Concrete Waste Management Based on BIM for Syrian Buildings

Mohammed Hasan[1] , Lama Saoud[2]

[1] Student of Building Information Modeling and management Master Program, Syrian Virtual University, Damascus, Syria

[2] Assistant Professor, Engineering and Construction Management Department, Faculty of Civil Engineering, Tishreen University, Lattakia, Syria

Emails: mohammed_ali_hasan_158849@svuonline.org; lama.saoud@tishreen.edu.sy

Abstract

This study focuses on the management of concrete waste from demolished buildings. It is a crucial issue globally and particularly in Syria due to the significant amounts of concrete waste resulting from the long war and the February 6, 2023 earthquake. The research aims to promote sustainability and resource conservation in the Syrian construction sector by introducing a method for managing demolition waste using Building Information Modeling (BIM) technology. A case study was conducted on a residential building in the old city of Homs that was demolished due to the war. The building was modeled using the Revit software, and mathematical modeling was applied to calculate and manage the demolition waste related to the building's structural frame. The study revealed potential economic savings of up to 4.2% of the total cost of the building's concrete framework through recycling the structural frame waste (coarse aggregate + fine aggregate only). Furthermore, the study estimated the financial returns that could be realized from managing demolished concrete waste across the entire Homs Governorate.

Keywords: Recycling; Sustainability; Construction Waste Management; Building Information Modeling (BIM); Building Waste Management Using BIM Technology.

1. Introduction

In light of the prolonged conflict Syria has experienced over the past decade, the country has faced immense destruction to its infrastructure, including buildings, facilities, industrial zones, and archaeological sites. This devastation was further exacerbated by catastrophic earthquakes, expanding the destruction to nearly all Syrian regions. Consequently, it has become essential to develop a suitable strategy for managing the vast amounts of rubble and exploring their use as sustainable materials in future reconstruction efforts. The attention of the construction industry is increasingly focusing on eliminating waste and inefficiency to improve quality and profitability [1] **.**The construction industry, in all its forms, is among the most resource-wasting and waste-producing sectors. According to [2] the construction industry generates approximately 17% of total waste produced globally. As the nature of projects has evolved and increased in complexity over time, these issues have intensified, becoming more pressing [3]. However, with recent technological advancements in construction—such as the maximum utilization of modern technologies like Building Information Modeling (BIM) and Virtual Design and Construction (VDC)—addressing these challenges has become more feasible. As concepts and standards of sustainability have crystallized within the Architecture, Engineering, and Construction (AEC) sector, the focus on sustainable materials and recycling practices has noticeably and significantly grown. In the specific context of Syria, the accumulated demolition waste from years of conflict has posed a significant challenge to the reconstruction and development process. According to the [4] as of January 2022, the total damages across cities and sectors were estimated at between

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

$8.7 billion and $11.4 billion, with approximately 68% of these damages (around $5.8 billion to $7.8 billion) attributed to physical infrastructure sectors. Additionally, the substantial damages resulting from the earthquake on February 6, 2023, were estimated by the World Bank to be around $5.1 billion [4]. This situation presents an enormous amount of waste that must be effectively managed and utilized. Reconstructing cities requires a comprehensive and innovative methodology for repairing damages or reusing debris from affected buildings. This approach can reduce environmental impact while providing cost savings, as economic factors play a central role in the reconstruction process [5]. Therefore, it is essential to consider economic and environmental solutions as primary approaches to address this issue comprehensively and effectively. In this context, the management of construction waste, supported by Building Information Modeling (BIM) technology, emerges as a promising solution that aligns with global standards due to its positive economic and environmental impacts, as well as its potential to create new job opportunities. Currently, BIM plays a significant role in the construction industry and has proven to be highly beneficial in addressing many of the current challenges faced by AEC (Architecture, Engineering, and Construction) projects. Researchers have presented numerous studies and research on the topic of construction waste management during the design and construction phases, such as [6], [7], [8] and others. However, there is a lack of research that specifically focuses on the management of demolition waste. Despite the enormous amount of demolition waste in Syria and the increasing global interest in maximizing the benefits of this waste as sustainable materials, there is still very little research focused on how to manage it and benefit from its economic returns. This paper aims to present a practical methodology for managing demolished concrete waste for the structural frameworks of buildings, showcasing a practical model applied to one of the residential buildings affected by the war in Homs Governorate using Revit 2018. It also addresses the calculation of the economic gains that can be achieved from the recycling of demolished concrete.

