.

2- Beams: The concrete beams in the case study were rectangular and had different dimensions. These dimensions include (250mm×500mm), (250mm×600mm), (250mm×700mm), (250mm×800mm), and (300mm×500mm). The researcher created these beams, as shown in Fig. 10.

3- Stairs: Many buildings have stairs, and the Revit software offers specific design tools for creating stairs. These tools give the user control over the fundamental construction components of stairs, such as treads, stringers, and risers. By establishing design rules for these elements, Revit software automatically constructs a 3D geometry of the stairs for the user. The case study contains two internal stairs, as shown in Fig. 11.

4- Slabs: Slabs refer to the horizontal building elements representing a building model's floors, ceilings, or roof structures. Slabs are essential for creating a detailed and accurate representation of construction and design. Using Revit software, the researcher efficiently modeled the slabs, i.e., thickness (180mm), depicted in Fig. 12. Additionally, adding slabs, columns, and beams using Revit was significantly quicker than traditional methods.

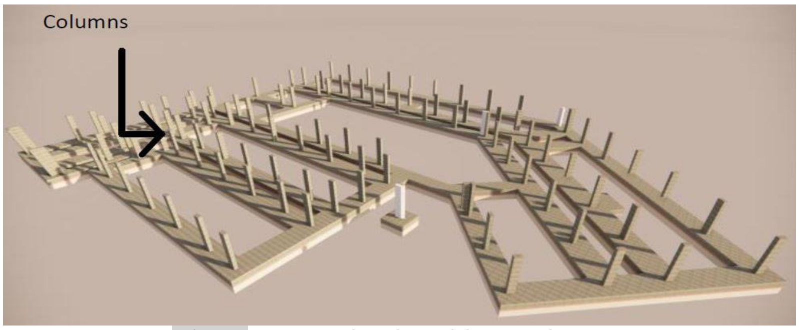

Fig. 9 Main School Building Columns.

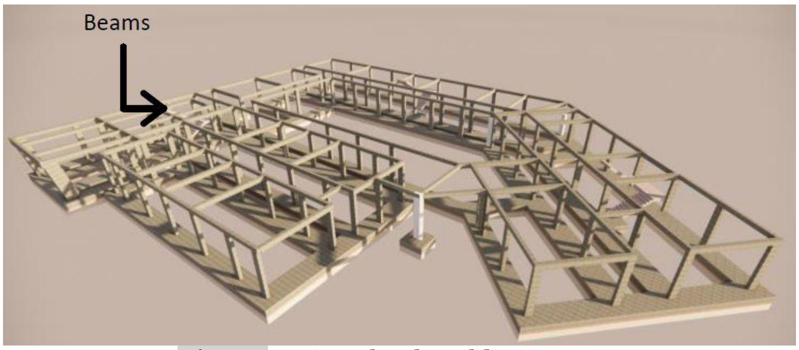

Fig. 10 Main School Building Beams.

