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Implementing 7D BIM Modeling into Construction Project Management to Enhance and Monitor Sustainability Principles: A Case Study in Iraq

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ABSTRACT

This research is led to examine and explore various critical rationales and positive impacts of 7D Building Information Modeling (BIM) technology implementation in the construction industry to enhance facilities' sustainability levels. Hence, Greenhouse Gas (GHG) emissions from buildings can be alleviated. A case study was addressed investigating a construction project of the Royal Baghdad building in Iraq. Quantity take-off evaluations using manual and numerical REVIT methods were considered. Also, 7D BIM technology was applied to predict some strategies through which the positive environmental effects of this building can be boosted. Based on those two approaches, the findings revealed that the BIM method adoption helped facilitate the quantity take-off process of the case study and provided accurate, high-performance, reliable, and environmentally friendly means of materials estimation, eliminating massive errors (90.7% to 99.9% accuracy). Furthermore, it was found that (a) minimizing the amount of heavy fuel used in transportation, (b) using efficient fuel (like green fuel) for trucks, (c) applying facility management, and (d) clarifying the maintenance tasks and operation policies in the construction project can enhance the level of sustainability. Applying those four critical aspects can, in turn, can make this project greener and environmentally friendly.

Keywords: Sustainability, environment, BIM technology, 7D modeling, construction, REVIT, quantity take-off.

1. INTRODUCTION

Adopting a new and modern strategy in the design and construction of sustainable buildings has become necessary due to the increase in environmental problems and the new requirements that aim to reduce the environmental impact when designing sustainable buildings by adopting a budget within the permissible limits and fulfilling these requirements and standards to achieve sustainability within the required period [1].

Architects must use not only analytical tools but also use tools that combine the perfect balance between the environment and the building systems to achieve the goals of sustainable architecture [2]. The primary purpose of designing sustainable buildings is energy effectiveness. This important factor results in the minimizing of the consumption of sources by the structure and justifies consequent options in terms of substances and techniques solutions which permit minimizing as well the environmental impact during the stage construction [3].

Sustainability estimation ways can be employed as methods in support of design, proposing a different function during the many design stages. In the primary assessment stage relating to design alternatives, they can be utilized in order to determine the requirements of sustainability and the identification of the goals relating to environmental impact. These ways are identified as support instruments for designers, contributing to helping them to gain a clear understanding of how the environmental factors of the building are impacted by design selections and how scholars can optimize the cost utilization [4]. Suppose the environmental impact of the building was taken into account via the utilization of substances and energy during the project stage. In that case, we could determine their environmental performance as the actual capability of the structure to achieve optimum utilization of the natural sources available during its serviceability life to obtain sustainability objectives [5].

Building Information Modelling (BIM) is one of the most important tools for transforming the construction industry and encouraging the use of information methodologies based on collaboration [6]. The BIM technology secures communication between project participants [7].

A BIM system can also be defined as the digital representation of the physical and functional characteristics of a building project, which acts as a common knowledge source for information about the project forming a reliable basis for decisions during its life cycle from inception onwards [8]–

[25].

[26] published a manuscript inspecting the vital effects and substantial advantages of using BIM technology and the active 7D principles to manage and monitor construction projects to lessen their harmful effects on the natural world. The scientists mentioned that present-day project cost management is best served by total process control of building expenditures. However, it is challenging to implement highly effective management due to the high number of partners involved in the project, the lengthy construction schedule, and the lack of common data platforms for all stakeholders. With the advent of BIM technology, things have shifted. The use of BIM technology throughout the process, from planning and design through building and operation, allows for more efficient cost management and faster turnaround times.

[27] implemented a study analyzing the vital role and critical benefits of using BIM technology and the active 7D concepts connected with it, construction projects may be managed, monitored, and their adverse effects on nature and the environment can be mitigated. The scholars reported that the rapid development of China's largest cities had necessitated the construction of ever-more-impressive structures for residential and commercial use. However, project management and financial investment are not always practical. A 7D BIM (building information model in seven dimensions) is created to address this issue. First, a 3D building information model (BIM) is produced, detailing everything from the structure's blueprints to its mechanical components. The 3D BIM has been combined with a 1D schedule management approach and a 3D project management approach (including enterprise quota management, process management, and bidding management) to build a 7D BIM for a complicated project. Engineers and project managers can use the proposed 7D model to facilitate clash detection, equipment installation, structural design, 3D project planning, post-construction, and alteration maintenance by offering a clear 3D view in modelling the construction process. A study of a complicated Chinese project shows how well the concept works in practice. According to the results of that research, implementing 7D BIM has resulted in significant time and money savings, in addition to an increase in project quality and productivity.

[28] directed an analysis exploring the stimulating effects and substantial advantages of utilizing BIM's active 7D

principles to oversee and control construction projects and limit their harmful effects on the natural surroundings. The scholars suggested that BIM's introduction of collaborative information management and real-time solutions for usage across the project lifecycle has radically altered the infrastructure construction business. Previous studies have shown the significance of BIM for that sector. However, further work is needed to elaborate and validate techniques for implementing this system. Their paper set out to examine such approaches from the perspective of the BIM system, taking into account all relevant factors. Figure 1 illustrates the various dimensions of the BIM system.

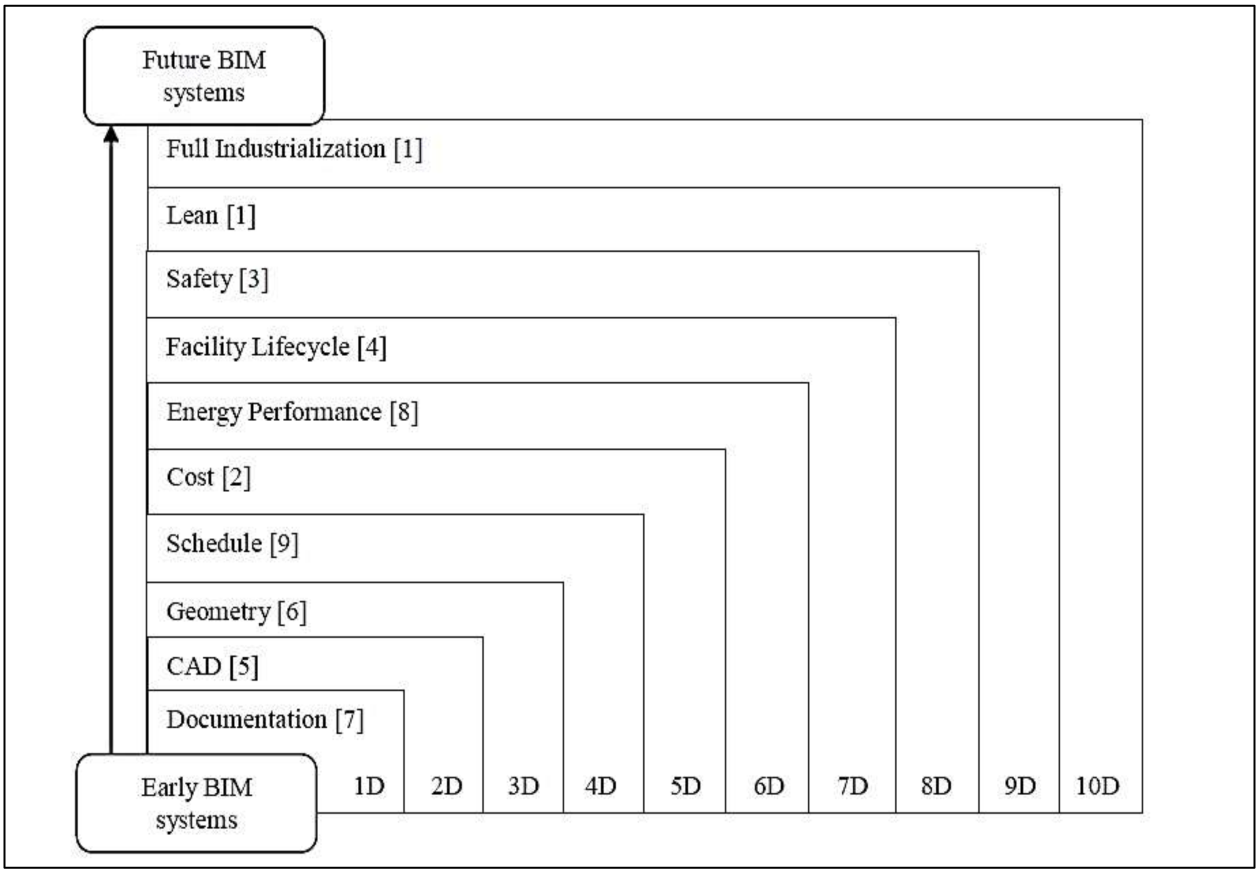

Figure 1. The Dimensions of the BIM System [28].