2. Reference Studies

The Syrian war has resulted in significant destruction of infrastructure and buildings, necessitating serious consideration of how to manage the debris from demolished structures and the sorting of building waste. It is crucial to maximize the use of these materials in the reconstruction phase. Researcher [9] presented a method for estimating the expected volume of debris in several Syrian cities, detailing the components of this debris, the costs of recycling, and the anticipated profits by proposing a work plan for managing the recycling process and suggesting an appropriate technological alternative for implementing this plan.

Another study indicates that a high percentage of building rubble in Syria can be reused, which reduces transportation and disposal costs for unwanted debris, minimizes environmental pollution, and provides economic value. The application of recycling and rehabilitation techniques in Syria could save approximately $17 billion [5]. Generally, there is a scarcity of research on integrating (BIM) Building Information Modeling in (DWM) Demolition Waste Management [10] ,[11] , [7]. Due to budgetary and time constraints, practitioners may hesitate to adopt BIM in DWM procedures without modern construction documentation to guide the process. Furthermore, prevailing issues such as the lack of BIM-compatible DWM functions and interoperability between BIM and waste management tools also pose significant challenges that need to be addressed in future studies [10].

In the research by [12] strategies for managing construction waste in reconstruction efforts in Iraq were discussed, aiming for effective and economical reconstruction while minimizing negative environmental impacts. A field survey was conducted in Mosul to determine the volume and nature of accumulated construction waste, which was then evaluated, classified, and identified for reuse and recycling. An economic comparison was made to determine cost savings in reconstruction resulting from the use of recycled and reused waste, with the study concluding a savings rate of 12.9% in the cost of constructing the University of Mosul presidency and a 37.3% savings rate in supplying natural stone for construction work at the Al-Hadba Minaret.

Summarized reviews conducted by the researcher on quantitative estimation methods for building demolition waste:

❖ **Estimation According to Physical Planning Models** [13]:

This is a unique method for estimating the volume of construction waste based on the physical planning shapes of waste on-site in Malaysia. Four forms of planning were proposed (stored, aggregated, scattered, and stacked) to record the amount of waste at different project stages. For example, for stockpiled waste, it is assumed to take the shape of a rectangular base pyramid shaped.

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

This method is criticized for its lack of accuracy and its unsuitability for direct application in various forms of demolition.

❖ **Estimation Based on Components in the Building:**

This research [14] introduced the "Component Index" approach, which estimates the quantity of Construction and Demolition (C&D) waste based on the type and quantity of building components in a construction facility. A building component is defined as the smallest unit that can be considered a specific and independent part of the construction for data collection and waste quantity determination. For each building component, the "Component Index" is used to estimate the waste quantity from various types (such as wood, concrete, and reinforcing steel). However, this approach heavily relies on the use of detailed spreadsheets and labor-intensive manual measurements and updates, making it challenging to implement in practice.

❖ **BIM-Based System for Estimating and Planning Demolition and Renovation Waste:**

This system was presented by [11] and developed to estimate and plan Demolition and Renovation (D&R) waste. A software interface was created that can be added as a plugin to Revit, allowing the BIM-based model to incorporate multidisciplinary information within a single digital building model. This system was applied to a 47-story residential building in Hong Kong to illustrate the demolition and renovation waste estimation and planning system. This model relies on volume change factors to estimate the waste volume. The values of the waste volume change factor were determined with reference to the demolition increase factor adopted by the Andalusian construction database (BAAC) [15]. However, access to and use of this software is limited, which imposes significant constraints on evaluating or working with this model.

❖ **Area-Based Estimation:**

The Researcher [16] presented the "Waste Index" method for estimating the total amount of new construction waste in a project. The "Waste Index" is defined as the quantity (in volume or weight units) of construction waste generated per square meter of gross floor area (GFA) or activity area [16]. This method is considered somewhat outdated, as it uses the building area as a primary factor for calculating the volume of construction waste. This is relatively inaccurate since construction waste characteristics are specific to each individual project.

