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RESEARCH

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Integrated framework for existing building alternatives by the building information modeling

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Abstract

Urban expansion is undergoing rapid growth, prompting several nations to create financial and administrative capitals outside congested urban areas, leaving the existing buildings unoccupied. To investigate the possibilities of changing the real estate's usage, the owners of these existing buildings turned to feasibility study experts for assistance in making the optimum alternatives. An integrated framework between value engineering and building information modeling, especially appropriate for existing buildings, is required to aid decision-makers in selecting the best options for current building utilization. Previous studies only investigated the value engineering alternatives during the design phase, when they decided to reduce project costs using construction materials alternatives. Still, they overlooked existing building alternatives in terms of changing the kind of usage of such buildings. So, they need an integrated model between value engineering and building information modeling, especially applicable to an existing structure, to determine the optimum usage type for the existing building. Value engineering and building information modeling must be connected to profit from both outputs simultaneously. And used the multi-criteria decision-analysis method. Today's analytic hierarchy process is the most widely used. This paper provides an integrated framework between value engineering and building information modeling that can be applied to existing buildings to assist in determining the best alternative in terms of the type of usage for such existing structures by conducting BIM methodologies such as a feasibility study which includes present value, cash flow and the bank interest rate, and BIM software such as Revit and Primavera. The multi-criteria decision analysis method was used to focus on what is important, logical, consistent, and easy to use. MCDA which considered a process for evaluating options with conflicting criteria and choosing the best solution, similar to a cost–benefit analysis, but evaluates numerous criteria rather than just cost. The findings revealed that this integrated framework, which includes feasibility studies and comparison tables, may be implemented in the future while taking into account time and location constraints.

Keywords: Building information modeling (BIM), Value engineering (VE), Optimal solution, Feasibility study, Integrated framework, The multi-criteria decision analysis method, The analytic hierarchy process (AHP)

1 Background

The real estate owners sought the assistance of an economic expert to help them decide the best options for changing construction usage. Most feasibility of this study aims to use the BIM technique in their research, where it can decrease calculation time and failure costs. Building information modeling (BIM) is a digital system in which all essential information is stored, used, and controlled by all stakeholders, starting with the design and ending with the constructed building. Where BIM is a technology that allows the creation of a structure with the help of many stakeholders, a construction-wide

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culture shift is required to achieve a unified commitment to BIM.

Building information modeling (BIM) and value engineering (VE) hybrid were developed to get the most out of both. The previous integrated models failed because they were limited only to the building VE alternatives at the design phase and did not include VE alternatives for the existing structure.

This paper presents a comprehensive model for guiding decision-makers to the optimum VE alternative for existing structures using BIM tools as a feasibility study, including BIM software such as Revit and Primavera. The feasibility studies with the banks' interest ratio, the real estate owners' ability to make some modifications during the development of the alternative, and the time required to implement the alternative and achieve goals were all used in this paper. One of its results is that the net present value (NPV) is a financial metric that seeks to capture the total value of an investment opportunity. The idea behind NPV is to project the future cash inflows and outflows associated with an investment, discount all those future cash flows to the present day, and then add them together. The resulting number after adding all the positive and negative cash flows together is the investment's NPV. A positive NPV means that, after accounting for the time value of money, you will make money if you proceed with the investment. Components of the integrated model technique are depicted in Fig. 1.

1.1 Value engineering methodology

Value engineering is described as a process for examining the purpose of the equipment, systems, services, and facilities to meet their essential duties at the lowest possible cost while maintaining required performance, dependability, quality, and security [1]. The major goal of the VE technique in construction is to eliminate superfluous expenses while increasing performance and quality standards that match or exceed the owner's objectives [2]. Reducing project costs while preserving or enhancing quality and performance requirements are three major characteristics of VE. However, the traditional VE approach has various flaws or restrictions that may make it difficult to attain the required results. The drawbacks of the VE approach are explored [3]. VE methodology is often cost-driven. Most project owners, it is determined, are more motivated to decrease the first cost, especially when using the VE as a tool for identifying system functionalities at the lowest price. Owners might overemphasize cost to jeopardize other important VE goals, such as enhancing quality and performance [4].

1.2 Building information modeling methodology

Building information modeling (BIM) is a technique that creates a virtual building to construct it physically. The integration allows designers and builders to collaborate on a single aim, allowing design and construction operations to develop in the most efficient way possible for the project rather than being locked into distinct phases as needed by over-the-wall delivery [5]. BIM is more than simply a piece of software; it is a mix of software and methodology. Furthermore, to properly implement BIM, nations all around the world are beginning to develop BIM guidelines [6]. Old structures lose their efficiency and functionalities with time, necessitating adaptive reuse. The ideal reuse option to choose is not straightforward, and it necessitates a variety of considerations owing to the many parties and criteria involved. Determining the best appropriate selection strategy in the adaptive reuse project is critical [3]. The goal of the BIM and VE integration is to leverage the BIM model to facilitate visualization so that users may see multiple project design options. The constructability and coordination, 4D scheduling, and 5D cost planning will all be affected by the evaluation and selection of a suitable alternative design through the 3D-BIM model [7], which helps to develop the maximum number of alternatives to deliver the functions cost-effectively through the following:

1. Create a list of innovative ideas for alternative methods to conduct each specified function
2. Provide optimal solutions among the available solutions to the project's essential functions at a lower cost.
3. Create a variety of viable options for performing the function to increase the project's value [8].

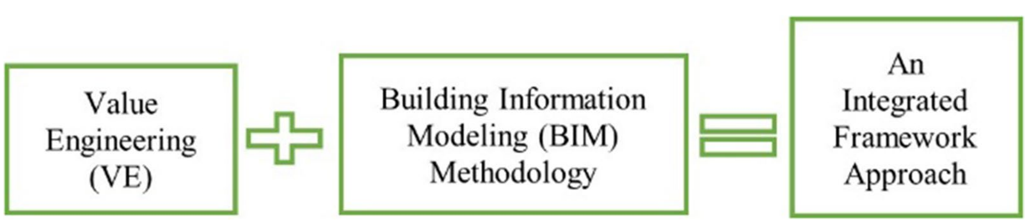

Fig. 1 The components of the integrated framework approach

The current practice of BIM education is very diverse according to the wide range of disciplines involved. In architecture education, the documentation and visualization tools of the BIM are enhanced, while the structural engineering discipline is strongly connected to structural analysis and design software, the management discipline is more involved in the collaborative platforms of BIM, and the construction-related subjects are usually dealing with scheduling, quantity statement, and cost estimate [9].

The concept of a successful building project should be implemented across the project's lifecycle phases to obtain maximum profits without compromising the standard. Although BIM implementation in developing countries is limited, much research has focused on BIM drivers. However, there is less evidence to thoroughly investigate the influence of BIM barriers and awareness on the project lifecycle [5].

1.3 Multi-criteria decision-making analysis

In multiple criteria decision-making, the analytic hierarchy process is the most utilized tool. In topics including planning, picking the best option, resource allocations, and optimization, much significant research has been published based on the AHP theory [10] . Decision-makers and scholars have benefited from the analytic hierarchy method since its inception [11]. The most creative challenge may be selecting the elements that are most successful in deciding. These aspects are organized in a hierarchical framework in AHP, starting with an overarching aim and progressing to criteria, sub-criteria, and finally, options [12].

1.4 VE and BIM integrated framework

Previous research employed simulation to get the data and focused on small components of the structure or a phase of the VE investigation. The following studies on BIM and VE integration can be found in the literature, which presented a BIM-based workflow for reengineering the shop drawing production process [13]. The BIM and VE were used to improve green building design; the study used simulation to develop different alternatives to the building envelope for optimum energy consumption; the study used simulation to develop different alternatives to the building envelope for optimum energy consumption [12]. And others proposed a framework for integrating VE and BIM in the divergent phases of a construction project, shown in Fig. 2 [14]. On the other hand, focused on the creativity phase of a value engineering workshop and developed a BIM-based prototype to help generate and retrieve ideas [15], it also proposed a framework for This is not the first time that BIM and VE have been combined [16].

