The Effectiveness of Applying BIM in Increasing the Accuracy of Estimating Quantities for Public Facilities Rehabilitation Projects in Syria After the War

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Abstract

Public facilities rehabilitation projects are the most discussed projects among humanitarian organizations working in Syria in the field of post-war rehabilitation. Since education is a basic right for every child, there is an urgent need for school rehabilitation projects, especially after the massive destruction caused by the war in Syria in the past decade. BIM technology has been used in the past years because it is an integrated and effective process for planning, studying, and implementing projects. However, BIM has not been properly used in the study of post-war rehabilitation projects, especially in developing countries. This research discusses the effectiveness of applying BIM in the rehabilitation projects of public facilities in Syria after the war by increasing the accuracy of quantities estimation for these projects. The main results indicate that the application of BIM in the Al-Ejref school rehabilitation project in the Al Qunaitra governorate represents great potential in increasing the accuracy of quantity estimation, as the traditional methods are limited and have a large margin of error.

Keywords: Rehabilitation; Public facilities; Post-war; Quantitative estimation using BIM; Syria; Schools

1. Introduction

During 11 years of war, Syria has suffered tens of thousands of lives lost, and millions displaced and migrating. In addition to the material losses in the public sectors and the destruction of more than five thousand schools and three hundred health units. Since 2018, following the end of the war and the spread of security, several organizations have carried out projects to rehabilitate residential apartments, schools, clinics, and infrastructure projects that were damaged during the war. But the AEC industry is still facing pressure due to the lack of available resources and the unstable economy [11].

Syrian engineering work is based on conventional methods, which it is characterized by continuous changes and conflicts, leading to deletion or revising projects' objectives, cost, and schedule [10]. The traditional study is carried out by manually measuring and calculating the quantities of works to be done by the studying engineer, and drawing the real plans of the building to be rehabilitated, including plans, elevations, and sections, using a two-dimensional drawing. In addition, because measurement and drawing are done in traditional ways, the margin of error is large in estimating quantities, and if there is a modification to the estimated quantities or to the plans, the engineer needs to re-study the

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project and modify all plans, elevations and sections. This causes a delay in the duration of the project's study, and therefore a delay in the time for completion and delivery of the project.

The use of Building Information Modelling (BIM) has become significant in the last few years [12,13]. While using BIM programs, the studying engineer models the building to be restored in 3D modelling and allocates the building materials to be implemented in the rehabilitation process. He forms a picture of what the building will look like after rehabilitation, and the program calculates the estimated quantities very accurately and in case of there is a modification, the engineer has only to modify one of the plans, elevations, or sections to apply the change in the entire model.

Therefore, this research was conducted to determine the effectiveness of BIM in increasing the accuracy of quantitative estimation in post-war public facilities rehabilitation projects in Syria.

1.1. Research Objectives

The emigration of skilled and experienced managers, engineers, and contractors and its travel outside the country, and their travel outside the country was one of the most prominent results of the war. While the spread of BIM across the region has been prevalent, the war has ravaged the Syrian society, and the training of cadres and competencies was not among the priorities in light of this crisis. Therefore, until now, the facilities to be rehabilitated are being studied manually and using traditional methods. The aim of this research is to find out the applicability of using BIM applications in calculating estimated quantities, and its accuracy compared to the quantities of the traditional method in public utility rehabilitation projects.

1.2. Research Method

The methodology of this research is based on reviewing the reality of public facilities in Syria after the war, reviewing the concept of BIM and its dimensions, and examining the reality of BIM in Syria and what are the obstacles that limit its development and proposing solutions. In addition, shedding the light on the concept of building rehabilitation and its assessment method. Also, determining the factors affecting the study of the rehabilitation of public facilities. Finally, reviewing the study of the estimated quantities for Al-Ejraf elementary School in Al Quneitra governorate that was done by using BIM and compared it with the study of the estimated quantities that was carried out using the traditional study.

1.3. Research Results

The research reveals that the application of BIM in rehabilitation projects for public facilities would increase the accuracy of estimating quantities and reduce the study time for small projects, in addition to an accurate estimate of the project cost.

2. Public facilities in Syria post-war

According to the Syrian Ministry of Education in its statement in 2019, titled Details of the Ministry of Education's plan to rehabilitate damaged schools, "the number of damaged schools has reached 5,288, of which 1,793 are currently invested and 3,495 are uninvested, in addition to the presence of 6,328 schools that cannot be reached and 31 schools that are used as temporary residence centres for people displaced by terrorism" [1].

