Quantity Take-Off Methods for Sustainable End-of-Life Strategies: 2D Drawings vs. 3D Scan-to-BIMs

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Abstract. The environmental crisis has made it imperative for the construction sector to adopt sustainable end-of-life strategies, such as the reuse of salvaged construction materials. A key factor in deciding on these strategies is accurately quantifying the construction materials in existing structures, a process that can be challenging. This study examines the advantages and limitations of various quantity take-off methods using the Frank Erwin Center (ERC) as a case study. Three approaches are evaluated to determine concrete quantities from the ERC's precast panels façade: (1) manual calculations with hard-copy 2D drawings, rulers, and Microsoft Excel, (2) software-based methods using 2D digital PDF drawings and Bluebeam Revu, and (3) creating 3D BIM models from a 3D point cloud (Scan-to-BIM) using Autodesk Recap and Autodesk Revit. By comparing the estimated concrete quantities derived from 2D drawings and the 3D point cloud, the study highlights the strengths and challenges of each method. The findings inform a discussion on selecting an appropriate quantity take-off (QTO) strategy for functionally obsolete structures, guiding decisions for sustainable end-of-life strategies.

Keywords: Quantity Take-off, Embodied Carbon, Concrete Element Reuse, Building Information Model

1 Introduction

The buildings and construction sector accounts for approximately 21% of global greenhouse gas emissions [1]. While the primary focus has been on decarbonizing infrastructure delivery and operations, addressing the end-of-life phase of buildings is equally essential. Research indicating that embodied greenhouse gas emissions account for around 50% of a structure's total life cycle emissions [2] underscores this urgent need.

Demolition remains the conventional practice for managing obsolete structures, yet deconstruction (aimed at reusing construction materials) presents significant environmental benefits. A key challenge to adopting sustainable end-of-life practices is the accurate quantification of construction materials that could be salvaged from existing buildings, as [3] illustrates for concrete structures. Reliable assessments of reclaimed components, along with their embodied carbon, are essential for evaluating the feasibility of reuse and other sustainable alternatives.

This study addresses this challenge by comparing 2D drawings (measured manually from hard-copy plans or digitally using specialized software) with 3D BIM models generated from point cloud scans for material quantification. Through a detailed case study, it evaluates the strengths and limitations of each approach, providing insights to support informed decision-making in sustainable building end-of-life practices.

2 State-of-the-Art in Construction Material Quantification

2.1 Current Industry Practices

Material quantification for existing buildings is still predominantly based on 2D drawings, supplemented by manual site measurements when drawings are outdated or missing [4]. These conventional workflows can be time-consuming and often introduce uncertainty due to drawing inaccuracies or undocumented modifications. The adoption of advanced techniques such as Scan-to-BIM remains limited due to cost, specialized equipment requirements, and the need for trained personnel [4-7]. As a result, many practitioners continue to rely on manual or semi-manual workflows despite their limitations, especially in developing countries [6].

2.2 BIM Workflows

The integration of 3D point cloud technologies and Building Information Modeling (BIM) has significantly advanced the field of quantity take-off (QTO). Early studies, such as those by [8], identified the challenge of converting 3D point cloud data into BIM models, emphasizing the potential for enhanced accuracy and efficiency in construction projects. [5] further explored BIM applications for existing buildings, comparing terrestrial laser scanning (TLS) with conventional measurement techniques, and demonstrated the advantages of integrating these technologies for QTO. The study also noted that while producing a BIM model with TLS required a 35% higher budget, it significantly reduced project site time and human exposure by half compared to conventional tools. Similarly,[9] investigated the application of BIM for QTO, identifying both challenges and advantages, such as enhanced visualization, through interviews.

Recent advancements have focused on the application of 3D laser scanning and automated data generation techniques. [10] proposed a BIM-based approach to automate QTO processes, while [11] demonstrated the effectiveness of combining BIM with 3D laser scanning for precise quantity management. [12] introduced a framework for automated BIM data generation from 2D drawings using drawing recognition, streamlining QTO, and reducing errors through text classification and object model generation.