A framework for integrating BIM with VE to develop and assess sustainable design at the early design stage of a project was provided [17], which included:

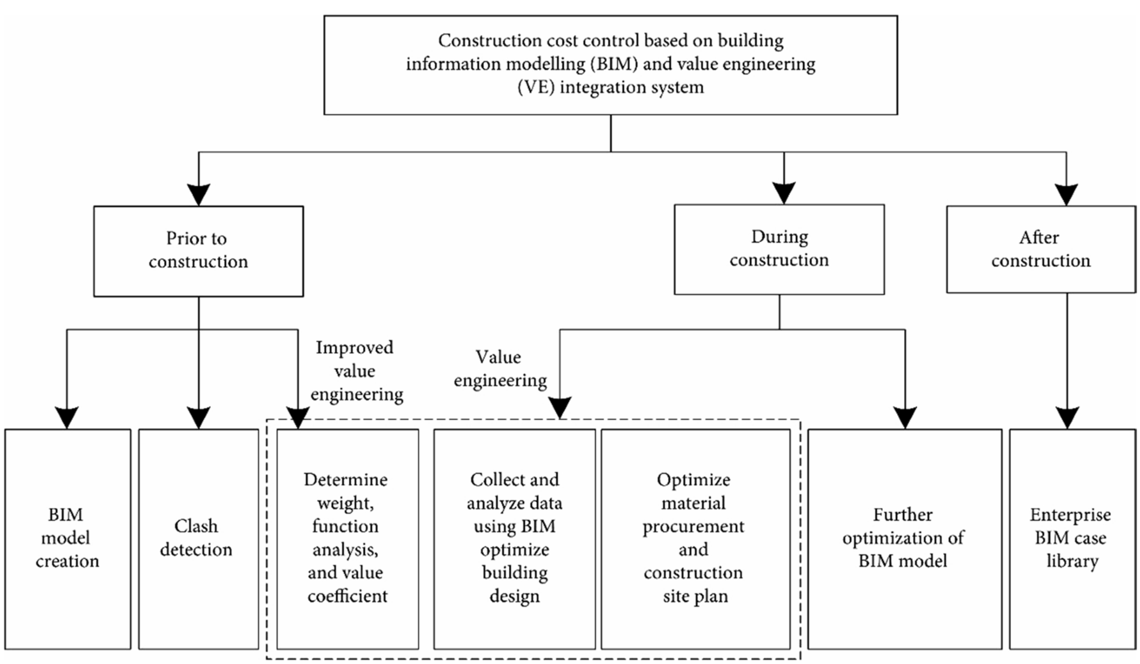

Fig. 2 The framework is based on BIM and VE integration [14]

1. Provide a survey to investigate the projected benefits of combining BIM with VE. The impact of the BIM application with VE was evaluated using the opinions of construction industry participants [6].
2. Create a 5D BIM model that combines BIM with VE [18]; this integration was built on numerous options for visualizing requirements, timetables, and budgets using the Navisworks simulation.
3. Use the Design-Builder tool to investigate building energy efficiency by evaluating weather and virtual environment data.
4. Evaluate the relative environmental implications of the alternative design's construction materials using SimaPro's environmental emission analysis.
5. Life cycle assessment is considered as part of the Leadership in Energy and Environmental Design (LEED) grading system, which is based on ISO 14040 standards.
6. Create a multi-attribute decision environment to help you identify the most sustainable design option. Visual Basic Studio proposes a methodology for AHP to assess the data using a computational programming platform in C# [19].

2 Methods and experimental

Applying value engineering techniques to existing buildings is not frequent in Egypt, consequently, this study aims to develop a framework to aid the value engineering team in implementing value engineering methodology [20].

As mentioned in the previous chapters, value engineering is critical for capital projects that demand significant resource commitments. Value engineering will aid in the development of better knowledge and appreciation of the project scope of work and reduce needless expenditures without compromising the needed functions of project components. Owners (decision-makers) have long struggled with determining the best option based on many criteria [21]. Because the selection criteria and their respective weights change from one project to another to fulfill owners' demands about project-targeted objectives, there is no consistent solution to this challenge [9].

This paper describes the techniques/methodology used to create an integrated framework. It employs a coded version of the AHP to assist the VE team in evaluating competing options [6]. The project BIM model was created with BIM applications, Revit 2021 and Navisworks 2021, which are used to build a 3D model, schedule tables (4D), and survey quantity tables (5D). Instead of conducting the calculations manually, the AHP client's account was facilitated by the website of (BPMSG, Business Performance Management Singapore), as well as a timetable chart prepared by the Primavera P6 application [22]. The research was organized into five primary stages, as shown in Fig. 3.

2.1 Research limitations

The study's spatial scope has been restricted to projects created and implemented in Egypt so that the effect of changing the location has been neutralized, and its negative or positive results have been removed.

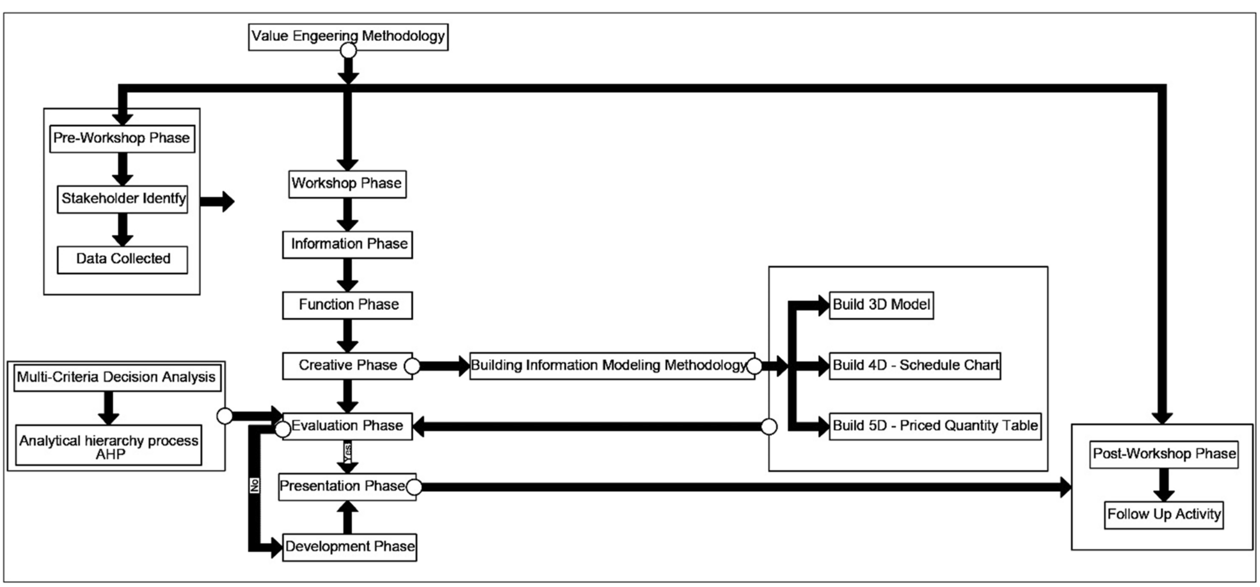

Fig. 3 An integrated framework flowchart

The initiatives under investigation have been confined to those conceived and implemented between 1970 and 1990. This period was chosen because it featured periods of economic and political stability and a standards-based architectural and structural design and building procedure. Concrete construction code standards are similarly constrained. As a result, the research area is limited to the common factors associated with the project's nature.

2.2 Research criteria

Based on the influence of BIM in displaying the VE options, such as 4D (time) and 5D (cost). The result will be an integrated framework of both methodologies that will assist decision-makers in selecting the best VE option based on particular criteria. This paper considers many options in terms of:

> The bank interest ratio—one of the feasibility study outcomes—was used to calculate the net present value of investment (**NPV**).
>
> The amount of time it takes to reach the highest alternative investment through the feasibility study outputs (cash flow)—(**Required Time**).
>
> The project owner's capacity to make any modifications with minimal loss during alternative implementation—(**Change Ability**) [23].

