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Original Research

Modular Integrated Construction Management of Post-Disaster Settlements

Ashraf Osman [1,*], Bira Wafaei Baneh [2], Masoud Rahmati Deiranloei [3], Koosha Wafaei Baneh [3]

1. Professor (Emeritus), Structural Engineering Department, Cairo University, Cairo, Egypt; E-Mails: ashraf.osman@dar.com; aosman@eng.cu.edu.eg
2. Department of Civil Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran; E-Mail: birawafaei@gmail.com
3. Independent Researcher, Tehran, Iran; E-Mails: rahmati.masoud1995@gmail.com; kwafaeibaneh@gmail.com

* **Correspondence:** Ashraf Osman; E-Mails: ashraf.osman@dar.com; aosman@eng.cu.edu.eg

Academic Editor: Emanuele Brunesi

Recent Prog Sci Eng
2026, volume 2, issue 3
doi:10.21926/rpse.2603019

Received: December 15, 2025
Accepted: August 25, 2026
Published: September 07, 2026

Abstract

This research addresses how BIM can help manage the construction of post-disaster settlements utilizing the MiC technique. First, previous research work in this field is reviewed. Then, the challenges explored through literature synthesis and prioritization of BIM usage in the management of MiC projects were identified based on the qualitative opinions of a group of experts. After that, an approach to achieve selected and potential applications of BIM in the management of temporary housing projects based on MiC is explained through a case study. Finally, measuring the effectiveness of BIM in managing construction projects in crisis conditions is done by organizing interviews with groups of experts. The results indicate that utilizing the BIM model in a prefab temporary housing project based on MiC effectively improves the 3D visualization and simulation of the project, creates better communication and coordination between designers and contractors, ensuring high quality for the product, helping in planning the assembly and management of the project, and supporting estimation and quantity surveying, and eliminating construction element interference.

Keywords
Modular Integrated Construction (MiC); Building Information Modeling (BIM); temporary housing; modular housing

1. Introduction

Disaster resilience is defined as the ability of countries, communities, and families to manage change by maintaining or changing living standards in the face of shock or stress [1]. In this regard, the construction industry plays a vital role in increasing disaster resilience since buildings are important in helping communities facing disasters. This is because when buildings are damaged or destroyed, a community's ability to function economically and socially is severely impaired. In such situations, the establishment of temporary accommodation, suitable services, and health centers became basic needs for crisis-affected communities. For these reasons, interdisciplinary actions to increase community resilience should include measures to strengthen the construction industry's resilience to disasters [2].

In the post-disaster stage, the construction industry must be able to adapt to sudden changes and increased workloads by providing temporary shelter and housing quickly and effectively [3]. Such urgency in developing new buildings with the associated vast amount of work be accompanied by quality and cost control [4]. Modular Integrated Construction (MiC), with its short construction time, excellent and durable construction quality, minimum waste, cost savings, and improved productivity compared to on-site construction, represents the most appropriate construction technique for this stage [5, 6]. However, adopting such technology requires unique business models, design, supply chain, stakeholder composition, construction, and management which significantly differ from those of traditional construction [7]. These risks engender manifold uncertainties and risk events which may derail the success of MiC projects. Recent studies indicated that successful delivery of conventional MiC projects was achieved in Hong Kong and the United Kingdom through the adoption of new digital technologies that facilitated exchange throughout the entire project life cycle [8, 9]. This digital technology is Building Information Modeling (BIM), Which can work as digital platform to optimize the benefits of prefabricated projects by increasing their speed, stability, safety, manufacturability, and quality and reducing their time [10-13], since both technologies are deeply intertwined, as BIM provides the critical digital infrastructure required to manage the off-site fabrication, complex logistics and on-site assembly of modular building components [14]. Therefore, the National Institute of Standards and Technology (NIST) has identified BIM as the main driver for modular construction [15]. However, there is still a dearth of knowledge about adopting BIM and MiC technologies for emergencies or humanitarian shelters. In fact, the BIM-MiC framework addressing rapid deployment is largely unexplored.

This research study examines the effectiveness of applying BIM in MiC as a tool for managing the construction of post-disaster settlements and shelters. In this research, previous studies on the use of BIM in MiC projects are assessed. Following that, the challenges identified from the literature review were forwarded to a group of experts to determine their prioritization for the management of temporary settlement projects. Then, a new approach to achieving selected and potential applications of BIM in the management of temporary housing projects based on MiC is explained through a case study. Finally, the effectiveness of BIM in managing construction projects utilizing MiC technology is determined.

2. BIM Utilization for MiC

2.1 Modular Integrated Construction (MiC)

The popularity of modular and off-site construction is increasing worldwide. The MiC technique has been identified as a practical approach to speeding up the construction schedule and solving the productivity and manpower problems of the industry since most of the construction work is done off-site and then delivered and installed on-site. In general, prefabricated units can be delivered to the site with doors, wall panels, floor panels, stairs, windows, walls, roof trusses, room-sized components, and even electro-mechanical fixtures. According to the literature, MiC is a panacea in cases of catastrophic crises since this technique allows for both on-site and off-site trades to run concurrently, reducing staffing and construction time by 50% and 33%, respectively [16]. Also, it reduces the project's total cost, improves the quality of the structure, minimizes adverse environmental impacts, and supports mass housing production [17]. However, in developing a temporary settlement utilizing modular integrated construction technology, the phases indicated in Table 1 up to phase A5 are usually followed. Then phases A6 and A7 are executed when the function of this settlement terminates. As can be noted from examining this Table, even though MiC technology has the potential to provide several advantages over traditional on-site construction techniques, it certainly has limitations in these phases. For instance, the need for higher design accuracy, better coordination among project parties, better transportation planning, and size restrictions that hinder the transportation of project components to the site. To overcome these limitations, BIM can provide a digital platform to optimize the benefits of MiC technology [7].

Table 1 Modular Integrated Construction (MiC) Phases [17].

Phrases	Code
Planning and design	A1
Manufacturing	A2
Logistics	A3
Assembly on site	A4
Set-up and maintenance	A5
Disassembly	A6
Recycling and landfilling	A7

2.2 Building Information Modeling (BIM)

BIM is commonly defined as a process for producing a virtual multidimensional model to facilitate data sharing among construction and design teams. This model includes building-related data such as detailed geometry, design details, specifications, schedules, quantity estimates, material quality, etc., to support the entire project phases, including design, on-site installation, and maintenance operations [17]. It enables the formation of intelligent digital semantic models of the entire building system, containing complete physical and functional information, including walls, beams, slabs, columns, and system-provided facilities. Also, it allows for integration with new visual technologies, including virtual reality (VR) and augmented reality (AR), to keep up with innovation and respond to changing needs [18].

