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Assessment of a Decision-Making Model for Monitoring the Success of a Project for Smart Buildings

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Abstract

Objective: To express the usage of intelligent concepts in the architectural building construction field that are primarily concerned with reducing building energy use. Improved energy-saving methods and the use of environmentally friendly design principles are essential in this field. This type of managerial decision-making is necessary for the success of these types of projects. *Methods*: monitoring the performance of intelligent buildings use the cost variance (CV) and schedule variation as standard metrics to track the progress of a project based on the save energy concept. Also, this research conducted a comparative study on Building Information Modelling (BIM) and (MCDM) decision-making limitations as presented in the article. *Analysis*: the conventional technique, on the other hand, is unable to offer data on variance from typical performance levels. The main point based on Delphi results of construction cost variables has been observed 19 effective factors. *Finding and Novelty*: The RII observed that the most effective aspects of an intelligent building are the number of floors in the building, the kind of structural design, and the size of the shadow cast on the surface of the building. The Multi-Criteria Decision Maker (MCDM) observed significant differences in planned value (PV) and actual value (AC) results. In addition, as a result of the current approach, it is possible to track project costs and timelines more precisely.

Keywords: Intelligent Building; Multi-Criteria Decision Maker; MCDM; MATLAB Code.

1. Introduction

Nowadays, construction manufacturing is the world's second largest industry, which has been transformed in an optimal way in the last ten years. The main issue is based on construction, as it can be identified as a unique sector characterized by the intensity of capital employed as well as the variability of turnover over time [1, 2]. Sustainability infiltrates all societal practices, especially the construction industry, because of its substantial impact on the environment. Furthermore, the success of building projects ultimately depends greatly on how well they are executed. Moreover, the effectiveness of construction projects was examined in several earlier studies [3]. The project's performance has been assessed based on the time, money, and deliverables parameters. It is a high-quality project that gains the support of all its stakeholders and is executed successfully and effectively as a result of all of these aspects [4, 5].

The construction industry prioritizes effective risk management based on a management strategy. Moreover, multiple threats exist in the main design, which is associated with the subsequent stages of construction projects [6, 7]. In order to achieve the goal of project performance, project failure must be avoided. The fact that an intelligent or smart building has a reasonable investment, great energy management, and a comfortable and convenient atmosphere is one of its most crucial qualities [8]. A smart building's design and operation deviate from the standard by utilizing cutting-edge control systems and networked technology [9].

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The main objectives of implementing intelligent buildings are energy conservation and energy savings, but because there are so many different aspects involved in their construction, making design judgments has proven challenging and necessitates the use of several criteria [10–12]. Moreover, building Information Modelling (BIM), as a widely adopted method and representative of the 4th manufacturing revolution [13, 14], is recognized as a state-of-the-art transformation in design, and construction, which is associated with maintenance procedures [15] as well as remains built upon the concept of storing also managing a diverse set of INFO produced throughout a building's lifecycle. There are several definitions of BIM [16]. As associated with the British Standards Institute, BIM is the process of information generation as well as management based on the whole lifecycle of the project. BIM is the integration of technologies associated with processes represented as a single system [17, 18]. Furthermore, BIM is considered an effective approach towards adoption in IBS projects due to the aforementioned numerous benefits, for instance, increasing the project's quality [19, 20], providing precise quantity take-offs [21], improving scheduling [22], adopting a circular economy [23], alleviating adverse environmental effects [24], as well as reducing total project contingency costs [25, 26]. Although it provides excellent opportunities, based on BIM adoption approach comes with a number of challenges. Additionally, optimal construction companies are familiar with conventional construction approaches, adopting BIM as a new application poses new risks that need to be addressed [27].

Consequently, the process of risk assessment might be more complex because the risks differ from the conventional ones with which construction managers are familiar. In addition, multi-criteria decision-making remains an analytical network process method that has been developed via Thomas L. Saaty and that remains developed based on expert opinion to aid in complex decision-making within different alternatives [28].