2.3 Software method

The BIM applications Revit 2021 and Navisworks 2021 are used to build a 3D model, schedule tables (4D), and survey quantity tables (5D). Instead of conducting the calculations manually, the AHP client's account was facilitated by the website of (BPMSG, Business Performance Management Singapore) [19], as well as a timetable chart prepared by the Primavera P6 application.

2.4 An integrated framework mechanism

As indicated in the flowchart in Fig. 4, the BIM methodology includes drawing 3D alternatives models with software BIM tools, extracting data from the 3D-BIM model, survey quantity, cost estimation, scheduling, NPV, and cash flow, which are all outputs of feasibility studies, and determining the criteria, which are an essential component in the process of evaluating different alternatives for judging alternatives. A 3D model, schedule tables (4D), and survey quantity tables (5D) are built using the software BIM program Revit 2021.

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Value Engineering Methodology			Muilti-Criteria Decision Analysis	Methodology	Software Tools	Framework Model Steps
Pre-Workshop Phase	Work Phase	Post-Workshop Phase				
1-takeholder Identi	-	-	-	VE	Excel - MS Office	1- Identify the Stakeholder - Set up a value engineering team
2- Data Collected	-	-	-	VE	Excel - MS Office	2- Conduct project Information
	1- Information Phase	-	-	VE	Excel - MS Office	3- Conduct the dicision maker and marketing needs, determine the bank interest ratio
					Excel - MS Office	4- Suggested the proposed alternatives
	2- Function Phase	-	-	VE - BIM	Rivet	5- Architectural drawings and views for each alternative
					PowerPoint -MS Office	6- Take Initial Approval for Suggested Alternatives
					Rivet Rivet	7- Determined the cost and quality
	3- Creative Phase	-	-	VE - BIM - Feasibility Study	Primavera	8- Create the Alternatives (4D Model - 5D Model)
					AHP	9- Conducted a feasibility study with cash flow
	4- Evaluation Phase	-	-	VE -Feasibility Study	Excel - MS Office	10- Calculated the net present value (NPV) of each alternative based on the cash flow
		-	Analytical Hierarch Process	VE - AHP	AHP	11- evaluated the alternatives by comparing the criteria with each other
	5- Presentation Phase	-	-	VE - BIM	PowerPoint -MS Office	12 The VE team presented the VE Report
		1- Follow Up Activity	-	VE - BIM	-	13- The optimal decision was implemented

Fig. 4 An integrated framework mechanism

(5D) are built using the software BIM program Revit 2021.

2.5 Case study

In this paper, an integrated framework was utilized in a case study to illustrate its capabilities and to emphasize the model's properties. The case study is used to build a model for BIM integration with VE to help with decision-making when examining options and deciding on the project's existing structure; the model is based on a database created using BIM software.

The model is meant to aid real estate owners in selecting the most appropriate utilization type of existing structure throughout the design and feasibility study phases by showing design, cost, and time performance on a BIM model. It provides a visual aid and alternate information and allows for the criteria analysis.

The building consists of five floors after the ground floor. The administrative headquarters of the Maadi Company for development and reconstruction subsidiary of the public business sector ministry, which is a public organization, were selected.

2.5.1 Steps to implement an integrated framework on case study

Step No. 1. A decision-maker (the company's CEO) and the technical and finance team members comprise the value engineering team. The group got together to determine how they might benefit from the company's vacant headquarters in the city's heart. The following criteria were devised for evaluating the project options based on your pairwise comparisons:

- **NPV**: The net present value of an Investment is one of the feasibility study's results, and it includes the bank interest ratio, which is ranked first with a 60% priority.
- **Required Time**: The time required to accomplish the greatest alternative investment through feasibility study outputs (cash flow), which are ranked second with a 30% priority.
- **Change Ability**: The project owner's ability to make any adjustments with minimal loss throughout alternative implementation, which is ranked third with a 10% priority.

Step No. 2. The corporate administration provided the data for the existing building case study. The information regarding the existing building case study is presented in Table 1 and Figs. 5, 6, 7, 8, and 9.

Step No. 3. A value engineering team and feasibility study specialist collect the property data and determine the bank interest ratio.

Step No. 4 Suggested the alternatives with a 5-year life-cycle, as shown in Table 2.

Step No. 5. Architectural drawings and views for each alternative (3D-models) were created using Revit 2021.

Alternative No. 1 is to convert the usage of the building into a commercial and administrative building. The ground floor contains three large restaurants; each has a kitchen, refrigerator, and pantry—the lady's and men's bathrooms with separate entrances from the restaurants. There are also outdoor seating and a car garage for restaurant goers. Each typical floor contains three administrative offices; each office has two rooms, a reception hall, a bathroom, and a buffet, as shown in Figs. 10, 11 and 12.

Alternative No. 2 is selling land, including the building on it, without any changes to the existing building.

Alternative No. 3 is selling land as vacant land; it means destroying the existing building.

Step No. 6. Decision-makers were shown and approved alternatives (3D-models).

Step No. 7. As shown in Table 3, the survey quantities of each alternative were calculated using the Revit Program 2021, and the elements of the survey amounts were also priced using market values for the year 2021.

The dollar price was calculated on May 1, 2022, equivalent to 18.28 Egyptian pounds.

Alternative No. 1 is to "Selling the building after converting use to commercial and administrative," which costs $263,927, divided into $150,816 for routine work plus $113,112 for electrical work, which is depicted in Table 4.

Alternative No. 2 is to "Selling land, including the building on it," which does not need any expenditure to convert the existing building.

Alternative No. 3 is to "Selling land as vacant land," which needs $65,416 to demolish the existing building, which is depicted in Table 5.

Table 1 Information about the case study

Location:	Ninth District, Extension of El Nasr St, Behind National Investment Bank, New Maadi. Cairo, Egypt. https://goo.gl/maps/MzLgjMMCbbHTVdkD9
Latitude and Longitude:	The building is in an existing urban area in the Maadi district at latitude 29°58′35.31″N and longitude 31°17′7.44″E. It rises above sea level 46.0 m
Total Built-Up Area:	3216.46-m^2
Building Components	Six floors (five typical floors and the ground floor)
Land Area:	2285.37 m^2
The price of land, including the building on it:	2440 \$/m^2
Price of vacant land:	3254 \$/m^2

Fig. 5 The location for the case study at the local map

Fig. 6 The location for the case study on the global map

Step No. 8. Development of a schedule for each alternative, as the start date has been fixed on January 1, 2022, as shown in Figs. 13 and 14.

Alternative No. 1 contains ten main items and 34 subitems in addition to electrical works. The alternative implementation takes 258 days and is finished on October 27, 2022. Alternative No. 3 contains 13 items. The alternative implementation takes 255 days and is finished on October 24, 2022.

Step No. 9. Conducted a feasibility study with cash flow according to the market condition for each alternative.

Alternative No. 1 is to "Selling the building after converting usage to commercial and administrative," which contains a commercial area—restaurants with an area of 608.57 m^2 and a suggested selling price of \$4.00/m^2, and an administrative area with an area of 2607.89 m^2 and a suggested selling price of \$3083/m^2.