❖ **Estimation Based on Quantities Extracted from Relevant Construction Databases:**

There are several models in different regions that use construction cost databases as a source for estimating waste quantities. One prominent example of this model is the Spanish model presented by [17]. This model is considered a quantitative method for construction and demolition waste based on the Andalusian construction database (BCCA) in Spain [15]. The model can be used to estimate the volume of waste related to construction and demolition activities. The model relies on four parameters:

- Apparent Construction Volume (VAC).
- Apparent Demolished Volume (VAD).
- Apparent Wreckage Waste Volume (VAR).
- Apparent Package Waste Volume (VAE).

By studying more than 100 residential projects, the relationships among the four parameters have been statistically summarized. For example, VAC for each element can be converted to VAD using the CT factor to account for the increase in material volume after demolition. The CT factor for concrete columns is 1.15, which means that columns increase their volumes by an average of 15% after being demolished and cannot be perfectly filled.

We will adopt this method in our research due to its high flexibility, as it specializes individual factors for each construction element and provides good results in terms of accuracy, as well as ease of use.

3. Research Methodology

To conduct this research, the researcher followed the following methodology:

Initially, the researcher reviewed previous studies to select the most suitable quantitative model for application. After completing this phase, a suitable case study was sought, and a residential building damaged by the war in the Old City of Homs was chosen. The building was modeled using Revit 2018. Following the modeling process, the quantities of concrete used in the building were quantified. Then, the Spanish model presented by [17] was applied to estimate the volume of demolished concrete. Subsequently, using the allowable reference ratios for recycled aggregate [18], [19]. The volume of recycled aggregate that could be used for the reconstruction of the building was calculated.

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

The current cost of recycling 1m³ of concrete waste was then determined, based on the study presented by researcher [9]. After that, the monetary return and the percentage of savings that could be achieved by using the allowable ratios of recycled aggregate in the reconstruction of the building were calculated. Next, the financial return that could be achieved from selling the remaining portion of the recycled aggregate was assessed. Based on the previous calculations, we estimated the potential financial returns that could be achieved from recycling 1m³ of demolished concrete. Using the estimated volume of debris in Homs provided by [9] the volume occupied by the demolished concrete in the debris was estimated with reference to [20]. Finally, the financial returns that could be achieved from the management of demolished concrete waste throughout the Homs Governorate were estimated.

3.1. Case Study

The author chose the case study (the residential building) due to the large number of demolished buildings in Syria, which gives significant importance to this topic. After obtaining the two-dimensional models (CAD drawings) of the demolished residential building from the branch of the Syrian Engineers Syndicate in Homs Governorate, the author created a three-dimensional (3D) model of the structural framework of the residential building using Revit software. This project is a residential building located in the old city of Homs, specifically in the Bab al-Dreib area. It consists of five floors: a basement, a ground floor for commercial use (with canopies), and three residential floors. The overall dimensions of this building are approximately (16.7 m * 32.2 m). The floor area is around 450 m², and the total height of the building reaches (17.15 m). The height of the basement is (2.8 m), the ground floor is (5 m), and the height of the residential floors is (3.3 m). A (3D) model of the residential building was created using Revit software, as shown in Figure (2).

