



RESEARCH ARTICLE - ENGINEERING (MISCELLANEOUS)

Identify the Optimal Path for Evacuating the Building's Occupants by Integrating GIS And BIM Technologies

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Article Info.	Abstract
<i>Article history:</i> Received 27 July 2025 Accepted 15 September 2025 Publishing 30 September 2025	Technologies such as Geographic Information Systems (GIS) and Building Information Modeling (BIM) have evolved into complementary instruments to increase the efficacy and safety of building evacuation planning. Although geospatial analysis is provided by GIS for determining safe places of assembly and simulating evacuation pathways, BIM technology makes it feasible to perform sophisticated 3D modeling. To maximize the effectiveness of fire evacuation protocols, this study produces a three-dimensional geographical model by integrating GIS and BIM. To locate the best places to congregate outside the building that are safe, reachable, and far from potential risks, access and distance criteria were assessed using ArcGIS Pro. The effectiveness of the recommended approach is illustrated through a case study of a two-story dorm building at the University of Diyala. Results show that using ArcGIS Pro's Model Builder enhances evacuation planning by finding locations that adhere to safety and standards for accessibility and cutting down on the time and distance to assembly points. This integration provides a reliable method to improve Plans for emergency evacuation and protect building occupants.
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1. Introduction

Ecosystems that are complex of people, materials, machinery, and infrastructure have resulted from the Fourth Industrial Revolution's technical breakthroughs. Good administration and optimization of these interconnected systems necessitate sophisticated approaches that can handle a number of connections and links across space and time [1].

Combining GIS and BIM technologies is one such development that has attracted a lot of interest lately e.g in construction management, combining BIM's detailed building data with GIS's geographic context improves site analysis and risk assessment. BIM provides thorough construction data that includes both semantic and geometric information. Its efficacy in tasks like spatial planning is limited since it lacks the wider geographic context needed for some applications [2]. Its efficacy in tasks like spatial planning is limited since it lacks the wider geographic context needed for some applications.

The seamless exchange of information between BIM and GIS has been made possible by the quick development of interoperability technologies. GIS programs like ArcGIS Pro can now read Autodesk Revit (RVT) formats, which makes it possible to visualize 3D BIM models. The possibilities of combining GIS and BIM for safety and security applications, namely in evacuation planning, have been investigated [3].

The complexity of contemporary high-rise buildings, where height and vertical navigation are crucial considerations, cannot be adequately addressed by traditional evacuation systems, which mostly rely on 2D platforms. Benefits of switching to 3D platforms include improved visualization, spatial analysis, and a deeper comprehension of evacuation situations [4].

3D BIM models that tackle these issues can be made using tools like SketchUp, Revit, and City Engine. Although the majority of research on emergency evacuation focuses on pathfinding and interior navigation [5-7]. Some emphasize the least dangerous routes.[4], networks that are easy to navigate and simple [8], or enhanced visualization and detail [7].

However, these studies often neglect the evaluation of outdoor gathering points, which are crucial for ensuring occupant safety during emergencies.

Nomenclature & Symbols

GIS	Geographic Information System	CAD	Computer-Aided Design
BIM	Building Information Modeling	IFC	Industry Foundation Classes
3D	Three-Dimensional	2D	Two-Dimensional
Arc GIS Pro	A Professional GIS Application Developed by Esri for Working with Maps and Geographic Data in both 2D and 3D Environments		

This study addresses this gap by utilizing GIS technology, specifically ArcGIS Pro, to analyze and identify the safest and most accessible gathering points outside a building during emergencies. Parameters such as the presence of facilities, street access, and distance to potential hazards are assessed using the Model Builder tool in ArcGIS Pro.

The proposed approach is demonstrated through a case study involving a two-story dormitory building. The paper is structured as follows: following the introduction in Section 1, Section 2 describes the proposed method, including details of the case study and the selection of assembly points. Section 3 presents the methodology, outlining the use of BIM and GIS technologies to create the 3D building model and analyse assembly points using ArcGIS Pro. Section 4 discusses the results, including network analysis and the identification of the most suitable gathering points. Finally, the conclusion is given in Section 5.

2. Proposed Method

2.1. Case study

The building under study is a two-storey dormitory for university students located at the University of Diyala as shown in Fig. 1. The building has a total area of 2860 m² and consists of 41 apartments, with 16 apartments on the ground floor and 25 apartments on the first floor. However, the building lacks emergency exits and external emergency staircases, which significantly increases the risk during fire or evacuation scenarios. This limitation emphasises the need to identify optimal assembly points outside the building to ensure occupant safety in emergencies.