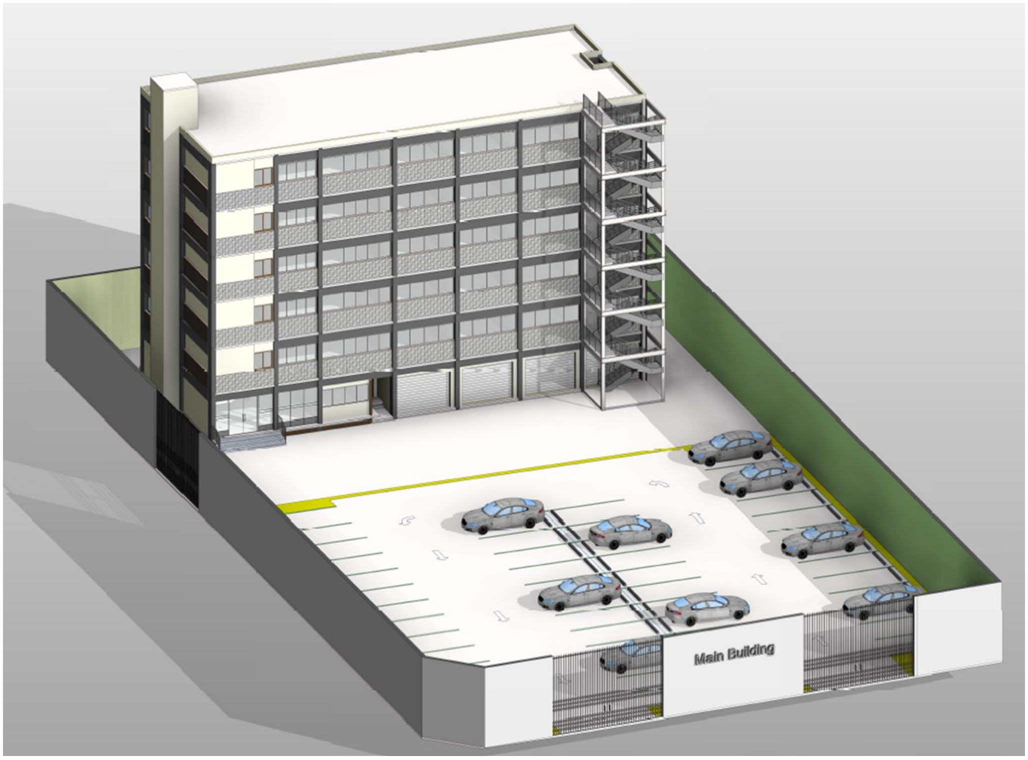

Fig. 7 The case study perspective

Thus, the total selling price for all commercial and administrative units of the building is $10,475,430. Alternative No. 1 implementation construction cost is $798,259 depending on the alternative quantity of surveying, administrative expenses 1.5% of the implementation finishing cost, the implementation supervision cost 2.5% of the implementation construction cost, and selling commission and marketing expenses 5% of the total proposed price of sale as shown in Table 6.

Figure 15 shows that the alternative no. 1 implementation will take just the first year of the alternative lifecycle (5 years). According to the sales strategy, the alternative units (commercial and administrative) will sell throw 3 years, with 60% of the units selling in the first year, 20% in the second year, and 20% in the third year. According to the Central Bank of Egypt (CBE), interest rate (where the case study existed) is equal to 12% in January 2022.

The unit selling mechanism is as follows: The unit price will be paid to throw the first year of the alternative lifecycle, with 10% of the unit price in 1st year, 25% of the unit price in 2nd and 3rd years, and 20% of the unit price in 4th and 5th years. The unit price will be paid to throw the second year of the alternative lifecycle, with 30% of the unit price in 2nd and 3rd years and 20% of the unit price in 4th and 5th years. The unit price will be paid to throw the third year of the alternative lifecycle, with 60% of the unit price in 3rd year and 20% of the unit price in 4th and 5th years.

Alternative No. 2 is to "Selling land, including the building on it," which has 2285.37 m^2 and a suggested selling price of $\$2440/m^2$.

Thus, the total selling price for vacant land is $5,576,303. Alternative No. 4 selling commission and marketing expenses are 5% of the total proposed price of sale, as shown in Table 7.

Figure 16 shows the alternative No. 2 lifecycle (5 years). According to the sales strategy, the land price, including the building on it, will be paid with equal payments throw 3 years. According to the Central Bank of Egypt (CBE), interest rate (where the case study existed) is equal to 12% in January 2022.

Alternative No. 3 is to "Selling land as vacant land," which has 2285.37 m^2 and a suggested selling price of $\$3254/m^2$.

Thus, the total selling price for vacant land is $7,436,594. Alternative No. 5 implementation construction cost is $65,416 depending on the alternative quantity of surveying; administrative expenses are 1.5% of the implementation finishing cost, the implementation supervision cost 2.5% of the implementation construction cost, and selling commission and marketing

Fig. 8 The architectural drawings ground floor perspective for the case study

expenses 5% of the total proposed price of sale as shown in Table 8.

Figure 17 shows that the alternative No. 3 implementation will take just the first year of the alternative lifecycle (5 years). According to the sales strategy, the vacant land price will be paid to throw the 2 years of the alternative lifecycle, with 50% yearly. According to the Central Bank of Egypt (CBE), interest rate (where the case study existed) is equal to 12% in January 2022.

Step No. 10. Calculated the net present value (NPV) of each alternative based on the cash flow, which was made in the previous step, according to the Central Bank of Egypt (CBE) interest rate (where the case study existed) equal to 12% in January 2022. Figure 18 shows an alternative NPV comparison chart throw the project's life cycle (5 years).

Step No. 11. The VE team evaluated the alternatives by comparing the criteria with each other; the alternatives are compared against each criterion identified by the stakeholders previously.

The pairwise comparison matrix decides criteria weights by the relative importance of the criteria. The criteria weights are estimated based on the importance and utility of the criteria in the feasibility study process, but some criteria are not measurable All the weights of the alternatives are located according to the previous criterion, which is computed in one matrix and multiply it with another matrix that represents the weight of the criteria as shown in Figs. 19, 20, and 21 using the website [9] to facilitate the calculations.

Step No. 12. The VE team presented the VE Report to the decision-maker, who chose the best alternative with the highest final score.

A (3×3) matrix is formed, showing the weight of each alternative in relation to each criterion. Also, a (3×1) matrix shows the weight of each criterion in relation to the other.

The multiplication of both matrices produces a (3×1) matrix that shows the weight (priority) of each alternative. Thus, we obtain an order of priority for each alternative (final score), as shown in Fig. 22

Fig. 9 The architectural drawings are typical floor perspectives for the case study

The final score of multiplication is alternative No. 1, having 42.08% priority; alternative No. 2, having 32.96% priority; and alternative No. 3, having 24.96% priority. So, Alternative No. 1 is the optimum solution depending on the criteria of the decision-maker.

Step No. 13. The optimal decision was implemented.

2.6 Results

The criteria necessary to meet the decision-maker's goals from the project were defined based on their priorities, which are NPV, required time, and change ability. As a result, these criteria were ranked in order of significance, with NPV accounting for 60% of their priorities, required time to complete the project accounting for 30% of their priorities, and change ability at any stage of the project accounting for 10% of their priorities. Each criterion's impact on each alternative was investigated independently, and the results were as follows:

NPV (first criterion): The results indicated that option No. 1 received 49.30% of the weight of the standard, alternative No. 2 received 31.01% of the weight of the standard, and alternative No. 3 received 19.60% of the weight of the standard after computing the NPV from the cash flow.

Time required (second criterion): The period for implementing each alternative was established using the Navisworks and Primavera programs after computing the inventory amounts generated by the Revit software, one of the BIM systems. The results were that alternative No. 1 received 20% of the standard's weight, alternative No. 2 received 40% of the standard's weight, and alternative No. 3 received 40% of the standard's weight.

Change Ability (third criterion): The ability to change at any stage of the alternative's implementation is a percentage based on decision-maker opinions to abandon the alternative's implementation, and thus, it was calculated. The results indicated that alternative No. 1 received 65% of the standard's weight, alternative No. 2 received 23% of the standard's weight, and alternative No. 3 received 12% of the standard's weight.