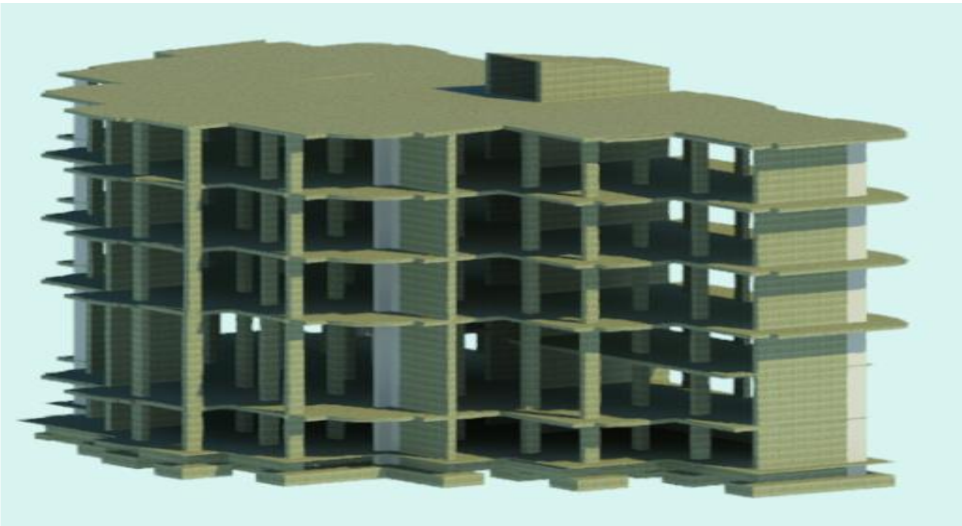


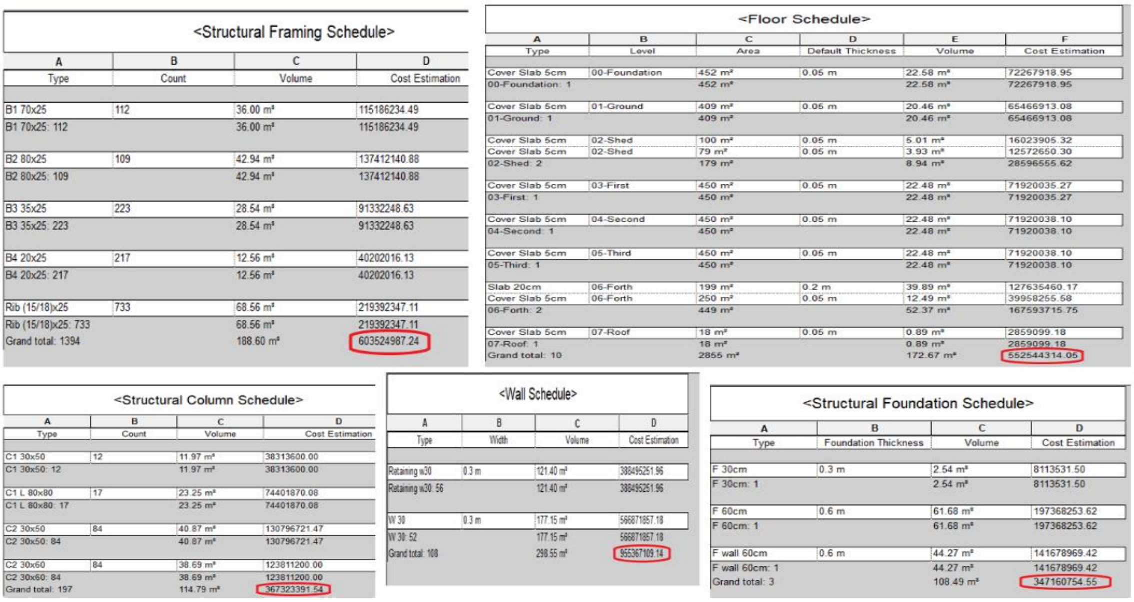
Figure 1: 3D view of the building model using Revit (2018).

4. Results and Discussion

4.1 Extraction of Bill of Quantities (BOQ)

for Concrete Used in Structural Work (Foundations, Columns, Slabs, Load-Bearing Walls), along with Cost Estimations Required for Completing These Works, as Shown in Figure (3). It was revealed, after conducting interviews with several supervising engineers and contractors, that the cost of one cubic meter of reinforced concrete with a strength of 350 and a reinforcement ratio of 100 kg is approximately 3,200,000 SYP/m³, based on material prices in the Syrian construction market for July 2024, on average, including materials, labor, and wastage.

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025



<Structural Framing Schedule>

A	B	C	D
Type	Count	Volume	Cost Estimation
B1 70x25	112	36.00 m³	115186234.49
B1 70x25: 112		36.00 m³	115186234.49
B2 80x25	109	42.94 m³	137412140.88
B2 80x25: 109		42.94 m³	137412140.88
B3 35x25	223	28.54 m³	91332248.63
B3 35x25: 223		28.54 m³	91332248.63
B4 20x25	217	12.56 m³	40202016.13
B4 20x25: 217		12.56 m³	40202016.13
Rib (15/18)x25	733	68.56 m³	219392347.11
Rib (15/18)x25: 733		68.56 m³	219392347.11
Grand total: 1394		188.60 m³	603524987.24