The Scan-to-BIM approach has been applied to heritage buildings [13] and building maintenance projects [14], highlighting its versatility and growing adoption in various construction domains. [15] discussed the challenges in BIM-based QTO (such as management, professional skills, software functionalities, and implementation cost), while highlighting opportunities for future improvements (such as software development and upskill training for seasoned professionals). [16] compared Scan-to-BIM with conventional methods for dismantling quantity estimation in nuclear power plants, revealing that conventional methods had errors ranging from 10% to over 100% due to outdated drawings. Scan-to-BIM reduced errors and revealed a 20% underestimation of dismantling costs by conventional methods.

These studies collectively underscore the transformative impact of BIM and 3D scanning technologies on the construction industry, paving the way for more efficient and accurate QTO practices.

2.3 Overview of Conventional vs. BIM Workflows

Conventional methods remain more economical in terms of training and equipment, yet their reliability depends heavily on the completeness and accuracy of existing drawings. As demonstrated in [4,6], missing information or undocumented modifications can result in inconsistent or misleading measurements, while [16] shows that reliance on outdated drawings may lead to substantial errors in large or complex projects.

In contrast, automated or semi-automated BIM-based and Scan-to-BIM workflows [10,12,15] generally reduce project uncertainty and improve reliability, particularly when dealing with complex geometries or limited documentation (despite higher initial costs). Nevertheless, the current evidence base remains fragmented. Therefore, additional studies are needed to systematically compare these methods with respect to cost, required instrumentation, applicability across building types, personnel requirements, and broader operational factors, enabling more informed, structured decision-making.

3 Methodology

Informed end-of-life strategies for obsolete structures depend on the availability of accurate data regarding construction materials that can be repurposed [3]. This study employs three distinct methods to assess and compare such data, providing insights into their effective utilization.

Two of the methods are based on the retrieval and analysis of 2D drawings. The first, manual method, involves obtaining the structure's documentation in hard-copy 2D format and using conventional tools such as rulers to measure relevant dimensions. Additionally, the structural material information available in the documentation is extracted, as it is essential for subsequent analyses (with limited supplementary testing conducted only where necessary). Quantity take-off is then performed through manual calculations. The second method utilizes a software-based approach with digital 2D drawings, typically in PDF format. The drawings are digitally calibrated, allowing for straightforward extraction of dimensions. Quantity take-off is carried out semi-automatically through simple software commands. The majority of material properties can be readily obtained from the documentation (complemented, where necessary, by targeted testing), as stated previously.

The third method, scan-to-BIM, involves capturing a point cloud of the structure using specialized scanning equipment and personnel. After acquiring the point cloud, the data undergoes preprocessing before being imported into suitable software to generate a 3D BIM model. It is important to select an appropriate level of development (LOD) for the model, with a lower LOD recommended initially to minimize effort. Given the availability of material information (primarily from documentation, supplemented by testing where needed), most software packages can automatically generate quantity estimates.

Once quantities are determined by any of these methods, emission-comparable fuels (ECF) factors or environmental product declarations (EPDs) are applied to calculate embodied greenhouse gas emissions, supporting sustainable decision-making for end-of-life strategies [2]. This methodology is summarized in Fig. 1 and demonstrated through the case study presented in the following section.