Table 2 Alternatives for the case study of an existing building

No	Suggested alternatives
1	Selling the building after converting usage to commercial and administrative
2	Selling land, including the building on it
3	Selling land as vacant land

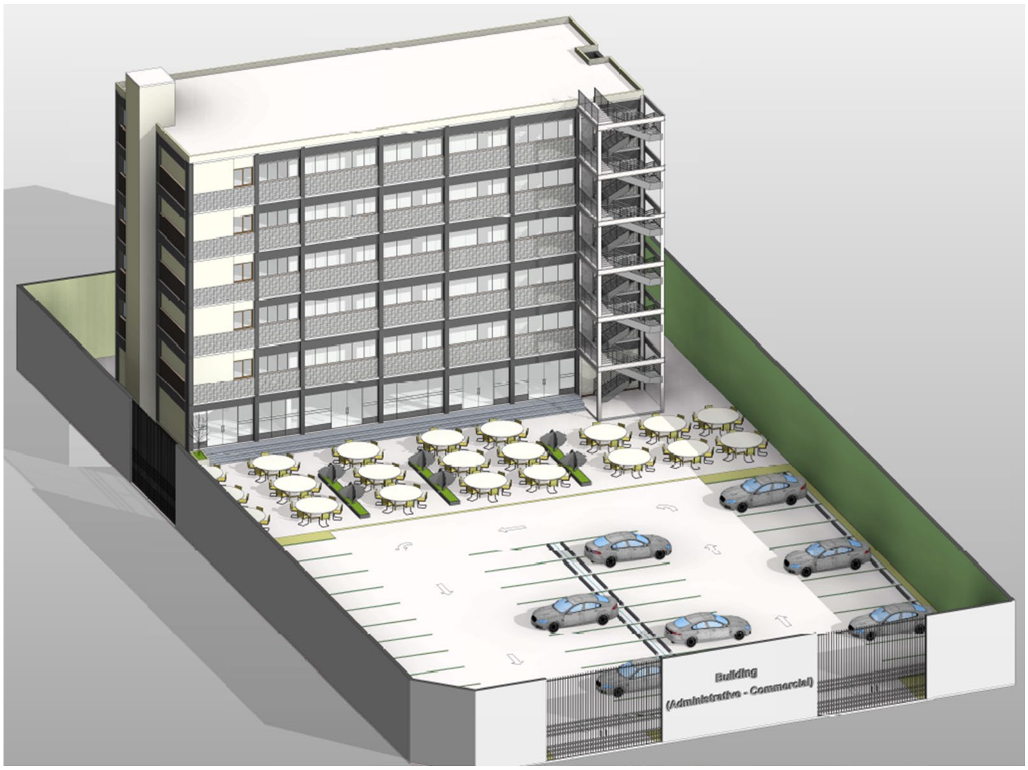

Fig. 10 Alternative No. 1 perspective

Fig. 11 Alternative No. 1 ground floor perspective

Fig. 12 Alternative No. 1 typical floor perspective

Two matrices were created, one with the weight of each criterion against the other and the other with the weight of each criterion alternative. When the two matrices were multiplied, alternative no. 1 received 42.08% of the priority, alternative No. 2 received 32.96%, and alternative No. 3 received 24.96%, as shown in Table 9. As a consequence, the findings revealed that alternative no. 1 is the optimum solution in terms of decision-maker criteria.

3 Discussion

To aid decision-makers in selecting the best options for current building utilization, an integrated framework between VE and BIM is required, which is especially appropriate for existing buildings. To benefit from both outputs at the same time, both value engineering (VE) and building information modeling (BIM) technologies must be integrated.

Previous integration techniques only integrated alternatives during the design phase, when the materials used in construction were chosen to reduce project costs, but they overlooked existing building alternatives in terms of changing the kind of use of such structures.

This research provides an integrated framework between VE and BIM that can be used for existing buildings to assist in making the best option in terms of the kind of use for such buildings using a feasibility study that includes NPV, cash flow, and the bank interest rate. As a result, the greatest advantage is obtained by the needs of decision-makers based on the defined criteria.

The research's spatial scope has been restricted to projects that were created and implemented in Egypt so that the effect of changing the location has been neutralized and its negative or positive effects have been removed.

The initiatives under investigation have been confined to those that were conceived and implemented between 1970 and 1990. This period was chosen because it featured periods of economic and political stability, as well

Table 3 Quantities of survey price for alternatives

No	Alternatives	Priced survey quantity
1	Selling the building after converting usage to commercial and administrative	$263,927
2	Selling land, including the building on it	–
3	Selling land as vacant land	$65,416

Table 4 Quantities of survey price for alternative No. 1

Routine work				
No	**Item**	**Cost $**	**Cost/Unit**	**Quantity**
1	By flat meter: Breaking mosaic tiles and transporting waste to public landfills	3314	2.46	1346.07
2	By linear meter: crushing the entrance stairs Marble with the transfer of waste to public landfills	31	2.46	12.42
3	By linear meter: crushing the Marble external stairs. including (existing and sleeping) with transporting waste to public landfills	12	2.46	4.96
4	By flat meter: crushing the entrance stairs Marble with the transfer of waste to public landfills	148	2.46	60.07
5	By the flat meter: crushing the clay brick walls and transporting the waste to public landfills	1484	2.19	678.42
6	By the cubic meter: crushing the clay brick walls and transporting the waste to public landfills	246	15.32	16.035
7	By the flat meter: crushing the cement brick walls and transporting the waste to public landfills	838	2.19	383.1
8	By the cubic meter: crushing the cement brick walls and transporting the waste to public landfills	–	15.32	0
9	By the flat meter: crushing the Ceramic tiles brick floor and transporting the waste to public landfills	163	1.64	99.58
10	By the flat meter: crushing the Ceramic tiles brick walls and transporting the waste to public landfills	776	1.64	472.73
11	By flat meter: Supplying and installation of 12 cm thick clay brick walls	2671	8.48	315
12	By cubic meter: Supplying and installation of 25 cm thick clay brick walls	9530	72.21	131.98
13	By flat meter: Supplying and installation of 12 cm thick cement brick walls	2315	9.03	256.52
14	By cubic meter: Supplying and installation of 25 cm thick cement brick walls	1472	72.21	20.39
15	By flat meter: Supplying and installation of tempered glass walls	768	32.82	23.39
16	By number: Supplying and installation of aluminum window for bathrooms, size 1.10 × 0.9 m	131	65.64	2
17	By number: Supplying and installation of aluminum window with two sliding folds for bathrooms, size 1.10 × 0.9 m	656	65.64	10
18	By number: Supplying and installation of accordion door for bathrooms, size 2.10 × 0.9 m	246	16.41	15
19	By number: Supplying and installation of administration office door, size 2.10 × 1.80 m	3692	246.16	15
20	By number: Painting and installing and disassembling an interior office door with lacquer paint, size 2.10 × 0.9 m	1280	35.56	36
21	By number: Painting and installing and disassembling an bathroom door with lacquer paint, size 2.10 × 0.9 m	924	35.56	26
22	By number: Supplying and installation of an tempered glass door with two sliding folds, size 2.10 × 1.8 m	574	191.46	3
23	By flat meters: supplying and roughening the interior walls	10,056	3.83	2626.12
24	By flat meters: Supplying and making plastic paints for interior walls and ceilings	29,292	7.11	4119.12
25	By flat meters: Supplying and installation of ceramic floors (60 × 60 cm)	39,213	24.62	1593
26	By flat meters: Supplying and installation of porcelain walls (40 × 40 cm)	3765	8.75	430.13
27	By flat meters: Supplying and installation of porcelain walls (25 × 35 cm)	6186	12.31	502.645
28	By flat meter: supplying and making an insulating layer for surfaces exposed to moisture, with a thickness of 4 mm	3765	8.75	430.13
29	By flat meters: supplying and making a layer of concrete to protect the insulation of bathrooms	4706	10.94	430.13
30	By flat meters: Supplying and installation of a white wash basin size 0.4 × 0.5 m	1015	144.96	7
31	By flat meters: Supplying and installation of a white toilet size 0.4 × 0.65 m	2929	172.31	17
32	By linear meter: Supplying and instillation of 1 in. diameter PP feeding pipes	505	12.58	40.1
33	By linear meter: Supplying and installation of 3/4 in. diameter PP feeding pipes	335	9.57	35
34	By linear meter: Supplying and installation of 1 in. diameter UPVC drain pipes	368	8.75	42
35	By linear meter: Supplying and installation of 3 in. diameter UPVC drain pipes	368	17.50	21
36	By linear meter: Supplying and installation of 3 in. diameter UPVC column drain pipes	881	18.60	47.35
37	By linear meter: Supplying and installation of 1.5 in. diameter UPVC drainage ventilation shafts	61	8.75	7
38	By number: Supply and installation of a 1 in. diameter stopcock	394	21.88	18
39	By number: Supply and installation of a 3/4 in. diameter stopcock	794	18.05	44
40	By lump Sum: Maintenance and scavenging of aluminum works—windows	821	820.52	1
41	By flat meters: Supply and installation of Trista marble for the entrance and corridors	6981	31.73	220.02
42	By lump Sum: Polished marble for staircases and entrances	821	820.52	1
43	By lump Sum: Facade repaint	2735	2735.08	1
44	By lump Sum: Coordination of the landscape works and the price includes all raw materials, crushing and transporting waste to public landfills	3556	3555.60	1