<Floor Schedule>

A	B	C	D	E	F
Type	Level	Area	Default Thickness	Volume	Cost Estimation
Cover Slab 5cm	00-Foundation	452 m²	0.05 m	22.58 m³	72267918.95
00-Foundation: 1		452 m²		22.58 m³	72267918.95
Cover Slab 5cm	01-Ground	409 m²	0.05 m	20.46 m³	65466913.08
01-Ground: 1		409 m²		20.46 m³	65466913.08
Cover Slab 5cm	02-Shed	100 m²	0.05 m	5.01 m³	16023905.32
Cover Slab 5cm	02-Shed	79 m²	0.05 m	3.93 m³	12572650.30
02-Shed: 2		179 m²		8.94 m³	28596555.62
Cover Slab 5cm	03-First	450 m²	0.05 m	22.48 m³	71920035.27
03-First: 1		450 m²		22.48 m³	71920035.27
Cover Slab 5cm	04-Second	450 m²	0.05 m	22.48 m³	71920038.10
04-Second: 1		450 m²		22.48 m³	71920038.10
Cover Slab 5cm	05-Third	450 m²	0.05 m	22.48 m³	71920038.10
05-Third: 1		450 m²		22.48 m³	71920038.10
Slab 20cm	06-Forth	199 m²	0.2 m	39.89 m³	127635460.17
Cover Slab 5cm	06-Forth	250 m²	0.05 m	12.49 m³	39958255.58
06-Forth: 2		449 m²		52.37 m³	167593715.75
Cover Slab 5cm	07-Roof	18 m²	0.05 m	0.89 m³	2859099.18
07-Roof: 1		18 m²		0.89 m³	2859099.18
Grand total: 10		2855 m²		172.67 m³	552544314.05

<Structural Column Schedule>

A	B	C	D
Type	Count	Volume	Cost Estimation
C1 30x50	12	11.97 m³	38313600.00
C1 30x50: 12		11.97 m³	38313600.00
C1 L 80x80	17	23.25 m³	74401870.08
C1 L 80x80: 17		23.25 m³	74401870.08
C2 30x50	84	40.87 m³	130796721.47
C2 30x50: 84		40.87 m³	130796721.47
C2 30x60	84	38.69 m³	123811200.00
C2 30x60: 84		38.69 m³	123811200.00
Grand total: 197		114.79 m³	367323391.54

<Wall Schedule>

A	B	C	D
Type	Width	Volume	Cost Estimation
Retaining w30	0.3 m	121.40 m³	388495251.96
Retaining w30: 56		121.40 m³	388495251.96
W 30	0.3 m	177.15 m³	566871857.18
W 30: 52		177.15 m³	566871857.18
Grand total: 108		298.55 m³	955367109.14

<Structural Foundation Schedule>

A	B	C	D
Type	Foundation Thickness	Volume	Cost Estimation
F 30cm	0.3 m	2.54 m³	8113531.50
F 30cm: 1		2.54 m³	8113531.50
F 60cm	0.6 m	61.68 m³	197368253.62
F 60cm: 1		61.68 m³	197368253.62
F wall 60cm	0.6 m	44.27 m³	141678969.42
F wall 60cm: 1		44.27 m³	141678969.42
Grand total: 3		108.49 m³	347160754.55

Figure 2: BOQ & Cost estimations of Concrete works for the building using Revit (2018).

These results were collected and arranged in Table (1) as follows:

Table 1: Quantities & Cost Estimations of Concrete works for the building.

Structural Element	Quantity and Unit	Cost
foundations	108.49 m³	347,160,754.55 SYP
columns	114.79 m³	367,323,391.54 SYP
slabs	361.27 m³	1,156,069,301.29 SYP
load-bearing walls	298.55 m³	955,367,109.14 SYP
Total	**883.1 m³**	**2,825,920,556.52 SYP**

4.2 Estimation of Expected Demolition Waste Volume

Based on the quantities extracted from Revit 2018, we applied the Spanish model for estimating demolition waste volume, as presented by [17].
The model states that to calculate the Apparent Construction Volume (VAC) from the quantities calculated in Revit, the following equation is used:

$$\mathbf{Vaci = Qi \times Cci} \qquad (1)$$

Where:
Vaci: apparent construction volume for the item (i) in (m^3).
Qi: Quantity of element (i) in its specific unit in (m^3).
Cci: Conversion ratio for the quantity of item (i) in Vac (m^3/Qi specific unit).