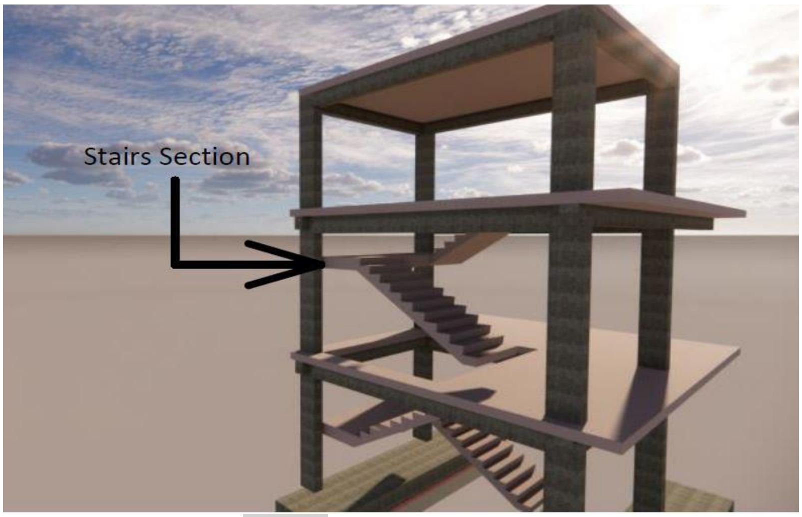

Fig. 11 3D Stair Section

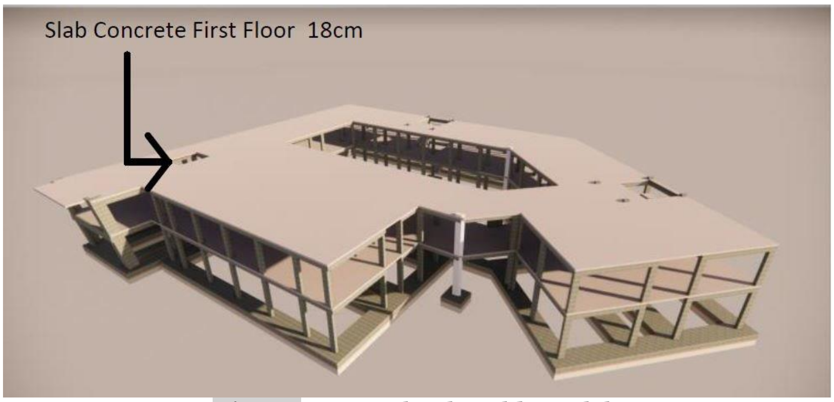

Fig. 12 Main School Building Slab.

7.2.6.Brick Construction Work

Walls are essential construction components that Revit software can readily build. Instead of mere collections of lines, walls in Revit are created by combining multiple layers of material to give them thickness. Architectural (non-structural) and structural Revit walls exist. The case study has four wall types. A 480mm brick wall was the first type. A 360mm brick wall was the second type. The third form was 240mm brick walls. The fourth form was a 120mm partition brick wall. The researcher used Revit to model the building walls, as shown in Fig. 13, resulting in a faster and error-resistant process than traditional methods.

7.2.7.Structural Model Complete

The researcher has finished finishing all the works related to the structural works, in addition to the building works, as shown in Fig. 14.

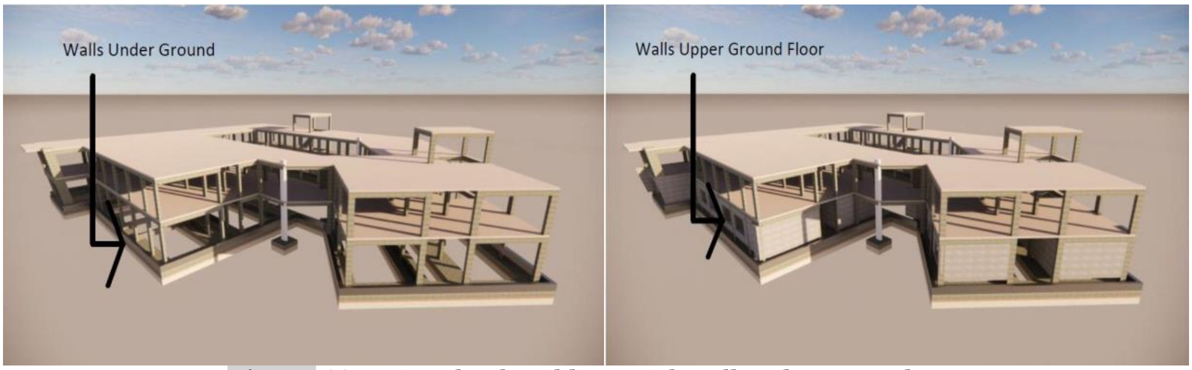

Fig. 13 (1) Main School Building Brick wall under Ground
(2) Main School Building Brick Wall Upper Ground.