2. Literature Review

2.1. The Decision-Making Issues

There are several different methods associated with the strategies offered in decision-making, so it is necessary to represent the characteristics as well as the restrictions of the decision problem [29]. In the same way, the distinction has been made with several identifications of the scope of the decision support the approach should provide. Moreover, several study projects based in this field have the objective of supporting the generation of design alternatives via knowledge-based inference algorithms [30]. Furthermore, in opposition to this forward-reasoning strategy, the Smart (DMF) has the objective of evaluating design alternatives already generated via a human development team (Figure 1). Additionally, the conventional is available at the beginning of the process in the main form of architectural building information. At the beginning of the process, Building Information Models (BIMs) are associated with the related analysis data. Subsequently, for the decision problem-making Models (BIMs) as well as related with analysis INFO [31]. Therefore, the decision of several problems means that the design alternatives remain limited, usually amongst (2) to (10-15) based on the case of a design competition [32].

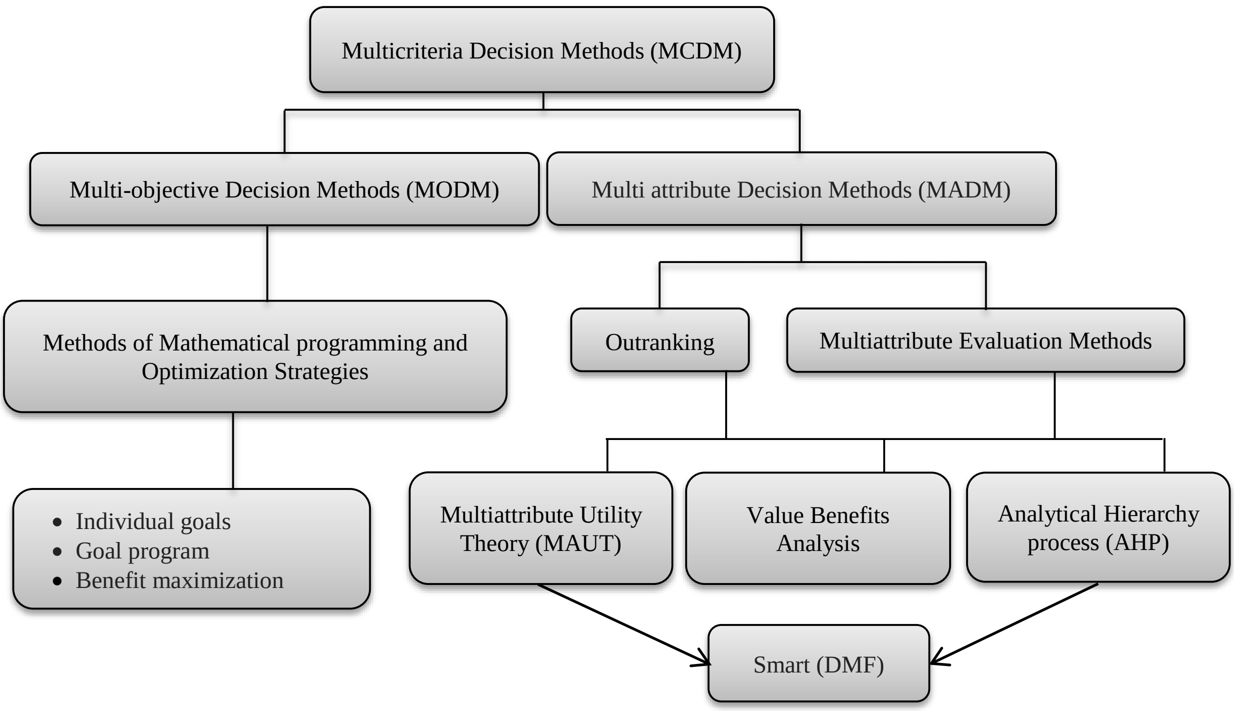

Figure 1. A schematic on multicriteria decision methods

3. Intelligent Building Factor

Smart building materials are those that can achieve controlled and predictable variability in one or more of their properties in response to external stimuli as well as changes in their environment. Temperature, light, pressure, magnetic or electrical fields, ambient humidity, or chemicals are examples of external changes. To maximize the potential benefits from this cheap and abundant resource, which is possessed by all countries, regardless of wealth, it is essential to ensure that all nations have equitable access to energy efficiency resources. The diverse selection of modern materials available today includes a wide variety of materials [32, 33]. When deciding, the weather, the condition of the site, the amount of money available, and the desired level of comfort are the most crucial factors to take into account [34, 35]. Performance of the building envelope, energy-efficient (HVAC) equipment, high-efficiency lighting systems, water resource management, renewable energy technologies, and the installation of intelligent control systems are all current research hot issues [36].