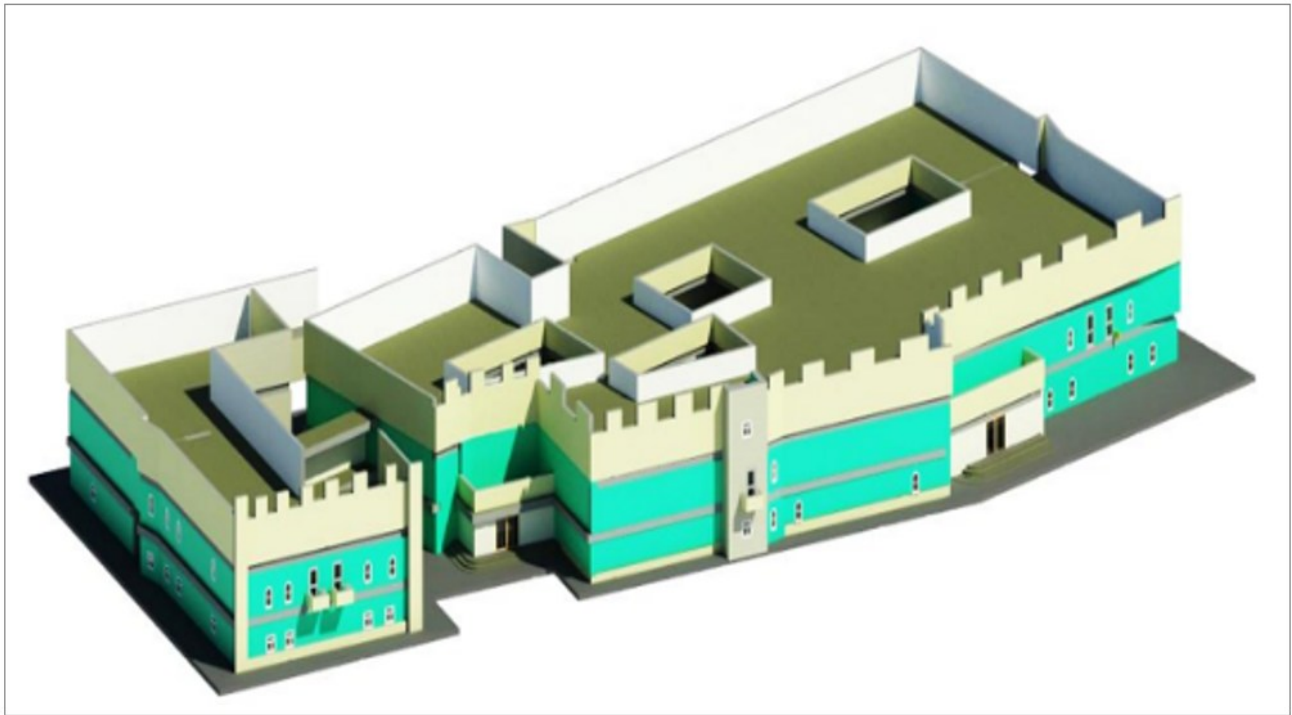


Fig. 1. 3D Visualization of the Building in Revit

2.2. Selection of assembly points

During emergencies, directing occupants to pre-designated assembly points is important to ensure organised and safe evacuations [9]. In situations such as fires, people often react with panic and fear, leading to disorganised and unsafe evacuations. However, poorly chosen assembly points can exacerbate risks, such as exposure to fire, smoke, and falling debris, or hinder emergency response efforts. For example, evacuees and rescuers may be put in danger and rescue operations may be delayed if assembly points are placed too close to the structure or in places that impede emergency vehicles [10, 11].

Therefore, accessibility, safety, and freedom from extra hazards must be given top priority when choosing assembly locations. Several aspects are taken into account during the choosing process, as summarised in Table 1[12]. These standards guarantee that gathering places are accessible, spacious enough to hold every occupant, and situated a safe distance from the structure. Furthermore, in order to minimize uncertainty and guarantee continuity in evacuation protocols, contingency plans must be established if the primary assembly point becomes inaccessible during an emergency. To determine the best gathering places, variables like accessibility, distance, and outside threats were assessed using GIS spatial analysis techniques [13]. Accurate mapping of evacuation routes to these locations was made possible by the accurate building geometry that the BIM integration supplied.