It was also mentioned in the 2019 Health Statistical Bulletin of the Syrian Ministry of Health that "the number of health units affiliated to the Ministry of Health reached 1864 health units until 2019, of which 85 health units were completely damaged, 277 units were partially damaged, and 323 units were not indicated in terms of damage" [2].

3. BIM and its dimensions

3.1. Definitions

As specified in PAS 1192-2:2013 by the British Standards Institution, Building Information Modelling is "the process of designing, constructing or operating a building or infrastructure asset using electronic object-oriented information" [3].

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BS EN ISO 19650-2 defines BIM as "The use of a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions" [4].

These two definitions can be reconciled as follows:

- "Build" is the verb "build" rather than the noun "building". It is therefore relevant to any asset of the built environment.
- "Model" refers to "a representation of a system or a process" rather than a "three-dimensional representation of a person or thing". Although there can be no doubt that engineering representation is important, we must be able to simulate various aspects of designing an asset (structural, architectural, building services, etc.), building the asset and operating the asset.
- Information (or more specifically, organized information sharing) is the core concept of BIM. This includes both engineering and non-engineering information such as item supplier, warranty information, reclassification, and corrosion and corrosion specifications.

3.2. BIM dimensions

3D BIM: The three dimensions refer to the graphical representation of the X, Y, and Z axes. These are the height, width, and depth of an object, in this case, the model.

4D BIM: When we apply "time" as an element to a 3D BIM model, we get to the next stage. 4D BIM enables convenient scheduling across design and construction phases, major or minor, and helps visualize project progression sequentially. Construction professionals can then plan, even backups in the event of inadequate site conditions or risks and threats.

5D BIM: We get 5D when the cost element is applied to the project model. All relevant professionals can visualize the cost of ongoing and future activities to give estimates of total project expenditures. It enables all stakeholders, including architects and owners, to have accurate and transparent budget information to advance the work.

6D BIM: The sixth dimension defines something important to the AEC industry today and that is "sustainability". Information in 6D provides analytics such as energy consumption and estimation, even from the initial design stage. The results can be used to predict the total energy consumption and subsequent cost of the entire project, ensuring that it is cost effective and sustainable.

7D BIM: 7D is all about facility management, a critical position for managers and owners. Specifies asset data, including technical specifications and condition, for future maintenance of the project. Since this is a Building Information Model, all data is aggregated into a single model which is most likely the same model used by all other stakeholders. Hence, we can ensure that the model is in its best possible use throughout the life cycle of the project.

8D BIM: 8D is essential for safety planning during construction by including safety information in the model from the design stage. This BIM technology can be used in combination with other advanced technologies such as VR (Virtual Reality) to view a typical site and visualize any potential site threats.

4. BIM in Syria, Obstacles and Solutions

In the opinion of the researcher, most workers in the construction sector are unaware of the importance of BIM system and do not have the knowledge and skill to apply it at present. Although it is implemented by some consulting offices. However, the adoption level of BIM remains much lower than expected [5,15,16]. Due to not only solving the massive problems with AEC industry projects and reaping the benefits from implementing BIM but also improving the project's performance and efficiency [6,13,14,15].

Several obstacles manifest the difficulty of applying BIM in the local market in Syria. As for the solutions that may help to get rid of the obstacles, as seen by the researcher, we mention them in Table 1:

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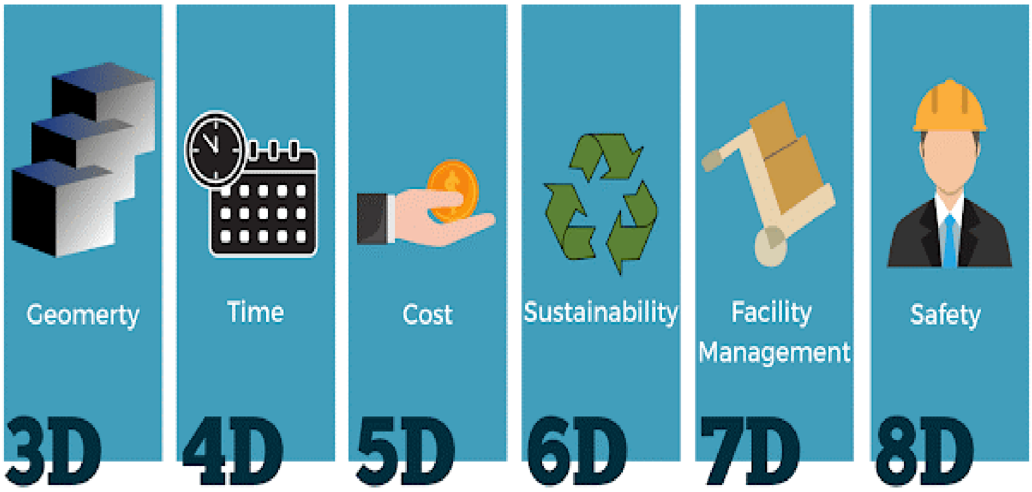

Figure 1: Dimensions of BIM.