3.1. Material Availability and Sustainability

A structure's lifespan is significantly shortened when inferior materials are used in its construction. The pressure that the surrounding environment produces on the building's structural components over time causes corrosion of the structure. Materials used during the planning phase have an impact because a structure's performance largely reflects its long-term influence. The outer walls of a structure can make or break it in terms of performance and energy use. A well-designed façade that controls the passage of exterior heat or cold ensures efficient energy utilization. Poor building materials affect more than simply the outside [37]. Volatile chemicals, such as those present in paints, insulators, and adhesives in significant quantities, can be harmful to human health [38]. This is particularly crucial given that most people spend the majority of their time indoors [39]. To meet the minimal standard for sustainability in building materials, the effectiveness of goods and building materials must be assessed against the three sustainability factors.

Table 1. Characteristics of the decision problem to evaluate BIM-based design evaluations

Characteristics of design alternatives	Characteristics of evaluation criteria	Author and Year	Ref. No.
Design alternatives available as BIMs	An evaluated Multiple criteria	Harmon & Gillen (2022)	[38]
		Dias & Ergan (2020)	[39]
		Shrivastava & Akhtar (2019)	[40]
(2-4) as well as up to (15) (design competition) and design alternatives	Criteria from different domains lead to complex decisions	Zahedi et al. (2022)	[41]
		Jang & Collinge (2020)	[42]
		Ma & Wu (2022)	[43]
Differs alternative in geometry or in details	Subjective and objective criteria that have to be considered	Xu et al. (2019)	[44]
		Ma & Wu (2020)	[45]
INFO available from BIMs	Criteria have different dimensions	Onososen & Musonda (2022)	[46]
		Abd Jamil & Fathi (2019)	[47]
		Schiavi et al. (2022)	[48]

3.1.1. Related Work

BIM outsourcing decisions have referred to selecting the optimal BIM outsourcing strategy. Furthermore, contractors have three main optional strategies when making BIM outsourcing decisions [40]. Furthermore, information technology outsourcing strategies and total insourcing indicate that the contractors conduct most of the BIM operations, for instance, BIM model creation, BIM utilize; internally, which occupies more than 80 percent of the BIM budget. In the same way, the contractors transfer most BIM operations responsibilities to an external provider, which costs more than 80 percent of the BIM budget. Despite the fact that contractors may choose BIM operations from an external provider [41], which takes up the BIM budget amongst 80 percent as well as 20 percent. On the other hand, making BIM outsourcing decisions effectively remains difficult. Therefore, outsourcing decisions, for instance, mining outsourcing, information framework outsourcing, BIM outsourcing remains a complicated as well as strategic option for contractors towards implement BIM. For instance, when making BIM outsourcing decisions, contractors based on the BIM outsourcing can bring financial advantages as well as benefits as well long-term competitive advantages, for instance, commercial exploitation. In addition, towards evaluating internal BIM utilize experience as well as estimate the requirement for BIM professionals from (BIM) outsourcing [42].

Table 2. A comparative study on Building Information Modelling (BIM) and (MCDM) decision-making limitations