Table 4 (continued)

Routine work				
No	**Item**	**Cost $**	**Cost/Unit**	**Quantity**
	Total		$150,816	

Electric work				
No	**Item**	**Cost**	**Cost/unit**	**Quantity**
1	By lump Sum: Supplying and installation of electrical works, and the price includes crushing and making of sand and transporting waste to public landfills (75% of the cost of routine works)	113,112	113,112	1
	Total	$113,112		

Quantity of survey	
Routine work	$150,816
Electric work	$113,112
Total	$263,927

as a standards-based architectural and structural design and building procedure. Concrete construction code standards are similarly constrained. As a result, the research area is limited to the common factors associated with the project's nature.

4 Conclusion

An integrated framework for existing buildings has been built utilizing VE and BIM to assist in making the best alternative in terms of utilizing such structures by employing feasibility studies that include NPV and cash flow with the bank interest ratio.

The maximum advantage is achieved by evaluating the offered alternatives according to the decision-makers needs from the provided criteria, where the process of evaluating different alternatives for judging alternatives begins with the extraction of data from the 3D-BIM model, followed by survey quantity, cost estimation, scheduling, NPV, and cash flow, which are all outputs of feasibility studies, and determining the criteria, which are an important component in the process of evaluating different alternatives for judging alternatives. The owner's relevance and utility of the criteria in the design process and the feasibility study conducted by the VE team are

Table 5 Quantities of survey price for alternative No. 3

Demolition work				
No	**Item**	**Costs**	**Cost/Unit**	**Quantity**
1	By cubic meter: crushing reinforced concrete and the price includes transporting waste to public landfills	29,798	11.87	2510.40
2	By cubic meter: crushing plain concrete and the price includes transporting waste to public landfills	810	1.50	540.00
3	By flat meter: Breaking mosaic tiles and transporting waste to public landfills	3050	1.30	2346.07
4	By linear meter: crushing the entrance stairs Marble with the transfer of waste to public landfills	23	1.25	18.63
5	By linear meter: crushing the Marble external stairs, including (existing and sleeping) with transporting waste to public landfills	558	1.25	446.4
6	By flat meter: crushing the entrance stairs Marble with the transfer of waste to public landfills	113	1.25	90.105
7	By the flat meter: crushing the clay brick walls and transporting the waste to public landfills	569	1.25	455.075
8	By the cubic meter: crushing the clay brick walls and transporting the waste to public landfills	605	1.50	403.2
9	By the flat meter: crushing the cement brick walls and transporting the waste to public landfills	194	1.50	129.525
10	By the cubic meter: crushing the cement brick walls and transporting the waste to public landfills	50	1.00	50
11	By the flat meter: crushing the Ceramic tiles brick floor and transporting the waste to public landfills	100	1.00	99.58
12	By the flat meter: crushing the Ceramic tiles brick walls and transporting the waste to public landfills	473	1.00	472.73
13	By lamp sum: crushing electrical works and the price includes transporting waste to public landfills	29,074	29,074	1
Total			$65,416	

Quantity of survey	
Total	$65,416

Commercial And Administrative		Classic Schedule Layout			
Activity ID	Activity Name	Units	Original Duration	Start	Finish
Total		14569	193	01-Jan-22	27-Oct-22
NEWPROJ-3	Commercial And Administrative	0	0		
NEWPROJ-3.1	Cruching Work	3076	11	01-Jan-22	12-Jan-22
NEWPROJ-3.2	Bricks Work	725	5	13-Jan-22	18-Jan-22
NEWPROJ-3.3	Tempered Glass	27	4	16-Jul-22	19-Jul-22
NEWPROJ-3.4	Doors and Windows	43	153	27-Jan-22	24-Jul-22
NEWPROJ-3.5	Plaster Work	2626	31	20-Jan-22	24-Feb-22
NEWPROJ-3.6	Paint Work	4182	105	07-May-22	05-Sep-22
NEWPROJ-3.7	Ceramic And Porcelain Works	2527	80	02-Feb-22	05-May-22
NEWPROJ-3.8	Isolation Works	862	6	19-Jan-22	25-Jan-22
NEWPROJ-3.9	Plumbing Work	279	159	19-Jan-22	23-Jul-22
NEWPROJ-3.10	Marble Works	221	10	26-Feb-22	08-Mar-22
NEWPROJ-3.11	Landscape Works	1	45	06-Sep-22	27-Oct-22

Fig. 13 Alternative No. 1 schedule chart

Activity ID	Activity Name	Clasic Schedule Layout			
Total		3487	255	January 1, 2022	October 24, 2022
	NEWPROJ-5. Selling Land As Vacant Land	0	0		
	NEWPROJ-5.1 Cruching Work	3487	255	January 1, 2022	October 24, 2022
03	By cubic meter: crushing reinforced concrete and the price includes transporting waste to public landfills	691	21	January 29, 2022	February 21, 2022
01	By cubic meter: crushing plain concrete and the price includes transporting waste to public landfills	540	210	February 22, 2022	October 24, 2022
02	By flat meter: Breaking mosaic tiles and transporting waste to public landfills	1,346	6	January 1, 2022	January 6, 2022
12	By linear meter: crushing the entrance stairs Marble with the transfer of waste to public landfills	13	1	January 1, 2022	January 1, 2022
07	By linear meter: crushing the Marble external stairs, including (existing and sleeping) with transporting waste to public landfills	5	1	January 1, 2022	January 1, 2022
11	By flat meter: crushing the entrance stairs Marble with the transfer of waste to public landfills	61	1	January 1, 2022	January 1, 2022
06	By the flat meter: crushing the clay brick walls and transporting the waste to public landfills	182	2	January 25, 2022	January 26, 2022
09	By the cubic meter: crushing the clay brick walls and transporting the waste to public landfills	20	2	January 26, 2022	January 27, 2022
08	By the flat meter: crushing the cement brick walls and transporting the waste to public landfills	52	1	January 27, 2022	January 25, 2022
04	By the cubic meter: crushing the cement brick walls and transporting the waste to public landfills	3	1	January 28, 2022	January 25, 2022
05	By the flat meter: crushing the Ceramic tiles brick floor and transporting the waste to public landfills	100	2	January 1, 2022	January 2, 2022
10	By the flat meter: crushing the Ceramic tiles brick walls and transporting the waste to public landfills	473	2	January 26, 2022	January 27, 2022
13	By lamp sum: crushing electrical works and the price includes transporting waste to public landfills	1	21	January 1, 2022	January 24, 2022

Fig. 14 Alternative No. 3 schedule chart

Table 6 Data analysis of alternative No. 1

Clause	Item	Value	Notes
Data	No. of floor	6	(Ground + 5 typical) floor
	Restaurants—commercial areas	608.57 m^2	m^2
	Administrative areas	2607.89 m^2	m^2
	Meter price of commercial	$4000	$
	Meter price of administrative	$3083	$
	The total price of alternatives area	$10,475,430	$
Cost estimation	Construction cost	$263,927	$
	Administration expenses	$3959	1.5% Of construction cost
	Supervising the implementation	$6598	2.5% Of construction cost
	Selling commission marketing expenses	$523,772	5% Of the selling price
	Total cost	$798,256	$
Net present value (NPV)		$629,160	From cash flow