Based on the discussion and review illustrated in the previous paragraphs, it can be observed that conventional methods utilized in designing sustainable buildings and calculating quantities are considered one of the troubles that need time, cost, effort, and the occurrence of mankind's mistakes because of arithmetic processes and transportation. Hence, this study is carried out to provide significant rates of sustainability depending on the 7D modeling and BIM technology implementation. Quantity take-off is also considered to compare the contributions of BIM principles in facilitating material evaluation. Briefly, it can be mentioned that the results of this article confirmed that using BIM technology could minimize the cost, effort, and time in estimating the project's cost. Also, using the 7D modeling concept could provide vital aspects that help boost the sustainability rates in construction projects.

Section Two indicates Materials and Methods,

Section Three presents the Results,

Section Four illustrates the Conclusions.

2. MATERIALS AND METHODS

A case study representing a building in Iraq is considered to make an analysis of 7D modeling, and BIM approaches adoption to enhance the rates of environmental responsibility, sustainability, and resilience of this Iraqi facility. Then, the results of the numerical results obtained by virtue of the BIM program(REVIT tool) will be assessed and examined with the help of a panel of BIM specialists, construction experts, and high-knowledge project managers who have rich experience in sustainability implementation in the construction sector.

2.1 Case Study Description

The case study considered in this work comprises a building in Iraq, whose overall area is 7,426.05 square meters. This building represents the "Royal Baghdad" project, located in Baghdad, Iraq. It is a multi-story commercial building. It contains different floors. For instance, the basement floor is utilized for parking purposes. At the same time, the building comprises the ground floor, a mezzanine floor, six floors and a penthouse. Figure 2 indicates the exterior design of the whole building.

Figure 2. An outline of the exterior design of the Royal Baghdad project.

A REVIT view of this building based on the Emerging Technologies Advisory Board

(ETAB) technology can be illustrated in Figure 3.

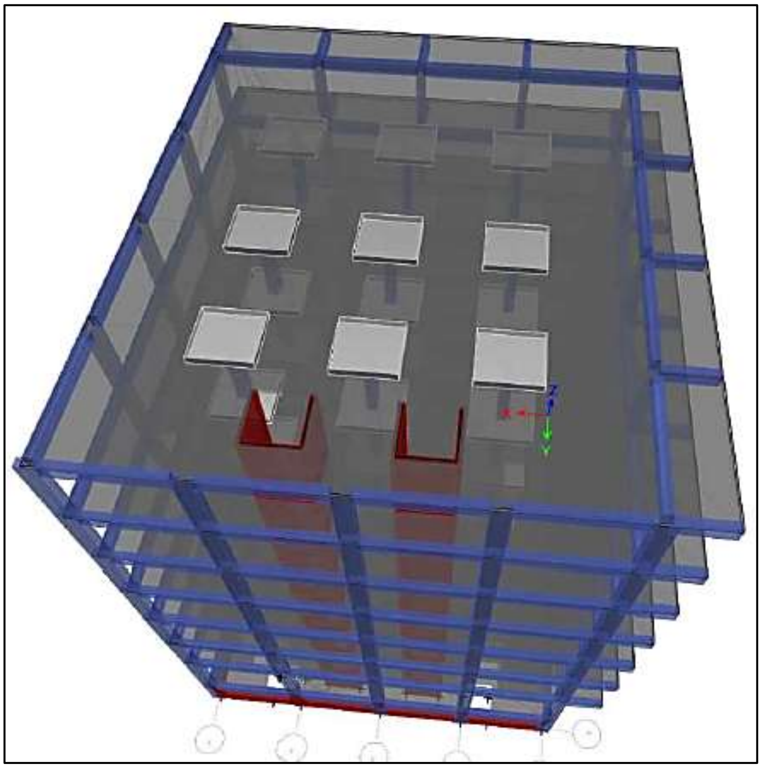

Figure 3. An ETAB model of the Royal Baghdad building investigated in this study.

The area of the Royal Baghdad Building and the critical uses of each building component can be described in Table 1.

Table 1. The total area of the Royal Baghdad project and the role of each floor.

Floor Symbol	Area (m^2)	The Main Role of this Floor
B_F	750	Lifts, stairs, Staff room, parking, Guard, cars entrance, store and W.C
G_F	907.50	Lifts, stairs, building entrance, electrical room, W.C and Hall.
M_F	103.55	Hall, Lifts and stairs
1^{st}	907.50	Offices, Lifts, stairs, stores, Halls and W.C
Typical Floor (2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th})	907.50	Offices, receptions, kitchens, Lifts, stairs, stores, Halls and W.C.

Penthouse Floor	220	Guard, kitchens, Lifts, stairs, stores and W.C.
Total area (m^2)		**7,426.05**

2.2 Research Tools and Numerical Analysis

In this work, the primary research tool used to assess the sustainability principles of this project comprises the ANSYS programpackage. In this programming tool, the 7D BIM modelling process is implemented. The 7D modeling technology is responsible for assessing the environmental impacts of the project and carbon emissions. Furthermore, the 7D BIM modeling is associated with facility management and other critical notations, which can be expressed in Figure 4.

On the other hand, an intelligent, high-performance, cost-effective, and accurate quantity take-off of construction materials can be considered another vital research tool that can reduce different types of errors. Hence, project managers can give more time to consider the sustainability aspects of their projects. At the same time, cost forecasting for the facility's whole life cycle can be attained by virtue of Level 7D BIM technology [29] [53].

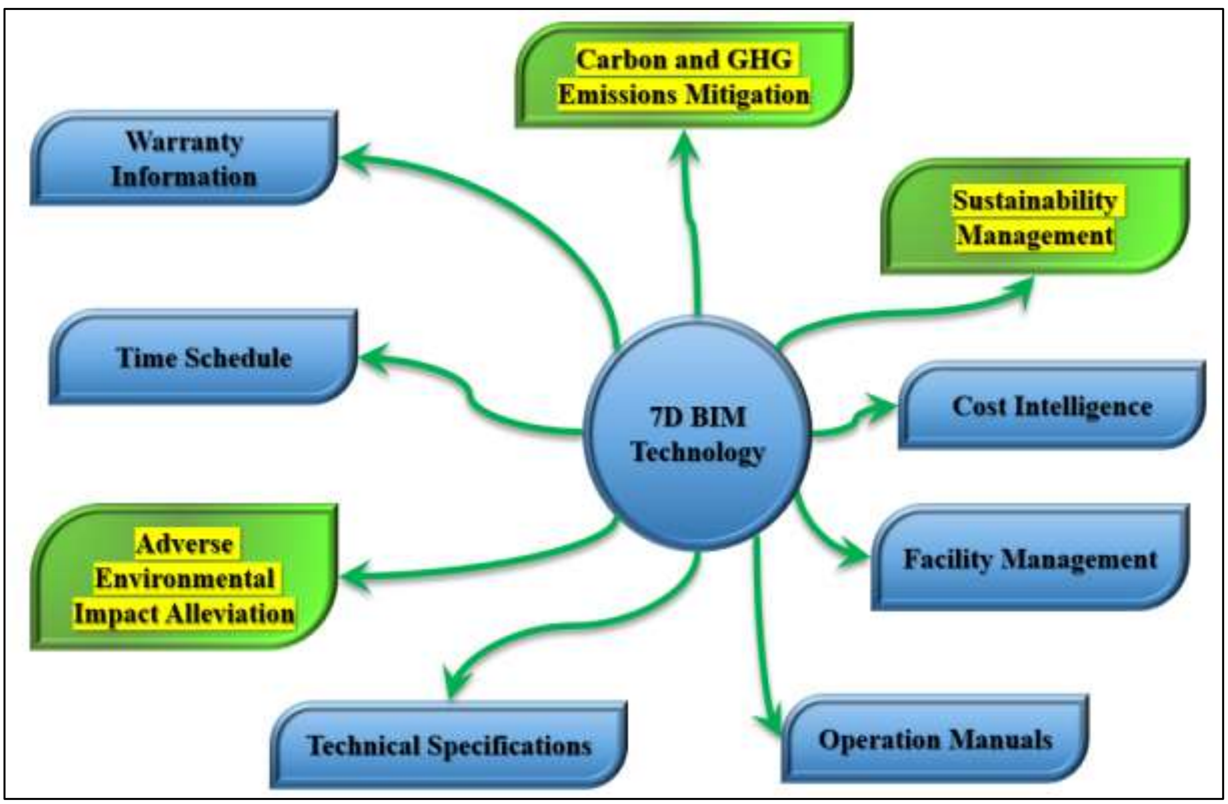

Figure 4. The major concepts and critical notations considered in the 7D BIM modeling technology (Author, 2023).

