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# Integrating BIM and Photogrammetry for Accurate As-Built Quantity Verification and Construction Cost Control

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## ABSTRACT

Building Information Modeling (BIM) is widely used in construction to plan, monitor, and estimate project costs. Yet, differences often occur between what is designed on paper and what is actually built on site. These gaps can create problems in quantity estimation, payment certification, and even material waste. This study investigated how combining BIM with photogrammetry improved the accuracy of as-built quantity verification. Using Autodesk Revit for the planned model and Autodesk ReCap for photogrammetry-based point clouds, high-resolution images of the construction site were captured and processed. A hostel project at the University of Diyala was used as the case study. The comparison revealed clear differences between the planned and actual work: floor areas were 27.27% less than expected, and wall areas were 10% less. Such discrepancies show how relying only on planned models may lead to inflated costs, over-ordering, and avoidable waste. By contrast, integrating photogrammetry with BIM provided a more realistic picture of the project's progress, ensuring fairer payments and tighter project control. Beyond financial accuracy, this method also supports sustainability by preventing overuse of materials and reducing construction-related carbon emissions. The findings suggest that BIM, when combined with photogrammetry, can deliver more reliable, transparent, and environmentally responsible outcomes in construction projects.

**Keywords:** BIM , Quantity , Cost , Scanning , As-Built Verification , Sustainable

## 1. Introduction

Building information modeling (BIM) is characterized as a work method focused on collaboration with all stakeholders involved in the project, the design, development, and operation of a building. The principal objective is to avoid using all construction data during a building's whole life cycle<sup>[1]</sup>. The next step is to create a digital twin of the future building that can be accessed by everyone in a shared digital network called Common/Shared Data Environment (CDE), together with all the associated semantic and geometric building data. The BIM model is the name of this digital instrument<sup>[2]</sup>. Building Information Modeling (BIM) is a process that involves all project stakeholders in the collaborative design, construction, and operation of a building. The primary objective is to utilize all of the building's data for the duration of its entire life cycle. Consequently<sup>[3]</sup> Building Information Modeling (BIM) consists of a structured, organized process for representing in a digital format the physical and functional characteristics of an asset. A BIM model provides a visual representation of the asset to aid in design coordination, estimating quantities, planning construction and documenting the ongoing use of the physical asset throughout its project lifecycle. Digital twins differ from traditional BIM models in that a digital twin represents an active, dynamic digital representation of an asset that evolves over time as real-time or near real-time information from sensors, monitoring systems and continuous deployments of reality capture technology is acquired. Digital twins allow for the ongoing evaluation of an asset's performance, allow for predictive analysis of potential future performance, and support decision-making regarding the maintenance and operation of an asset during the asset's operational phase. It is necessary to develop a digital twin of the future building that includes all pertinent geometrical and semantic data and is available to all stakeholders in a common data environment (CDE), a shared digital area. The BIM model is the name of this digital twin<sup>[4]</sup>. The term "Building Information Modeling" (BIM) refers to a way of working with all project stakeholders that is centered on the collaborative design, construction, and operation of a building. The primary objective is to continuously use all building data for the duration of a building's life cycle. In order to accommodate all stakeholders in a common data environment (CDE), a digital twin of the future building must be built. It must contain all pertinent semantic and geometrical data about the construction. We refer to this digital twin as the BIM model<sup>[4]</sup>.

Structure-of-motion, or multi-image (SfM). A 2D to 3D digitization method called picture metering creates photographic datasets of surfaces, objects, and landscapes. Generally speaking, photogrammetry compares several images provided by SfM to identify the precise points of the image or position using a machine-specific method<sup>[5]</sup>. SfM simulation may be applied as a very simple documentation approach for common devices such as consumer computers, digital cameras, UAVs, and any software. For both field and object applications, there are already accessible good archeologic practices for SfM documentation and guidance on SfM utilizing Single Image Photography and other 3D (e.g., laser scanning) approaches<sup>[6,7]</sup>.

In order to make high-quality visual data sets more accessible and inexpensive, SfM can also be used by educators and those interested in public outreach. The capturing of accurate models can be carried out by standard devices like consumer computers, digital cameras, and the required software<sup>[8,6]</sup>. There are also proven good standards of practice for SfM documentation. In particular, in the archeological fieldwork, Sapirstein and Murray (2017) suggested using the photogrammetric recording as a medium for recording small items. Field and target applications have also been studied as another resource for non-specialist SfM and single photogrammetry and laser scanning. We found no discussion of the generality of these best practice recommendations and the usability of future implementation alternatives instead of a software analysis used to build a specific 3D model in a case study<sup>[9]</sup>. In one case study, comprehensive comparisons of software are presented, but the emphasis is not on the reality of usage. Instead, priority is given to the visual consistency of the final model. When photogrammetry is used to record a site, software and cross-compatibility of produced data are as important as the photo-set acquisition technique and the precise finishing model. Unlike conventional optical and satellite geodesic methods, the key benefits of laser scan technology are their high geometric precision and their remarkably rapid calculation (up to one million points per second). Laser scanning results close to the photographic surveys include high-resolution photographs, triangulated surface designs, 3D point nuclei, and surface texture models—laser scanning results. All kinds of laser scanning technology provide the right, efficient and straightforward solution for 3D data acquisition on a built-in BIM model (terrestrial, handheld, and airborne).

This gives laser scanning technologies a vast opportunity to develop integrated BIM versions. The relatively high cost of laser scanning technology for previously constructed BIM systems should nevertheless be considered. The creation of BIM models for historical buildings has revealed some critical results in literary examinations<sup>[10-12]</sup>. (HBIM). Furthermore, due to the decreasing cost of laser scanning, the value of built-in BIM models for digital twins or digital assets for existing manufacturing plants is growing<sup>[13,14]</sup>. Different analyses of the as-modeled BIM of manufacturing objects have been performed. For example, the analysis of the dimensions of industrial tube structures on-site has proposed an advanced approach (Nguyen & Choi, 2018). Despite the high detection rate, some items remained unknown due to inadequate scanning.

In both new and current buildings, the procedure for creating a BIM model varies. The use of BIM-based information often relies on internal systems. Figure (1-5) sets out the way and updates the as-design model BIM to produce a new as-built model based on recent construction changes. However, the BIM template is seldom used to be updated using as-built drawings to reflect the current building status.

"Rough point clouds are produced when a facility's spatial information is scanned, which is the present status of the scan-to-BIM process. Further auxiliary devices, such as cameras and Radio Frequency Identifications (RFID), record the semantic data of the facility, such as material, cost, etc. A unique point cloud is produced by registering the raw point clouds in a shared coordinate system. After segmenting the registered point cloud, geometry is affixed to volumes or surfaces. Ultimately, a BIM model of the scanned facility is produced, semantic information is appended, object characteristics and connections are constructed, and." [15]

BIM applications can be implemented into a BIM methodology for the new building. They can benefit from structural alternative measuring measures, costs assessments, quantification materials, data collection, reporting as built-in, constructive state analysis, development plans, and more [16]. Established houses are viewed differently from recent BIM developments. The BIM model as built-in can be generated as an upgrade or a new one in some instances to an existing BIM model. 80% of buildings in Europe were constructed before 1990, most of which are without a BIM model to be incorporated into this work. In these cases, reverse engineering is becoming standard practice using 3D laser scanning and photography surveys [17]. While BIM has become central to modern construction, its integration with reality-capture technologies like photogrammetry remains relatively underexplored. Most traditional studies focus on laser scanning due to its high precision; however, photogrammetry offers a cost-effective and accessible alternative, particularly for developing countries or projects with limited budgets. For example, Dore and Murphy (2017) demonstrated how 3D laser scanning supports historic building documentation, but highlighted its expense as a limiting factor. In contrast, Sapirstein and Murray (2017) proposed photogrammetry as a flexible solution for archaeological sites, showing its ability to generate accurate models using simple cameras. This same logic can be extended to construction projects, where affordability and speed are critical.