Table 1: The main obstacles that hinder BIM implementation and their solutions.

Administrative Obstacles	
Insufficient BIM experience to change	Introducing BIM into university curricula (long-term) and staff training (short-term).
Insufficient support from higher management for BIM accreditation	Senior management must be persuaded to support this change to make the decision to make BIM mandatory.
Resistance to change	Understanding the need for change and recognizing the benefits rather than being prepared for change involving people, processes and technology. A bottom-up and top-down approach should be adopted simultaneously to expedite BIM implementation [7]. Implement successful change management strategies to eliminate any potential resistance to change.
Technical Obstacles	
Difficulties in managing a BIM model	The appointment of a BIM manager is necessary to eliminate the risks related to the BIM model who is authorized to edit data for the main unified BIM model.
Lack of skilled resources and complexity of BIM software	Syrian educational bodies need to allocate more time and effort to qualify engineers and help them keep up to date with the latest technologies [8].
Surrounding Environment	
No demand from governments/customers to use BIM	Perceptions of governments and customers about the importance of BIM.
Financial Obstacles	
Costs associated with implementing BIM	Governments should provide training programs to educate staff of organizations on how to implement and use BIM and provide awareness sessions through professional institutes and academia to enhance organizations' awareness of the importance and benefits of BIM, to encourage them to invest in BIM.
Legal and Contractual Obstacles	
Unclear intellectual property rights	Intellectual property rights with responsibilities and rights of all parties and the level of data transmission (LOD) must be presented in a contract document by the government in a standard document or by the customer.

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5. Buildings Rehabilitation

5.1. Definition

The Electronic Code of Federal Regulations defines rehabilitation as “the improvement of the condition of a property from deteriorated or substandard to good condition. Rehabilitation may vary in degree from the gutting and extensive reconstruction to the cure of substantial accumulation of deferred maintenance. Cosmetic improvements alone do not qualify as rehabilitation under this definition. Rehabilitation may also include renovation, alteration, or remodelling for the conversion or adaptation of structurally sound property to the design and condition required for use under this part, or the repair or replacement of major building systems or components in danger of failure” [5].

5.2. Assessment procedure

Pedro (2008) stated that the assessment is based on a visual inspection of the buildings where possible. During the survey, all information collected is recorded in a checklist according to the criteria specified in the application instructions developed for this purpose.

During the survey, each building is assessed in two different ways: the first is that the building is isolated from nearby buildings, and the second is its relationship to other nearby buildings.

In the assessment of a building considered isolated, the defects in its constituent structural elements are first investigated, and then the architectural defects, the result being expressed by the level of rehabilitation needs. This concept refers to the relationship between rehabilitation works necessary to maintain the type and use of spaces and to correct existing defects in the same capacity and functions. This indicator can also be used to determine the feasibility of building rehabilitation and maintenance.

The assessment the interrelationship between buildings includes analysing the problems that may arise, the result being expressed by the 'level of defects in the interrelationship with other buildings'.

5.3. Level of rehabilitation needs

In the assessment of structural elements, each element is assessed on three different factors: severity of the defect, extent and complexity of the intervention. The assessment of each structural element begins with identifying the existence of defects and classifying their severity on a four-point scale according to the criteria given in Table 2:

Table 2: Rules for assessing the severity of building defects.

Very Slight	No defects or defects without effect.
Minor	Aesthetics defects.
Medium	Defects detrimental to use or comfort.
Severe	Defects that endanger health and safety.

If the defects found are minor, medium or severe, the extension and complexity of the intervention required to repair them must be determined. The extent of rehabilitation work is assessed in four categories, taking into account the work deemed necessary to repair the identified defects, as shown in Table 3:

Table 3: Rules for assessing the extent of the intervention.

Located	Occasional defects affecting the structural element, extension does not exceed 25% of the total area.
Medium	Anomaly affecting limited areas of the structural element, extending between 26% and 50% of the total area.
Extent	Defects affecting large areas of the structural element, extending between 51% and 75% of the total area.
Total	Anomalies affecting almost all structural elements, extension exceeding 75% of the total area.

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"Rehabilitation complexity" is the concept of taking the difficulties of implementing a rehabilitation together with comparing the cost of the process of building a new component. Complexity is evaluated in three categories as shown in Table 4:

Table 4: Rules for assessing the degree of complexity of the intervention.