Moreover, the 7D BIM analysis is a technique that takes into account not only the conventional 2D drawings and plans of a building project but also the 3D models, timelines, cost intelligence, and sustainable practices of that project. Builders and project managers use 7D BIM during all stages of a project's life cycle, beginning with the planning phase and continuing through operation and maintenance. Building information modeling (BIM) would benefit from the use of 7-dimensional computer-aided design (CAD), which would improve project management beginning with the design phase and continuing through the demolition phase [30]-[33]. The REVIT programis another major study tool used in this work to carry out two primary functions:

A- Quantity take-off, and

B- Sustainability assessment.

Hence, in this work, those two goals will be implemented in the construction project investigated in this case study.

2.3 Theory and Mathematical Model

There are some general formulas and mathematical equations implemented in this research to conduct the necessary computations and evaluations of the construction materials using the traditional quantity take-off method. One of these equations is the weight of reinforcement steel bars used in the project. This equation can be expressed using the following correlation:

$$SBW = \frac{D_{SB}^2}{162} \quad (1)$$

Where:

SBW	:	Steel bar weight (in kg/m)
D_{SB}	:	Diameter of the steel bar (mm)

In addition, the weight of the steel bar (in kg) can be calculated using another formula expressed in the following correlation:

$$TSBW = SBL \times SBW \times NSB \times NCI \quad (2)$$

Where:

$TSBW$	:	The total steel bar weight (kg)
SBL	:	The steel bar weight (in kg/m)
NSB	:	Number of steel bars
NCI	:	The number of calculated items

The estimation of those two equations depends on the weight of each steel bar corresponding to its diameter, which can be obtained from the information illustrated in Figure 5.

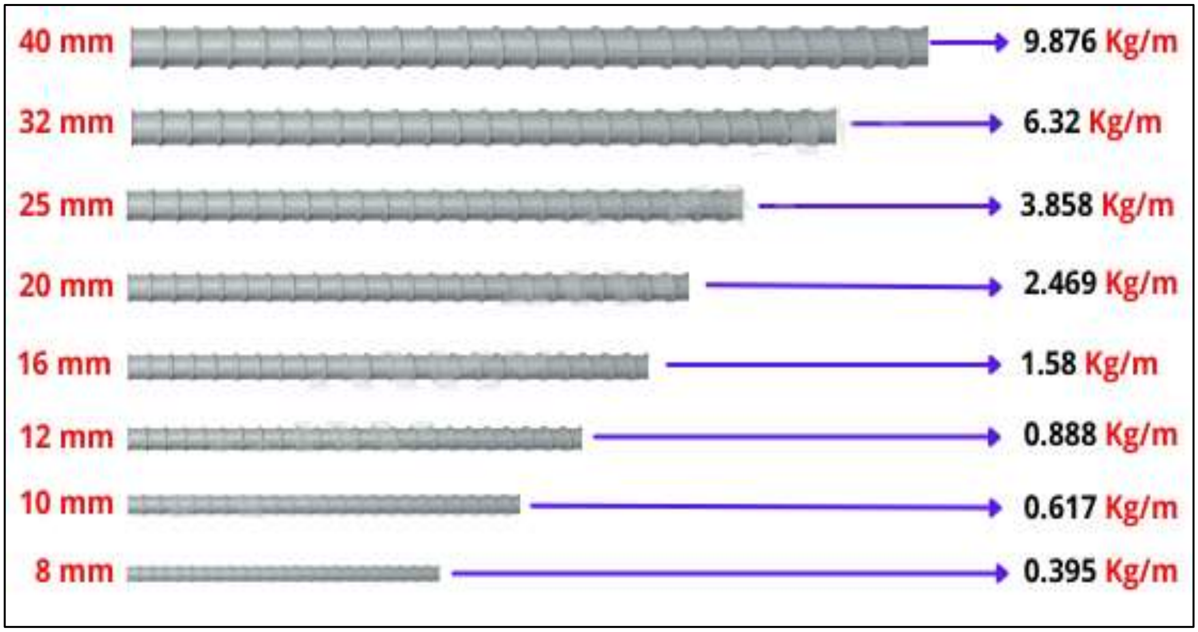

Figure 5. The weight of the steel bar based on its diameter.

Furthermore, Table 2 illustrates the minimum lap length for the steel bar (unless it is noted or mentioned in the shop drawing).

Table 2. The minimum lap length for the steel bar (unless it is noted or mentioned in the shop drawing).

Steel Bar Diameter (mm)	10	12	16	18	20	22	25
Lap Length in Columns (mm)	400	500	600	650	700	800	900
Lap Length in Other Places (mm)	400	600	700	800	900	1,000	1,250

Furthermore, Figure 6 indicates the required concrete cover (in terms of the concrete thickness) used to make the necessary foundation in the construction project, including concrete reinforcement thickness in slabs, beams, columns, walls, slab on grade, and raft foundation.

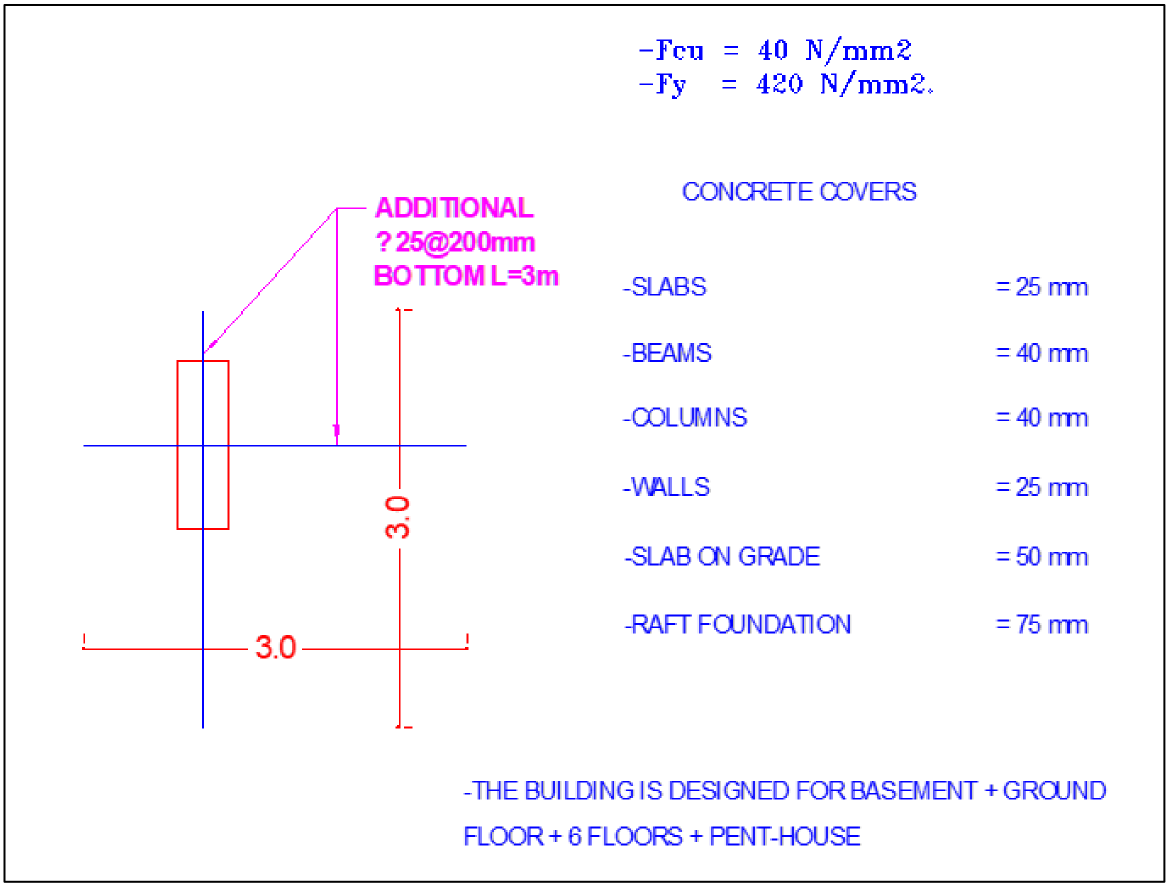

Figure 6. The optimum thickness of concrete covers required in the construction project.