To estimate the volume of demolition waste, the Apparent Demolition Volume (VAD) is calculated from VAC using the following equation:

$$\mathbf{VADi = Vaci \times Cti = Qi \times Cci \times Cti} \qquad (2)$$

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

Where:
Vadi: apparent demolition volume of item (i) in unit (m^3)
Cti: Factor to convert VAC to VAD.

According to [12] (cti) for foundation, columns, beam, concrete wall, and slab have a value of 1.01, 1.15, 1.25, 1.18 and 1.20 respectively.

By applying the above relationships to the quantities calculated using Revit 2018. We obtain the apparent demolition volume of concrete waste for each structural element of the building, as illustrated in Table (2).

Table 2: Estimation the volume of concrete waste for the building.

No	Waste type	Qi (m^3)	CCi (m^3/ m^3)	CTi	VACi (m^3)	VADi (m^3)
1	foundations	108.49	1	1.01	108.49	109.57
2	columns	114.79	1	1.15	114.79	132.01
3	load-bearing walls	298.55	1	1.18	298.55	352.29
4	slabs	361.27	1	1.20	361.27	433.52
Total Apparent Volume of Demolished Concrete						**1027.4**

4.3 Calculation of Savings in Reconstruction Costs Due to the Use of Recycled Aggregates as Raw Materials for Construction

For the residential building model, the amount of concrete waste generated from demolition is (1027.4 m^3). From the quantities extracted using Revit software, we find that the total amount of concrete required for the structural work of the residential building is (883.1 m^3). Given that the standard concrete mix ratio used in engineering work in Syria is (1:2:4), which means that the mix contains one part cement, two parts sand, and four parts gravel, this implies that we will need approximately (725 m^3) of coarse aggregate (gravel) and approximately (371 m^3) of fine aggregate (sand) for the structural work of this building.

According to [18] a percentage of up to 50% recycled coarse aggregate (RCA) can be used from the total amount of natural coarse aggregate in the concrete mix. Additionally, according to [19] a percentage of up to 30% recycled fine aggregate (RFA) can be used from the total amount of natural fine aggregate in the concrete mix.

Therefore, to reconstruct the same residential building, we can use ($0.5 * 725 = 362.5$ m^3) of recycled coarse aggregate and ($371 * 0.3 = 111.3$ m^3) of recycled fine aggregate.

According to a study presented by [9] the cost of recycling one cubic meter of rubble in Syria was approximately 1440 SYP (equivalent to 2.88 $) in 2019. Considering the significant economic inflation and the increase in the exchange rate between 2019 and 2024, which approached about thirty times (3000%), the approximate current cost is around 43,000 SYP per cubic meter.

In contrast, the cost of one cubic meter of coarse aggregate is 110,000 SYP, and fine aggregate is 290,000 SYP, according to current material prices in Syria (excluding transportation costs).

Therefore, we have:

- The cost of the recycling process for the aggregate (which can be used in the reconstruction of the building) is:

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

$$(362.5+111.3) \times 43{,}000 = 20{,}373{,}400 \text{ SYP}$$

- The expected return (on the building) from using the permissible ratios of recycled aggregate in the reconstruction of the building is:

$$362.5 \times 110{,}000+111.3 \times 290{,}000 = 72{,}152{,}000 \ SYP$$

- The net savings obtained from recycling coarse and fine aggregates is:

Net Savings (Ns) = Expected Return from using permissible ratios of Recycled aggregate – Cost of the Recycling Process

$$Ns = 72{,}152{,}000 - 20{,}373{,}400 = 51{,}778{,}600 \ SYP$$

- The percentage savings from the total cost of the aggregate required for the building is:

$$\text{Savings Percentage (Sv1)} = \frac{\text{Cost Saved in Required Construction Materials (Ns)}}{\text{Total Actual Cost of These Materials}} * 100$$

$$Sv1 = \frac{51{,}778{,}600}{725*110{,}000+371*290{,}000} * 100 = 27.6\%$$

On the other hand, we find that:

- The percentage of concrete waste that will be used in the reconstruction of the building (362.5 + 111.3 = 473.8 m^3) from the total volume of concrete waste generated by the demolition of the building is:

$$\frac{473.8}{1027.4} * 100 \approx 46\ \%$$

Thus, there is an approximately 54% remaining percentage of this waste that can be utilized in other reconstruction projects or sold in the local construction market at a competitive price, thereby benefiting from the financial returns generated.