Both AR and VR originated in the fields of games and entertainment, but recently fields like marketing, tourism, sports, and education have also utilized AR and VR technologies [19]. Around the world, companies across industries use AR and VR for training and to improve productivity. However, AR and VR technologies are still not strong and reliable enough to match real-life industrial needs. Technical limitations like narrow field of view, low tracking accuracy, and low display resolution, in addition to economic and health/safety concerns, are the main factors that lead to the non-approval of these important technologies in dynamic construction environments. However, it should be noted that regardless of these limitations and concerns of AR and VR, there is a need to study the real effectiveness of AR and VR for specific tasks in the construction field and to develop targeted research in the direction of implementation [20].

It is assumed that by inserting augmented reality (AR) technology in MiC, computer-generated information and images can be transferred into the real environment to increase the user's understanding of their surroundings [21, 22]. It creates visualizations using a mobile device, tablet, or head-mounted display (HMD). On the other hand, virtual reality (VR) is a technology that, after creating a virtual environment by a computer, can complete the user's understanding of the surrounding real environment through a head-mounted display (HMD), glasses, etc., by being in the digital virtual environment produced [23]. Both technologies can help designers and contractors understand the project components and the construction sequence, which in turn accelerates and facilitates the shelter's construction.

2.3 BIM in MiC

In the last decade, BIM has been widely adopted to increase production productivity and reduce on-site labor requirements. However, it is considered one of the new technologies that can accompany modular construction. BIM applications seem to offer functionality that supports and complements the modular approach, revealing its potential. Therefore, BIM and the modular approach are two paradigms that have been proposed to address potential issues such as efficiency and productivity and are increasingly being applied jointly applied in the construction industry [17].

3. Research Methodology

To validate the effectiveness of using BIM technology in the project management of post-disaster temporary settlements based on MiC technology, a research study was developed. This study was executed in the following steps:

3.1 Step 1: Identification of BIM Applications in MiC

As a first step towards validating BIM applications in MiC, a review of the available literature was conducted. According to this review, the uses and purposes of employing BIM applications in MiC are listed in Table 2. As can be noted, in each of the references indicated, BIM was used for a specific purpose in MiC. These purposes were coded from B1 to B9 and listed as activities that were forwarded later to many experts to assess the importance of such activities on the usage of BIM in the MiC industry.

Table 2 BIM usage in MiC.

Usages	**References**
B1- 3D visualization and simulation	[24]
B2- Clash detection	[21, 25]
B3- Better communication and coordination	[26]
B4- Optimization	[27]
B5- Parametric modeling	[28]
B6- Assembling training with BIM	[29]
B7- Quantity surveying and estimating	[30]
B8- Logistics planning and management	[31]
B9- Improvement of prefab level	[32]

3.2 Step 2: Checking and Verifying the Usage of BIM in MiC

The verification of the previously identified applications for BIM in MiC was conducted based on the judgment of a group of 37 experts. A survey of the opinions of those experienced experts regarding the identified BIM applications in MiC was conducted. Those experts were selected for having more than 10 years of experience in the construction industry and at least 5 years of research experience in BIM. Among them, 19% have Ph.D. degrees in logistics management (7 professionals), and 38% have Ph.D. degrees in civil engineering and construction management (14 professionals). Another 43% of experts were senior engineers in project management and construction (16 professionals). Those knowledgeable and experienced experts gave due credit to the survey results.

3.3 Step 3: Developing a Case Study

As mentioned earlier, to validate the use of BIM in the MiC industry to create temporary housing after crises, a case study will be needed. Based on library studies and in line with the research objectives, the case study should overcome many of the problems related to temporary settlements assembled for crisis victims. According to these studies, the settlement shouldn't only be low-cost but also be sent in pieces so that the users can use it to be assembled easily and should be suitable for a long-term stay.

3.4 Step 4: Evaluation of the Following Approach for the Case Study

After initially designing the case-study temporary settlement, the steps previously described for developing BIM-based modeling were followed to achieve the BIM applications as approved by experts. These steps included eliminating interference, performing quantity surveying, preparing assembly sequence schedules, simulating the site's actual situation, and finally producing dedicated software and programs based on AR and VR technologies that are needed for simulation and visualization of the project to improve interaction and knowledge with the project. Then, a brainstorming session was held to examine the applications of BIM in the phases of the MiC project, and organized interviews were conducted later with previously consulted experts.

4. Results and Discussion

4.1 Evaluation of BIM Usage in MiC

To assess how BIM is applied within the Modular Integrated Construction (MiC) industry, a panel of experts reviewed a list of BIM-related applications. It indicated their level of agreement with each. The resulting consensus percentages are presented in Table 3, which summarizes expert agreement for every application considered.

Table 3 Expert evaluation of BIM usage in the MiC industry for temporary housing project management.

	Notes	
	Agreement %	
B1- 3D visualization and simulation	100%	Experts consider 3D visualization to be a common and useful application for all kinds of projects, including MiC.
B2- Clash detection	100%	All experts stated that this usage helps to minimize design errors in the early stages.
B3- Better communication and coordination	73%	27 experts stated that this would greatly assist the construction team in a MiC project.
B4- Optimization	43%	Experts believe that this usage is useful but overly time-intensive during crises, given the need for manual data entry into BIM.
B5- Parametric modeling	27%	Experts felt its advantages were not clearly evident, though it may be more relevant for complex systems.
B6- Assembling training with BIM	86%	32 experts approved this application, while 5 disagreed, arguing that real proficiency can only be gained through hands-on experience.
B7- Quantity surveying and estimating	100%	Experts agreed it enables faster and more efficient quantity calculations for surveyors.
B8- Logistics planning and management	100%	Fully endorsed for its overall performance, though experts noted that execution doesn't always go as planned due to factors like traffic congestion and unforeseen disruptions.
B9- Improvement of prefab level	100%	Experts agreed that BIM enhances module prefabrication accuracy by generating precise drawings and integrating advanced manufacturing technologies.

Based on this evaluation, any application (or barrier) that achieved less than 50% expert agreement was subsequently excluded from further analysis. This 50% cut-off reflects the "majority agreement" tier recognized in the Delphi consensus literature and is well supported in methodological guidance as an appropriate minimum bar for initial screening — ensuring that only items rejected by a clear majority of the panel were removed, while those with partial, non-majority support were retained for deeper qualitative examination. The applications meeting this threshold, together with the corresponding partial agreements and expert commentary, are presented in Table 4, where they are re-coded from C1 to C7 for ease of reference.

Table 4 Usages which experts partially agreed on with acceptable percentage.

Usages	Code
3D visualization and simulation	C1
Clash detection	C2
Better communication and coordination	C3
Quantity surveying and estimating	C4
Improvement of prefab level	C5
Logistics planning and management	C6
Assembling training with BIM	C7

In summary, experts agreed that using BIM in MiC for temporary settlements would be very effective because of the integration of these technologies for initial coordination and design approval and, subsequently, facilitating production and manufacturing in the factory. Also, they stated that using BIM in MiC leads to faster and more sustainable construction. However, some of the experts pointed out that BIM is more effective in the design phase than in the construction phase. Some of the applications, like "optimization" and "parametric modeling", were not accepted by many experts, who claimed that these applications required additional work and entered a significant amount of data, which is not favored in cases of temporary settlements.