Several scholars have compared the benefits and challenges of using photogrammetry versus BIM-only workflows. Volk et al. (2014) [18] reviewed BIM for existing buildings and noted that as-built updates are often neglected, leading to discrepancies between models and actual conditions. Bosché et al. (2015)[19] emphasized the role of Scan-to-BIM techniques in bridging this gap but acknowledged that photogrammetry can provide comparable insights without costly equipment. Recent efforts by Roberts et al. (2018) and Nguyen and Choi (2018) also highlight how digitalization improves project monitoring, but stop short of fully integrating photogrammetry into the BIM workflow.

BIM models are created or updated using three-dimensional data from reality capture technologies such as laser scanning and photogrammetry (Scan-to-BIM). Laser scanning has traditionally been the technology of choice due to the quality and volume of point clouds generated with laser scanning systems, plus the high level of geometric accuracy provided by laser scanning equipment. However, the cost, specialty equipment, and operational limitations associated with laser scanning create a barrier for using laser scanning in low-budget or restricted construction environments [20]. Recent research from 2020 to 2024 has highlighted alternative and/or hybrid Scan-to-BIM workflow processes designed to provide increased accessibility with comparable accuracy. The primary focus of these studies has been related to quantity verification, construction progress monitoring, and the identification of discrepancies between as-planned and as-built conditions. While laser scanning still represents the most significant advance in the industry, many are beginning to recognize photogrammetry as an equally viable alternative for building-scale applications where cost and flexibility are concerns.[21]

In this context, our study contributes to the literature by demonstrating that photogrammetry, when combined with BIM, not only verifies as-built conditions but also supports sustainability. Unlike previous works that treat quantity verification purely as a financial control tool, this research frames it as both an economic and environmental issue. The reduction of material waste, avoidance of over-ordering, and prevention of unnecessary embodied carbon emissions position BIM-photogrammetry integration as a driver of sustainable construction practice.

It is essential that the section not only presents the context of BIM and photogrammetry in construction but also forthrightly delineates the research gap, questions, and objectives in order to bolster the scientific foundation of the present study. The existing literature has not yet comprehensively addressed the integration of both technologies to offer accurate as-built quantity verification since various articles have reported the already mentioned potentials, among them, the use of BIM in design coordination and project planning, photogrammetry as a low-cost tool for 3D reconstruction, and the existing research focusing on either the precision of laser scanning or the conceptual advantages of BIM. Moreover, on the one hand, the literature leaves a gap concerning practical, cost-effective workflows suitable for projects with limited financial or technological resources. To make matters worse, the researchers have hardly ever related the quantity discrepancies to the wider issues of cost overruns, payment disputes, and sustainability impacts.

In consideration of the aforementioned research gaps, the current study poses the following questions:

- (1) What is the procedure to effectively fuse photogrammetry (SfM) with BIM so that dependable as-built models can be produced under actual construction circumstances?
- (2) How far does this fusion of technologies boost quantity estimation over traditional methods like tender documentation, manual measurement, and BIM-only workflows?
- (3) What are the costs for controlling the project, the waste of material, and the sustainability outcomes due to discrepancies in as-built quantities?

This research presents a number of theoretical implications. The study that integrates photogrammetry with BIM for as-built quantity verification, expands the current knowledge of reality capture work processes and also participates in the

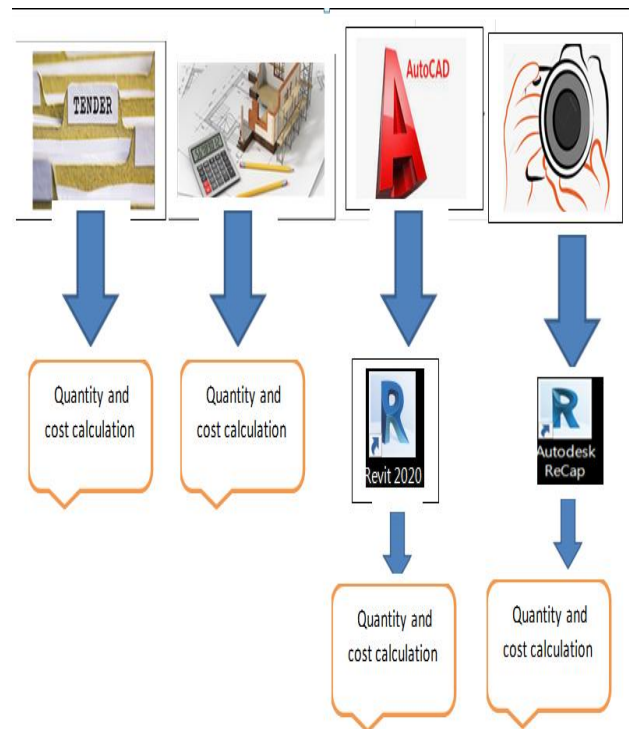
discussion about digital construction technologies. It proves that low-cost image-based modeling can reach the same accuracy level as that of expensive scanning methods, thus questioning the conventional beliefs in the Scan-to-BIM literature regarding accuracy. Moreover, the research connects quantity deviations with their financial consequences as well as environmental impacts, thereby emphasizing the theoretical relationship between digital verification. The new workflow, from a practical viewpoint, gives construction professionals a method to validate project progress that is replicable, economical, and efficient. The method can be applied by contractors and site engineers to solve disputes about quantities, grant fairer payment certifications, and detect deviations at an early stage to avoid expensive rework. Project owners and consultants are equally in the loop with improved transparency and accurate evaluations of material consumption that aid both cost control and resource management in an eco-friendly way. The case study proves that the use of BIM and photogrammetry together can elevate decision-making and project performance even in contexts with limited access to advanced technologies, material efficiency, and reduction of carbon footprint—an issue that is still very much neglected by the researchers.

The purpose of this study is to create and test a combined approach using Photogrammetry and Building Information Modeling (BIM) to accurately and reliably verify the types and quantities of materials used on construction projects, through as-built quantities that are generated by using combined methods for measurement. This research has three specific objectives. These include:

1. To create a practical workflow for using BIM and Photogrammetry to produce accurate and complete as-built models based on real-world construction conditions.
  2. To evaluate quantitatively how accurate are the quantities obtained through Photogrammetry vs. the quantities specified in the contract documents, realised quantities measured on-site, and quantities calculated using BIM.
  3. To investigate the impact of using inaccurate or incomplete quantities on various factors, including cost control, payment certification, material waste, and sustainability.
  4. To demonstrate that using Photogrammetry can provide a cost-effective and reliable alternative to Laser Scanning for As Built verification, especially for projects that have low budgets or not have access to advanced technology.
- This study is divided into 5 sections. In section 2, we describe our methods and materials, including how we selected the building used as a case study, collected data, processed photos to create models using photogrammetry and building information modeling, and assessed the accuracy of each technique. Section 3 presents the results of our comparison of quantities estimated from each method and our analyses of deviations from these methods with respect to the quantity estimated from each method. In section 4, we provide insights regarding our findings in regards to current international research, implications for cost control and sustainability. Finally, in section 5, we outline the main conclusions of this study, identify its contributions to knowledge, and suggest directions for further research.