3. RESULTS

This section indicates the manual and numerical results obtained from the quantity take-off conducted for the case study. Also, the following paragraphs show the 7D modeling results.

3.1 Manual Quantity Take-Off Calculations

The final volume of the reinforced concrete used in this project can be listed and illustrated in Table 3.

Table 3. The research findings related to the total reinforced concrete volume in this project.

Foundation	**807.63 (m^3)**
Walls and Columns	**735.19 (m^3)**
Slabs	**1,567.75 (m^3)**
Drop Beams	**217.74 (m^3)**
Results	**3,328.31 (m^3)**

It is indicated from Table 3 that the most considerable quantity of the reinforced concrete used in this project is associated with the slabs, corresponding to a volume of roughly 1,567.75 m^3. On the other hand, the lowest amount of concrete volume is present in the drop beams. Also, Figure 4.1 indicates the overall volume of the reinforced concrete used in this project in terms of ratios.

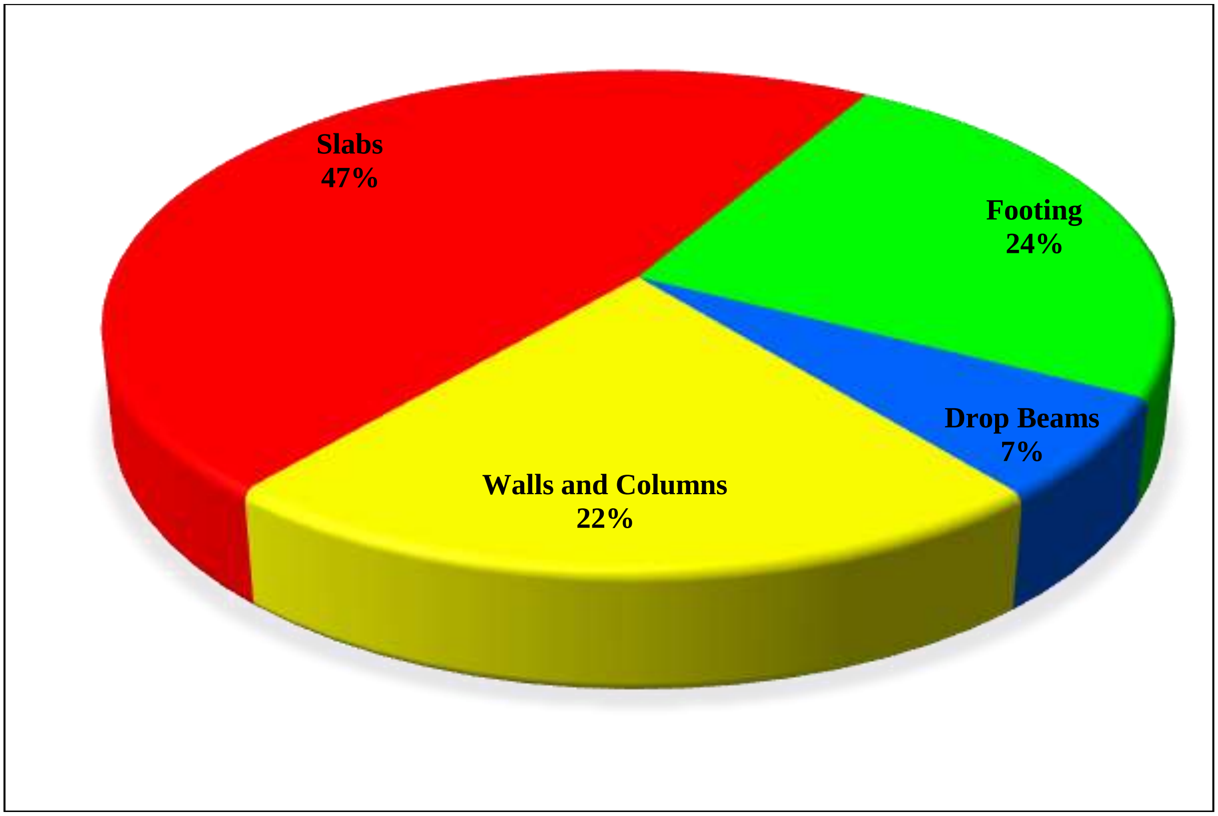

Figure 7. The overall volume of the reinforced concrete used in this project in ratios.

It can be concluded from the results obtained in Figure 7 that the most significant ratio of the reinforced concrete used in this construction project was 47%, corresponding to the concrete used in slabs. In contrast, the lowest percentage of concrete volume used in the building amounted to drop beams, corresponding to a concrete ratio of 7%.

Table 4 illustrates the total reinforcement weight in this building with the help of the conventional estimation method.

Table 4. Total reinforcement weight in this Building (Using conventional estimation method).

Part of Project	Weight (ton)
Raft Footing	68.634
Columns & Walls	147.440
Drop Beams	42.338
Slabs	201.033
Stair Case	9.697
Result	469.142 tons

It can be concluded from the results shown in Table 4 that the amount of steel bar weight consumed in this project for the whole project reached approximately 469.142 tons. The largest steel bar weight consumed in this project was for the slabs, corresponding to a weight of roughly 201.033 tons. At the same time, the lowest amount of steel bar weight consumed in this project was in the staircase, corresponding to 9.697 tons. Also, Figure 8 illustrates a graphical representation of the overall reinforcement weight of the steel bar used in this construction project in terms of percentage.

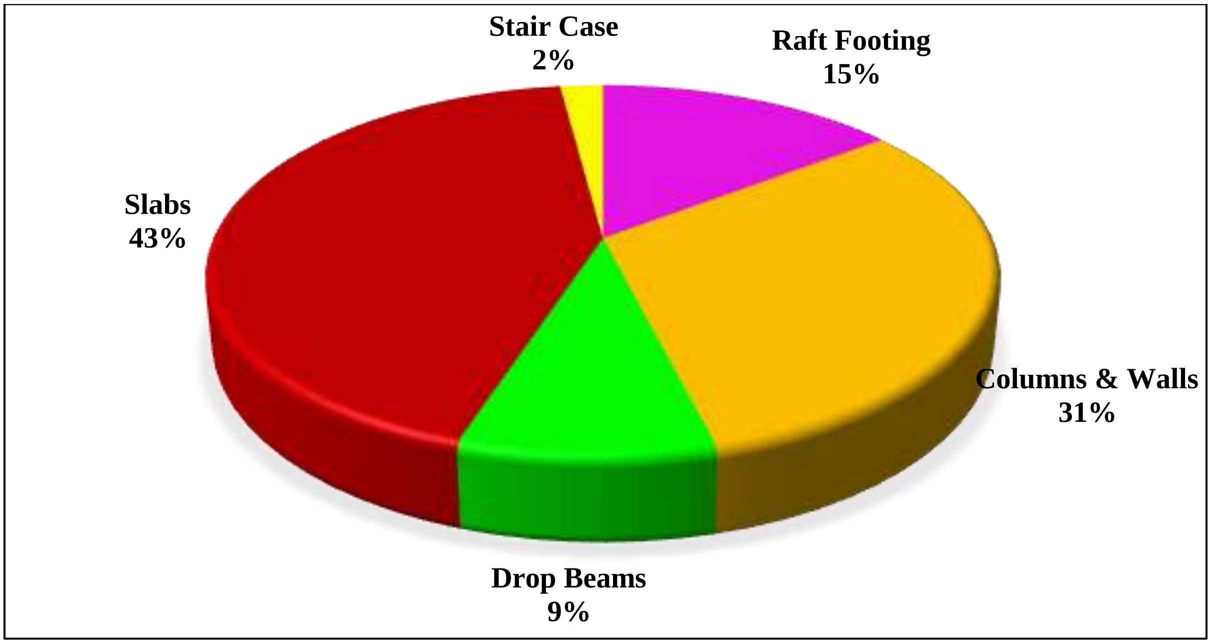

Figure 8. The overall reinforcement weight of the steel bar used in this construction project in terms of percentage.