4.2 Developing the Case Study by BIM

For the case study shelter, hexagonal plan units of 40 square meters were utilized. These units can be combined in different types of clusters to create gardens and gathering spaces inside as well as between these combinations, as shown in Figure 1. These green spaces are reminiscent of courtyards and urban parks that can improve social interaction between residents and their lives in a damaged community. In addition, the hexagonal unit configuration offers less wall material, structural efficiency, better thermal performance in clusters, and the ability for repetition without gaps [33]. Clusters consisting of hexagonal units, due to their geometric flexibility, can be easily adapted to urban and suburban plans with different linear or radial configurations. The hexagonal plan allows flexibility in the size and design of structures. For example, these hexagonal units can be used to create mosques, schools, hospitals, markets, and military camps in addition to settlements.

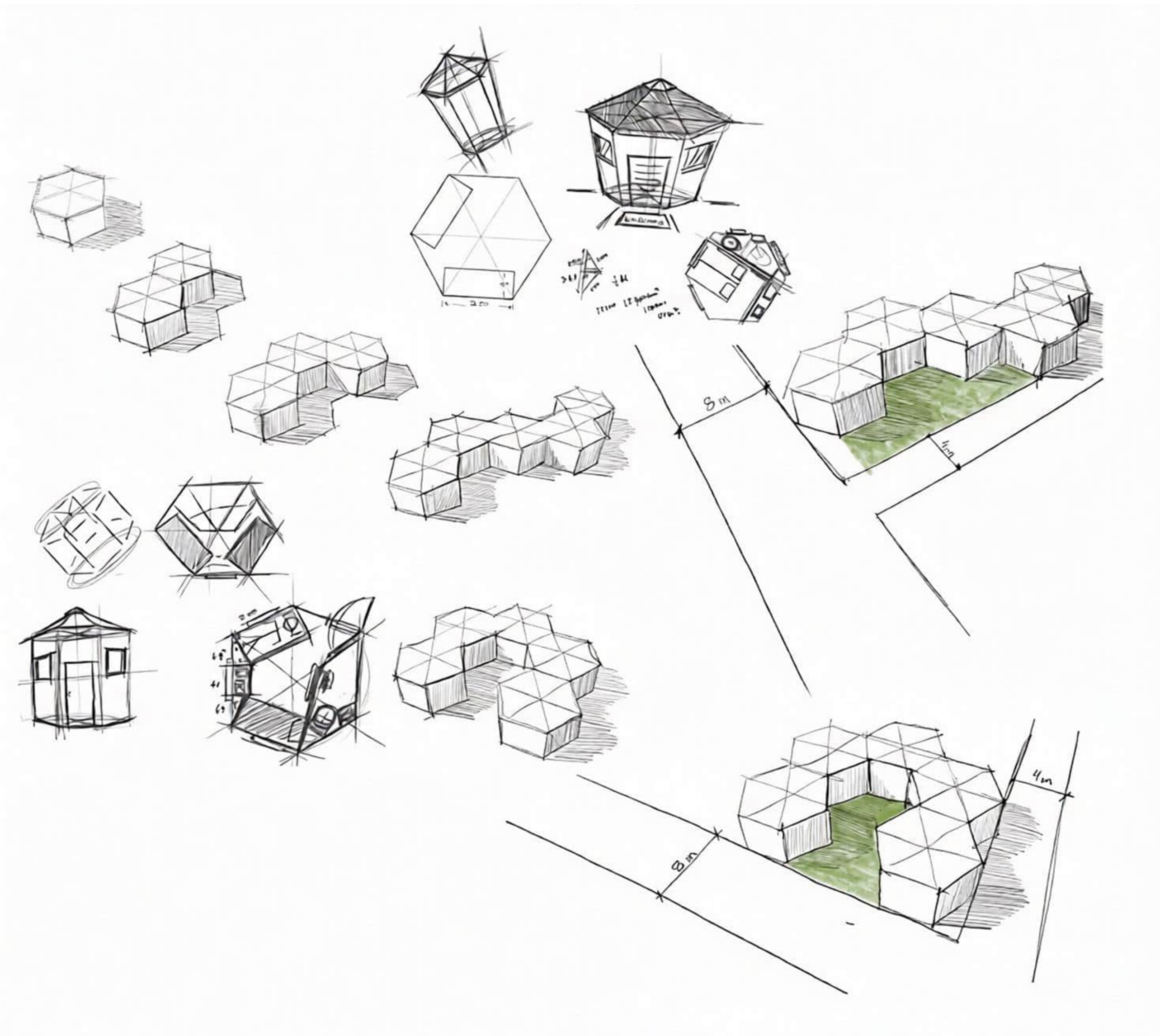


Figure 1 Sketches of the habitation model.

Building information modeling using Revit software allowed the development and review of the design at all stages and led to optimizing the design process. As can be seen in Figure 2, the BIM model for the studied cluster allowed the design team to convert their 2D drawings and documents into advanced digital models and execute the building once and for all in a virtual way. Also, it helped to automatically detect collisions between the work of different disciplines during the design phase and before the start of construction. Figure 3 shows how this was applied to the cluster proposed for the construction of the temporary settlement.