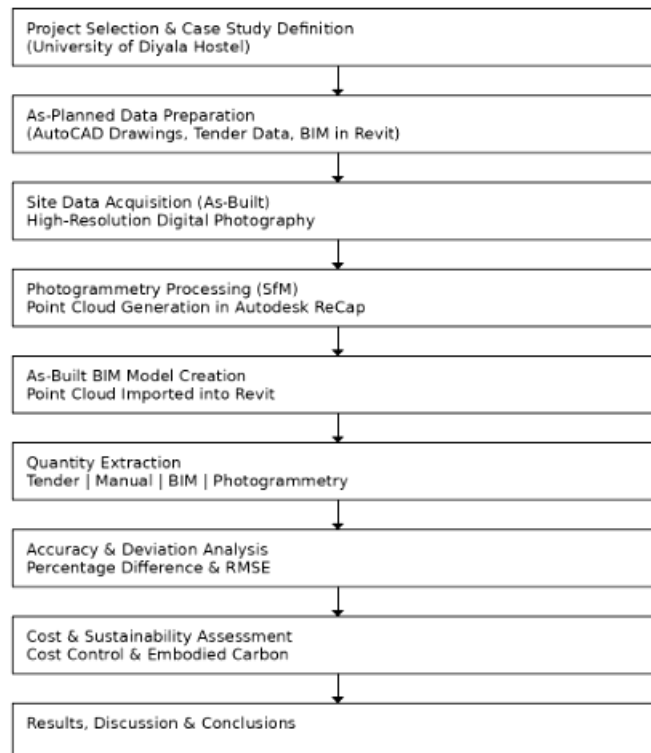
## 2. Materials and Methods

In this work, high-resolution cameras were used in order to take an image for the building and at different stages according to the progress schedule in order to compare the as-planned with as-built, AUTODESK RECAP software was used to calculate the as-built quantity, and REVIT was used to calculate as planned quantity. A comparison will be made between tender, the measured quantity by the site engineering, REVIT, and AUTODESK RECAP, the methodology a shown in figure (1), which show different methods for estimating the quantity and calculating the cost, as the first one depends on the tender, the second on the measurement by the engineer, the third one depend on the Revit and the last one depending on the Recap exported to Revit :



**Figure 1.** Comparison of different quantity and cost estimation approaches used in the study, including tender-based estimation, manual site measurement, BIM-based as-planned quantities, and photogrammetry-based as-built quantities.

The flowchart for the work as follow:



**Figure 2.** Research WorkFlow

Figure 2 provides an overview of the flowchart detailing the research methodology that was utilized within this study. Data was collected from a construction site using high-resolution digital images or photographs. The photographs were reconstructed into a dense point cloud of the built environment using Structure from Motion (SfM) techniques in Autodesk ReCap. In parallel to constructing a point cloud from the photographs, an as-planned building information model (BIM) was developed for the

project using AutoCAD drawings and tender documentation in Autodesk Revit. The photogrammetrically derived point cloud was imported into Autodesk Revit in order to create an as-built BIM for the project.

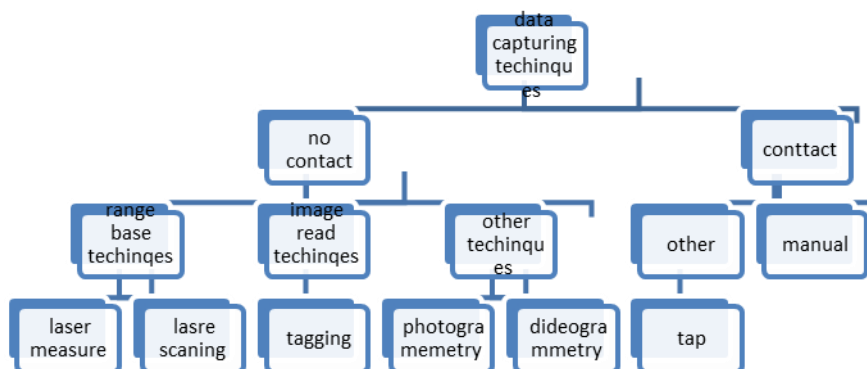
Quantities for the project were obtained using four different methods: 1. Tender documents 2. Manual measurements taken on site 3. Quantities from the BIM/as-planned model 4. Quantities from the BIM/as-built model created from the photogrammetric point cloud. The collected quantity data were compared by calculating percentage deviations, as well as Root Mean Square Error (RMSE), which provided a means of determining the accuracy, cost implications, and sustainability effects associated with each method employed.

## 2.1 Description of the case study:

Hostel with a cost of 2,627,865,000.00IQD and time of 330 days at the University of Diyala. The steps for the AUTODESK RECAP are as follow:

## 2.2 Data Capture

The first movement in the BIM scan is data capture. The scan target for BIM and the desired use of the model specifies the LOD that directly affects data collection techniques selection and accuracy. Since data gathered for the BIM scan is the basis for the next step, the consistency of the model and time and efforts in the construction of model 46 is essential. The data is captured using a camera that is used in several techniques and non-contact techniques. This is seen in Figure(3) by categories and subcategories). The non-contact approach is divided between the picture clusters, the continuum, and other strategies. Communication approaches and other methods have been interrupted<sup>[23]</sup>



**Figure 3.** Overview of data acquisition techniques for BIM-based modeling, highlighting contact and non-contact methods used to capture as-built construction information.

In this work, two methods are used: camera and tape measurements to describe the building . A commercial digital camera that is fit for construction-site documentation was used for image acquisition. The camera had a CMOS sensor and a fixed focal-length lens, which allowed taking high-resolution images that were sufficient for Structure-from-Motion (SfM) reconstruction. The resolution of the images was more than 12 megapixels, which is in line with the recommended minimum standards for ensuring the reliability of photogrammetric modeling in built environments. To keep the images consistent throughout different site conditions, automatic focus and exposure control were utilized.. In order to guarantee effective feature matching and precise point cloud creation, an image overlap of about 70 to 80 percent was kept between successive images. The images were taken from different angles and heights, using both circular and linear patterns around the building. This method not only reduced the occurrence of occlusions but also increased the amount of geometry information which is very important for strong SfM reconstruction. To remove the irrelevant items like workers, temporary scaffolding, and construction equipment, noise reduction and manual cleaning were carried out. The point clouds from the manual cleaning were then registered into a single coordinate system before being integrated into Autodesk Revit. Manual registration was used because of the complicated conditions on-site and the restrictions of automated alignment methods in the presence of heavy occlusions. The construction practice and literature review suggest that an error threshold of  $\pm 3-5\%$  was considered acceptable for estimating quantities at the project progress and payment certification level. When comparing to ground truth measurements, the results indicated that the BIM-photogrammetry workflow stayed within or very near this threshold, and it also greatly exceeded tender-based and manual estimation methods. Manual site measurement and certified payment records drawn up by the site engineers were used to set the ground truth quantities. The reference baseline for assessing the reliability of BIM-derived and photogrammetry-derived quantities was given by these measurements. The comparison revealed that photogrammetry-based quantities were more in line with ground truth values than quantities that were only derived from as-planned BIM models. Figures 4, 5,6, and 7.8.9.10,11show different images were taken for the building and at different stages of the project life cycle.



**Figure.3** Initial Stage of the Projects



**Figure 4** Projects Progress



**Figure 5** Projects Internal Compounds



**Figure 6.** Projects External Compounds



**Figure 7.** Projects with External Framework Completed



**Figure8.** External Finishing Start of the Projects



Figure.9 External Finishing Progress of the Projects

### 2.3 Data processing

Data from various locations (image) are combined into a single coordinate system of one source during this stage.

- 1- Upon registration, all data are added to a single file named "photo," which is initially uploaded to Autodesk Autodesk ReCap photo to become point cloud and subsequently downloaded to Autodesk ReCap to process and improve those resources, as seen in figure (10).