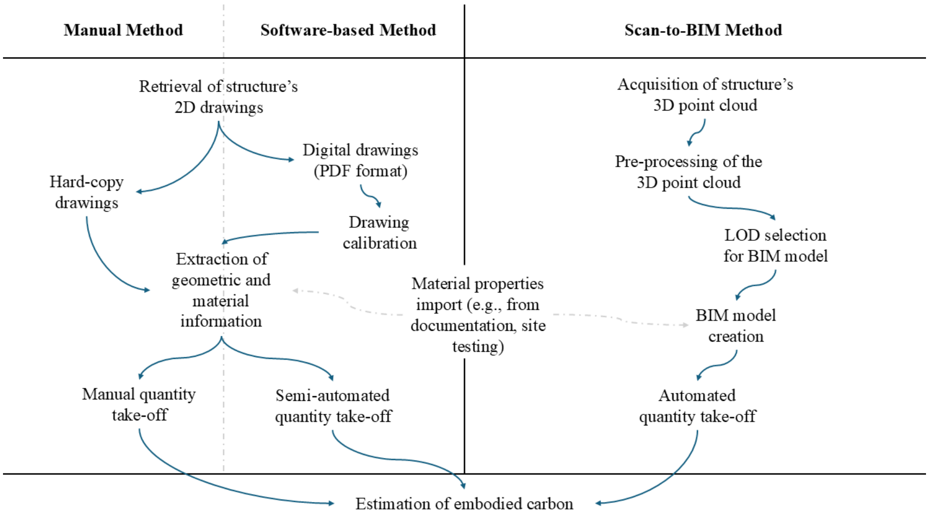

Fig. 1. Methodology overview: 2D drawings (manual and software-based methods) and 3D point cloud (scan-to-BIM method)

4 Case Study

The Frank Erwin Center (Fig. 2), a multipurpose arena on the University of Texas at Austin (UT) campus, was demolished in 2024. The structure contained significant quantities of steel and concrete, sparking interest in its potential deconstruction and reuse. However, barriers such as uncertainty about material quantities limited this opportunity. This study focuses on the exterior precast concrete panels of the ERC façade, selected for their substantial quantity, geometric properties, accessibility, and good condition (factors that made them ideal candidates for deconstruction and reuse).

Constructed in 1977, the available documentation for the Erwin Center consisted of 2D drawings, which is typical for older structures. Manual techniques, such as ruler measurements and spreadsheets, were used to extract material quantities from hard-copy drawings. Additionally, Bluebeam Revu software was employed to analyze the PDF 2D drawings for similar information.

A few months before its demolition, a 3D laser scanner captured a point cloud of the structure's exterior façade. This data was processed using Autodesk Recap and Autodesk Revit to create BIM models and estimate the quantity of concrete panels. The results from these three methods (manual, software-based, and scan-to-BIM) were compared to evaluate their accuracy, efficiency, and practical application for similar projects.

Fig. 2. The Frank Erwin Center prior to its demolition

4.1 Quantity Take-off from 2D Drawings

This subsection explores two methods for conducting quantity take-off based on the available 2D drawings (Fig. 3). It is important to note that the original drawings of the ERC concrete panels did not include detailed quantity tables. Although certain geometric parameters, such as panel thickness, were explicitly specified, other critical dimensions needed to be derived from the elevation drawings using the provided scale.

Additionally, certain material properties were not provided in the retrieved drawings. Consequently, limited testing was required to determine these properties. However, this process falls outside the scope of the present study, which focuses primarily on the quantity take-off methodology. A detailed account of the testing procedures will be presented in a separate publication.

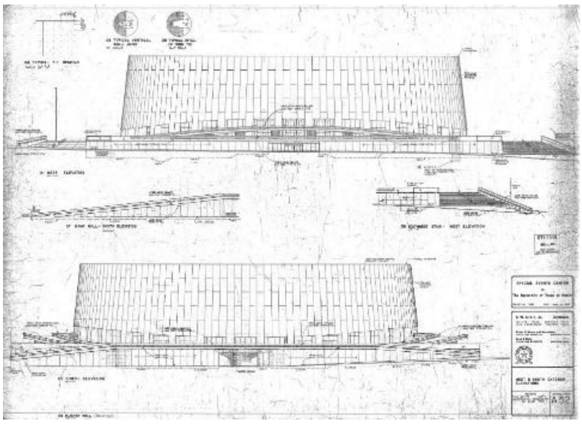

Fig. 3. Representative sample of available architectural drawings for the Frank Erwin Center

Manual Method. The first approach utilized the manual method. Hard-copy 2D drawings were measured using a ruler to determine the geometric properties of the panels (Fig. 4). Given the diverse geometries of the ERC panels, detailed measurements were necessary to calculate their areas, volumes, and other relevant parameters. These calculations were subsequently performed in Microsoft Excel, where formulas were developed to process the collected data, as illustrated in Table 1. Although this method was time-consuming due to the extraction of measurements and the setup of calculations, it was considered highly reliable and accurate, since the data were derived directly from the original drawings. It should be noted that no alterations were made to the façade during the 2001 renovation of the facilities, thereby ensuring the accuracy of the drawings.