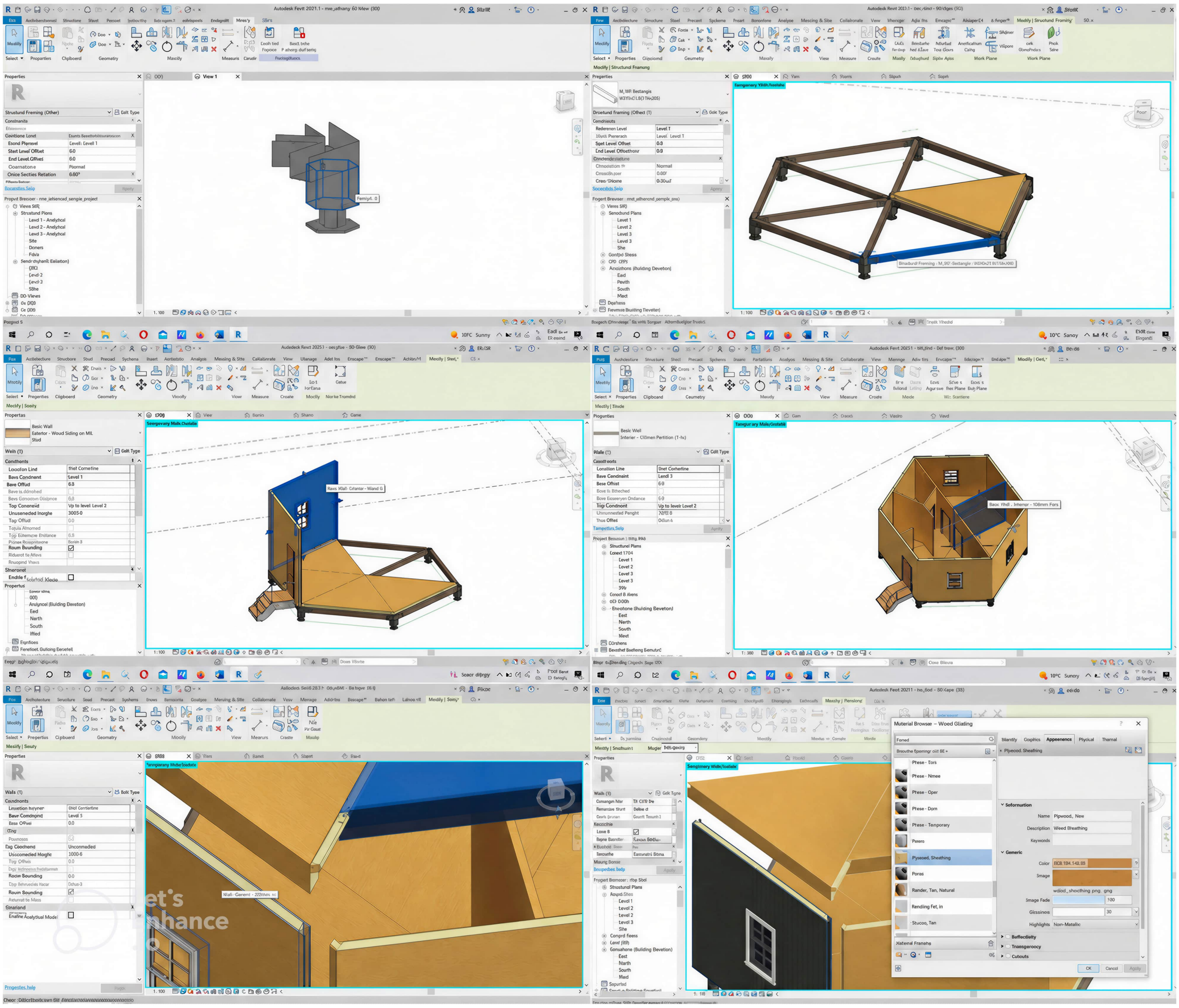


Figure 2 BIM-based modeling in Revit software.

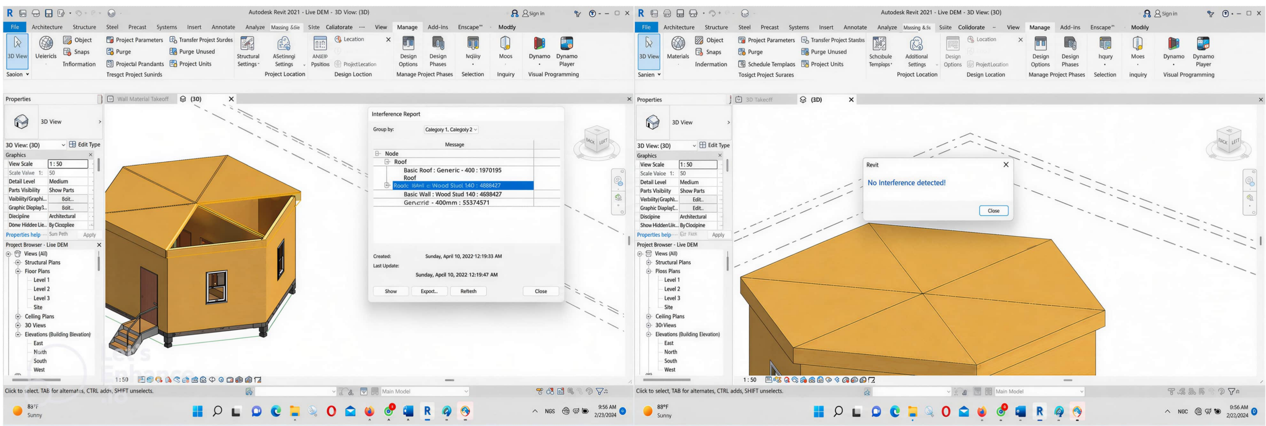


Figure 3 Identification of clashes in Revit software.

Detecting conflicts at early stages of projects will allow for making the required corrections in simpler ways, employing cheaper solutions, and spending less time, which in turn will accelerate the construction at the site and result in cost savings.

In addition to the previously indicated benefits, building information modeling (BIM) was used in managing interactions, project planning and scheduling, Quantity surveying, estimating, etc. Utilizing the tools for material takeoff allows for the calculation of the amount of material used in each layer of the floor, ceiling, wall, false ceiling, and family information such as length, width, area, volume, etc. As shown in Figure 4, when the material takeoff option is selected, the New Material takeoff window opens, and the designer can select the desired category. In the properties window, one can select the desired information related to the calculation table in the available fields section. Accordingly, tables like those shown in Figure 5 and belonging to the concerned cluster will appear within a few seconds, and the software will do quantity surveying and estimation to the desired specifications and information.

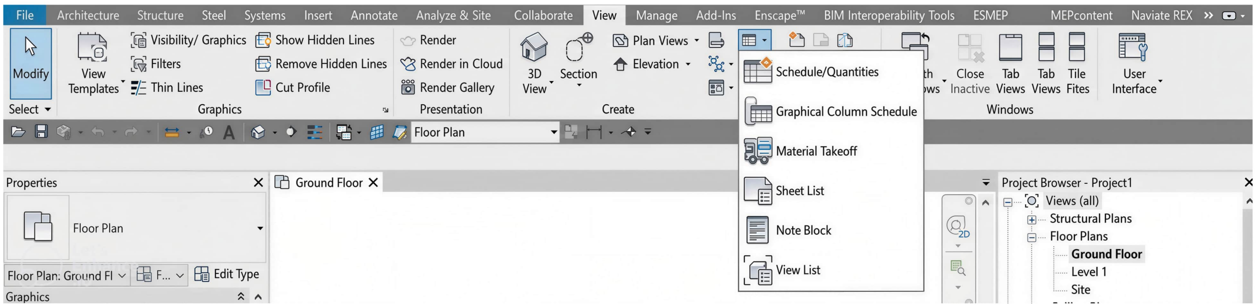


Figure 4 Revit software environment for quantity surveying and estimating.