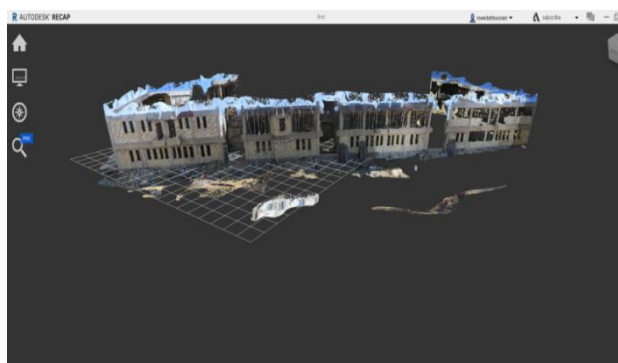


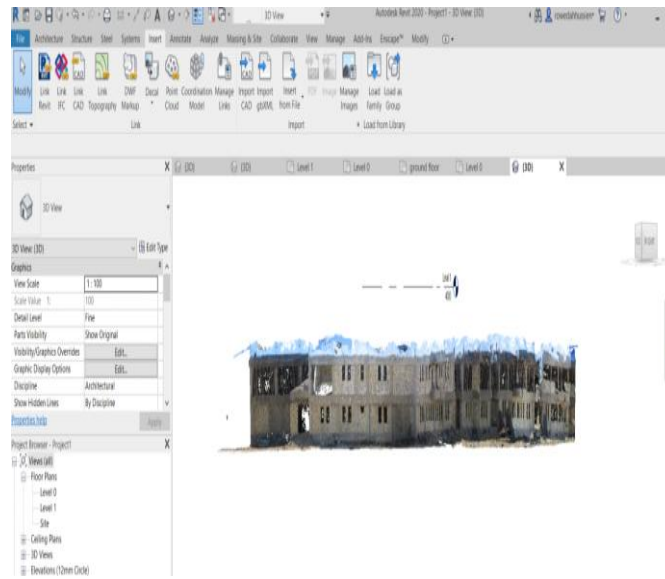
Figure.10 Autodesk ReCap Model

- 2- The next step is to clean up the cloud point. The undesirable and redundant details and confusion are known as 'noise,' which is taken from the point cloud at this time. This can include footpaths, road vehicles, parking, reflections, and so on. Cleaning points in the cloud can be a lengthy process based on certain noises in the point cloud. The period is one of the main factors during data collection. The running time can be very variable depending on different factors. The accuracy of the obtained information and its file size is among the factors that significantly affect the processing time. After importing the files into ReCap, the registration process was started.
- 3- They were recording data sets using the Auto Registration function. The results are entirely outdated and collapsed, and the computer does not seem to overlap them. As the auto registration results were unsatisfactory, this action has been taken by hand. There are various methods for manual registration. The last construction job for ReCap was to clear the cloud dot. As a vast number of people were included in the capture and laser scan, the point cloud was shadowed greatly. Different objects could not be deleted by ReCap's automatic program sufficiently, so this process was done by hand. Various software tools can select and delete occlusions manually for this purpose.

### 2.4 Object recognition

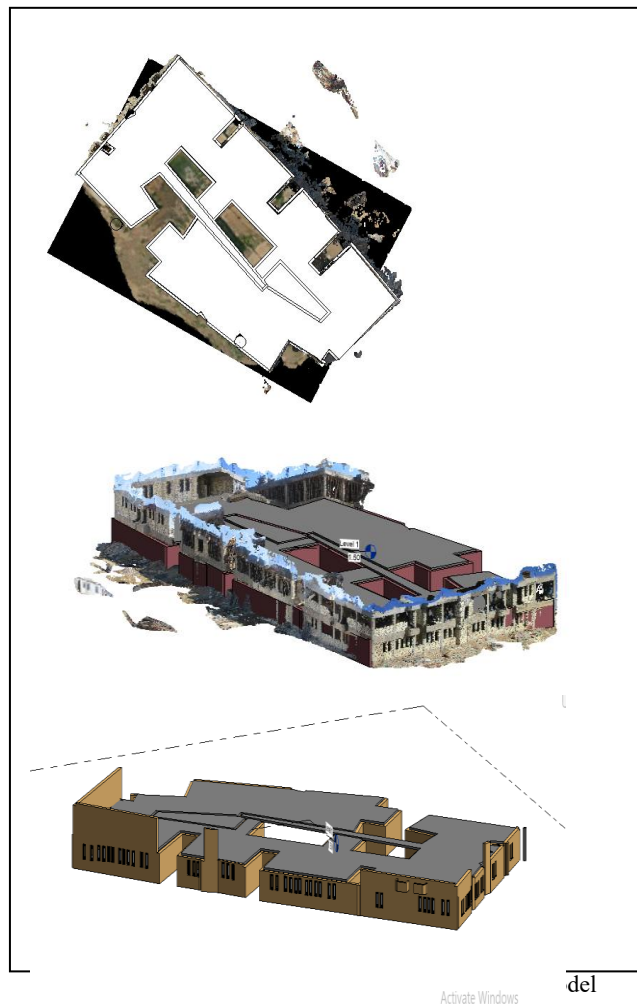
After analyzing the collected data and developing the point cloud, the building elements should be converted into BIM Family products. In order to provide characteristics and functionality required of the entity during this procedure, called object recognition, the points that represent the geometry of building elements should be combined with semantical knowledge about the associated object [19,20,22];

In this project, an image taken from Google earth was merged with the project in order to complete the building from all its sides, as drone camera was not allowed to be used on the site, and it was prevented by both the contractor and the owner; therefore it was depended both on image taken and Google earth image. Figures (11) show the project in the Revit software.



**Figure.11** Autodesk Revit Model

After importing the point cloud, the model starts to be build depending on the actual quantity and starts to insert walls, floors, columns, windows, and doors. Figure (14) shows the stage for building the point cloud



The same building was model using Revit depending on AutoCAD drawing, and by depending on these drawings, the building and as supposed to be at the first invoice as shown in figure (13).

The methodology followed in this study was designed to be both rigorous and practical. Data capture began with high-resolution digital cameras, selected for their affordability and accessibility compared to specialized laser scanners. Images were taken at regular intervals and at various angles to ensure sufficient overlap, a key requirement for Structure-from-Motion (SfM) photogrammetry. Typically, an overlap of 60–80% was maintained, which allowed the software to stitch images into coherent 3D point clouds. Lighting conditions, weather, and shadows were carefully managed during site visits, as these factors can significantly affect image clarity and model accuracy.

Once captured, the images were processed in Autodesk ReCap. The software automatically generated a dense point cloud, but manual cleaning was required to remove irrelevant elements such as construction equipment, vehicles, and temporary scaffolding. This stage is critical because noisy point clouds can distort measurements, leading to inaccurate quantity estimations. After cleaning, the point clouds were imported into Revit, where they were compared with the as-planned BIM model created from AutoCAD drawings.

The geometric accuracy of the photogrammetry-derived model was evaluated using the Root Mean Square Error (RMSE), calculated by comparing corresponding dimensions extracted from the point cloud and the ground truth measurements. RMSE was computed using Equation (1):

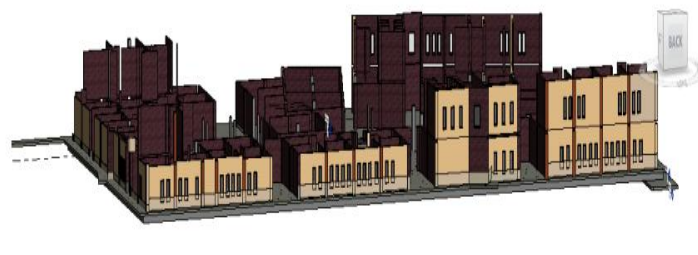
$$\text{Percentage Difference} = \sqrt{\frac{1}{n} \sum_{i=1}^n d_{pc,i} - d_{gt,i}^2} \quad (1)$$

where:

- $d_{pc,i}$  is the dimension extracted from the photogrammetry-based point cloud,
- $d_{gt,i}$  is the corresponding ground truth physical measurement,
- $n$  is the total number of compared measurements.

### 3. Results

Four methods of quantity estimation were then evaluated: tender documentation, manual measurement by site engineers, Revit (as-planned), and ReCap (as-built). Each method was compared to assess accuracy and reliability. The inclusion of multiple approaches ensured that results were not biased toward a single tool, and also reflected the real-world practices of contractors, consultants, and project owners. This triangulation strengthened the validity of the findings and demonstrated the added value of integrating photogrammetry into existing BIM workflows.



**Figure.13** As planned Project with the First Invoice

“The comparison shows clear differences between the as-planned model and the as-built condition. These discrepancies can be attributed to several technical, contractual, and managerial factors.”The project was in the second award, which means the contractor receives the project with the foundation. Some parts are completed, but these parts are exposed to be destroyed; therefore, it has to be rebuilt or repaired, which took longer than scheduled.