Table 1. Key factors for assembly point selection

No.	Factor	Description
1	Size	All residents must be able to fit in the fire assembly point. Multiple primary assembly points may be necessary for large buildings with numerous exits.
2	Access	Clear, unobstructed passageways must be available for easy access to assembly points.
3	Backup	In order to reduce uncertainty during evacuation, backup preparations should be in place in case the primary assembly point becomes inaccessible during an emergency.
4	Location	Assembly points should be in open, well-lit, and well-marked areas. They must not obstruct emergency services like driveways or parking lots or be located in dead ends or high-risk zones.
5	Distance	Assembly points must be located at a safe distance from the building, far enough to avoid exposure to heat, smoke, and falling debris.
6	Other risks	Verify that the assembly point is free from external hazards, such as traffic or other dangerous conditions, and ensure evacuees are informed of these risks.
7	Instruct and Counsel	Occupants must be informed of evacuation procedures and assembly locations through drills and training to ensure smooth evacuations.
8	Fire Wardens	Adequate fire wardens must be assigned based on the size and complexity of the building to manage evacuation and ensure compliance with safety protocols.

3. Methodology

To respond effectively to emergencies and determine the best evacuation routes and assembly points outside the building, the study follows the overarching methodology outlined in Fig. 2.

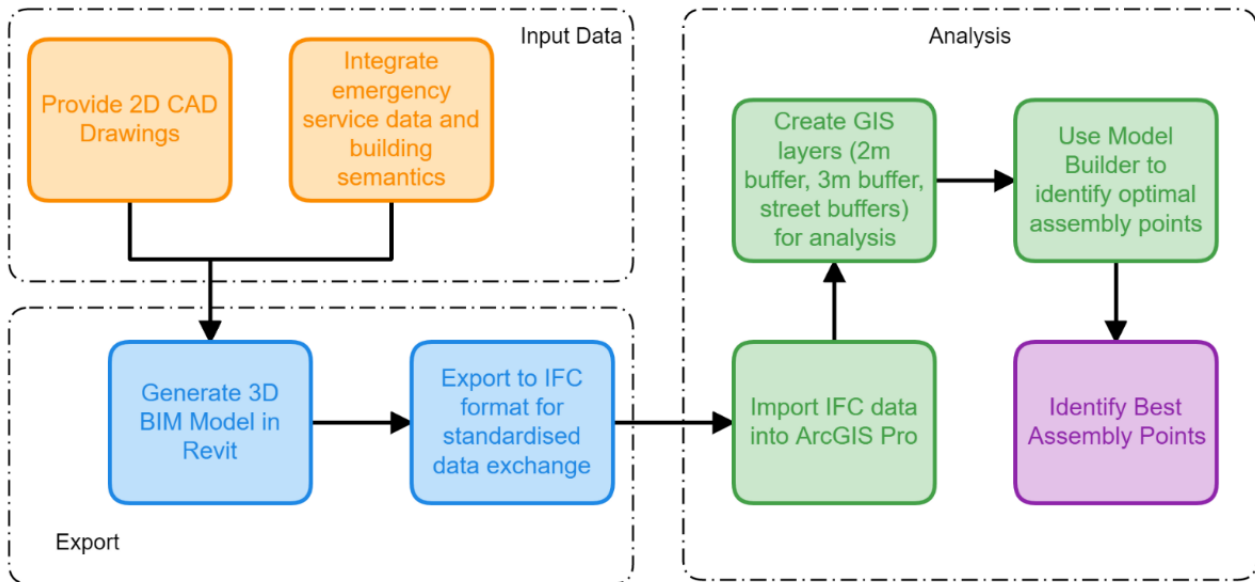


Fig. 2. The overarching methodology

The process begins with converting initial 2D CAD files of the building into 3D models using Revit, enabling the creation of 3D BIM models enhanced with technical and structural data, including furnishings, architectural details, indoor space definition, staircases, and other elements aiding in detailed modelling of the building's interior. Meanwhile, semantic data and emergency service information were integrated into the 3D model. The Industry Foundation Classes (IFC) format was used to export the finished model, an open and standardized format for exchanging BIM data [14, 15]. The finished model was then exported to the Industry Foundation Classes (IFC) format, a standardised and open format for BIM data exchange [14]. The elements of the 3D structure were imported into the Esri geodatabase format using the Data Interoperability extension in ArcGIS Pro. With properties stored in attribute tables that match, each IFC entity was represented as a GIS layer. Using ArcGIS Pro, a Model Builder workflow was created to do spatial analysis and identify the ideal assembly locations. GIS layers were generated to represent key parameters, including (1) A two-meter buffer for safety around the building for evacuation zones (2) A three-meter buffer for security and accessibility considerations (3) Intersection analysis of these layers to evaluate potential assembly points (4) A street layer with a 2m buffer to ensure optimal accessibility for emergency responders. This extensive study provides a trustworthy approach for identifying the most accessible and secure gathering places outside the building in case of an emergency.