The sort of decision method	Description	Limitation	Author and years	Ref. No.
Building Information Modelling (BIM), Management Information Systems (MIS).	Recommending a framework for decision-making in case there are many alternatives as well as options to choose from in design phase in the AEC industry. Utilizing Building Information Modelling (BIM), Management Information Systems (MIS) as well as simulation tools, the framework can be fully automated as well as to assist decision-making optimization.	1. Designers, managers, project owners as well as builders can benefit from this framework to evaluate more options in their decision-making process. 2. The decision-making process has been automated + An Application Programming Interface (API) 3. A designed construction processes in the Architectural, Engineering and Construction (AEC) industry. 4. A smart building's equipment for energy consumption as well as cost trade-off. 5. An Application Programming Interface (API) can help with making automating permutation out of possible options.	Mashayekhi & Heravi (2020)	[23]
A smart building such as security control, energy management, control as well as monitoring of Heating, ventilation also air conditioning (HVAC) system, water management, lighting systems, health system of elders and fire detection.	Reduces the burden of frequent interruption or control by the humans. Smartness makes the ability towards interconnect more real time parameters by (Machine to Machine) interaction and make wise decisions in harmful situations. Many low-cost devices are available in the market to collect the real time data and transmit them using Internet of Things (IoT).	1. To analyse with the technical advances which can bring better solutions automatically. To identify the issues faced by current methodologies with these applications. 2. To give a guideline for future research. 3. The buildings construction and usage can depend on the applications. 4. The smart system can respond intelligently for traditional buildings will be automotive based on HVAC.	Vijayan et al. (2020)	[24]
Complex proportional assessment (COPRAS).	A hybrid Multiple Criteria Decision Making (MCDM) model approach which remains proposed. Step - wise Weight Assessment Ratio Analysis (SWARA) as well as Complex proportional assessment (COPRAS) framework.	1. Monitoring as well as controlling architectural project contains a decision problem with multi-varieties analysis. 2. To evaluate construction projects of hotels regarding environmental sustainability. 3. A private construction project is supposed as a case study. 4. The project has been implemented in a five-star hotel in Tehran, Iran. 5. The (SWARA) produces criteria weights and (COPRAS) will rank decision alternatives. 6. A strategic route can be used in other fields.	Zolfani et al. (2018)	[35]
Receiver Operating Characteristics (ROC) are used in Area Under Curve (AUC) accounts.	A fuzzy multi-criteria decision-making approach is applied by incorporating different wetland conversion influencing factors and a knowledge-based approach	1. Vulnerability assessment is essential in reformulating conservation strategies. 2. To identify the wetland conversion vulnerable areas within the East Kolkata Wetland. 3. This high vulnerability condition demands immediate plan formulation for protecting this ecologically rich wetland. 4. Develop urban built-up on a high and very high vulnerable zones. 5. Fuzzy MCDM method and for formulating an appropriate plan. 6. Receiver Operating Characteristics (ROC) is used Area Under Curve (AUC) 7. A high reliability and accuracy of the Fuzzy MCDM. 8. Immediate attention of the local authority for conserving this wetland.	Ghosh & Das (2019)	[36]
Building Information Modelling (BIM) and Multi-Criteria Decision Making (MCDM).	Integrating building information to support decision-making has been a key challenge in the Architecture, Engineering, and Construction (AEC) industry.	1. To improve information integration and decision-making. 2. To identify strategies to improve the synergy between MCDM and BIM. 3. The major application domains are sustainability, retrofit, supplier selection, safety, and constructability. 4. Improve the synergy between (MCDM) as well as (BIM). 5. A benchmark for evaluating the application of decision techniques. 6. Combining (MCDM) with (BIM) for integrated decision-making.	Tan et al. (2021)	[49]

Building information modeling (BIM) as well as (MCDM).	Building information modelling (BIM) as well as (MCDM) has been utilized because of its optimal advantages for various stages of the life cycle of a building.	1. To improve practitioners' understanding of the process for BIM as well as (MCDM) adoption towards sustainable construction through energy efficiency. 2. A survey was used for construction professionals as well as building industry experts in Malaysia. 3. To identify key factors affecting sustainable building via reducing both embodied as well as operational energy also carbon emissions. 4. The model developed consisted of 3 clusters with 6 nodes, which is associated with the stage of a compared pairwise with one another. 5. Design optimization, as well as minimized material requirements remain important factors based on some sustainable construction buildings that has used (BIM) application.	Haruna et al. (2021)	[50]

4. Material and Methods

4.1. Relative Important Index (RII)

The decisions made during the cost management process are influenced by the decision-makers' cost tolerance as well as the expense's magnitude and severity [43, 44]. The decision that a person, a business, or an organization is willing to make is influenced by the willingness of people, consumers, and society to endure a given cost level. It is crucial to determine an acceptable cost level before making any decisions on the budget, timeline, technical solutions, construction techniques, and other factors. In order to make the best decisions possible in the early stages of the project, the acceptable cost barrier must be defined early [45]. The acceptable cost level should be stated in the project's cost policy. The degree to which a decision-maker is willing to accept a particular cost determines the level of cost acceptance.

$$RII = \sum(P_i U_i)/N_n \tag{1}$$

where RII is Relative importance index, P_i is Respondent's rating of cost, U_i is Number of respondents placing identical weighting/rating on the cost, N is Sample size people who responded to the survey, and n is the highest attainable score for each cost.