- 1- The contractor himself gives a significant portion of the project to the subcontractor, which leads to delay.

- 2- The term and conditions for implementing the project are based on the SBD, in which the contractor is not familiar with its terms and conditions, for example, the essential condition is to prepare the project progress with MS project, not with excel that took time as the staff has no experience in the program.
- 3- The most significant factor is that the contractor has previously known that the owner has no cash or the first invoice to pay, which gives him confidence that the owner has no word to say even if he is late.

The invoice has been made on four-time schedules: the first one made in 12/2019, the second one in 5/2020, the third one 7/2020, and the last one 12/2020.

It there is a gap between the time of the preparing and proposed the invoice that returns to the most important reason which is Covid 19 which stop almost all the projects as due to curfew imposed by the governorate, the project has to stop for almost three month as shown in figure (14)

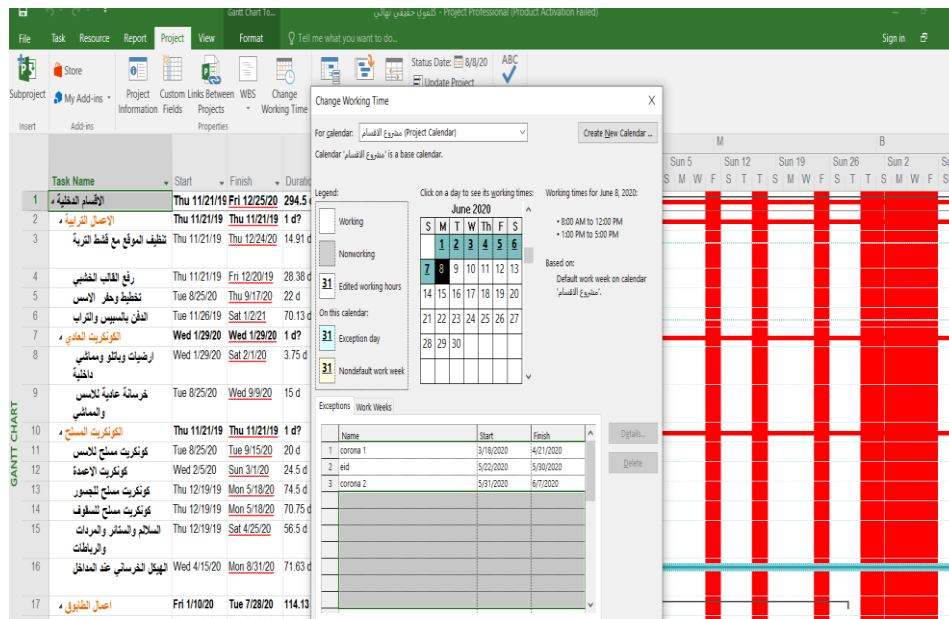


Figure14. Project schedule illustrating construction suspension and delays caused by COVID-19 curfew measures.

In the first and second payment include . the quantity include those one DPC layer which is not included in this scope of work, the third payment include , the brickwork and then issued for the owner to be paid, the quantity and cost calculated in the first two payment by the four methods is shown in table (1).

Table 1 Comparison of Floor and Wall Quantities Estimated Using Different Methods

Item	Method	Quantity	Unit	Cost	Currency
Floor	Tender (Method 1)	2750	m <sup>2</sup>	35,750,000	IQD
Floor	Site Measurement (Method 2)	2365	m <sup>2</sup>	30,745,000	IQD
Floor	BIM – Revit (Method 3)	2039	m <sup>2</sup>	26,507,000	IQD
Floor	Photogrammetry – ReCap (Method 4)	2000	m <sup>2</sup>	26,000,000	IQD
Wall	Tender (Method 1)	600	m <sup>2</sup>	21,000,000	IQD
Wall	Site Measurement (Method 2)	600	m <sup>2</sup>	21,000,000	IQD
Wall	BIM – Revit (Method 3)	500	m <sup>2</sup>	17,500,000	IQD
Wall	Photogrammetry – ReCap (Method 4)	540	m <sup>2</sup>	18,900,000	IQD

To evaluate the discrepancy between different estimation methods, the percentage difference was calculated using Equation (2):

$$\text{Percentage Difference} = \frac{[Q_{\text{method}}]_B - [Q_{\text{method}}]_A}{[Q_{\text{method}}]_A} * 100 \quad (2)$$

- $Q_{\text{Method B}}$  = reference quantity (e.g., tender or BIM)
- $Q_{\text{Method B}}$  = comparison quantity (manual, Revit, ReCap, etc.)

The two items only include as part of the scope of the work. It can be noticed that there is a slight difference between the two methods as the contractor try hard to compile with tender, but as comparing withdrawing there is a significant difference, as it shows the as-planned that supposed to be built, however when compared with actually build with Recap software it shows the as-built and the different between each method as a percentage as follow:

Percentage of method 1/2 for floor

$$\frac{35750000 - 30745000}{35750000} * 100 = 14.8\%$$

Percentage of method 1/2 for Wall

$$\frac{21000000 - 21000000}{21000000} * 100 = 0\%$$

The difference was shown significantly in the floor as a change order was made to delete a specific part of the floor and replaced it with another type instead of concrete.

Percentage of method 1/3 for floor

$$\frac{35750000 - 26507000}{35750000} * 100 = 25.8\%$$

Percentage of method 1/3 for Wall

$$\frac{21000000 - 17500000}{21000000} * 100 = 16.66\%$$

Percentage of method 1/4 for floor

$$\frac{35750000 - 26000000}{35750000} * 100 = 27.27\%$$

Percentage of method 1/4 for Wall

$$\frac{21000000 - 18900000}{21000000} * 100 = 10\%$$

Percentage of method 3/4 for floor

$$\frac{26000000 - 26507000}{26000000} * 100 = -0.195\%$$

Percentage of method 3/4 for Wall

$$\frac{18900000 - 17500000}{18900000} * 100 = 7.5\%$$

According to the calculation above, the third and the four show slightly different between them; however, they show significant difference what the contractor has produced to the owner, which means there is inaccuracy in the calculation.

While the building and invoice for the third time include as shown in table 2.

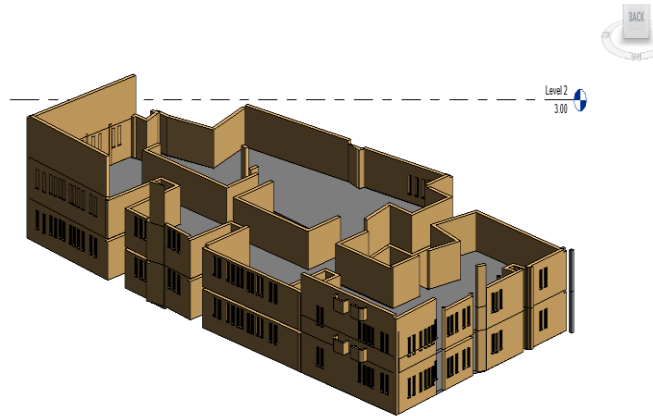


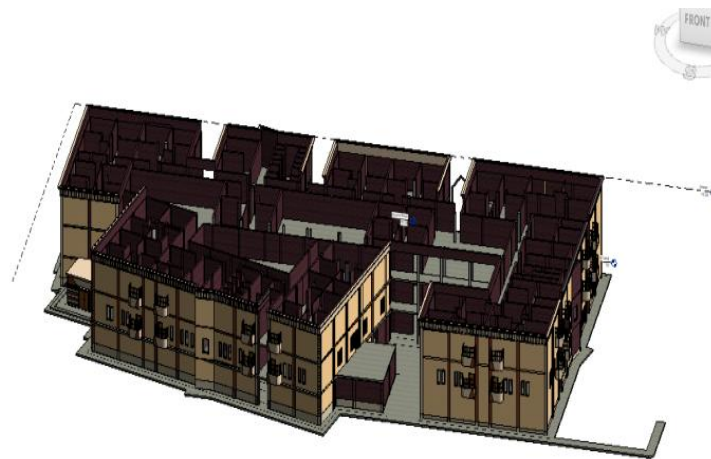
Figure.15 The Model for the Third Invoice

Table 2 Comparison between the Different Methods for Calculating the Third Payment

Comparison	Floor Difference (%)	Wall Difference (%)
Tender vs Site Measurement	14.8	0.0
Tender vs BIM (Revit)	25.8	16.7
Tender vs Photogrammetry (ReCap)	27.27	10.0
BIM vs Photogrammetry	-0.2	7.5

Table (2) shows a difference between the cost of the wall in the last method. As previously mentioned, it depends on the actual build, while the internal door, the researcher take the photo from inside the building in order to check the number and the type of door that used.