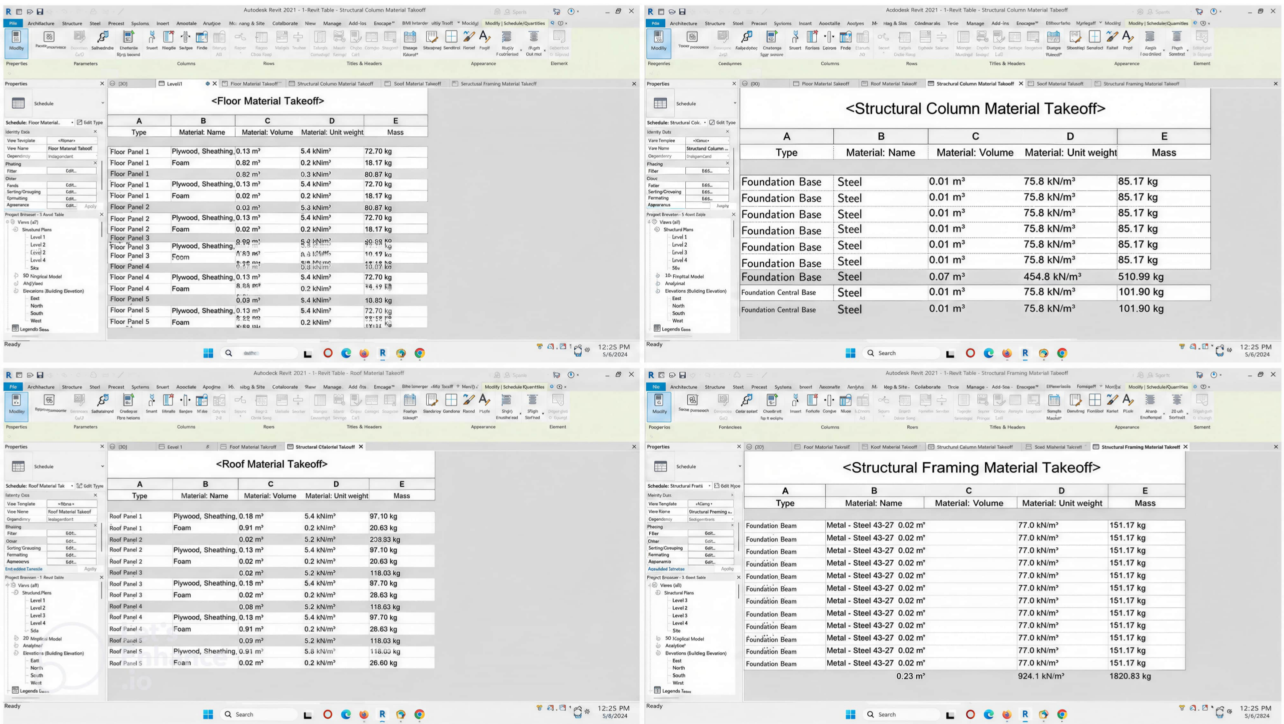


Figure 5 Extraction of quantity surveying and estimating tables in Revit software.

For preparing the project schedule, following the importing of the model file into the Navisworks software, loading the model completely, and displaying it on the screen, the design team was able to enter the planned time and observe the output of delay or urgency. Figure 6 illustrates the application of this process to the concerned cluster.

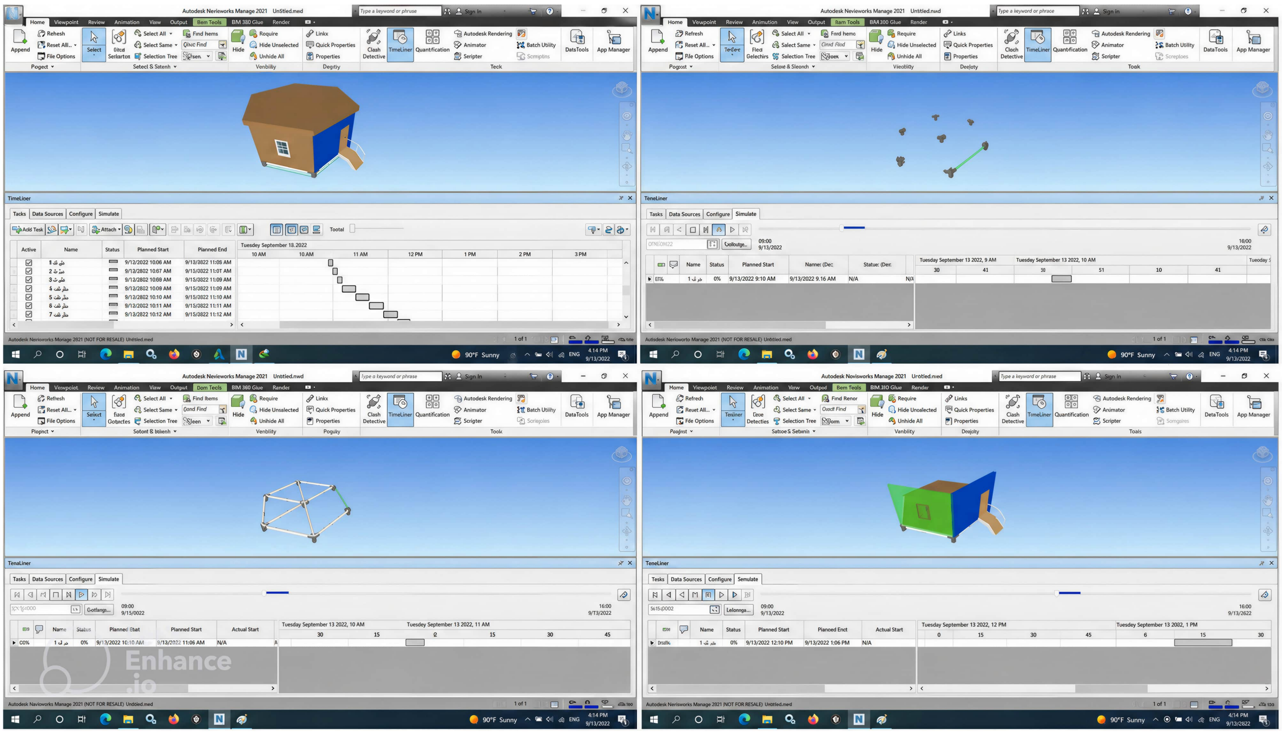


Figure 6 Navisworks software environment for timing output.

For the studied case, the next step was simulating and modeling the site, including topography. Due to the urgent nature of actions in crisis management and the need to speed things up, without using the time-consuming techniques of mapping, the topography model of the site or the desired area is received through the CadMapper website and entered into the Revit software to simulate the project, as shown in Figure 7. CadMapper can convert OpenStreetMap, NASA, and USGS data into CAD files. Then, the output data can be exported to Revit software in general DXF formats.

Figure 7 Simulation of the topography of the project site through the CadMapper website.