4.2. Building Information Modelling (BIM) Model

Revit is one of the most well-known pieces of software for almost all engineering fields because of its adaptability, high level of precision, and speed. It is BIM (Building Information Modelling) software called Revit. The development of information modeling facilitates the process of storing all facts, information, and analysis. The project's outcomes will be combined with the supporting framework to produce a realistic image. In order to translate something more accurately, more information about the source text is required. Panels are present on both sides. The principles of project time and cost control were evaluated, along with current methods, in order to offer recommendations.

4.3. MCDM Design

The MCDM is a method that combines parts of mathematics and psychology to organize and understand complex topics. There are numerous workable answers to the current dilemma, all of which fall under the heading "ultimate objective" or "problem" in technical parlance. The MCDM framework offers a workable method for selecting a course of action by quantifying the requirements for that decision, listing the potential courses of action, and connecting those elements to the main goal. Utilizing a hierarchical structure, the criteria were arranged from most important to least important, starting with the ultimate goal at the top and working their way down. The top level of the hierarchy is represented by the stated goal, while the second level is comprised of the two relevant selection criteria for projects. There are many other cultural variables to consider when it comes to evaluating a hierarchy as presented in Figure 2.

4.4. Collecting Data

In addition to the information acquired from prior studies, the researcher also conducted questionnaires (see Appendix I, Table A-1). An external questionnaire design and Table A-2. An internal questionnaire design adapted from [46]; and interviews with the objective of acquiring additional data. Since each interview is conducted independently, this method typically produces results with a sample size that is quite tiny. This is because each interview is conducted separately, allowing for a more thorough analysis. In this kind of research, as much information as feasible is requested from the respondent. This research methodology offers the most accurate and comprehensive information about the investigation's subject compared to less personal surveys. Although this approach does not permit data gathering, it does permit researchers to assess the interviewee's personal preferences and goals. Interviewing is praised as an "excellent qualitative method" for encouraging people to share their personal opinions and experiences. These methods can be used to reveal how people evaluate and classify their surroundings. As the researcher asks questions, the interviewer is taking notes.