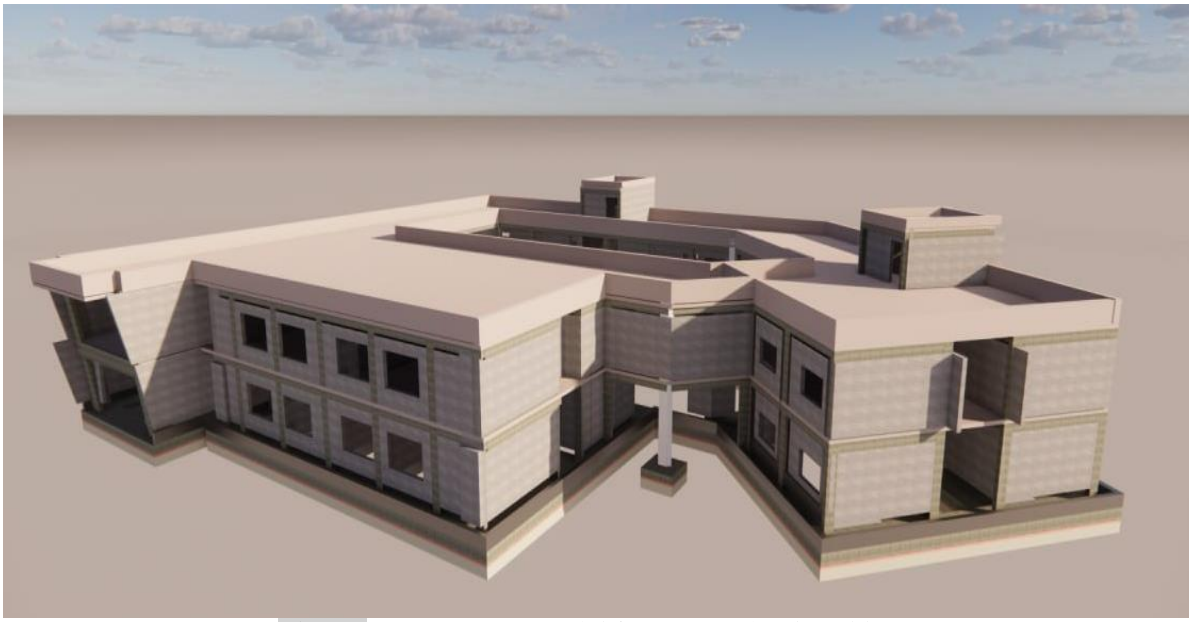

Fig. 14 3D Structure Model for Main School Building.

8.EXTRACT THE ESTIMATE QUANTITIES FROM REVIT

Extracting estimate quantities from Revit requires using tools and methods to access the model data and perform quantity take-offs, as follows:

1- The schedule/quantities or material take-off are used to determine the quantities of each element. Therefore, depending on the element type, the bill of quantities can be classified into various types, such as columns and bridges, as shown in Fig. 15.

2- All structural components, including foundations, columns, beams, and slabs., are included in the structural model. Following the selection of the specialization, the columns displayed for the element's properties, whose amounts are computed, are decided, as shown in Fig. 16, including materials, dimensions, numbers, size, area, and type.

3- Automatically connecting values to charts and using the computer to check all aspects reduces the possibility of forgetting or leaving out some, as shown in Fig. 17. Therefore, the BOQ is automatically generated once the BIM modeling process is complete. All objects in all charts and tables will have links made to them for any changes to be reflected in the quantities, interfaces, and sections in case of a difference not mentioned in conventional approaches.

4- After finishing the quantities in the Revit program, they are exported as a report to the Excel program and formatted by the specifications, as shown in Fig. 18.

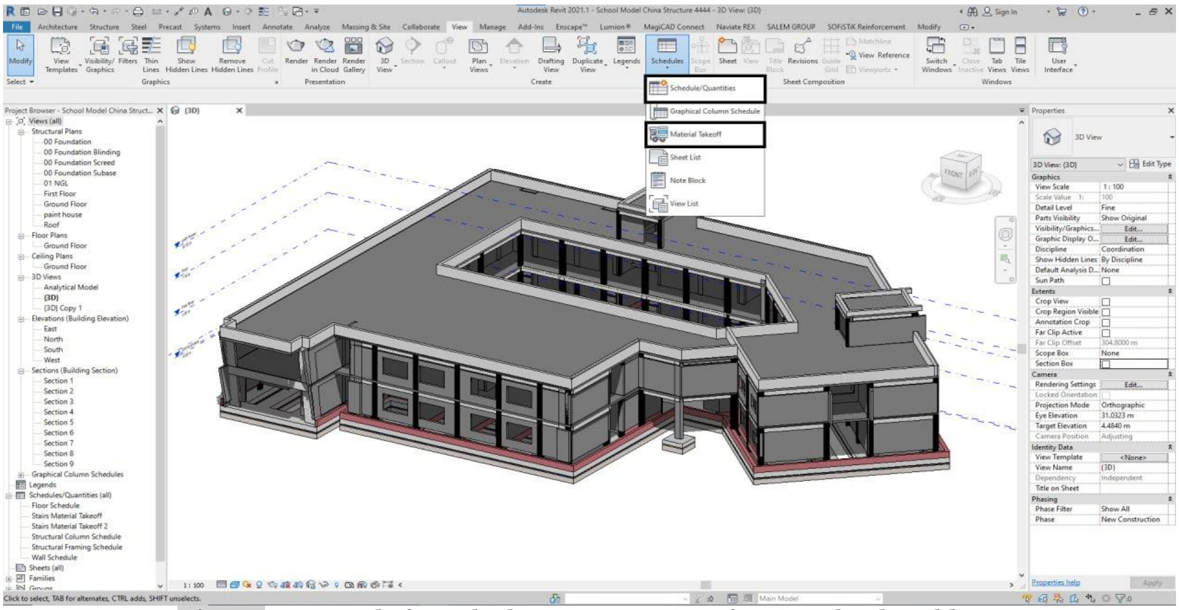

Fig. 15 BIM Tools for Calculating Quantities of Main School Building.