For the purpose of the calculation, let us assume that this remaining quantity of aggregate has been sold in the local market. According to [9] the price of recycled concrete aggregate ranges from 83.3% to 100% of the price of natural aggregate in each region.

We will assume that this remaining quantity was sold at a price of 90,000 SYP for coarse aggregate and 240,000 SYP for fine aggregate, averaging 165,000 SYP (approximately) per cubic meter for both coarse and fine aggregates combined (these prices are below the minimum percentage of the internationally prevailing price). Therefore:

- The profit realized from the sale is:

$$165{,}000 \times (1027.4-473.8) = 91{,}344{,}000 \text{ SYP}$$

- The total profit realized from recycling the concrete waste for the building (1027.4 m^3) is:

$$91{,}344{,}000 + 72{,}152{,}000 - (1027.4\times 43{,}000) = 119{,}317{,}800 \text{ SYP}$$

- The approximate net return expected from recycling 1 m^3 of concrete waste is:

$$116{,}549{,}800 / 1027.4 \approx 116{,}000 \text{ SYP/m}^3$$

- The percentage savings from the total cost of the structural concrete work is:

$$\text{Savings Percentage (Sv2)} = \frac{\text{Total Profit Realized from Recycling}}{\text{Total Cost of Structural Concrete Work}} * 100$$

$$Sv2 = \frac{119{,}317{,}800}{2{,}825{,}920{,}556.52} * 100 \approx 4.2\%$$

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

Given the simplicity of the model that was worked on and the results achieved from recycling concrete alone, without considering other construction waste, we see that in Syria, there are substantial financial savings that can be obtained by implementing recycling processes for various construction wastes, including concrete, metals, bricks, gypsum, plastics, and others.

Below, we will provide an approximate mechanism for the financial savings that can be achieved from recycling concrete aggregate (only) in Homs Governorate, for example. The estimated quantity of construction waste in Homs Governorate is 7.5 million tons [9].

According to [20] reinforced concrete constitutes approximately 58% of the total quantity of building debris. Therefore, the approximate expected quantity of concrete waste in Homs Governorate is:

$$0.58 \times 7,500,000 = 4,350,000 \text{ tons}$$

Since the bulk density of reinforced concrete is (2500 kg/m³), or (2.5 tons/m³), the corresponding volume for this quantity is:

$$4,350,000 / 2.5 = 1,740,000 \text{ m}^3$$

Given that we have the approximate net return that can be achieved from recycling 1 m³ of concrete, we can calculate the total approximate net return from the concrete recycling process in Homs Governorate as follows:

$$1,740,000 \times 113,000 = 201,840,000,000 \text{ SYP}$$

Which means approximately 202 billion Syrian pounds.
Note that all these estimates and prices are based on the prevailing prices in the Syrian construction market for July 2024.

5. Conclusions

After studying the issue of demolition waste management using the Building Information Modeling (BIM) system, the authors reached several important conclusions. They found that there are various quantitative models for estimating the volume of construction waste; however, the Spanish model proved to be the most flexible and can be adapted through experimental studies on the values of the coefficients and modified to suit the region or country. It was noted that there are enormous quantities of debris in several Syrian governorates, and utilizing them as sustainable materials presents significant economic gains, as well as preserving the country's natural resources. Based on a number of reference studies, this research provided an approximate value for the expected financial return from recycling waste for the studied building model. The study concluded that a savings rate of up to 4.2% of the total cost of the structural concrete work for the building can be achieved through the recycling process. Furthermore, an approximate mechanism was presented for estimating the expected financial return from recycling 1m³ of demolished concrete. Based on the volume of construction waste estimated by a previous researcher, the expected financial return at the level of Homs Governorate was calculated to be around 202 billion Syrian pounds. And this figure is considered a conservative estimate since we assumed the selling price of coarse aggregate (90,000 SYP) and fine aggregate (240,000 SYP), which is lower than the internationally prevailing price for recycled aggregate (between 83.3% and 100% of the price of natural aggregate). Additionally, we have not included the transportation costs saved due to using recycled coarse and fine aggregates. Therefore, it is essential to give this topic adequate attention and extensive study due to its substantial financial benefits for the national economy, as well as its significant role in preserving national natural resources.