After that, the design team produced an image of the model from a virtual model to display it on the screen using rendering software. In this process, the 3D model was converted into a visible pixel image. Such a rendering process helped the design team to reduce design costs through visualizing and carefully checking the settlement before construction in order to fix possible defects. In this research, the Enscape rendering engine (EnscapeTM tab) from the main Revit toolbar was activated to start the process. Then, the rendered environment is displayed in a real-time window, where the changes made in the model can be seen at the same time. Then, by setting the camera, framing the scene, and selecting the Screenshot icon, the rendering of the desired scene was produced as shown in Figure 8.

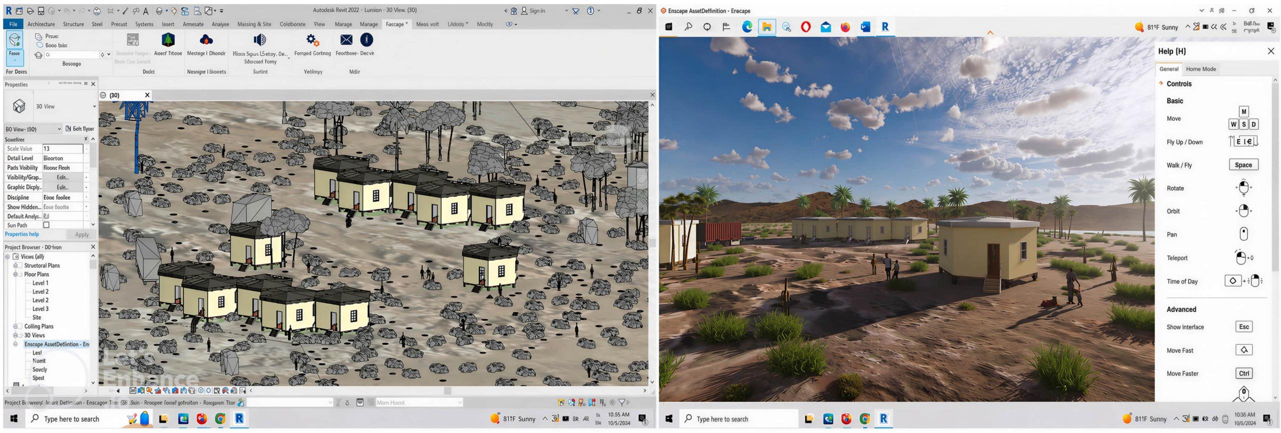


Figure 8 Rendering of the simulated model.

In recent years, virtual reality and augmented reality technologies have been welcomed as new tools for creating visualizations, and research has confirmed the high potential of these technologies in the construction industry. For these purposes, two approaches to implementing augmented reality (AR) with different features were used during meetings and assembly projects on site. These approaches are either map-based (Figure 9) or location-based (Figure 10).

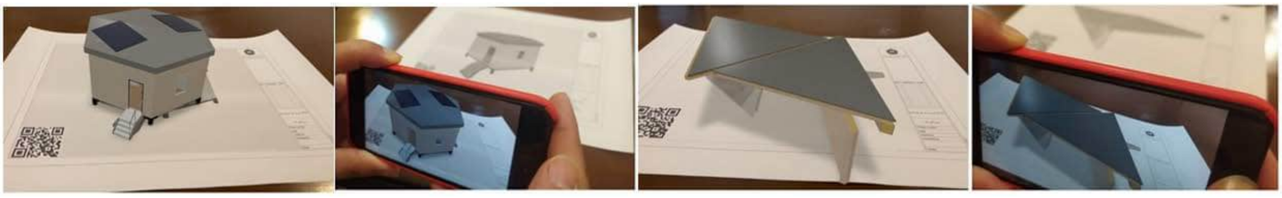


Figure 9 Map-based Augmented Reality project presentation application.

Figure 10 Displaying the model as an augmented reality location-based application.

For implementing virtual reality, two approaches can be taken. This can be done by executing the BIM model of the project in real time through the Enscape plugin in Revit. For the case study, an Asus TUF Gaming laptop with an Nvidia GeForce GTX 1650 graphics processor and Oculus Quest 2 VR glasses were used. The Enscape rendering engine gives the project parties the ability to understand design changes and corrections in the BIM model immediately and as a walking experience using virtual reality glasses or a video game in the BIM model, as shown in Figure 11.

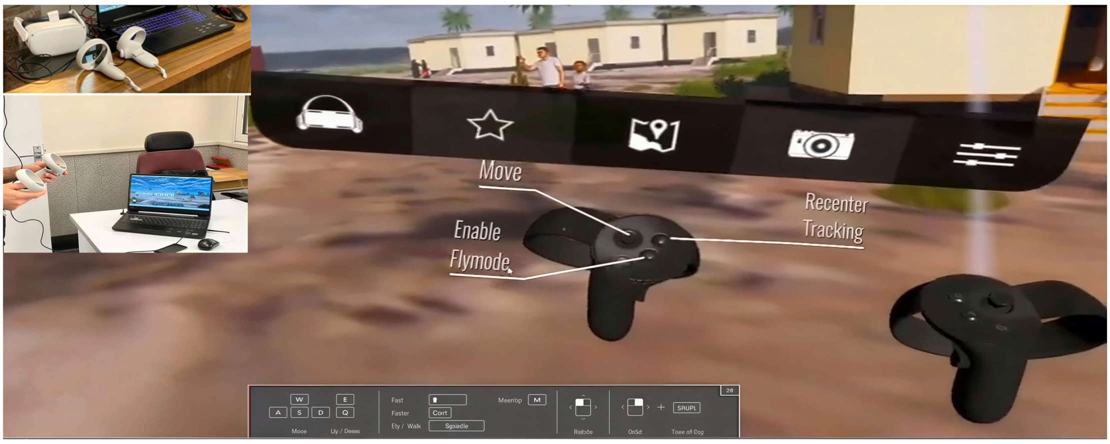


Figure 11 Usage of virtual reality technology.

Another approach to using virtual reality (VR) technology is a presentation based on 360° rendering. In this method, after processing the BIM model in the rendering engine and determining the specifications of the camera station, 360° rendering is performed at the designated stations. The types of presentations based on 360° rendering in this research include the design and production of virtual visit software for the future project and the virtual assembly of MiC settlements, as shown in Figure 12. First, to produce this software, the 360° renders are entered into the 3Dvista virtual tour design software, and by applying motion communication between the 360° renders, the possibility of interactive movement in the BIM model using VR glasses or screens is provided. In virtual visit software, the available details can be enriched with information and content such as photos, videos, text, etc.

Figure 12 Exclusive software for the future virtual visit of the project.

Virtual Montage software is like virtual visits, but it is designed step by step using 360-degree renderings. In this regard, the renderings prepared at the fixed points from the assembly stages of the project model are entered into the virtual tour design software and matched. So that in an interactive scene, the assembly sequence of the project can be checked step by step, as shown in Figure 13.