$798,256						Cost of Construction without Land Price	
Duration Life						Period	
Total	5th Year	4th Year	3rd Year	2nd Year	1st year	Duration of construction	1
100%	0%	0%	0%	0%	100%	schedule Costruction	2
$798,256	0	0	0	0	798,256	Cost depend on schedule Costruction	3
	$10,475,430					Total Revenue	4
100%	0%	0%	20%	20%	60%	Sales distributed over three years	5
100%	20%	20%	25%	25%	10%	1st year payment rates	6
100%	20%	20%	30%	30%	0%	2nd year payment rates	7
100%	20%	20%	60%	0%	0%	3rd year payment rates	8
	2,095,086	2,095,086	3,456,892	2,199,840	628,526	Revenue per year	9
$2,240,580	2,095,086	2,095,086	978,027	-279,024	-2,648,595	Annual surplus/deficit	10
$7,436,594	0	0	2,478,865	2,478,865	2,478,865	Total Price of vacant land	11

Financial indicators including the price of the land

5	4	3	2	1	Period	1
2,095,086	2,095,086	978,027	(279,024)	(2,648,595)	Cash Flow	2
629,160	(559,648)	(1,891,113)	(2,587,253)	(2,364,817)	NPV	3
				12.00%	Interest Ratio	

Fig. 15 Alternative No. 1 cash flow

Table 7 Data analysis of alternatives No. 2

Clause	Item	Value	Notes
Data	Land area	2285 m^2	m^2
	Meter price of land, including the building on it	$2440	$
	The total price of land	$5,576,303	$
Cost estimation	Selling commission marketing expenses	$278,815	5% Of the selling price
	Total cost	$278,815	$
Net present value (NPV)		$4,215,504	From cash flow

$278,815						Cost of Construction without Land Price	
Duration Life						Period	
Total	5th Year	4th Year	3rd Year	2nd Year	1st year	Duration of construction	1
100%	0%	0%	0%	0%	100%	schedule Costruction	2
$278,815	0	0	0	0	278,815	Cost depend on schedule Costruction	3
	$5,576,303					Total Revenue	4
100%	0%	0%	33%	33%	33%	Sales distributed over one year	5
100%	0%	0%	0%	0%	100%	1st year payment rates	6
100%	0%	0%	0%	100%	0%	2nd year payment rates	7
100%	0%	0%	100%	0%	0%	3rd year payment rates	8
	0	0	1,858,768	1,858,768	1,858,768	Revenue per year	9
$5,297,488	0	0	1,858,768	1,858,768	1,579,952	Annual surplus/deficit	10

Financial indicators including the price of the land:

5	4	3	2	1	Period	1
0	0	1,858,768	1,858,768	1,579,952	Cash Flow	2
4,215,504	4,215,504	4,215,504	2,892,470	1,410,672	NPV	3
				12.0%	Interest Ratio	

Fig. 16 Alternative No. 2 cash flow

Table 8 Data analysis of alternative No. 3

Clause	Item	Value	Notes
Data	Land area	2285 m^2	m^2
	Meter price of the vacant land	$3254	$
	The total price of vacant land	$7,436,072	$
Cost estimation	Construction cost	$65,416	$
	Administration expenses	$981	1.5% Of construction cost
	Supervising the implementation	$1635	2.5% Of construction cost
	Selling commission marketing expenses	$371,830	5% Of the selling price
	Total cost	$439,863	$
Net present value (NPV)		$5,891,377	From cash flow

used to calculate the criteria weights. The AHP is used to create the model as a dynamic decision-making tool.

An integrated framework was used in a case study to demonstrate its capacity to select an appropriate alternative and to highlight the framework's characteristics. The findings revealed that this integrated framework, which includes feasibility studies and comparison tables, may be implemented in the future while taking into account time and location constraints.

The author advises that more research is being done to increase the criteria by the construction time and place factors and add more dimensions to BIM.

5 Limitations

The study's limited sample size could have an impact on the findings. So, further research on a larger sample of the exited building is required to corroborate the findings.

$439,863						Cost of Construction without Land Price	
Duration Life						Period	
Total	5th Year	4th Year	3rd Year	2nd Year	1st year	Duration of construction	1
100%	0%	0%	0%	0%	100%	schedule Costruction	2
$439,863	0	0	0	0	439,863	Cost depend on schedule Costruction	3
	$7,436,594					Total Revenue	4
100%	0%	0%	0%	50%	50%	Sales distributed over one year	5
100%	0%	0%	0%	0%	100%	1st year payment rates	6
100%	0%	0%	0%	100%	0%	2nd year payment rates	7
100%	0%	0%	100%	0%	0%	3rd year payment rates	8
	0	0	0	3,718,297	3,718,297	Revenue per year	9
$6,996,731	0	0	0	3,718,297	3,278,434	Annual surplus/deficit	10

Financial indicators including the price of the land:

5	4	3	2	1	Period	1
0	0	0	3,718,297	3,278,434	Cash Flow	2
5,891,377	5,891,377	5,891,377	5,891,377	2,927,173	NPV	3
				12.0%	Interest Ratio	

Fig. 17 Alternative No. 3 cash flow

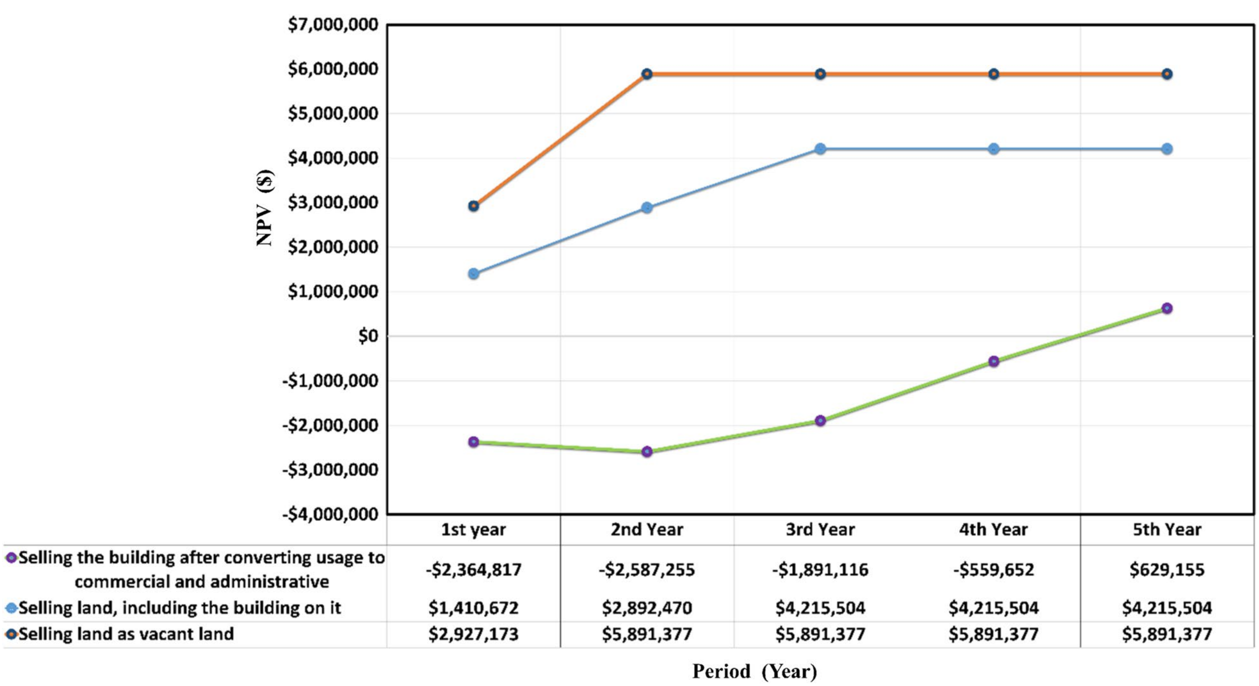

Fig. 18 Alternatives net present value (NPV) comparison chart throws life cycle

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat		Priority	Rank	(+)	(-)
1	Alternative 1	49.3%	1	11.3%	11.3%
2	Alternative 2	31.1%	2	7.1%	7.1%
3	Alternative 3	19.6%	3	4.5%	4.5%