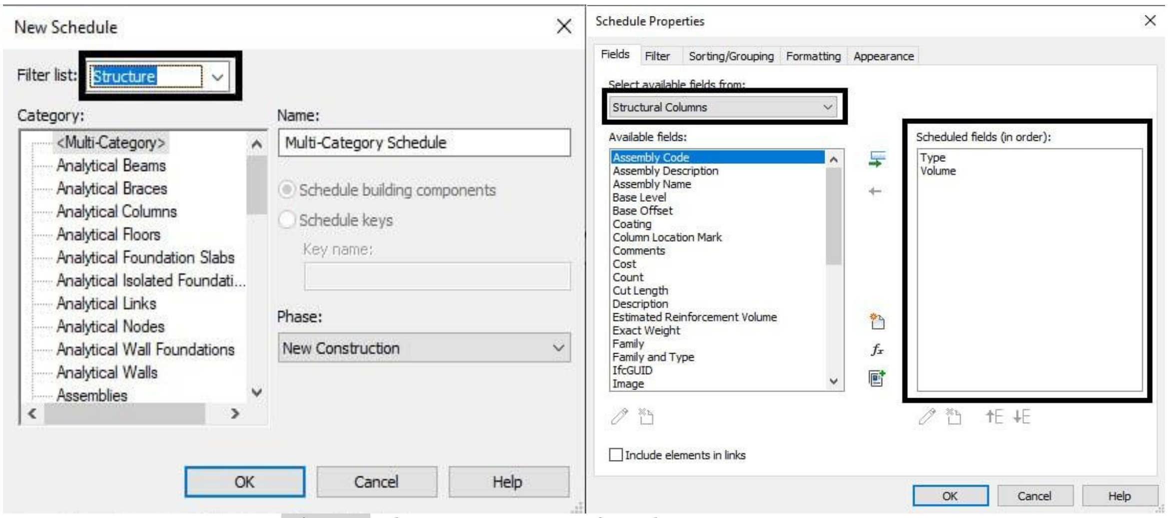

Fig. 16 The Revit Process for Obtaining Quantities.