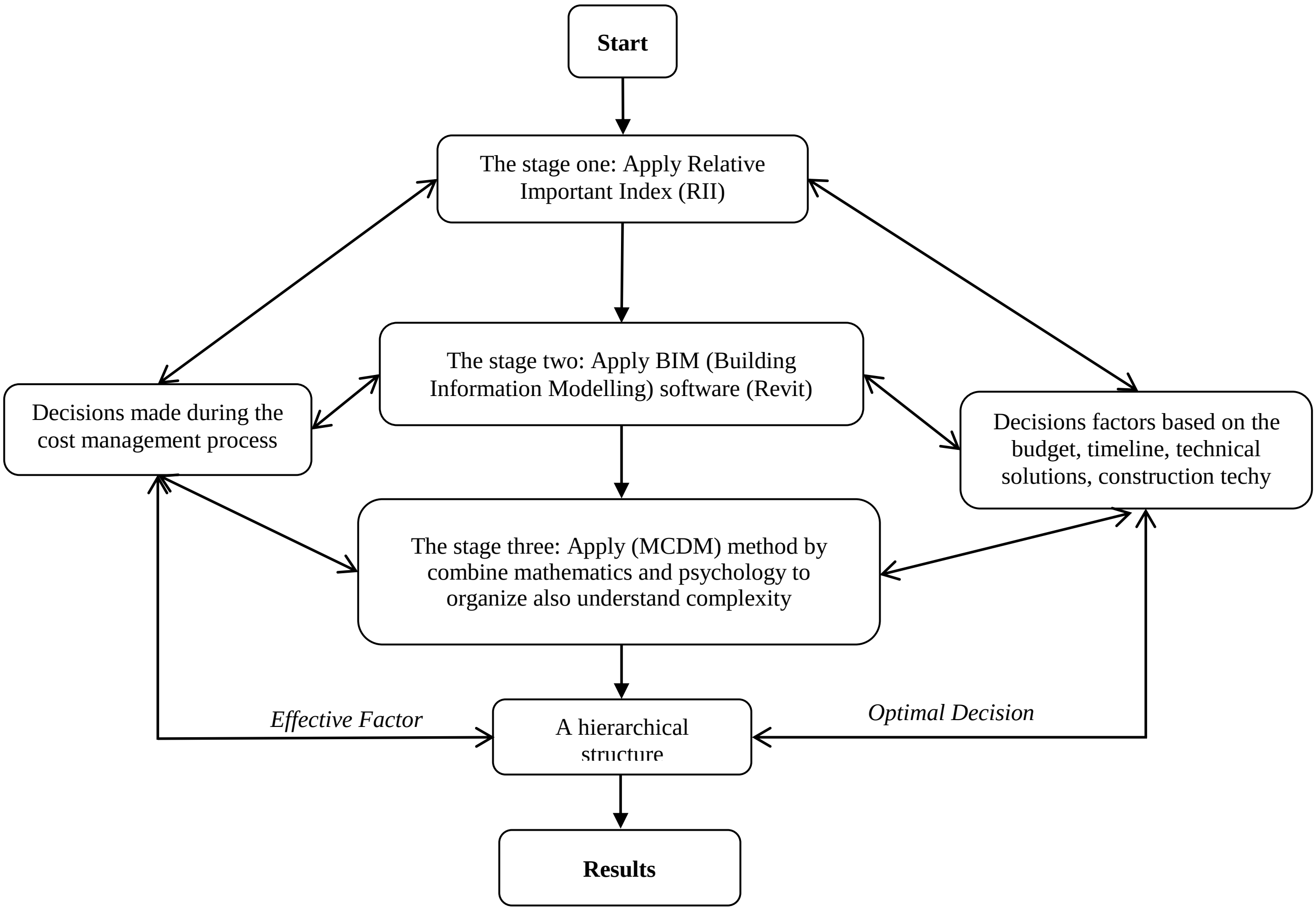

Figure 2. The research method

4.5. Ranking Process

The researcher collected data using questionnaires (see Appendix I, Table A-1). An external questionnaire design and Table A-2. An internal questionnaire design was adapted from [37, 47], as well as interviews, to enhance the information obtained through earlier initiatives. This method frequently employs a small sample size because the interviews are conducted one-on-one and provide in-depth information about the study's subject. The interviewee gives the researcher as much information as they can use this method. This research strategy offers the most accurate and comprehensive data regarding the research topic when compared to less personal surveys, but it prevents the researcher from personally examining the interviewee's preferences and goals.

5. Results

Many academics are attempting to improve this procedure because the effectiveness of monitoring and analysis may determine a project's success or failure. When utilizing conventional approaches, the common metrics for monitoring project progress are cost variance (CV) and schedule variation (SV). On the other hand, the traditional method is unable to provide information on deviations from normal performance levels. With the existing method, project costs and timelines may be tracked more precisely. The performance rating in this study was based on information from a real construction project. Real data should be used to check the normality of the PV indexes. The main statistical analysis tool was MATLAB R2018. To estimate the anticipated performance of the project, for instance, process models or routine operational data are utilized in construction control performance monitoring. The current method can be used to monitor construction projects, which enhances it. These choices were examined using a series of formulas in Chapter 3.