Number of comparisons = 3
Consistency Ratio CR = 5.6%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3
1	1	2.00	2.00
2	0.50	1	2.00
3	0.50	0.50	1

Principal eigen value = 3.054
Eigenvector solution: 4 iterations, delta = 2.1E-8

Fig. 19 AHP priorities of alternatives by NPV criteria

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat		Priority	Rank	(+)	(-)
1	Alternative 1	20%	3	7.1%	7.1%
2	Alternative 2	40%	2	11.3%	11.3%
3	Alternative 3	40%	1	11.3%	11.3%

Number of comparisons = 3
Consistency Ratio CR = 5.6%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3
1	1	2.00	2.00
2	0.50	1	2.00
3	0.50	0.50	1

Principal eigen value = 3.054
Eigenvector solution: 4 iterations, delta = 2.1E-8

Fig. 20 AHP priorities of alternatives by required time criteria

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat		Priority	Rank	(+)	(-)
1	Alternative 1	65%	1	16.3%	16.3%
2	Alternative 2	23%	2	4.1%	4.1%
3	Alternative 3	12%	3	2.6%	2.6%

Number of comparisons = 3
Consistency Ratio CR = 5.6%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3
1	1	5.00	5.00
2	0.20	1	2.00
3	0.20	0.50	1

Principal eigen value = 3.054
Eigenvector solution: 4 iterations, delta = 1.0E-8

Fig. 21 AHP priorities of alternatives by change ability criteria

No.	Alternative	NPV	Required Time	Change Ability
1	Selling the building after converting usage to commercial and administrative	49.3%	20.0%	65.0%
2	Selling land, including the building on it	31.1%	40.0%	23.0%
3	Selling land as vacant land	19.6%	40.0%	12.0%

χ

Criteria	Priority
NPV	60%
Required Time	30%
Change Ability	10%

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No.	Alternative	Priority
1	Selling the building after converting usage to commercial and administrative	42.08%
2	Selling land, including the building on it	32.96%
3	Selling land as vacant land	24.96%

Result

$$\begin{bmatrix} 0.493 & 0.2 & 0.65 \\ 0.311 & 0.4 & 0.23 \\ 0.196 & 0.4 & 0.12 \end{bmatrix} \times \begin{bmatrix} 0.6 \\ 0.3 \\ 0.1 \end{bmatrix} = \begin{bmatrix} 0.493 \times 0.6 + 0.2 \times 0.3 + 0.65 \times 0.1 \\ 0.311 \times 0.6 + 0.4 \times 0.3 + 0.23 \times 0.1 \\ 0.196 \times 0.6 + 0.4 \times 0.3 + 0.12 \times 0.1 \end{bmatrix} = \begin{bmatrix} 0.4208 \\ 0.3296 \\ 0.2496 \end{bmatrix}$$

Fig. 22 All the weights of the alternatives (final scores)

Table 9 Prioritization of alternatives

No	Alternative	NPV (%)	Required time (%)	Change ability (%)	Final score (%)
1	Selling the building after converting usage to commercial and administrative	49.00	20.00	65.00	44.15
2	Selling land, including the building on it	31.00	40.00	23.00	32.00
3	Selling land as vacant land	20.00	49.00	12.00	23.8

Abbreviations
BIM: Building information modeling; VE: Value engineering; NPV: The net present value; AHP: Analytic hierarchy process; L.E: The Egyptian pound currency; MCDA: Multi-criteria decision-making analysis; CBE: The Central Bank of Egypt; LEED: Leadership in Energy and Environmental Design.

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Consent for publication
Not applicable.

Competing Interests
The authors have declared that there are no competing of interests.

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References

1. Bush L (2016) The value engineering handbook. Emereo Publishing, Brisbane
2. Othman AA, Mohamed F (2020) The impact of risk factor on value engineering proposals for the architecture projects. J Eng Appl Sci 67(5):1059–1076
3. Othman AA, Mohamed F (2020) Integrating the risk factor within the value engineering equation in architectural projects. J Eng Appl Sci 67(5):1059–1076
4. Elbaz MM, Wahba SM, Abdelaziz HM (2020) Assessment of hidden transaction cost in integration with value engineering in hotels. J Eng Appl Sci 67(2):295–313
5. Nath T, Attarzadeh M, Tiong RLK, Chidambaram C, Yu Z (2015) Productivity improvement of precast shop drawings generation through BIM-based process re-engineering. Autom Constr 54:54–68. https://doi.org/10.1016/j.autcon.2015.03.014
6. Saleeb DN (2018) Organisational information requirements for successful BIM implementation. Global Constr Success. https://doi.org/10.1002/9781119440345.ch22
7. Ranjbaran Y, Moselhi O (2013) Integrated computational model in support of value engineering (Master dissertation). Master Thesis, Building, Civil and Environmental Engineering Department, Concordia University, Canada, Concordia, pp 110–112

8. Alizadehsalehi S, Koseoglu O, Celikag M (2015) Integration of building information modeling (BIM) and laser scanning in construction industry. AEI. https://doi.org/10.1061/9780784479070.015
9. Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1(1):83. https://doi.org/10.1504/ijssci.2008.017590
10. Bhushan N, Rai K (2004) The analytic hierarchy processes. Strategic Decis Mak. https://doi.org/10.1007/978-1-85233-864-0_2
11. Saaty TL, Peniwati K (1996) The analytic hierarchy process and linear programming in human resource allocation. In: Proceedings of the international symposium on the analytic hierarchy process. https://doi.org/10.13033/isahp.y1996.068
12. Wei T, Chen Y (2019) Green building design based on BIM and value engineering. J Ambient Intell Humaniz Comput 11(9):3699–3706. https://doi.org/10.1007/s12652-019-01556-z
13. Park C-S, Kim H-J, Park H-T, Goh J-H, Pedro A (2017) BIM-based idea bank for managing value engineering ideas. Int J Project Manage 35(4):699–713. https://doi.org/10.1016/j.ijproman.2016.09.015
14. Olanrewaju OI, Kineber AF, Chileshe N, Edwards DJ (2022) Modelling the relationship between Building Information Modelling (BIM) implementation barriers, usage and awareness on building project lifecycle. Build Environ 207:108556. https://doi.org/10.1016/j.buildenv.2021.108556
15. Taher AH, Elbeltagi EE (2021) Integrating building information modeling with value engineering to facilitate the selection of building design alternatives considering sustainability. Int J Constr Manag. https://doi.org/10.1080/15623599.2021.2021465
16. Ajtayné Károlyfi K, Szalai D, Szép J, Horváth T (2021) Integration of BIM in architecture and structural engineering education through common projects. Acta Tech Jaur 14(4):424–439. https://doi.org/10.14513/actatechjaur.00641
17. SAVE International. (2018). Value Methodology Glossary Definition.
18. Bolton JD, GOAL/QPC Incorporated (2008) Value methodology: a pocket guide to reduce cost and improve value through function
19. Goepel K (n.d.) AHP Priority calculator. https://bpmsg.com/ahp/ahp-calc.php. Retrieved 16 April 2022
20. Multiplication (n.d.) http://www.calcul.com/category:/math/matrix/multiplication Retrieved 16 April 2022
21. Szalai D, Horváth T (2022) Design of multi-layered building structures using BIM method. IOP Conf Ser: Mater Sci Eng 1218(1):012055. https://doi.org/10.1088/1757-899x/1218/1/012055
22. El-Alfy AE (2010) Design of sustainable buildings through value engineering. J Build Apprais 6(1):69–79. https://doi.org/10.1057/jba.2010.14
23. Mahmoud HM, Fayad AA, Nassar AH (2022) Investigating the impact of changing the usage type of existing structure using BIM. Civ Eng J 8(8):1606–1621. https://doi.org/10.28991/CEJ-2022-08-08-06

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