It is inferred from the results obtained from the manual calculations of the steel bar in this project that the most part that consumes a large portion of steel bar quantity is the slab, followed by columns and walls, corresponding to 43% and 31%, respectively. In contrast, the staircase consumed the lowest weight of steel bars in this project, with a ratio of 2%.

3.2 Numerical REVIT ProgramQuantity Take-Off Estimation Findings

Table 5 explains the total values of reinforced concrete volume attained using the REVIT quantity take-off method.

Table 5. Total Reinforced concrete Volume (Using the REVIT quantity take-off method).

Foundation	**805.62 (m^3)**

Walls and Columns	**734.61 (m^3)**
Slabs	**1,545.20 (m^3)**
Drop Beams	**209.98 (m^3)**
Results	**3,295.41 (m^3)**

It can be concluded from Table 5 that the largest amount of concrete volume was consumed and required to build the slabs in this project, corresponding to a concrete volume amount of 1,545.20 m3, followed by the foundation concrete volume, which required roughly 805.62 m^3.

Moreover, Figure 9 explains the overall reinforced concrete volume based on the REVIT numerical quantity take-off approach.

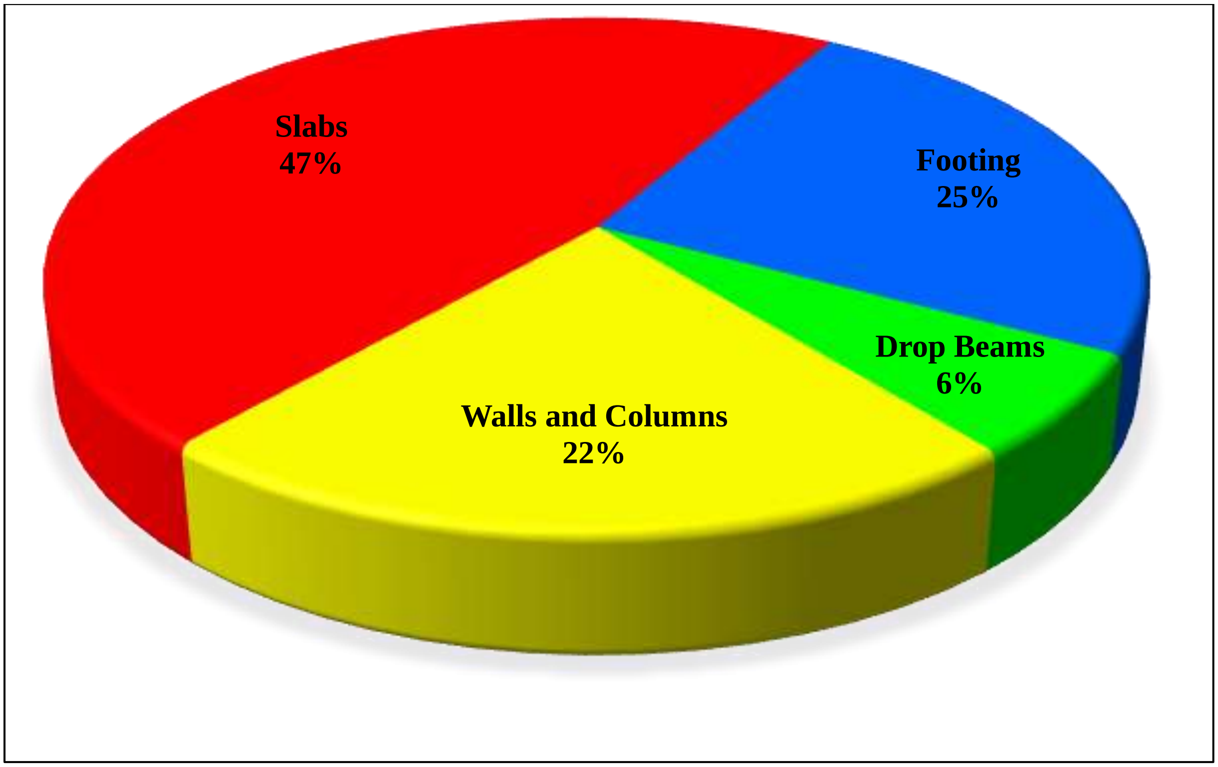

Figure 9. The overall reinforced concrete volume based on the REVIT numerical quantity take-off approach.

It can be indicated from the results presented in Figure 9 that the more significant ratio of the concrete volume needed in this project was for the slab, accounting for approximately 47%. In contrast, the lowest proportion of concrete volume was for the drop beams, which consumed only 6%.

Table 6 depicts the total reinforcement weight in this building depending on the REVIT programtool.

Table 6. Total reinforcement weight in this Building (Using the REVIT Method).

Part of Project	Steel Bar Weight (ton)
Raft Footing	65.518
Columns and Walls	143.610
Drop Beams	41.049
Slabs	192.362
Staircase	8.790
Results	451.329 tons

It can be indicated from the results illustrated in Table 6 that the overall amount of steel bar weight used in this case study reached roughly 451.329 tons. In addition, it can be inferred that the large steel bar weight quantity was for the slabs. The slabs consumed approximately 192.362 tons, followed by the columns and walls, which required around 143.610 tons. In contrast, the staircase took only 8.790 tons of steel bars in this project. An overall summary based on a graphical representation of the overall steel weight ratios associated with the project parts can be illustrated in Figure 10.

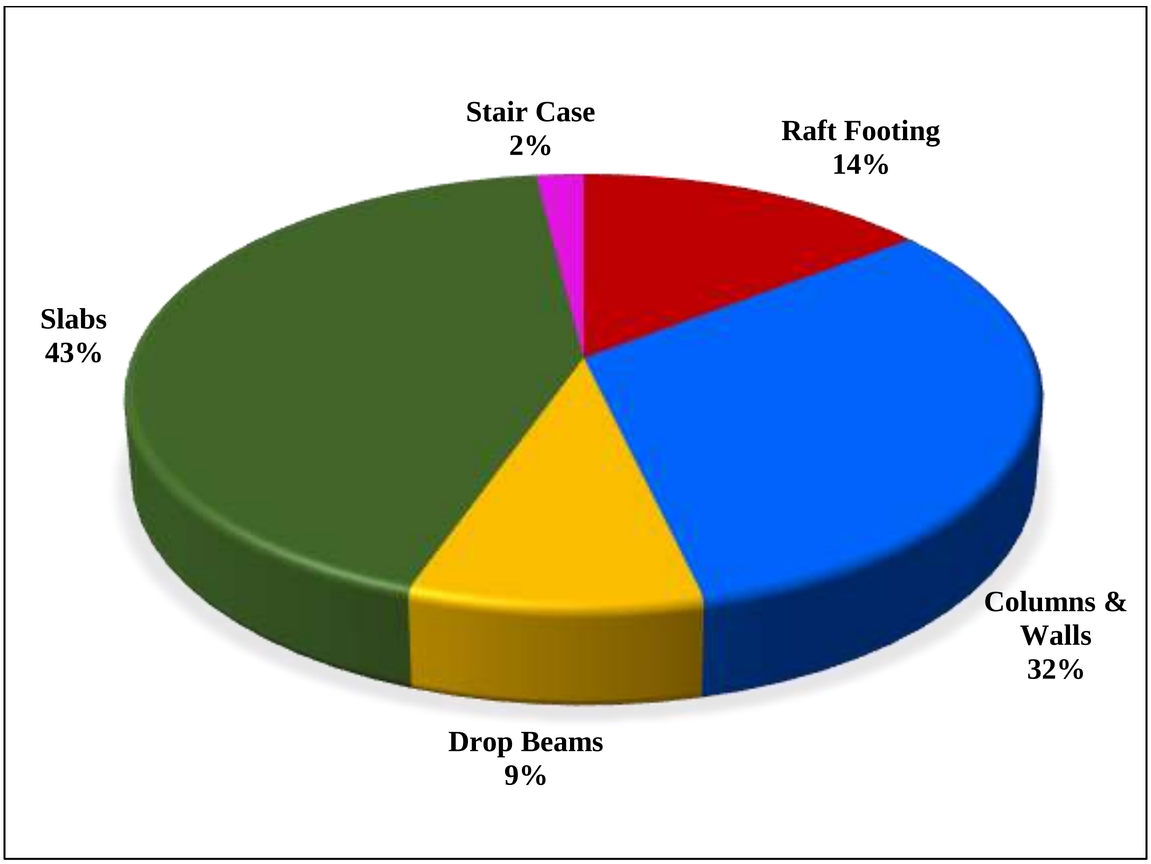

Figure 10. A graphical illustration of the overall reinforcement steel bar weight in this building.