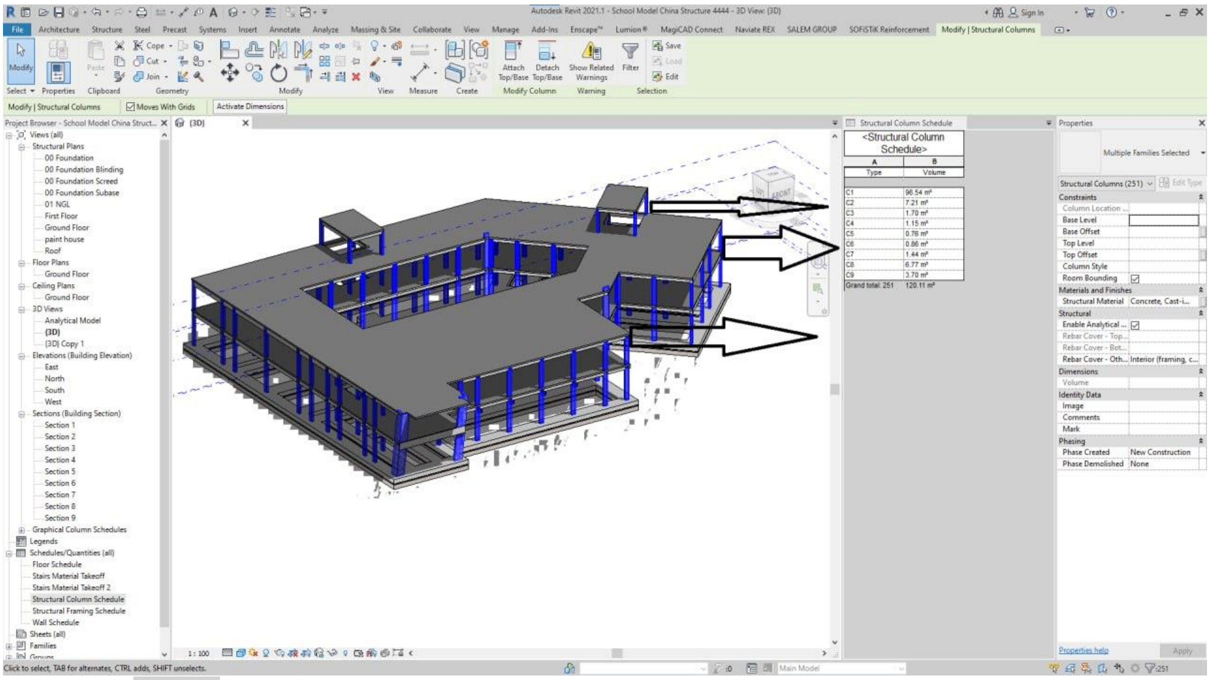

Fig. 17 Automatic Chart and Bill of Quantities Linkage for Any Item Using BIM.

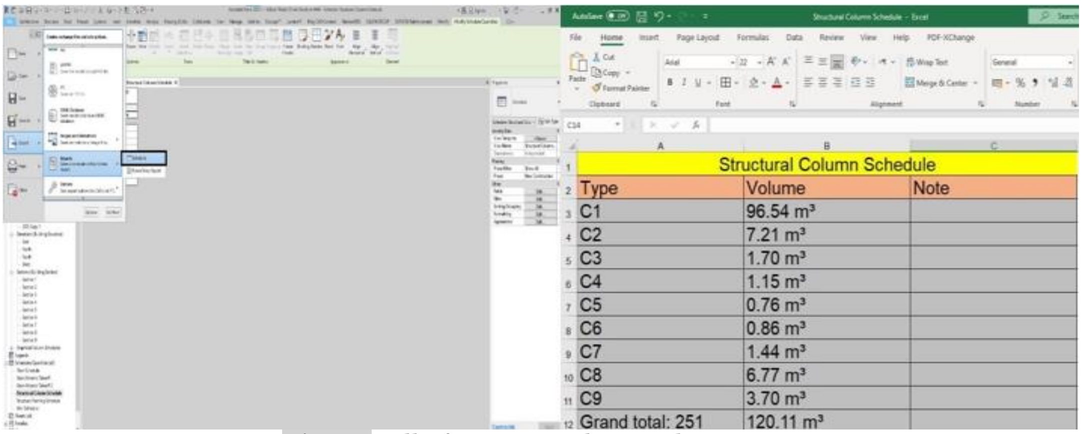

Fig. 18 Bill of Quantities by Excel program.

9.COMPARISON BILL OF QUANTITIES

The information is arranged into a table format that makes subsequent analysis easier after the prior processes are finished, and the quantities report is obtained from Revit to Excel, making comparing the quantities of various components simple. A contrast is drawn between the quantities derived from the actual building progress and the estimated quantities included in the tender. The quantities obtained using Building Information Modeling (BIM) technology are also considered.

9.1.Comparison Bill of Quantities for Excavation Work

The quantities of excavation work are shown in Table 3, showing the percentages of the differences between Revit's BIM-calculated quantities and the actual quantities, the estimator's bill of quantities. Although the same designs were used to calculate excavation work quantities, the BIM quantity surveying approach differs from the tender approach. Where the differences were (116 m^3) in the strip foundation and (2.6 m^3) in the separated foundation due to a miss calculation from the traditional estimator that relied on the estimated excavation depth, while the BIM relied on the depth calculated according to the structural drawing, especially the foundation drawing that shows the layers through which the excavation depth is calculated because hand-recalculating the excavation work yielded 1705 m^3, which is closer to BIM's quantity.

9.2.Comparison Bill of Quantities for Backfilling

Table 4 shows the differences between the quantities of backfilling with sub-base calculated by the three approaches. Where the quantities calculated by BIM are proven to be the closest to the actual quantities. A significant difference between them and the quantities calculated by the traditional estimator (Tender) was observed because this quantity relied on the estimated backfilling width. The BIM relied on the width of the backfilling calculated according to the design drawings.

Table 3 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Excavation Work of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Excavation work for							
- Strip foundation	M^3	1704	1820	1490	116	214	330
- Separated foundation	M^3	15.4	18	14	2.6	1.4	4.0

Table 4 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Backfilling of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Backfilling with sub-base (500mm) thick							
- Strip foundation	M^3	524.4	552	522	27.6	2.4	30
- Separated foundation	M^3	5.68	6	2.4	0.32	3.28	3.6

9.3. Comparison Bill of Quantities for Blinding Concrete

There are no big differences in blinding concrete quantities calculated by the BIM and actual construction progress; however, there are significant of the big differences between the quantities calculated by the Revit and quantities calculated by the estimator (Tender) can be attributed to several factors like Guesswork is based on imprecise estimations and assumptions, which might not always match the actual numbers, similar to estimation errors. Without accurate measurements or data, estimating quantities might result in considerable differences, according to Table 5.