Fig. 4. Manual method for quantity take-off: example of ruler-based measurements

Table 1. Manual method for quantity take-off: example of Excel-based calculations

ERC - Exterior Precast Concrete Panels		
Total Number of Panels (all types)	432	
Total Area of Panels (all types)	101,007	ft^2
Total Volume of Panels (all types)	50,503	ft^3
Total Weight (all types)	3,585	tons
Panel Type 1		
Height	32.0	ft
Width	8.5	ft
Thickness	0.5	ft
Area	272	ft^2
Volume	136	ft^3
γ	142	pcf
Weight per Panel	9.7	tons
Number of Panels per Quadrant	18	
Number of Quadrants	4	
Total Number	72	
Total Area	19,596	ft^2
Total Volume	9,798	ft^3
Total Weight	695.6	tons

Software-based Method. The second approach employed Bluebeam Revu to extract information from the original 2D drawings in PDF format. While the drawings included a written scale, they lacked a graphical scale bar, which introduced potential inaccuracies when analyzing the PDFs. To mitigate this issue, the scale was calibrated manually using dimensions obtained from the hard-copy 2D drawings.

Once properly scaled, Bluebeam Revu provided simple commands to quickly calculate areas, lengths, and other geometric properties in seconds (Fig. 5). Although the process was highly efficient, it required careful oversight to verify the software's accuracy, ensuring the results aligned with the original drawings.

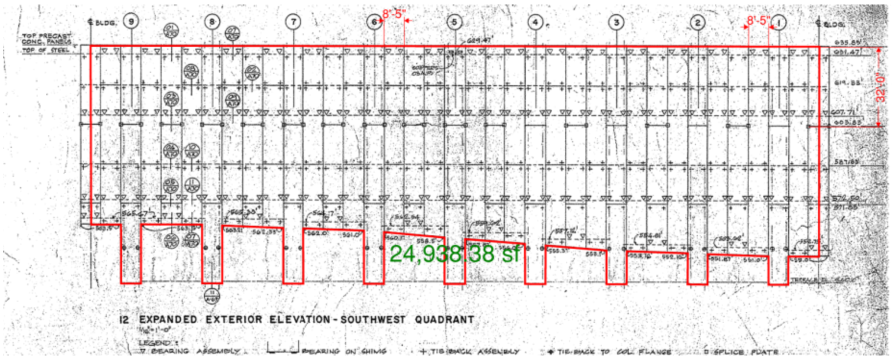

Fig. 5. Software-based method for quantity take-off: Bluebeam Revu example

4.2 Quantity Take-off from 3D BIM (Scan-to-BIM Method)

The process began by loading the point cloud data into Autodesk Recap (Fig. 6). It is important to note that acquiring a high-quality 3D point cloud requires a laser scanner (a considerable investment), dedicated software, and trained personnel. This data acquisition stage (conducted prior to the present investigation) was outside the scope of this study but demands substantial time, resources, and expertise.

Since the point cloud encompassed an area extending beyond the exterior of the ERC panels, extraneous points were removed to streamline subsequent processing. After completing the cleaning process, the point cloud was imported into Autodesk Revit to initiate the modeling phase.

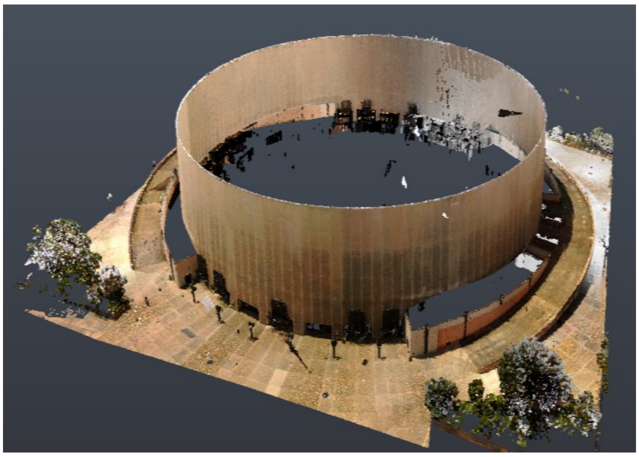

Fig. 6. The 3D point cloud of the Frank Erwin Center, processed and visualized using Autodesk Recap