5.1. RII Results

Each of the numerous phases of a construction project, which includes construction, will have a major effect on the overall cost of the operation. The majority of respondents think that the most crucial determining factors for construction costs are floor area and floor count. On the other hand, they think that the influence of building type, slab style, and retaining wall size is minimal. This study's goal is to examine the fundamental elements that are essential in intelligent buildings, which differ from ordinary structures in that they include additional functions. The column gap length is one of the few extra parameters that has a significant impact on the project's final cost. The table, which also demonstrates that all of the criteria have a major impact, can be used to deduce the outcomes of the Delphi study and the RII technique. Because participant responses can be used to identify the majority of significant criteria, relative relevance index analysis is an effective method for ranking indicators using Likert-type scales. As a result, it is a desirable method for ranking indicators. A relative index analysis was carried out to rank the criteria and evaluate their relative importance. The tables that can be viewed below (Table 3) for each category present the results of the relative index study. Based on these rankings, risks received a high rating in the evaluation of the effects of cost overruns in construction projects.

Table 3. The Main Effective Factors

Factor	RII	factor	RII
Number of floors in the building	0.716	Type of walls	0.576
Max. floor height	0.596	Type of electrical works	0.556
Building height	0.664	Type of external plastering and warping	0.444
Type of used foundation	0.632	Type of tilling	0.524
Building area	0.628	Number of windows	0.584
Depth of foundation	0.696	Number of sanitary works	0.576
Type of structure design	0.772	size of the used solar energy system	0.556
Type of slab	0.444	effect of isolation materials	0.676
Type of doors	0.524	size of shadow	0.968
Type of windows	0.584	-	-

The number of floors, kind of structural design, and size of the shadow cast on the building's surface are the features of an intelligent structure that are most effective. By examining the number of floors in the building, comparing this data with the materials used, and examining the project's overall cost, it is easy to identify the major contributors to the cost [51]. For each category, the results of the relative index analysis have been gathered and are shown in Table 4. In accordance with these rankings, risks were ranked highly in the assessment of the expenses related to construction projects based on their impacts (Figure 3).

Table 4. Ranking the Main Effective Factors in the Present Study

Factor	RII	Rank
Number of floors in the building	0.716	3
Building height	0.664	6
Type of used foundation	0.632	7
Building area	0.628	8
Depth of foundation	0.696	4
Type of structure design	0.772	2
Effect of isolation materials	0.676	5
Size of shadow	0.968	1

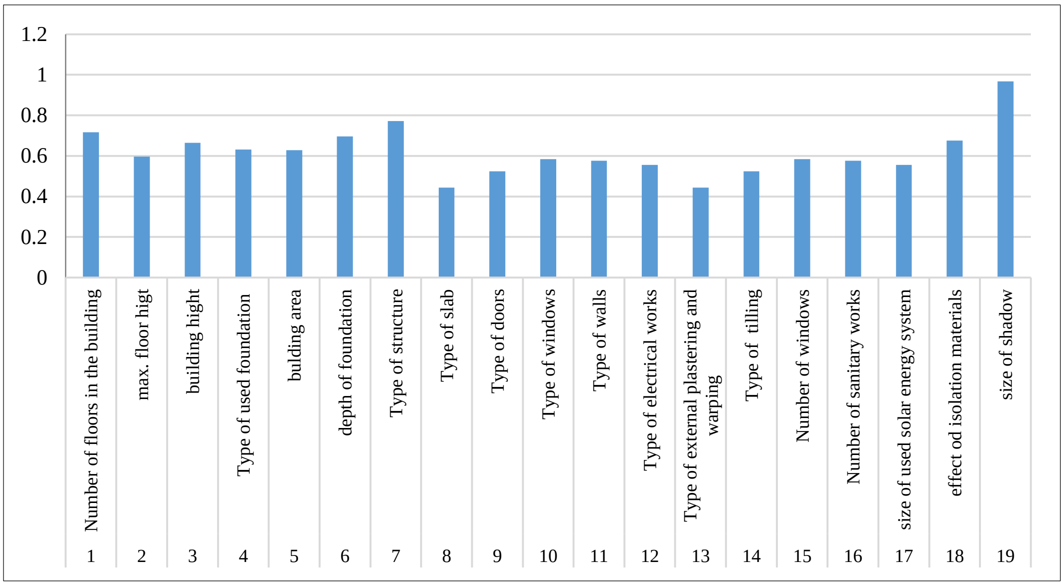

Figure 3. The Differences in RII Rank Results of the Used Factors

The biggest effect is caused by external finishing and isolations like a shadow. A designer can assess the amount of available sunlight access to various areas of the site and building design using shadow analysis. It is critical to consider how physical barriers affect access to solar radiation in both the present and the future when designing new structures or restoring existing ones. Many zoning requirements call for doing a shadow study to show how a new building affects the current situation.