Simple	Work done in a single process and with only one specialty involved. Cleaning, painting or surface rehabilitation of building elements.	Works at a much lower cost than building a new functional item.
Medium	The works were carried out in several operations that required the intervention of different specialties. Jobs that require demolition or removal of cladding to allow intervention and subsequent reconstruction.	Works at a lower cost than building a new functional item.
Difficult	Technically complex works, which require the application of procedures, materials and/or technologies that are not in use. Rehabilitation work for a functional element to meet functional requirements. Demolition or removal of a functional component, and subsequent reconstruction.	Works at a cost equal to or greater than the cost of a new functional item.

The level of rehabilitation needs is defined in three categories: minor, moderate and severe. It should be noted that the training and experience of the engineers are essential in all this process and they determine the result according to the criteria given in Table 5:

Table 5: Criteria for assessing the level of rehabilitation needs.

Slight rehabilitation	Coating repairs. Minor repairs to the perimeter of the building. Spatial repairs in major or minor elements.
Medium rehabilitation	Replacement of coatings. Repair and construction of new facilities. Spatial repairs, replacement or reinforcement of major or minor elements.
Severe rehabilitation	Repair, replacement or reinforcement of major or minor building elements.

5.4. The level of defect in the interrelationship with other buildings

For this level, three different aspects are assessed that cannot be easily verified using existing maps: The aspects assessed are:

- The existence of parts of adjacent buildings above or below the building being assessed.
- The distance is the building being assessed and other nearby buildings.
- The building being assessed is located on the edge of an adjacent plot of land.

Taking these aspects into account the functional requirements of safety, each of these aspects is assessed on the approved four-level defect severity scale (Table 1). The result of the defect level in the interrelationship between buildings for each building is expressed as the most severe defect level obtained.

6. Factors effecting public facilities rehabilitation projects

These difficulties are represented in several points:

- Availability of the necessary engineering staff to study the project for the rehabilitation one of the public facilities damaged by the war in Syria.

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- Accurately specifying the estimated bills of quantities for the work required in the public facilities rehabilitation project.
- Determine the project cost accurately.
- Mobility needs are met, especially since most of the damaged facilities are located in the rural areas of the governorates.
- Existence of public facilities engineering plans due to the burning and damage of documents during the war.
- Existence of means and devices that help in detecting the safety of buildings and facilities to be rehabilitated.

7. Al Ejref elementary school using BIM

Al-Ejref Elementary School is a school in Al-Ejref village in Al-Quneitra Governorate, affiliated to the Syrian Ministry of Education. It was damaged by terrorist acts in Syria in 2014. The school consists of seven classrooms, one administrative room and three service facilities. This school was chosen because it is the only school in the village, and the nearest elementary school is about 6 km away from the village in the absence of public transportation.

The engineering unit of Department of Ecumenical Relations and Development (GOPA-DERD) started studying Al-Ejref school rehabilitation project in February 2022 and started implementing the project in May 2022. The studying engineer created plans and an estimated BOQ based on traditional methods.

The researcher prepared an estimation BOQ using the Revit 23 program, which is one of BIM programs that specializes in modelling in a three-dimensional environment with parametric accuracy, in order to issue an estimated BOQ and compare it with the estimated BOQ based on traditional methods.

Structural elements such as foundations and ground beams were assumed due to the burning and damage of the original plans during the war.

The construction of the school was modelled, consisting of foundations, ground beams, columns, beams and slabs, and then the walls were added with external and internal finishing, aluminium windows, interior wooden doors, exterior metal doors, ceramic tiles for bathrooms and lighting devices only for the sake of producing clear images.

- A comparison will be made between several items:
- Providing and implementing of a Tyrolean plaster.
- Providing and implementing water-based paint for walls and ceilings.
- Providing and implementing oil-based paint for walls.
- Providing and installing interior wooden doors.
- Providing and installing aluminium windows.
- Providing and installing ceramic floor tiles.
- Providing and installing ceramic wall tiles.

Numerical items such as lighting and sanitary devices were not shown in the school model because they will be counted by the studying engineer, whether the study is traditional method or using the Revit program.

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Figure 2: 3D modelling of the school using Revit.

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After calculating the BOQ of the school using Revit, it was compared with traditional method BOQ as shown in Table 6:

Table 6: Difference ratios between the traditional study and the study using BIM.