For simplicity, the panels were modeled as single continuous blocks per vertical section rather than as individual panels. However, the modeling process posed several challenges. The panels were not perfectly vertical but exhibited a slight slope, and although each panel was straight, the overall façade followed a circular alignment. These factors increased the complexity of modeling from the point cloud data. Furthermore, the point cloud did not include information on panel thickness, which was therefore obtained from the 2D drawings (0.1524 m or 0.5 ft).

Two 3D BIM models were developed during this analysis. The first model (i.e., Scan-to-BIM 1) adhered closely to the geometry captured in the point cloud. However, it became apparent that some structural elements behind perimeter obstructions were not captured by the laser scanner. To address this limitation, the second model (i.e., Scan-to-BIM 2) was refined using supplementary information from the 2D drawings, ensuring that these hidden elements were included in the quantity take-off (Fig. 7). Both generated BIM models can be classified as Level of Development (LOD) 200, indicating they provide approximate information on orientation, size, and quantities. This LOD was selected as it meets the requirements of the preliminary analysis stage for determining a building’s end-of-life strategy, which constitutes the focus of this study. If further investigation is warranted, the models can be refined to attain higher LODs. Consequently, LOD 200 is deemed appropriate for this stage, while allowing for potential future enhancements.

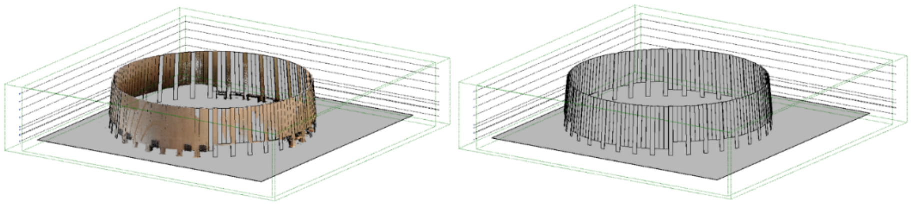

Fig. 7. The “Scan-to-BIM 2” model in Autodesk Revit shown with the 3D point cloud (left) and without (right)

Once the BIM models were complete, Revit's built-in commands enabled quick and efficient quantity take-off calculations (Fig. 8). While the actual QTO process was straightforward, the creation of the models proved to be time-consuming and challenging, especially without consulting the original drawings. Similar conclusions were drawn by [14] who found that the whole Scan-to-BIM process required 23% more time than conventional manual measurement methods.

A	B	C	D	E	F	G	H	I
Area	Assembly Code	Assembly Descriptio	Assembly Name	Base Constraint	Top Constraint	Top Offset	Volume	Width
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
612 SF	B2010	Exterior Walls		L3b	Up to level: L7	0' - 0"	306.21 CF	0' - 6"
612 SF	B2010	Exterior Walls		L3b	Up to level: L7	0' - 0"	306.21 CF	0' - 6"
612 SF	B2010	Exterior Walls		L3b	Up to level: L7	0' - 0"	305.62 CF	0' - 6"
612 SF	B2010	Exterior Walls		L3b	Up to level: L7	0' - 0"	306.21 CF	0' - 6"
612 SF	B2010	Exterior Walls		L3b	Up to level: L7	0' - 0"	306.21 CF	0' - 6"
612 SF	B2010	Exterior Walls		L3b	Up to level: L7	0' - 0"	305.94 CF	0' - 6"
808 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.94 CF	0' - 6"
592 SF	B2010	Exterior Walls		L3	Up to level: L7	0' - 0"	295.76 CF	0' - 6"
590 SF	B2010	Exterior Walls		L3	Up to level: L7	0' - 0"	294.36 CF	0' - 6"
596 SF	B2010	Exterior Walls		L3	Up to level: L7	0' - 0"	297.92 CF	0' - 6"
808 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.94 CF	0' - 6"
604 SF	B2010	Exterior Walls		L3	Up to level: L7	0' - 0"	301.77 CF	0' - 6"
612 SF	B2010	Exterior Walls		L3	Up to level: L7	0' - 0"	305.80 CF	0' - 6"
616 SF	B2010	Exterior Walls		L3	Up to level: L7	0' - 0"	308.10 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"
807 SF	B2010	Exterior Walls		L1	Up to level: L7	0' - 0"	403.74 CF	0' - 6"