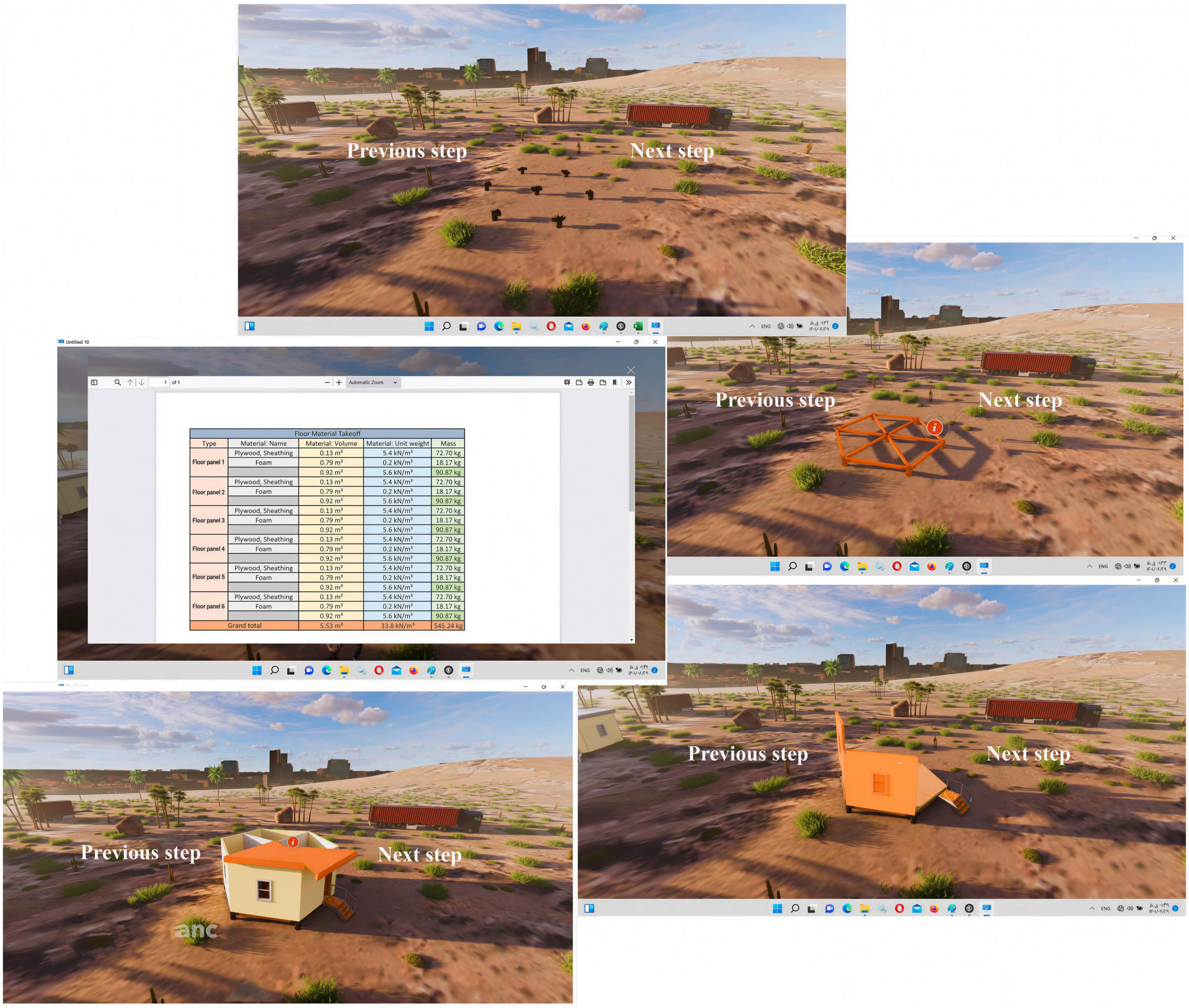


Figure 13 The software designed for the assembly sequence in a case study project.

In this research, the proposed settlement is for the temporary settlement of affected communities, is suitable for long-term residence, and can be integrated into the context of big cities. Temporary settlements mostly face a range of social, economic, and cultural problems. Affected communities often live in uncomfortable, unsanitary, and inhumane conditions for long periods. The research case study is a stable, fast, and low-cost settlement based on insulated panel technology, which can be transported as packages and easily assembled by the end user. The purpose of the proposed settlement is to create an environment that allows all members of the affected community to interact and live with dignity and respect.

4.3 Evaluation of the Approach Followed for the Study Case

The evaluation process involved designing the temporary settlement utilizing BIM-based modeling and achieving a model that satisfies the BIM requirements approved by the experts. In this regard, the final design eliminated interference, performed quantity surveying, prepared the assembly sequence schedule to simulate real-world conditions, and programmed the site and model designs using dedicated software based on AR and VR technologies for simulation and visualization to improve interaction and education. Then, interviews with each of the 37 experts were held to assess the importance of BIM application in the MiC project. During these sessions, each expert was asked, using a Likert scale, to evaluate from their perspective the effectiveness of applying BIM in MiC for the design and construction of settlements. They were asked to rate the applications on a scale of 1 to 5, with 1 being “less effective” and 5 being “effective”. For example, 14 experts rated “3D visualization and simulation” 5, another 14 rated it as 4, and 9 others rated it as 3. Consequently, the overall mean score, as the results came out, was 4.135. Table 5 lists these results.

Table 5 Weighted realization of BIM applications in the MIC-based temporary settlement project.

BIM application	Mean score values	Weighted percent
C1- 3D visualization and simulation	4.135	0.1675 ≈ 0.17
C2- Clash detection	3.000	0.1215 ≈ 0.12
C3- Better communication and coordination	3.837	0.1555 ≈ 0.16
C4- Quantity surveying and estimating	3.297	0.1336 ≈ 0.13
C5- Improvement of prefab level	3.145	0.1270 ≈ 0.13
C6- Logistics planning and management	3.567	0.1445 ≈ 0.14
C7-Assembling training with BIM	3.703	0.1500 ≈ 0.15

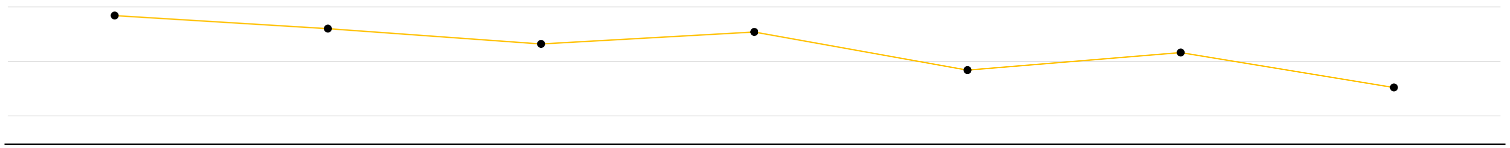
During these same expert sessions, participants also assessed the extent to which each BIM application influences the different phases of the MiC project; detailed results are presented in Appendix A.