Item	BOQ using Traditional Method (m^2)	BOQ using BIM (m^2)	Difference ratios due to the Traditional Method
Providing and implementing of a Tyrolean plaster.	541	485	+%11.55
Providing and implementing water-based paint for walls and ceilings.	914	948	-%3.59
Providing and implementing oil-based paint for walls.	854.6	516	+%65.62
Providing and installing interior wooden doors.	48.2	54	-%10.74
Providing and installing aluminium windows.	96	100	-%4.00
Providing and installing ceramic floor tiles.	55	54	+%1.85
Providing and installing ceramic wall tiles.	100	118	-%15.25

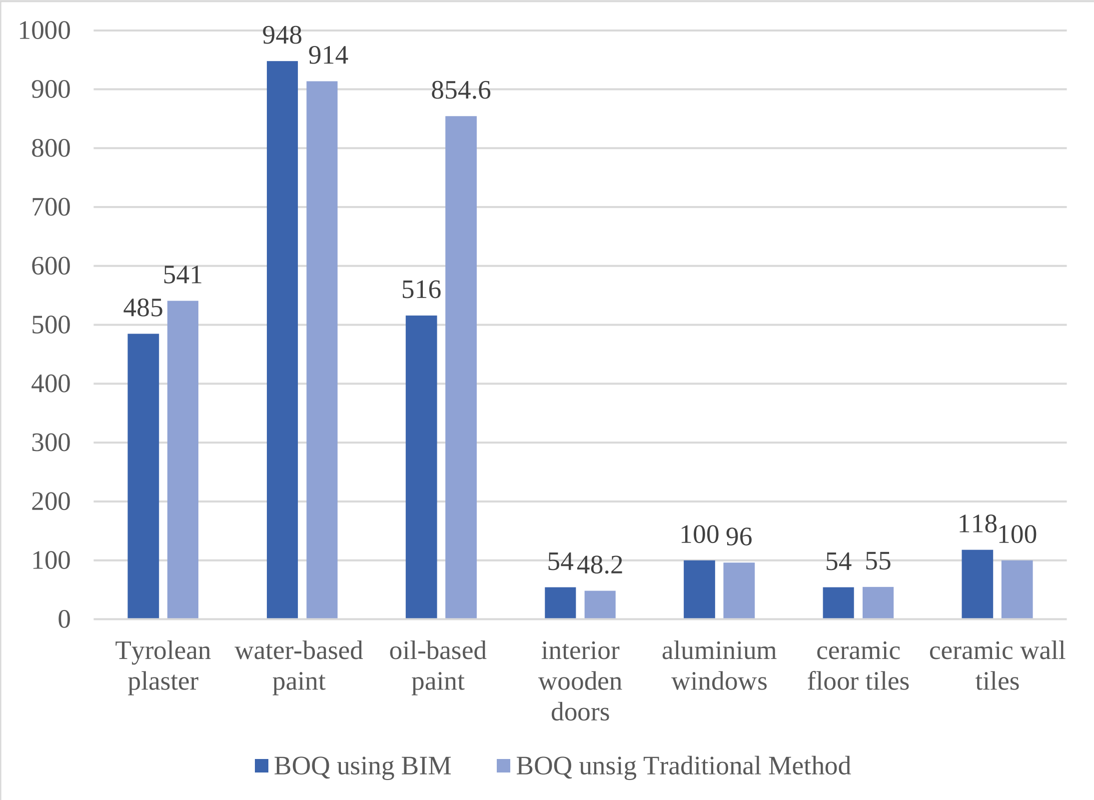

Figure 3: Difference chart between the traditional study and the study using BIM.

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8. Conclusion

Rehabilitation of public facilities after the war is a topic of concern to all the people of Syria. Despite its difficulty and the absence of laws that help in the planning, studying and implementing these projects. and the absence of studying and implementing methods generalized to specialists in the field of rehabilitation of public facilities. In this research, the effectiveness of applying BIM technology in increasing the accuracy of quantity estimation for public facilities rehabilitation projects in Syria after the war was tested, especially Al-Ejref School rehabilitation project in Al-Quneitra governorate. The search yielded the following points:

- BIM applications are interactive and dynamic compared to two-dimensional plans and traditional study methods. As a result, it is possible to increase the accuracy of estimating quantities in post-war rehabilitation projects in Syria by using BIM applications.
- Increasing the accuracy of estimating quantities in small projects results in reducing the study time, in addition to an accurate estimation of project cost. In large projects, the modeling period may be long, but the later stages of the study are greatly accelerated.
- The use of BIM applications in projects to rehabilitate public facilities in Syria after the war helps reduce the cost of the study in terms of human cadres to transportation expenses.
- In addition, it contributes to establish a database of plans and models of rehabilitated public facilities after the original plans were damaged during the war, which helps the governmental departments to re-document and save the plans.
- Finally, it helps GOPA-DERD engineering unit to implement future schools rehabilitation projects with greater professionalism and precision.

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