Fig. 8. Scan-to-BIM method for quantity take-off: example of automated quantity extraction in Autodesk Revit

4.3 Comparison of Results

Quantity Take-off. The manual method, which is considered the most reliable for this study, is compared with the results from the 2D Software-Based and 3D Scan-to-BIM approaches. As summarized in Table 2 and compared in Fig. 9, the results across all methods are generally consistent, with some deviations, as expected based on similar studies in the literature (e.g., an 8.8% variation reported in the case study by [14]). Notably, the refined Scan-to-BIM 2 model demonstrated a significant improvement in accuracy compared to the Scan-to-BIM 1 model. Scan-to-BIM 2 model is considered the most reliable BIM approach in this investigation, as it closely adhered to the initial project documentation.

Table 2. Summary of concrete quantity between take-off approaches

Method	Area (SF)	Area (m^2)	Volume (CF)	Volume (m^3)
Manual	101,007	9,384	50,503	1,429
Software-Based	99,754	9,267	49,877	1,412
Scan-to-BIM 1	93,327	8,670	46,664	1,321
Scan-to-BIM 2	98,057	9,110	49,029	1,388

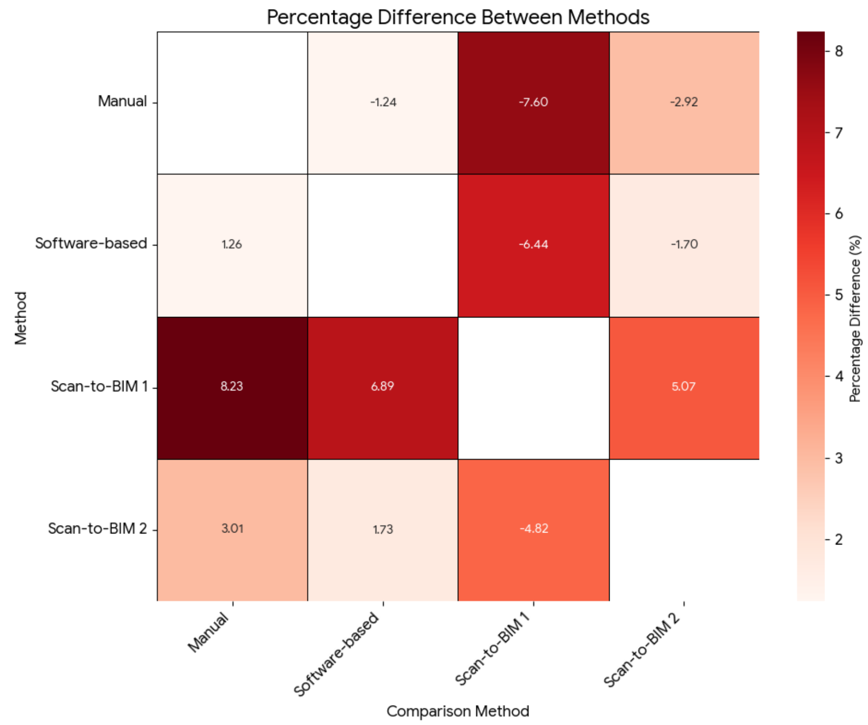

Fig. 9. Summary of comparisons and heatmap visualization between quantity take-off approaches

Embodied Greenhouse Gas Emissions. The primary objective of investigating the quantity take-off methods was to identify the most efficient way to quantify the components of existing infrastructure, enabling informed decisions about their end-of-life strategies. To explore this, a comparison of the embodied carbon of the ERC panels was conducted using the emission-comparable fuels (ECF) factors provided by [2]. These factors address the "Product" emissions (i.e., the embodied emissions), including the stages of “Raw Material Supply (A1),” “Transport (A2),” and “Manufacturing (A3)” within a life cycle assessment analysis. It is assumed for this analysis that the ECFs suggested by [2], which refer to the United Kingdom, apply to the United States and the case study in question. The selected ECFs for the reinforced concrete panels are presented in Table 3 for concrete and its reinforcing steel.