4. Results and Discussion

To ensure effective evacuation preparation, A model for path analysis was developed using ArcGIS Pro with 2D keeping routing in mind. The network dataset included multiple layers, encompassing the road, distance, and facilities layers, to determine the best routes from the building's entrance to the suggested gathering spots. Using the tools in the Model Builder in ArcGIS Pro, the workflow was created to determine the

optimal assembly locations by analyzing spatial relationships, as shown in Fig. 3. There are four steps in the workflow. The initial step, Input Layers, includes datasets such as Distance, Facilities, Street, and an additional Distance (3) layer for further analysis. The "Distance" layer may correspond to spatial measurements, such as closeness to features, whereas the "Facilities" layer depicts places of interest, such as schools or hospitals. The road networks are part of the "Street" layer, and "Distance (3)" represents an additional distance-related dataset for further analysis. Spatial buffers are applied to each input layer in the second stage, known as the buffering process, to establish proximity or zones of influence around features. For example, the Distance layer receives Buffer (1), the Facilities layer receives Buffer (2), the Street layer receives Buffer (3), and the Distance layer receives Buffer (4). In the third step, Intermediate Results are generated by transforming the buffered layers into new spatial datasets. For example, the Distance layer becomes Dis Buffer, the Facilities layer becomes Facilities Buffer, the Street layer is transformed into StrBuffer, and the Distance (3) layer becomes Distance Buffer. The final step, the Intersection process, uses these intermediate results as inputs to identify overlapping areas that satisfy particular spatial criteria. These finished products are refined geographical datasets that help identify the best places for assembly.

The Model Builder Analysis Tools are made in the ArcGIS Pro grid, while the points and solvers are made in the Arc Catalog as shown in Fig. 4.