Applying the proposed methodology for using BIM to manage temporary settlement projects after a disaster, the interview findings are presented in two parts: Table 6 ranks the BIM applications within MiC according to the proposed model-development approach. In contrast, Table 7 ranks the MiC project phases by their applicability to BIM use.

Table 6 Ranking of applications of BIM in MiC based on the BIM model in the case of a temporary settlement after the disaster.

BIM usage in MiC / **Phases of MiC projects**	C1	C2	C3	C4	C5	C6	C7	**Weighted sum**	**Rank**
A1	185	179	173	185	154	161	154	170.32	1
A2	156	148	128	131	166	148	136	144.49	2
A3	122	74	142	135	135	161	62	119.28	4
A4	159	115	161	68	163	137	173	141.75	3
A5	89	49	105	49	117	61	62	77.23	6
A6	100	49	123	49	173	91	155	107.41	5
A7	37	37	43	81	66	49	37	49.13	7
Weighted sum	144.1	78.12	140	90.74	126.62	113.1	116.85		
Ranking	1	7	2	6	3	5	4		

Table 7 Calculating the weighted sum of the impact of BIM applications in each phase of the MiC project.

MiC-based temporary settlement project phases	Planning and design	Manufacturing	Logistics	Assembly on site	Set-up and maintenance	disassembly	Recycling and landfilling	
The potential of BIM by different phases of the MiC project	 92%	78%	64%	77%	42%	58%	27%	
BIM applications in MiC								Weighted sum
3D visualization and simulation	100%	93%	67%	87%	47%	53%	20%	79%
Clash detection	97%	70%	40%	63%	27%	27%	20%	41%
Better communication and coordination	93%	70%	77%	87%	57%	67%	23%	76%
Quantity surveying and estimating	100%	70%	73%	37%	27%	27%	43%	49%
Improvement of prefab level	83%	90%	83%	90%	63%	93%	30%	69%
Logistics planning and management	87%	80%	87%	77%	33%	50%	27%	62%
Assembling training with BIM	83%	83%	33%	93%	33%	83%	20%	65%

As shown in Table 6, 3D visualization and simulation have the highest scores, while Clash detection has the lowest. The reasons might be that BIM is focused more on the design stage, and in settlement, the finishes and MEP work are simple, so later stages do not directly require extra work. This general bias can be further confirmed by the rankings of the applications focusing on the construction stage, such as Quantity surveying and logistics planning, which are lower than the applications focusing on the design stage. Also, from Table 6, we can notice that Planning and design have the highest score, and Recycling and landfilling have the lowest score for the potential of MiC project phases based on their ability to use BIM. Finally, the results indicated in Table 6 were converted into percentages for better presentation, as shown in Table 7.

5. Conclusions

This research demonstrated the effectiveness of utilizing BIM to manage the design and construction of post-disaster settlements employing the MiC technique. Its outcomes indicated that the development of the BIM model in a prefabricated temporary settlement project based on MiC is very beneficial in improving 3D visualization and simulation of the project, creating better communication and coordination between different design disciplines and execution contractors, ensuring high quality for the product, helping in planning the assembly and management of the project, and supporting the estimation and quantity surveying, and eliminating construction element interference. The usefulness of this approach was illustrated by creating a case study for a temporary settlement project. On the other hand, in terms of the impact of each of these applications on the phases of the MiC project, the highest impact was on Planning and design, followed by Manufacturing, then Assembly on site, with the lowest impact on Logistics, disassembly, Setup and maintenance, and Recycling and landfilling, respectively.

Also, the results showed significant achievements from the use of AR and VR technologies for 3D visualization and simulation, in line with the development of the BIM model. Also, designing and programming specialized AR software to present project maps in augmented reality mode with the ability to enlarge the digital model of the settlement in real-time scale and position. Another distinguishing feature of this research was the planning of a program to experience a virtual visit to the settlement in a simulated situation in the form of a computer game, which provided access to information enriched in the BIM model as well as training and practice in assembling the parts of the settlement project in an interactive mode.

It is worth noting that these findings are based on the responses and opinions of only the thirty-seven experts involved and that this study did not require formal ethical approval as it involved only the collection of professional expert opinions from consenting adults. All participants provided informed consent and no sensitive or personal data were collected.

Appendix A

This appendix presents the survey outcomes. Each cell represents the number of experts assigned this grade to the applications of BIM in each modular integrated construction phase.

For C1 (0.17)	5	4	3	2	1
A1	37	0	0	0	0
A2	15	15	7	0	0

A3	0	18	12	7	0
A4	18	12	7	0	0
A5	0	7	12	7	11
A6	0	13	6	12	6
A7	0	0	0	0	37
For C2 (0.12)	5	4	3	2	1
A1	31	6	0	0	0
A2	10	17	10	0	0
A3	0	0	6	25	6
A4	0	18	12	0	7
A5	0	0	0	12	25
A6	0	0	0	12	25
A7	0	0	0	0	37
For C3 (0.16)	5	4	3	2	1
A1	25	12	0	0	0
A2	6	12	12	7	0
A3	6	19	12	0	0
A4	19	12	6	0	0
A5	0	6	19	12	0
A6	6	6	19	6	0
A7	0	0	0	6	31
For C4 (0.13)	5	4	3	2	1
A1	37	0	0	0	0
A2	7	6	24	0	0
A3	6	12	19	0	0
A4	0	0	6	19	12
A5	0	0	0	12	25
A6	0	0	0	12	25
A7	0	6	7	12	12
For C5 (0.13)	5	4	3	2	1
A1	12	19	6	0	0
A2	18	19	0	0	0
A3	6	12	19	0	0
A4	18	16	3	0	0
A5	0	12	19	6	0
A6	25	12	0	0	0
A7	0	0	7	15	15
For C6 (0.14)	5	4	3	2	1
A1	19	12	6	0	0
A2	12	13	12	0	0
A3	19	12	6	0	0
A4	6	14	17	0	0
A5	0	0	6	12	19
A6	0	6	12	12	7

A7	0	0	0	12	25
For C7 (0.15)	5	4	3	2	1
A1	12	19	6	0	0
A2	11	11	7	8	0
A3	0	0	0	25	12
A4	31	0	6	0	0
A5	0	0	0	25	12
A6	19	12	0	6	0
A7	0	0	0	0	37

Author Contributions

Both Eng. Bira Baneh and Koosha Baneh were responsible for collecting the data, preparing the questioners and performing the interviews, Eng. Masoud Deiranloei was responsible for the study development and designing the settlement project and Prof. Osman was responsible for drafting the paper and performing the analyses.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Data Availability Statement

All data generated or analyzed during this study are included in this published article. Furthermore, they are available from the corresponding author upon reasonable request.

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