It can be inferred from the graphical representation of the overall quantity of the steel bar weight considered in this project that the most significant part of the building that consumed massive amounts of steel bar weight is the slabs, corresponding to a ratio of 43%. On the other hand, the lowest rate of steel bar weight was recorded for the staircase, which registered a percentage of 2%. Furthermore, Figure 11 indicates a 3D model of the construction project considered in this work using the REVIT programnumerical analysis.

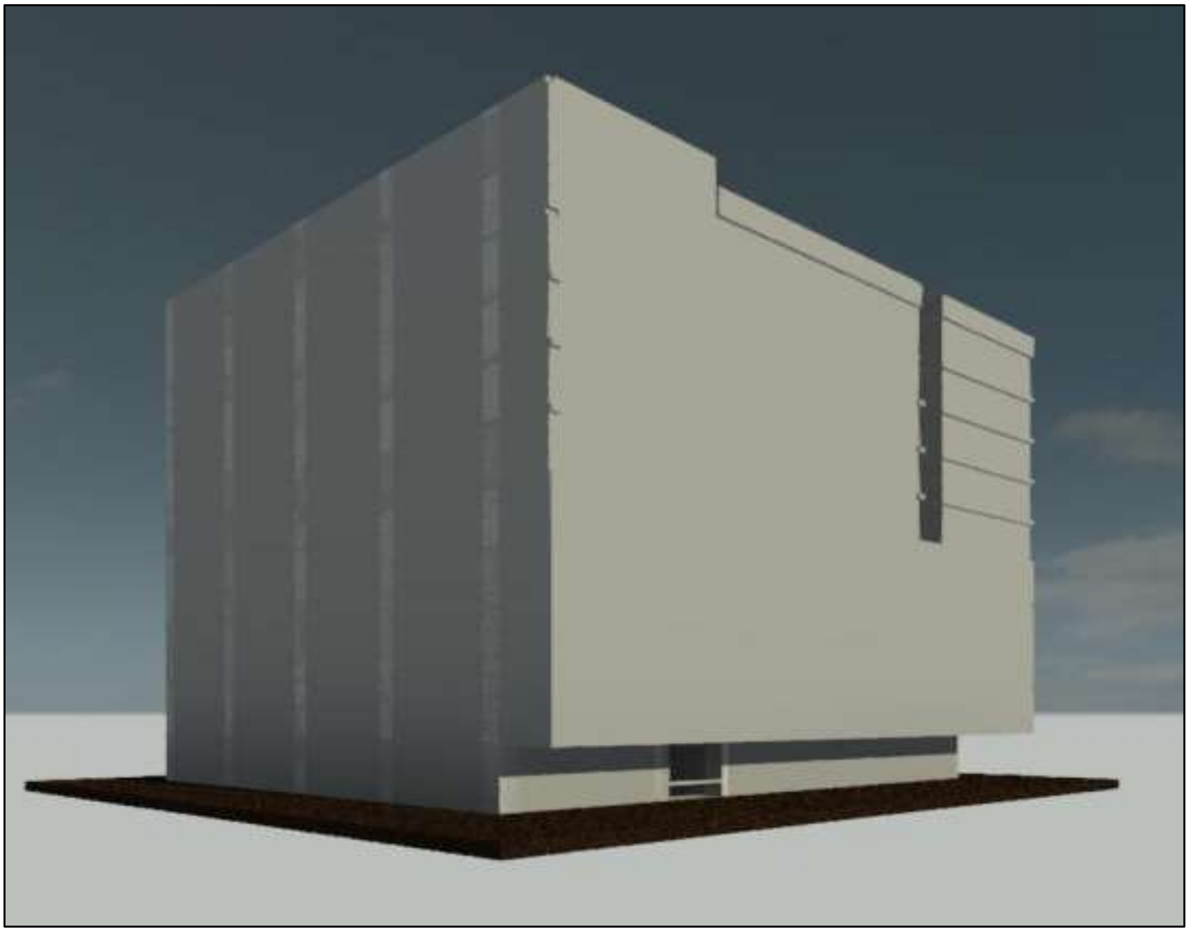

Figure 11. A 3D model of the construction project considered in this work using the REVIT programnumerical analysis.

3.3 Quantity Take-Off Comparative Analysis

A comparative analysis was carried out to validate the effectiveness of the BIM technology and REVIT programin conducting high-performance, reliable, and accurate quantity take-off associated with the amount of materials considered and used in the construction project, which represents here the case study of the Royal Baghdad project. The comparative analysis examines here the percentage of improvement that can be accomplished by the REVIT programming tool compared with manual calculation. Table 7 illustrates the results of this comparative analysis considered for the cut, blinding, and bolder.

Table 7. The results of the comparative analysis considered for the cut, blinding, and bolder.

Category	Method of Quantity Take-off		Rate of Accuracy (%) $(\frac{Q.Revit}{Q.Manual})\times 100$
	Manual (m^3)	REVIT (m^3)	
Cut	4,658.14	4,632.83	**99.46%**
Blinding	76.10	74.68	**98.13%**
Bolder	190.26	187.98	**98.80%**

Based on the comparative investigation between the REVIT programand the manual quantity take-off method described in Table 7, it can be inferred that the rate of accuracy provided by the REVIT programwhen the calculations of cut, blinding, and bolder were executed amounted to a significant rate of precision, which corresponds to 99.46%, 98.13%, and 98.80%, respectively. These results indicate the importance and vital contributions of the REVIT programin carrying out an accurate quantity take-off process for the construction material estimation. A graphical comparison between the bolder and blinding volumes can be represented in Figure 12.