Then the project in the last invoice, as shown in figure (16)



**Figure.16** The Model for the four Payment

The difference between the four methods as in previous payments in table (1), the method four by using Recap is the most accurate as depending as-built not as planned; therefore, the method four used for calculating the quantity is the most accurate. The method is most suitable, especially in a risky environment. The project stopped for a period of time, so the camera can calculate what been existing without loss or damage and measure the quality of the work. Figure (16) shows the project after render.



**Figure.17** The Model After Render

BIM (Building Information Modeling) BIM uses design drawings, specifications, and material properties to create a *digital twin* of the project. From this model, material quantities can be extracted with high accuracy before construction begins. Any design change updates these schedules instantly, helping avoid over-ordering and ensuring resources are allocated efficiently.

Photogrammetry(Structure-from-Motion) Photogrammetry captures the *as-built* state of a project using high-resolution site images, which are processed into 3D point clouds (e.g., in Autodesk ReCap). This allows direct measurement of actual installed materials and makes it possible to spot discrepancies between the as-built and the original BIM plan.

Case Study Insight In the case study, comparing BIM/Revit (as-planned) with ReCap (as-built) revealed:

- 27.27% less flooring installed than planned
- 10% less wall area than planned

Such gaps can result from design changes, repairs, or scope adjustments. Without as-built verification, procurement would have been based on inflated estimates—leading to excess orders of concrete, bricks, and steel, and ultimately to

unnecessary waste. Table 3 presents a detailed comparison between as-planned and as-built quantities for key building elements, highlighting discrepancies that directly affect cost estimation and material procurement.

**Table 3** As-Planned vs. As-Built Comparison

Item	Method	Quantity	Unit	Cost	Currency
Wall	Tender / Site	1097	m <sup>2</sup>	10,970,000	IQD
Wall	BIM – Revit	1000	m <sup>2</sup>	10,000,000	IQD
Wall	Photogrammetry – ReCap	540	m <sup>2</sup>	9,720,000	IQD
Door Type 1	All Methods	136	No.	54,400,000	IQD
Door Type 2	Tender / BIM	42	No.	21,000,000	IQD
Door Type 2	Photogrammetry	20	No.	10,000,000	IQD

Why this matters for sustainability:

- Extra materials increase *embodied carbon emissions* from manufacturing.
- Transport and storage requirements grow unnecessarily.
- Disposal or recycling consumes additional energy and cost.

Estimating the RMSE value using photogrammetry-derived quantities as ground truth shows that there was a much higher degree of difference between the tender-based quantities and the BIM-based quantities. The floor quantities generated a significantly higher RMSE value (482.1m<sup>2</sup>), which means that there are considerable mis-evaluated floor area estimates in the as-planned models. With the walls, a fairly moderate to higher RMSE value is produced for wall quantity estimates depending on the stage of payment being examined. The door quantities produced the least deviation from the other two materials. Therefore, the RMSE analysis of quantity estimates also confirms the findings of the cloud-to-BIM deviation maps that indicate where there are localized discrepancies due to changes in design and reconstruction activity. Table 4 reports the RMSE values calculated using photogrammetry-based quantities as the reference, providing a quantitative assessment of accuracy for each estimation method.

**Table 4.** RMSE Accuracy Assessment Using Photogrammetry as Ground Truth

Element Type	n	Mean Deviation	RMSE
Floors (m <sup>2</sup> )	3	384.7 m <sup>2</sup>	482.1 m <sup>2</sup>
Walls – Payments 1–2 (m <sup>2</sup> )	3	53.3 m <sup>2</sup>	54.2 m <sup>2</sup>
Walls – Payment 3 (m <sup>2</sup> )	2	508.5 m <sup>2</sup>	511.4 m <sup>2</sup>
Doors Type 1 (No.)	1	0	0

Element Type	n	Mean Deviation	RMSE
Doors Type 2 (No.)	1	22	22

### 3. Material Sustainability and Recycled Materials

When BIM’s precise planning is combined with photogrammetry’s reality capture, it supports a more sustainable, circular construction process:

- Optimized Ordering of Recycled Materials**  
 For materials like reclaimed concrete aggregate (RCA) or recycled bricks, accurate quantity tracking prevents over-extraction from recycling facilities.  
*Example:* If flooring needs are 27% less than expected, orders for recycled concrete can be reduced, conserving resources.
- Targeted Reuse in Retrofits**  
 By knowing exactly what has been installed, leftover recycled materials from one project can be directly allocated to another, minimizing waste.
- Waste Diversion Reporting**  
 As-built models can confirm the actual recycled content used, supporting sustainability certifications such as LEED and BREEAM.
- Efficient On-Site Logistics**  
 Precise tracking of steel members and precast components allows for controlled dismantling and reuse instead of random demolition. **Table 5 summarizes the combined benefits of BIM, photogrammetry, and their integration in terms of accuracy, waste reduction, and sustainability performance.**

**Table 5** Summary of Benefits

Feature	BIM	Photogrammetry	Combined Impact
Design Accuracy	High for planned scope	Low (captures actual reality)	Accurate baseline for procurement
As-Built Verification	Limited (manual updates)	High (3D site scans)	Immediate discrepancy detection
Waste Reduction	Prevents overestimation	Identifies unused/excess	Minimizes waste at all stages
Recycled Material Use	Tracks planned content	Confirms installed content	Aligns procurement with reality

The analysis shows a significant difference between each of the four estimation methods. The tender-based estimates resulted in inflated quantities of actual installed work when compared with quantities determined by using photogrammetry. In the case of floor areas, tender estimates were 27.27% higher than the quantities determined by the photogrammetry-derived as-built quantities, while for wall quantities, estimates from tenders exceeded photogrammetry-derived estimates by 10%. The BIM-based as-planned model produced estimates closer to those obtained through photogrammetry in each case, with floors having a deviation of ±1% and walls having a 7.5%. This finding supports the conclusion that using BIM improves estimation accuracy relative to the traditional method of estimating; however, it still requires systematic updates to reflect what is found in the field instead of just relying on what was estimated through the use of BIM.

**Table 6.** Percentage Differences between Quantity Estimation Methods

Comparison Method	Floor Difference (%)	Wall Difference (%)
Tender vs. Site Measurement	14.8	0.0
Tender vs. BIM (Revit)	25.8	16.7
Tender vs. Photogrammetry (ReCap)	27.27	10.0
BIM (Revit) vs. Photogrammetry (ReCap)	-0.2	7.5

Table 6 summarizes the percentage differences between the various quantity estimation methods for floor and wall elements. Presenting these results in tabular form allows for a clearer comparison of deviations and highlights the improved accuracy achieved through photogrammetry-based as-built verification.