Funding: “This research received no external funding”

Conflicts of Interest: “The authors declare no conflict of interest.”

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

References

[1] Hossain MU, Ng ST, Antwi-Afari P, Amor B. Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. Renewable and Sustainable Energy Reviews. 2020 Sep 1;130:109948.

[2] S. S. B. a. K. M. Coventry, "Demonstrating waste minimization benefits in construction," *UK, London:CIRIA Publication C536,* 2001.

[3] K. N. J. &. G. V. Sakshi Gupta, "Proposing building information modeling-based theoretical framework for construction and demolition waste management: strategies and tools," *International Journal of Construction Management, 22(12), 2345-2355.,* p. 5, 2020.

[4] World Bank, "https://www.worldbank.org/en/country/syria/brief/syria-joint-damage-assessment-2022-q-a," World Bank, 2022.

[5] F. A. a. A. A. A.-D. Ayman A. Awad, "Innovative Rehabilitation Methodology of Recycling Buildings' Debris in Damaged Districts (IRMIDD)," 19 may 2022. [Online]. Available: http://www. jeaconf. org/UploadedFiles/Document/fc4bde01-85c2-4fb5-b71d-7c7d3e11ac5a..

[6] L. B. &. W. D. Jayasinghe, "Development of a BIM-based web tool as a material and component bank for a sustainable construction industry.," *Sustainability, 12(5), 1766.,* 2020.

[7] Y. C. H. W. H. P. J. W. &. C. G. W. Kim, " An estimation framework for building information modeling (BIM)-based demolition waste by type.," *Waste Management & Research, 35(12), 1285-1295.,* 2017.

[8] A. M. R. M. S. M. M. A. &. A. T. H. Yousfani, "Building Information Modelling (BIM) based framework for construction and demolition waste estimation and management.," *Jurnal Kejuruteraan, 35(5), 1101-1109.,* 2023.

[9] B. H. J. Y. O. Hassan Ali, "Method of Making the Decision to Find the Optimal Technological Alternative to Treat the Demolition Waste in the Syrian Case," 2019.

[10] D. K. M. &. R. A. Han, "Building information modeling (BIM) for construction and demolition waste management in Australia: A research agenda.," *Sustainability,* pp. 13(23), 12983., 2021.

[11] J. C. &. M. L. Y. Cheng, "A BIM-based system for demolition and renovation waste estimation and planning.," *Waste management, 33(6), 1539-1551.,* 2013.

[12] A. S. Noaman, "Utilization of Construction Waste in Reconstruction of War-Destroyed Projects," in *Doctoral dissertation, University of Baghdad,* 2019.

[13] H. H. W. A. &. L. P. Lau, "Composition and characteristics of construction waste generated by residential housing project.," 2008.

[14] S. Jalali, "Quantification of construction waste amount.," *In 6th International Technical Conference of Waste,* p. (Vol. 432)., October 2007.

[15] Andalusian Government-Dwelling Counseling, "Base de Costes de la Construccion de Andalucia (BCCA) (Andalusian Construction Costs Database).," Seville, 2010.

[16] C. S. Y. T. W. &. N. L. H. Poon, "A guide for managing and minimizing building and demolition waste.," Department of Civil & Structural Engineering, Hong Kong Polytechnic University., Hong Kong, China., 2001.

[17] M. M. M. V. M. A. R.-d.-A. Jaime Solís-Guzmán, "A Spanish model for quantification and management of construction waste," *Waste Management,* 2009.

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025

[18] G. S. P. D. SUDHIR P.PATIL, "RECYCLED COARSE AGGREGATES," *International Journal of Advanced Technology in Civil Engineering* , 2012.

[19] S. S. S.K. Kirthika, "Durability studies on recycled fine aggregate concrete," *Construction and Building Materials*, 2020.

[20] M. E.-F. G. C. Issam Srour, "Pilot-based assessment of the economics of recycling construction demolition waste," 2013.

Doi: https://doi.org/10.54216/IJBES.100207
Received: October 19, 2024 Revised: December 22, 2024 Accepted: January 18, 2025