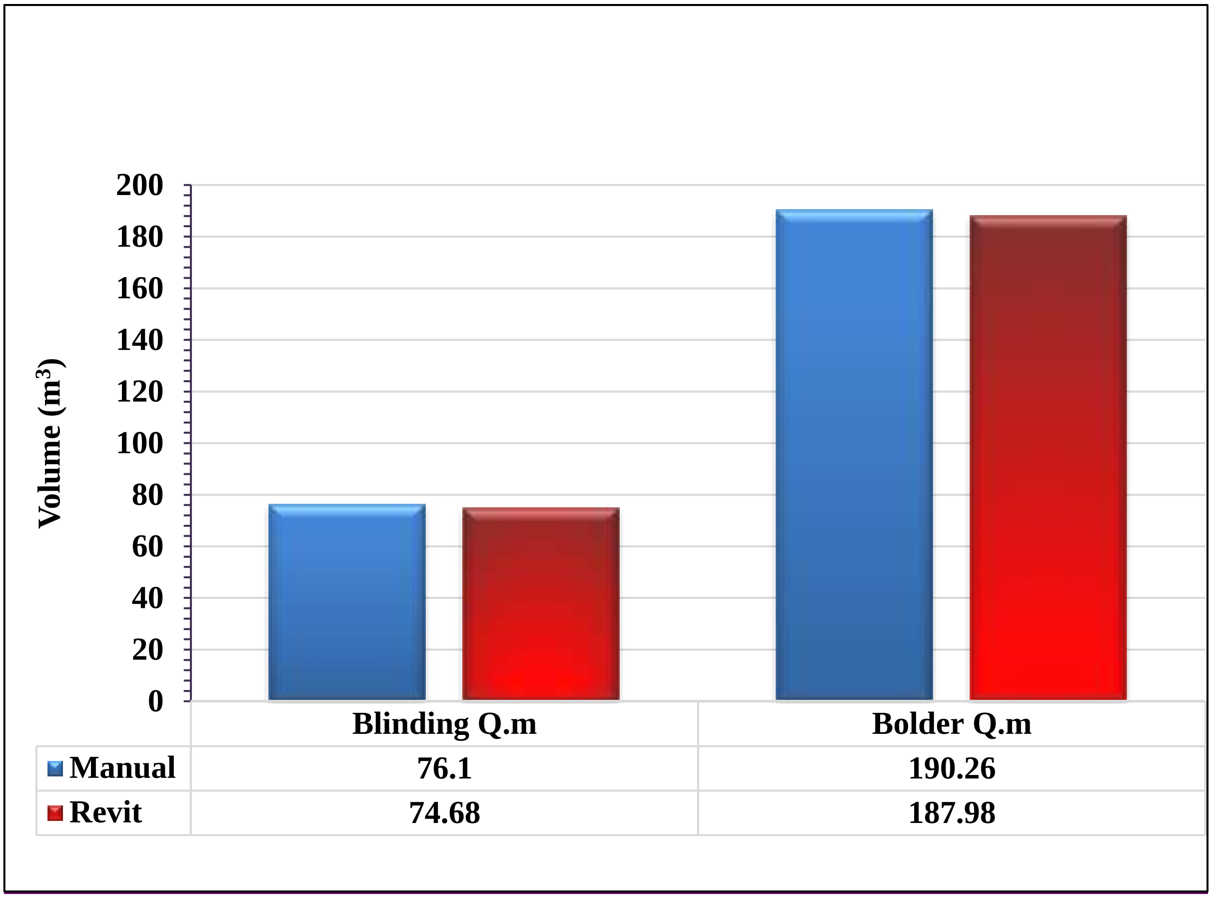

Figure 12. A graphical comparison between the bolder and blinding volumes.

It can be inferred from Figure 12 that the results of the REVIT programobtained from the implementation of BIM principles gave remarkably accurate findings to the hand calculation outputs with a considerable degree of efficiency. Besides this figure, another configuration is represented in Figure 13, explaining the comparison between the manual and REVIT quantity take-off levels related to the cut volume for the project.

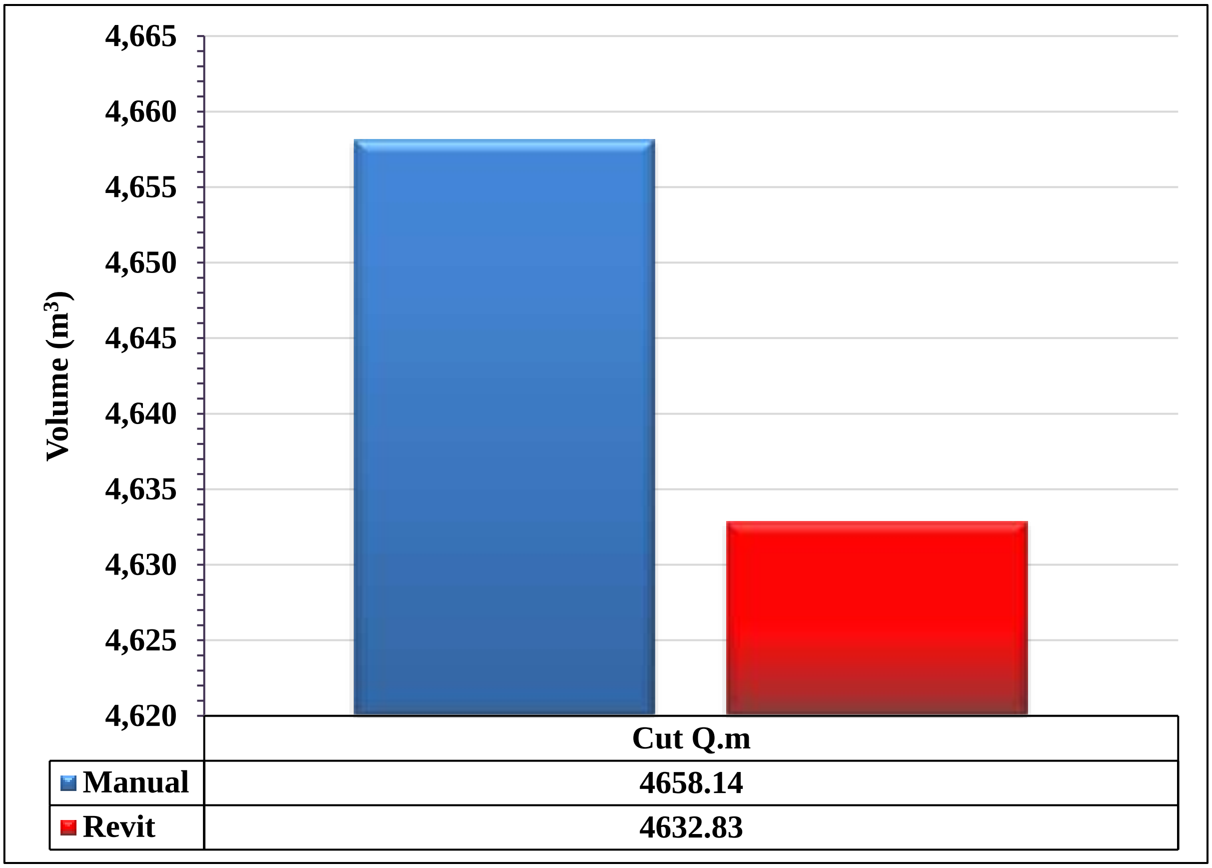

Figure 13. A comparison between manual and REVIT quantity take-off estimation approaches of the cut volume

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It can be concluded from the findings obtained from the results attained in Figure 13 that the amount of cut estimated by the REVIT programtool is significantly lower than that evaluated by virtue of manual calculations. However, based on the accuracy obtained from all cases, it is indicated that the quantity estimated by the REVIT programwould be more accurate compared with the volume estimations followed using manual methods. Hence, the most precise value is related to the REVIT programming tool. Hence, this result is considered.

3.4 Comparative Sustainability Assessment of the Construction Project

The 7D BIM analysis is a method that considers not only the traditional 2D drawings and plans but also the 3D models, schedules, cost intelligence, and sustainability of a building project. 7D BIM is used by builders and project managers for all phases of a project's life cycle, from planning to operation and maintenance [34]. Incorporating 7-dimensional computer-aided design (CAD) into building information modeling (BIM) would improve project management from the design phase all the way to demolition. Furthermore, the 7D BIM modeling is significant to conduct some beneficial impacts for project managers in the construction project, including the following aspects [35]:

A- From the planning stages through to the deconstruction phase, 7D BIM is an invaluable tool for keeping track of how a building or other asset is being managed,

B- During a building's lifecycle, it can simplify the process of replacing components and repairing the structure as a whole,

C- It can specify the maintenance procedure that the contractor needs to follow.

Figure 14 illustrates some beneficial impacts of using 7D modeling principles by BIM technology in the construction sector.