Embodied carbon is simply quantity  $\times$  carbon factor. If the quantity is inflated, the carbon is inflated one-for-one. That's why your measured gaps between as-planned and as-built matter so much. Industry guidance frames the calculation exactly this way. One of the most significant contributions of this research is its link between accurate quantity verification and sustainability. In construction, every cubic meter of concrete, every brick, and every ton of steel carries not just a financial cost but also an environmental burden. Embodied carbon—the greenhouse gas emissions generated during the production and transportation of materials—is increasingly recognized as a critical factor in project sustainability. Over-ordering due to inaccurate take-offs inflates embodied carbon in direct proportion to the wasted material. For instance, the 27.27% difference observed in flooring translates into more than just financial loss. Assuming a 150 mm thick concrete slab, this discrepancy would equal roughly 112.5 cubic meters of surplus concrete. Using ICE database factors, this corresponds to between 11 and 39 tonnes of avoidable CO<sub>2</sub> emissions. Similarly, the 10% discrepancy in wall quantities results in hundreds of excess bricks, equating to nearly 2 tonnes of CO<sub>2</sub> emissions if traditional clay bricks are used. These figures illustrate how technical inaccuracies can cascade into significant sustainability consequences. By adopting BIM integrated with photogrammetry, project teams can avoid such errors, aligning with broader global goals such as the UN Sustainable Development Goals (SDGs). In particular, SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) are directly supported by minimizing material waste and emissions. Moreover, this workflow promotes a circular economy approach. Surplus materials, once quantified accurately, can be catalogued for reuse in other projects instead of being discarded. This study therefore reframes BIM not only as a design and cost management tool but as a mechanism for environmental accountability. By verifying as-built conditions in near real-time, project teams can make informed decisions that reduce both economic and ecological costs.

- Flooring (27.27% gap) — In your study, floors were planned at 2,750 m<sup>2</sup> but built at 2,000 m<sup>2</sup> (a 27.27% overestimate). If that floor layer were a concrete slab:
  - For a 75 mm screed: the “extra” 750 m<sup>2</sup>  $\approx$  56.25 m<sup>3</sup> of concrete. Typical embodied carbon for concrete is on the order of  $\sim$ 100–350 kgCO<sub>2</sub>e/m<sup>3</sup> (mix-dependent). That's  $\sim$ 5.6–19.7 t CO<sub>2</sub>e of avoidable emissions.
  - For a 150 mm slab:  $\approx$  112.5 m<sup>3</sup> “extra”  $\rightarrow$   $\sim$ 11.3–39.4 t CO<sub>2</sub>e wasted. (Carbon factors from the ICE database and allied Circular Ecology resources.)  
These numbers scale linearly with thickness and with the concrete mix you actually specify.
- Walls (10% gap) — You recorded 600 m<sup>2</sup> planned vs 540 m<sup>2</sup> built (10% over). For clay brickwork, ICE shows about 0.53 kgCO<sub>2</sub>e per brick, and a rule-of-thumb of  $\sim$ 60 bricks per m<sup>2</sup> for a one-brick-thick wall. That's  $\sim$ 31.8 kgCO<sub>2</sub>e/m<sup>2</sup>, so the “extra” 60 m<sup>2</sup>  $\approx$   $\sim$ 1.9 t CO<sub>2</sub>e in bricks alone (mortar/transport not included).
- Steel (illustrative) — If inaccurate take-offs lead to, say, +5 t of reinforcing bar ordered “just in case,” primary steel typically carries  $\sim$ 1.8–2.0 kgCO<sub>2</sub>e/kg (lower for high-recycled EAF steel,  $\sim$ 0.4–0.8). That single cushion could add  $\sim$ 2–10 t CO<sub>2</sub>e unnecessarily. (ICE database ranges.) These are not edge-cases. They are direct consequences of quantity error—exactly the type your project surfaced (27.27% floor, 10% wall).

Store product-stage (A1–A3) carbon factors in BIM object parameters (preferably from EPDs; fall back to vetted databases like ICE when EPDs are missing). Use a consistent WLCA method (RICS) so project teams talk the same language.

- Wire schedules so every quantity change (areas, volumes, counts) auto-recalculates embodied carbon (quantity  $\times$  factor). This pushes real-time “carbon budgets” to designers and estimators before anything is procured.

- At key milestones, run site photogrammetry and compare as-built point clouds to the BIM as-planned model. Flag material variances early (like your 27.27% floor delta) so POs and deliveries can be right-sized before waste occurs. Your study already shows this approach works in practice.
- Set tolerance bands (e.g.,  $\pm 3\text{--}5\%$ ). If photogrammetry shows an element drifting beyond tolerance, pause or trim orders. Require just-in-time release based on verified quantities instead of bulk “round-ups.”
- Where feasible, switch to mixes with SCMs, recycled steel (EAF), or reclaimed brick/concrete aggregates. Because the BIM schedules are exact, you can order the right volume of recycled inputs (not too much, not too little), minimizing both over-extraction from recyclers and on-site surplus.
- Create two BIM parameters for each element: Planned Recycled Content and Installed Recycled Content. After photogrammetry verification, lock the latter for audit trails and certifications (e.g., LEED/BREEAM).
- If the model shows surplus (e.g., due to a scope change), the BIM schedule can package those exact leftovers (dimensions/weights) for reuse on another project, rather than downcycling or disposal. That’s faster when you already have verified quantities

Combining BIM and photogrammetry provides not only accurate quantity control but also a powerful way to monitor the quality of material installation throughout a project’s life cycle. BIM offers a precise digital reference of the intended geometry, specifications, and tolerances, while photogrammetry captures high-resolution images of the actual construction, converting them into 3D point clouds for direct comparison. This integration allows teams to detect subtle deviations that might otherwise go unnoticed. For concrete works, photogrammetry can reveal differences in slab thickness, detect areas of under-pouring, and highlight surface defects such as uneven curing, honeycombing, or early cracking—all of which can reduce the slab’s load-bearing capacity and long-term durability. In brickwork and blockwork, orthophotos generated from site scans make it possible to check alignment, bonding patterns, mortar joint thickness, and verticality. If the as-built wall dimensions are smaller than planned without a documented design change, it may indicate incomplete sections, voids, or dismantled areas that could compromise structural stability. Quantity deviations can thus be more than just a sign of over- or under-ordering; they may point to hidden defects or poor workmanship that present future safety risks. By regularly comparing BIM models with photogrammetry scans at key stages, these issues can be identified early, investigated for cause—whether design changes, construction errors, or material defects—and rectified before they escalate into costly delays, rework, or failures. This proactive quality assurance approach ensures that the built structure not only matches its planned dimensions but also meets the required performance and safety standards, ultimately reducing waste, preventing structural risks, and extending the building’s service life conclusions that can be drawn.

#### 4. Discussion

According to the findings of this study, when Building Information Modeling (BIM) is utilized in conjunction with photogrammetry, it can enhance the ability to determine accurate data about existing structures and consequently allow for improved accuracy in the estimation of quantities of materials required for a building project. The comparison of tender-based quantity estimations, manual measurements of quantities, BIM models based on plans, and photogrammetry-based measurements taken directly from an existing structure show significant differences, particularly regarding the quantity of floor and wall area. Specifically, there is a deviation of 27.27% for flooring quantities as compared to the tender and a deviation of 10% for wall surface areas when only using the tender quantity estimation and manual measurement techniques to estimate the quantities of building enclosures, making it easy to see why relying on only the planned models or measuring methods could result in erroneous billing amounts, under-estimated material quantities or the purchase of unnecessary materials for construction projects.[24]

These results support what was found in earlier work by Volk et al. (2014) and Bosché et al. (2015), who documented an ongoing discrepancy between how a project has been designed and constructed because BIM models were not updated completely. However, unlike these previous works (which primarily focused upon laser scanning), this research demonstrates that photogrammetry when utilised in a systematic way can provide a considerable cost-saving and sufficiently accurate alternative to laser scanning, particularly where financial or logistical limitations make the use of laser scanning impractical. This provides a critical contribution to the available literature, which has been largely absent of low-cost realistic capture techniques available to developing nations or projects with limited budgets.