Table 3. Summary of ECF factors for the production of new steel and concrete (as used by [2]).

ECF factor for Stages A1-A3 ($kgCO_2e/kg$)	
Concrete	Steel
0.178	0.684

The results of the embodied emissions are summarized in Table 4. The calculated embodied emissions across all methods show similar patterns. Therefore, the choice of method should depend on the stage of development. For preliminary assessments, the software-based method (Bluebeam Revu) offers the best balance of time efficiency and accuracy. The manual method remains valuable for its accuracy and for verifying other methods, though it may be time-consuming. The Scan-to-BIM method, while requiring significant effort, provides long-term value. Once a 3D BIM model is created, it can be leveraged for multiple applications, making it a valuable tool for more detailed investigations and future analyses.

Table 4. Embodied greenhouse gas emissions of ERC concrete panels for each take-off approach

Method	Embodied Emissions (metric tons of CO_2e)
Manual	608.21
Software-Based	600.67
Scan-to-BIM 1	561.97
Scan-to-BIM 2	590.45

5 Discussion

This study explored three methods for estimating the quantity of materials in existing structures to support decisions regarding their end-of-life strategy. It found that while the conventional manual method is time-consuming and error-prone, it offers the most reliable results and can be used to verify findings from more efficient techniques. Software-based (semi-automated) methods, such as using Bluebeam Revu, are currently the fastest and most efficient. Scan-to-BIM workflows demand considerable effort to develop the BIM model, despite the rapidity of quantity take-off once the model is established. Additionally, the labor hours involved in acquiring the 3D point cloud must be accounted for, alongside the costs associated with specialized equipment (e.g., laser scanners) and the requisite expertise of personnel responsible for operating the equipment and processing the captured data. This makes them more suitable for advanced stages of the end-of-life decision-making process rather than the preliminary phases. However, BIM offers the added advantage of being reusable for other purposes besides quantity take-offs.

The demand for salvaging materials from existing structures is expected to rise for both environmental and economic reasons. Automating the creation of BIM models from 2D drawings appears to be key for the future, reducing effort and expanding the applications of these investigations. Additionally, software, such as Autodesk Revit, will need to improve its interfaces for more seamless integration of point clouds, as current tools present challenges. Such software should also integrate region-specific embodied carbon coefficients and more comprehensive material datasets to enable automated and contextually accurate embodied carbon estimation. Finally, techniques for modeling non-standard elements, such as inclined surfaces, should be enhanced to improve the accuracy and efficiency of the process. To address these issues, sector-wide standards should be introduced, as current practices rely primarily on client-specific criteria, as noted by [7].

6 Conclusion

This study addressed the critical role of quantity take-off methods in supporting decision-making for sustainable end-of-life strategies of existing structures. While prior research has compared conventional and emerging QTO techniques, few have explicitly focused on their implications for sustainable material reuse and end-of-life management. To fill this gap, three distinct methods for estimating construction material quantities were evaluated using the Frank Erwin Center case study: manual calculations based on hard-copy 2D drawings, software-based take-offs from digital 2D drawings, and a Scan-to-BIM approach leveraging 3D point clouds for creating BIM models. The manual method, though time-intensive, demonstrated reliability, whereas the software-based approach improved efficiency but required professional expertise and calibration to ensure accuracy. The Scan-to-BIM method offered a modern, detailed quantification through 3D modeling but involved higher complexity and resource demands. Each method presents specific strengths and limitations, suggesting that their suitability depends on the stage and requirements of the end-of-life strategy evaluation. Ultimately, these insights can guide practitioners in selecting appropriate QTO methods to facilitate sustainable management of construction materials in obsolete structures.

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