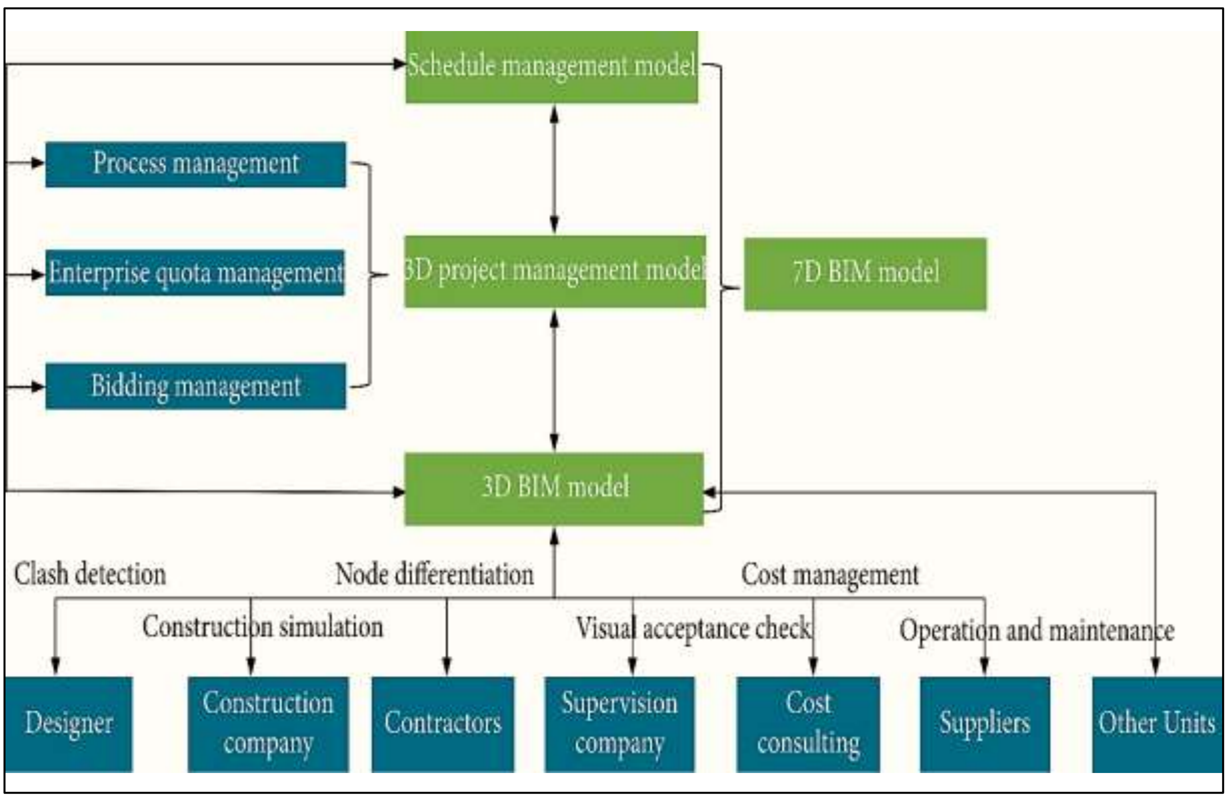

Figure 14. The definition and major principles of 7D BIM modeling (facility management) and analysis of sustainability aspects in construction projects [36] [60].

Furthermore, Figure 15 explains the results of the REVIT programtool used to assess the sustainability aspects using the 7D BIM modeling technology for the Royal Baghdad Project.

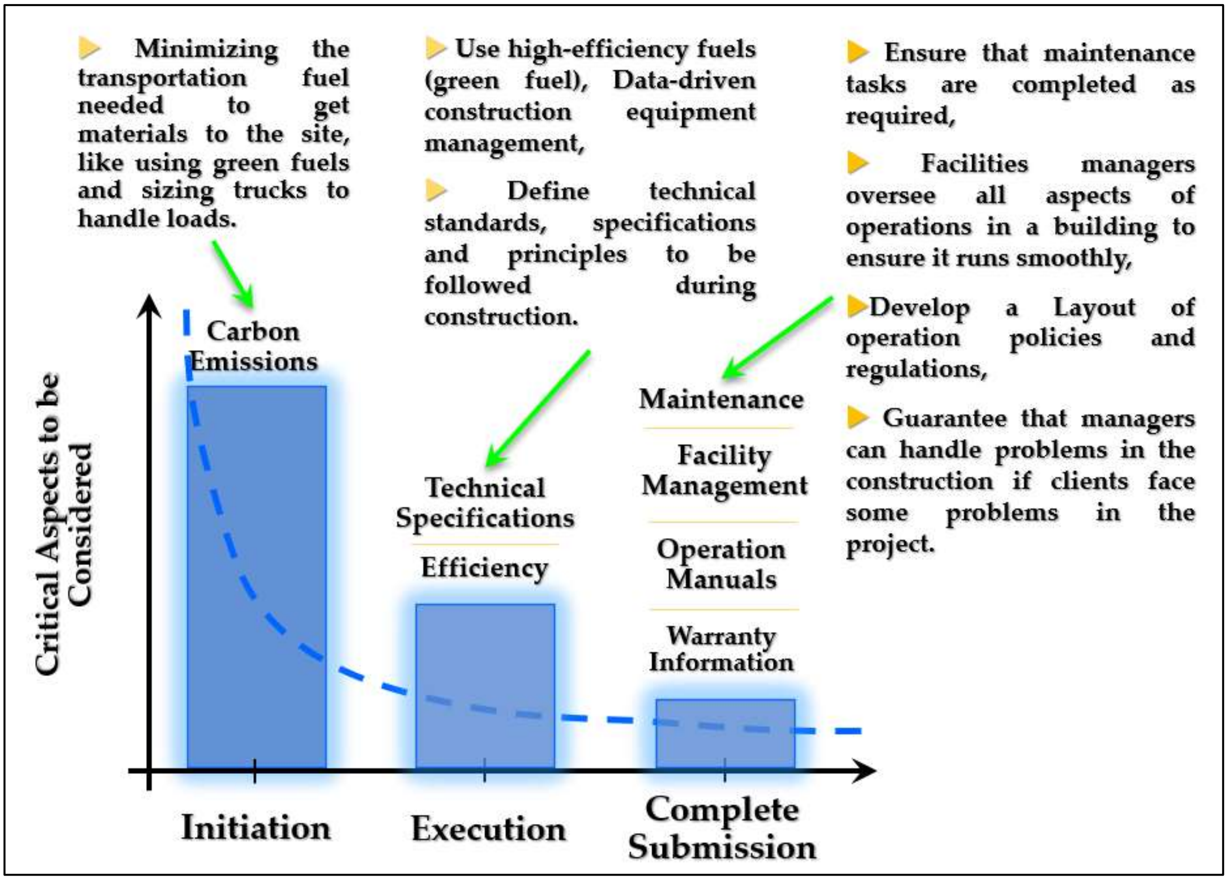

Figure 15. The sustainability aspects that are addressed using the 7D BIM modeling technology for the Royal Baghdad Project.

It can be inferred from Figure 15 that there are some critical considerations and vital issues that should be taken into account before, during, and after the complete execution of the construction project. For instance, carbon emissions can be managed using 7D BIM modeling principles by virtue of the utilization of green fuels and high-efficient transportation. In addition, minimizing carbon emissions can be done by implementing 7D BIM technology by considering the sizing of trucks and determining the exact weight of loads associated with the construction materials required to be transferred to the site.

4. CONCLUSIONS

This master's study was directed to analyze and examine the pivotal roles and beneficial contributions of 7D BIM model technology implementation in the construction sector to help enhance sustainability and reduce carbon emissions and other harmful environmental conditions. The research depended on a case study representing a Royal Baghdad construction project. Manual and REVIT evaluation methods were applied to make quantity take-off of the construction materials used in this project. Furthermore, the REVIT 7D modeling was conducted to determine some critical approaches that can be followed to enhance the sustainability of this project. Based on the two techniques used and sustainability assessment by 7D BIM modeling, the research outputs can be listed in the following points:

A- The BIM technology, including the REVIT programtool, plays a critical role in facilitating the management of large construction projects, like the commercial one considered in this case study, offering a positive rationale for better time, cost, and effort management, with accuracy rates between approximately 90.7% and 99.9%.

B- The total steel bar reinforcement weight used in this project reached around 469.142 tons compared with 451.329 tons using conventional and REVIT methods.

C- The total reinforced concrete volume amounted to 3,328.31 m^3 and 3,295.41 m^3, using the conventional and REVIT estimation methods, respectively.

D- Implementing this innovative technology could help complete the required work quickly and efficiently without various human mistakes and calculation errors. Hence, it can be said that these BIM applications, including the functional REVIT programtool, are the future of modern construction projects.

E- Employing the REVIT programtool provided significant accuracy, performance, and reliability rates in estimating the quantity of various construction materials, offering optimum levels of reliability, performance, and cost-effectiveness required for the quantity take-off compared with the manual quantity take-off.

F- Considering the 7D BIM technology in the Royal Baghdad project can manage some challenging issues that may cause adverse environmental impacts, including carbon emissions.

G- Facility management, Maintenance and Operation (M&O), efficiency, warranty, and other vital aspects can be monitored and amended with the help of 7D BIM technology to ensure that the project has significant rates of sustainability.

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