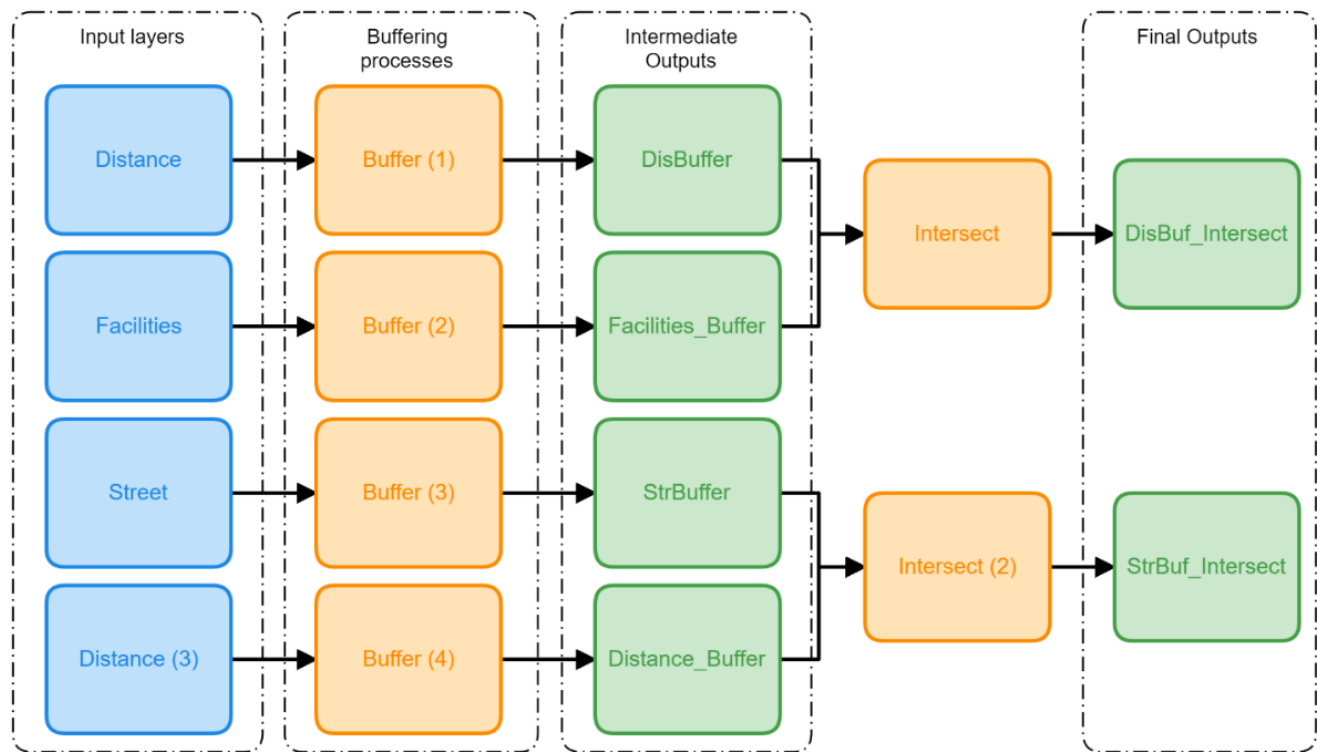


Fig. 3. Spatial analysis workflow using model builder in ArcGIS Pro



(a) Buffer facilities



(b) Facilities layer



(c) Buffer street layer



(d) Street layer



(e) Building a fence layer



(f) Distance layer



(h) Intersection of layers for the building

Fig. 4. ArcGIS Pro's building and assembly point layers

A few points were excluded from consideration due to safety and accessibility concerns. For example, Point (2), while located inside the building fence, is vulnerable to fire threats and too close to the structure, smoke, and potential explosions from equipment that uses electricity. Additionally, it lacks a clear exit route, rendering it inappropriate for evacuation. Likewise, Points (3) and (4), also located inside the perimeter, were excluded due to obstructive facilities and the absence of clear pathways of departure. Points located outside the building, such as Points (6), (7), and (8), were also deemed unsuitable. These points obstruct emergency vehicle access, which could delay rescue operations and increase risks for both evacuees and responders. As a result, these points were excluded from the final recommendations. A summary of the suitability of proposed assembly points is provided in Table 2. Based on the analysis, Point (5) is the optimal choice due to its accessibility, safety, and proximity to emergency services. Point (1) serves as a secondary option, meeting safety requirements but with slightly less favorable conditions. All other points were excluded due to significant safety or accessibility concerns.

Table 2. Suitability of proposed assembly points

Point	Suitable (✓) or Not Suitable (X)	Reason
1	✓	Outside the building, it does not obstruct the movement of ambulances.
2	X	Inside the building, exposed to fire and smoke, close to the fence.
3	X	Inside the fence, no clear exit, and obstructed by facilities.
4	X	Inside the fence, no clear exit, and obstructed by facilities.
5	✓	Outside the fence, it is well-lit, easily accessible, and clear for emergency vehicles.
6	X	Ambulance traffic blocks access.
7	X	Ambulance traffic blocks access.
8	X	Ambulance traffic blocks access.

5. Conclusion

This study illustrates the integration of BIM and GIS technologies as a trustworthy and efficient method for maximizing building evacuation plans. Combining the sophisticated geographical analytic tools of GIS with the comprehensive 3D modeling capabilities of BIM, A thorough approach was developed to identify the safest and most accessible Points of assembly that are easily accessible outside a two-story dormitory building at the University of Diyala. Several spatial layers were included in the investigation., encompassing the structure, layers of streets, fences, facilities, and distance, to assess the suggested assembly points' acceptability using safety and health standards. Using the Model Builder feature in ArcGIS Pro, intersection processes and spatial buffering were applied to exclude unsuitable points and identify the optimal evacuation locations. Points inside the construction fence, such as Points (3) and (4), were excluded due to obstructive facilities and insufficient routes of departure. In the same way, Points (6), (7), and (8), located outside the building, were considered unsuitable as they obstructed emergency car access and posed additional dangers to evacuees. The research found that Point (5), located in front of the structure, is the most appropriate location for assembly. This location is well-lit, readily available, and ensures unobstructed access for first responders making it perfect for reducing hazards and improving evacuation effectiveness. A secondary option, Point (1), located on the side of the building, was considered suitable but less advantageous because of its proximity to possible dangers. The suggested approach offers a useful framework for assessing gathering places according to their safety, accessibility, and closeness to emergency services. By switching to 3D spatial models from conventional 2D platforms this method improves evacuation scenario analysis and visualization.

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