9.4. Comparison Bill of Quantities for Screed Concrete

The differences between the quantities of screed concrete layer calculated by the three approaches are displayed in Table 6. The significant discrepancy between the quantities calculated in BIM and the actual quantities is due to incorrect calculation methodologies. For example, the thickness of the screed, coverage area, or volume calculations are some of the methodologies used to calculate the quantity of screed concrete. Quantity estimation errors may result from using the improper methodology or carrying out the analyses incorrectly.

9.5. Comparison Bill of Quantities for Foundation Concrete

The foundation quantities, determined using three approaches, are shown in Table 7. It has been noted that the value offered by the tender had discrepancies of more than (30 m^3). Investigation into this discrepancy revealed that while the thickness and width of the foundation layer were known, the estimator had calculated the length of the strip foundation and separated the foundation incorrectly, resulting in the estimated quantities being greater than the actual quantities.

Table 5 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Blinding Concrete of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Blinding concrete (100mm) thick							
- Strip foundation	M^2	896.5	955	895	58.5	1.5	60
- Separated foundation	M^2	7.8	10	7.3	2.2	0.5	2.7

Table 6 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Screed Concrete of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Screed Concrete (50mm) Thick							
- Strip foundation	M^2	800	862	800	62	0.0	62
- Separated foundation	M^2	7.76	8	7	0.24	0.76	1.0

Table 7 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Screed Concrete of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Foundation concrete (500mm) thick							
- Strip foundation	M^3	400	431	400	31	0.0	31
- Separated foundation	M^3	4.38	4	3.5	0.38	0.88	0.5

9.6. Comparison Bill of Quantities for Column Concrete

The quantities of the concrete columns were, as shown in Table 8, after the building's columns had been positioned, showing the discrepancies between the numbers computed using the three methodologies. The gap between BIM predicted quantities and tender quantities is less than twenty cubic meters (-20 m^3), as stated in the table below, which might be ascribed to the specifics that the designs did not include. Additionally, when the estimator calculated the number of columns, the thickness of the ceiling was not deducted from the column's overall height, which caused the estimated quantity to increase. While there is a discrepancy of more than (2.5 m^3) between BIM estimated amounts and actual quantities, it might still be considered a reasonable, close gap in proportion to real quantity.

9.7. Comparison Bill of Quantities for Beam Concrete

In the project, the concrete beam quantity in Table 9 exceeded the tender estimate by less than 40 cubic meters, as calculated by Revit. Manual calculations showed a total beam length of approximately 1350 meters, consistent with the estimate that an experienced estimator prepared. The total length was determined using BIM based on individual beam dimensions and design drawings. Unlike the traditional method, it tended to overestimate quantities by multiplying the total length by the largest dimensions. BIM provided more accurate results aligned with reality.

9.8. Comparison Bill of Quantities for Stairs Concrete

It is often said that stairs are accurately represented in Revit; however, its ability to calculate concrete quantities is often criticized, especially when calculating the concrete area of tread and risers. The case presented in this study is excluded from exposure to this flaw. Table 10 shows the quantities of the stair concrete, calculated by three approaches. It is noticed that the quantities of concrete were approximately similar for the three readings.

9.9. Comparison Bill of Quantities for Slab Concrete

The quantities of slab concrete utilized in the floors, as calculated by Revit, as well as the actual and tender quantities, are shown in Table 11. Where it was noted that there was a discrepancy between tender quantities and actual quantities of less than fifteen cubic meters (15 m^3). When this discrepancy was investigated, it was discovered, by trial and error, that the estimator, when calculating the quantity of slab, used a hand method to estimate the slab's quantities, assuming that the same areas were used in both results and considering that the thicknesses used by Revit were eighteen centimeters (18 cm) for both floors, as specified in the blueprints.

Table 8 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Column Concrete of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Column Concrete	M^3	103	123	103	20	0.0	20

Table 9 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Beam Concrete of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Beam Concrete	M^3	119.3	160	117.3	40.7	2.0	42.7

Table 10 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Stairs Concrete of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Stairs Concrete	M^3	20.5	22	19	1.5	1.5	3.0

Table 11 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Slab Concrete of Main School Building.