This research also provides a significant contribution in demonstrating how digital verification (as accomplished via photogrammetry) aids in developing more sustainable construction practices. By identifying areas of excess that may otherwise go unnoticed, this approach supports the goals of sustainability such as reducing the amount of material wasted, increasing the efficiency of resource use, and reducing the amount of embodied carbon released into the atmosphere. For example, the 27.27% discrepancy found on the flooring could lead to a significant reduction in the amount of cement, aggregate, and energy consumed if it had been discovered prior to purchasing those materials. This confirms what Roberts et al. (2018) stated regarding the potential impact of digitalisation on the sustainability of the construction industry, although no figures were provided to demonstrate that impact.<sup>[25]</sup>

In theory, these findings enhance the knowledge of how BIM-based workflows are enriched with low-cost reality-capture technology. Additionally, the use of photogrammetry for both visualization and documentation, and for use in making quantitative decisions, helps fill a gap in the Scan-to-BIM literature. The use of quantifiable metrics, such as variance percentages, cost implications, and embodied carbon impacts, makes this research an important step towards establishing standardized evaluation criteria for verifying as-built conditions. From a practical standpoint, the methodology has immediate benefits for contractors, consultants, and project owners. The developed workflow allows contractors to certify that payment is based on verified evidence, which eliminates the potential for payment disputes. This method enhances a project's ability to monitor progress and increases a project's ability to mitigate and reduce the risks associated with poor project performance and incomplete work. In addition, the use of low-cost technology, such as conventional cameras and Autodesk ReCap, allows for the development of advanced methods for monitoring progress on projects where the use of drone and laser scanning technology is limited or restricted. The findings from this research also provide insight into a wide range of issues that affect overall construction performance. The delays and variances found in the case study highlight problems arising from poor coordination among subcontractors, or when subcontractors misunderstand their contractual obligations. Moreover, the financial uncertainties arising from the timeframe between payment request and actual payment may also negatively impact the speed and efficiency of construction.<sup>[25,26,27]</sup>

This study's results are in line with other studies showing inconsistency between planned and actual project site conditions. Volk et al. (2014) and Bosché and associates (2015) found that when BIM models are not updated to reflect the actual job site conditions, there is a difference in the temporal and spatial accuracy of the work performed. In contrast to previous studies that utilized laser scanning technology, this study provides evidence that photogrammetry can be equally effective, with considerably lower costs to the owner. The discrepancies in quantities directly correlate to payment certification and contract administration. Overestimating quantities results in higher-than-necessary interim payments by owners, disputes between owners and contractors regarding price and payment, and wasted cash flow. Using photogrammetry in conjunction with BIM gives objective verification of the actual executed work, rather than relying solely on subjective manual measurements. Also, providing accurate quantity verification will promote sustainable construction practices. The 27.27% increase in floor area results in a significant amount of excess concrete material produced, transported, and placed, thus creating unnecessary embodied carbon emissions. The integration of BIM and photogrammetry will help align purchasing decisions to reflect accurately the quantities of as-built work and will help support responsible use of natural resources through carbon-reduction efforts.

This research shows that combining point clouds derived from photogrammetry techniques with building information modeling (BIM) is more effective in verifying as-built quantities than relying on estimated quantities in the original plans (tender) or measurements completed manually. The variations seen between the intended design quantities and the actual construction quantities in this study confirm what has been demonstrated in previous studies related to Scan-to-BIM, which are that the designs used to create the Building Information Models often vary from what is actually built unless there are systematic updates occurring through reality capture. The findings of this research demonstrate that the methodology and empirical contributions of the combined use of BIM and Photogrammetry will provide construction managers with more accurate verification of quantities, create less waste and increase sustainability through evidence-based research, therefore providing an excellent platform to continue to develop additional academic research related to the combined use of BIM and Photogrammetry.<sup>(28)</sup>

According to recent international research, integrating point clouds and Building Information Modeling (BIM) provides access to automated/semi-automated systems for matching BIM objects with point clouds or 3D scanned data to allow for improved detection of BIM objects regardless of the condition of the data (occlusions, etc.) or conditions under which the scans were taken. As the findings of this current study have shown, the use of Reality Capture provides an objective basis for verifying that As-Built conditions correspond to the tender documents and decreases the uncertainty associated with the use of pre-construction only and/or manual estimations. In the past, many researchers have acknowledged that while laser scanning provides greater geometric accuracy than other methods, the costs, logistics, and accessibility of laser scanning present challenges—especially when using the technology in constrained work environments. To address these challenges, increased research has been dedicated to investigating alternative, lower-cost methods for generating usable As-Built models and supporting verification tasks using either Photo/Videogrammetry techniques. The results of the current research demonstrate that a camera-based workflow can effectively support Construction Monitoring and Quantity Verification if Planned for Overlap and Angles, and Plans incorporate Registrations and Cleans.<sup>(29,30)</sup>

## 5. Conclusions

This study introduces a groundbreaking and useful workflow that combines Building Information Modeling (BIM) and photogrammetry (SfM) to enhance the accuracy of as-built quantity verification in construction projects. The work's novelty is that it proves that low-cost, image-based reality-capture techniques—when thoroughly integrated with BIM—can yield trustworthy quantity measurements that compete with more sophisticated and costly technologies like laser scanning. Thus, the suggested workflow is especially applicable to projects with tight budgets or limited access to specialized equipment, which in turn, increases the usage of digital construction methods in different contexts.

Through the use of a systematic workflow including data collection, processing of point cloud information, recognizing objects, and measuring quantitatively, the authors responded to the research questions that were posed in the Introduction.

The first of these answers is that photogrammetry is a reasonable means of recording actual material quantities in an accurate manner, so long as it is coupled with BIM.

Secondly, through a combination of using photogrammetry and BIM, the accuracy of the recorded actual quantity of materials will be higher than would have been obtained using either method alone. Through the combination of photogrammetry and BIM, the amount of variation between the expected quantities and the recorded actual quantity of materials will be significantly less than using traditional measuring methods or using a manual measuring technique; this difference is quantified at approximately 27.27% for floor area and 10% for wall area.

Third, based on the fact that differences exist in the quantity of material reported and the quantity of material actually required, the authors have shown how the differences have a measurable impact on the way contracts are managed, the waste created from material used and the effect of using excess material on the environment; thus answering the final research question about the sustainability and resource efficiency involved in this type of measurement process. The primary contribution of this research is to connect digital verification of quantities, both financially accurate and environmentally sustainable, to carbon footprint reduction by using embodied carbon reduction and material waste prevention. The second contribution is to establish photogrammetry as a replaceable alternative to 3D laser scanning within the Scan-to-BIM process and provide an evidence-based discussion about the influence of discrepancies between as-planned and as-built projects on project results. While this study presents many benefits, the following are some shortcomings: first, the conventional camera limited the resolution of images taken from drones, and also affected the accuracy of depths because it was less advanced than most other sensors currently on the market. Second, since there was no option for deploying drones, we had to rely on Google Earth to collect additional data, which may create minor geometric distortion in the overall results. Third, point clouds had to be processed by hand (cleaned and registered) as a result of being captured with a camera that created noise and occlusions. These two issues also increased the time needed to process data and introduced greater chances for subjectivity. Fourth, the results are based on only one case study, which might limit the ability to generalise findings from this case study to future work. Future studies may want to test these workflows on more than one type of building and use AI for automated object recognition, as well as build larger sample sizes.

## Author Contributions

Conceptualization: Rouwaida Ali, Hadi Aljumaily; Methodology: Rouwaida Ali, Sawsan Rasheed Mohammed; Data collection and site investigation: Rouwaida Ali; Photogrammetry processing and point cloud generation: Rouwaida Ali; BIM modeling and quantity extraction: Rouwaida Ali, Sawsan Rasheed Mohammed; Formal analysis and accuracy validation: Rouwaida Ali; Results interpretation and discussion: Rouwaida Ali, Hadi Aljumaily; Writing—original draft preparation: Rouwaida Ali; Writing—review and editing: Sawsan Rasheed Mohammed, Hadi Aljumaily, Supervision: Sawsan Rasheed Mohammed.

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## Data Availability Statement

We encourage all authors of articles published in our journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required.

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## Conflicts of Interest

“The authors declare no conflict of interest.”

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