Details	Unit	Quantity			Difference between BIM and as- Tender	Difference between BIM and as- Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Slab Concrete (180mm) thick	M^3	506.3	515	500	8.7	6.3	15

9.10. Comparison Bill of Quantities for Brick Work

The quantities of brickwork are illustrated in Table 12, which shows the differences between the quantities calculated by Revit according to BIM. The quantities calculated by the estimator as presented in the bill of quantities and the actual quantities. Although the same blueprints were used in calculating the brickwork quantities, there were differences between the traditional approach, BIM, traditional, and the actual approaches of quantity surveying (Under D.P.C). While the difference increased due to the difference in the used approach in the twenty-four centimeters (24 cm) width wall was less than fifty cubic meters (50 m3). The difference was more than twenty-five cubic meters (25 m3) in the thirty-six centimeters (36 cm) width wall, which might be attributed to a miss calculation from the traditional estimator because when the quantity of the thirty-six centimeters (36 cm) width wall was recalculated by hand, it was seventeen a cubic meter (17 m3), which is closer to the quantity obtained by BIM.

10. THE VALIDITY TEST

The validity of calculating the quantities by BIM, Tender, and Actual was proved using accuracy percentage, which measures how closely a measurement or test resembles its actual or ideal value. The accuracy percentage of the B.O.Q estimated by (Revit vs. As-tender, Revit vs. As-built, and tender vs. As-built) was found by applying Eq. (1) rearranged as follows [18]:

$$A\% = 100\% - \frac{\left(\sum_1^n \frac{|Xi-Yi|}{Yi} \times 100\right)}{n} \quad (1)$$

Were

A is the Accuracy percentage.

Xi is the Estimated quantity using Navies work or the estimated quantity using the traditional method (Tender).

Yi is the Estimated quantity (As-built).

n is the total number of items.

In Table 13, the percentage of differences was calculated based on the following Eqs. (2)-(6) may be rearranged as follows [19].

$$\text{Error \% BIM (Revit) vs. As} - \text{Estimate (Tender)} = \frac{\text{BIM quantities} - \text{Estimate quantities}}{\text{Estimate quantities}} * 100 \quad (2)$$

$$\text{Error \% BIM (Revit) vs. As} - \text{Actual (as built)} = \frac{\text{BIM quantities} - \text{Actual quantities}}{\text{Actual quantities}} * 100 \quad (3)$$

$$\text{Error \% Tender vs. As} - \text{Actual} = \frac{\text{Tender Quantities} - \text{Actual quantities}}{\text{Actual quantities}} * 100 \quad (4)$$

$$\text{Mean error \%} = \Sigma\ \text{error}/n \quad (5)$$

$$\text{Accuracy} = 100\% - \text{mean error} \quad (6)$$

Table 12 Comparison Estimate (Actual), Estimate (Tender), and Estimate (BIM) Quantities for Brick Work of Main School Building

Details	Unit	Quantity			Difference between BIM and as-Tender	Difference between BIM and as-Actual	Difference between Tender and as- Actual
		B.O.Q Revit (BIM)	B.O.Q Estimate (Tender)	B.O.Q Estimate Actual			
Brick Wall Under D.P.C							
-240mm	M3	53.22	100	45	46.8	8.22	55
-360mm	M3	15	40	14	25	1.0	26
Above D.P.C							
-120mm	M2	149	155	136	6.0	13	19
-240mm	M2	2471	2640	2116	169	355	524
-360mm	M2	133	175	130	42	3.0	45
-480mm	M2	9.3	16	9.0	6.7	0.3	7.0

Table 13 The Accuracy Comparison of Actual, Tender, and BIM Quantities for Main School Building.

Item	Unit	B. O.Q Revit (BIM)	B. O.Q Estimate (Tender)	B.O.Q Actual	Error% BIM vs. as-Tender	Error% BIM vs. as- Actual	Error% Tender vs. as- Actual
Excavation, depth between (1.5-3m):							
- Strip foundation	M3	1704	1820	1491	6.4	14.29	22.07
- Separated foundation	M3	15.4	18	14	14.4	10.0	28.57
Backfilling with sub-base materials (500mm)							
- Strip foundation	M3	524.4	552	522	0.46	0.46	5.75
- Separated foundation	M3	5.68	6	5	5.33	13.6	20.0
Blinding Concrete thickness (100mm):							
- Strip foundation	M2	896.5	955	895	6.13	0.17	6.70
- Separated foundation	M2	7.8	10	7	22.0	11.43	42.86
Screed Concrete thickness (50mm):							
- Strip foundation	M2	800	862	800	7.19	0.0	7.75
- Separated foundation	M2	7.76	8	7	3.0	10.86	14.29
Concrete foundation thickness (500mm)							
- Strip foundation	M3	400	431	400	7.19	0.0	7.75
- Separated foundation	M3	4.38	4	4	9.5	9.5	0.0
Concrete Column	M3	103	123	103	16.26	0.0	19.42
Concrete Beam	M3	119.3	160	117	25.44	1.97	36.75
Concrete Slab							

Thickness (180mm)	M^3	506.3	515	500	1.69	1.26	3.0
Concrete Stairs	M^3	20.5	22	19	6.82	7.89	15.79
Brick Wall							
Under D.P.C							
-240mm	M^3	53.22	100	45	46.78	18.27	122.22
-360mm	M^3	15	40	14	62.50	7.14	185.71
Above D.P.C							
120mm	M^2	149	155	136	3.87	9.56	13.97
240mm	M^2	2471	2640	2116	6.40	16.78	24.76
360mm	M^2	133	175	130	24.0	2.31	34.62
480mm	M^2	9.3	16	9	41.88	3.33	77.78
Σ error%					**321.79**	**138.82**	**689.76**
(A%)					**83.911**	**93.059**	**65.512**

11.RESULTS

The study's results can be summarized based on the results of the practical side of the study as follows:

1- The design group's obligations were found to be lax (because of incorrect use of advanced computer programs), which increased claims for inaccurate quantities and the discrepancy between planned and realistic quantities for the project during the implementation phase.

2- The quantities for the main school building have been calculated from the Revit program. By applying Eq. (1) on the main school building quantities, the accuracy of BIM vs. as-Tender (83.911) and the accuracy of BIM vs. as-Actual (93.059), which was more than the accuracy of Tender vs. As-Actual (65.512).

12.CONCLUSIONS

Through studying the project documents and reviewing the meeting of the project team, in addition to conducting structured interviews with the implementing agency and after reviewing and matching building plans using BIM, it was found that most of the claims that caused the issuance of deletion orders and a decrease in the quantities of the project arose from errors, omissions and lacking perception. In the step of the design phase, depending on the BIM functions (3D coordination, visualization, collision detection, and quantities take-off), accuracy was achieved in calculating quantities by 93.059%, while using traditional methods in the case study revealed a significant discrepancy in some items between the quantities of the tender and the quantities completed on the job site (Actual) because inaccurate quantity calculations resulted in the filing of change orders. Thus, the 3D BIM level adds great importance to designers, contractors/executors, and beneficiaries in making decisions during design and avoiding problems and errors that occur in the implementation stages, as in implementing the Study Status Project. Table 14 illustrates the most important conclusions by comparing the traditional system that designed the original project and the BIM system for the study's case project.

Table 14 Comparing the Traditional System that Designed the Original Project and the BIM System.

No	Design According to the Traditional Method	Design According to the BIM System
1	The original project was designed and implemented according to the traditional method known as Design Bid Build (DBB) . Declaration as a tender - implementation	The BIM study case project adopted the known method of DB (Build-Design) design and construction, which requires the presence of the contractor/or executor in the early stages of the design process and continues to the implementation process is a requirement of the BIM system
2	The original project was designed by AutoCAD software with approval on paper drawings two-dimensional and three-dimensional representation of Project 3D, characterized by a lack of detail.	The BIM study status project was characterized by creating the triple digital model Dimensions in the Revit program, rich in clear and accurate details.
3	Traditional design lacks national libraries containing materials and detailed elements adopted according to the Iraqi codes.	During work on the study status project designed in modelling programs for the system BIM, they need to identify micro-detailed materials involved in the operations has arisen the project, which must be known in Iraqi codes to work with Modeling programs within item libraries.
4	The project's lack of an information classification system for components and objects is according to internationally approved systems for easy access by Participants.	Project elements and objects information are classified in the program, contributing to preparing quantity schedules and linking them in the future to the schedule and simulating the sequence of its implementation and easy access to this information.
5	The traditional method lacks a system for managing and exchanging information between a team design work and establishing digital storage for file storage and follow-up work from a central location in the design and implementation phase.	Ability to develop a management system and exchange information between participating teams within a site centralized with a database containing all project information with updates over the project's life cycle from design to construction to operation to Maintenance.
6	The lack of standards governing engineering work among design team members produced uncoordinated designs between different specialty models and subsequent conflicts in the implementation phase.	Standards governing engineering work and requiring interdisciplinary coordination of different engineering with contradiction detections resulting in design free of conflicts.

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