To gather all of the required data for each project, a data sheet was created and used. We looked at the large majority of Iraqi universities that offer degrees in building engineering. A collection of building projects was gathered from various engineering companies and governmental organizations. The number of floors in the building serves as the second input after the shadow process, and there is a strong linear relationship between these two inputs and the ultimate cost of the project. The basement or the roof are each included as one level for the purposes of this computation because the number of floors becomes such a significant element. The fact that there are more projects in the later categories than in the first category, despite the fact that there are fewer projects in the latter category overall, shows that the model's prediction that adding floors to a building will raise project costs is accurate. The ultimate cost is significantly influenced by the foundation, slabs, reinforcement, and brick used in the building. The four most commonly utilized foundation types are isolated, strapped, heaped, and mat. The quantity of projects that come under each subcategory of foundation, as well as the proportion of overall projects that each foundation represents. The type of slab also affects the project's overall cost because of the quantity of concrete and reinforcement that must be used. For instance, three distinct types of slabs are employed: the solid slab, which is used 50% of the time, the ribbed slab, which is used 22% of the time; and the slab with drop beams, which accounts for 28%. The type of finishing that is done to a structure can have a big impact on its cost. In Iraq, tiling is a common and significant architectural feature seen in a great number of structures, including houses, mosques, and schools.

The main advantage of multi-criteria decision making (MCDM) is its capacity to confirm and minimize the divergent viewpoints of experts. Finding substantial value differences is the first step, after which it is possible to rank the various cost components according to relevance. A variety of questionnaires and interviews with Iraqi managers and engineers were conducted in order to reach this result, as presented in Table A-1. An external questionnaire design and Table A-2. An internal questionnaire design adapted from [37]. Those who make decisions employ their own assessments of the relative relevance of the aspects during the comparison process. The first step in the MCDM process is to identify the current issue and determine the level of skill required to solve it. The weighting of the priorities at the level below was based on the outcomes of the comparisons. The priorities that were determined as a result of the comparisons were used for this. After that, in order to determine the impact that expense had on the project's overall costs, the researcher used the MCDM approach. The challenge that will likely prove to be the biggest for this project is figuring out how to handle the enormous amounts of data that will be involved in it.

The sections that will follow this one will reveal the findings of the MCDM study. The findings of the MCDM research have been presented in Tables 5 to 8, for each MCDM result from the first case study (Figure 4). Furthermore, the expenses that were chosen have been accepted as having high priority levels in the process of analyzing the costs of projects based on their cost-effectiveness, and according to the findings of this ranking, the results have been presented in the research conclusion.

Figure 4. Front View of the Used Case Study

Table 5. RII Results for Factors of Different Types of Building

	School	Mosque	Residential	Mall	University
Factor	**RII**	**RII**	**RII**	**RII**	**RII**
Number of floors in the building	0.688	0.716	0.716	0.728	0.772
Building height	0.664	0.416	0.664	0.664	0.664
Type of used foundation	0.632	0.632	0.632	0.632	0.632
Building area	0.672	0.628	0.628	0.628	0.764
Depth of foundation	0.696	0.696	0.696	0.696	0.696
Type of structure	0.772	0.772	0.772	0.772	0.772
Effect isolation materials	0.676	0.676	0.676	0.676	0.712
size of shadow	0.808	0.808	0.968	0.808	0.808

Table 6. MCDM Weight Factors for Different Types of Building

Factor	School	Mosque	Residential	Mall	University
Cost	0.15	0.16	0.15	0.15	0.15
Number of floors in the building	0.10	0.11	0.11	0.11	0.11
Building hight	0.66	0.42	0.66	0.66	0.66
Type of used foundation	0.10	0.10	0.09	0.10	0.09
Depth of foundation	0.11	0.11	0.10	0.11	0.10
Type of structure	0.12	0.12	0.11	0.12	0.11
Effect of isolation materials	0.10	0.11	0.10	0.10	0.10

Table 7. MCDM Results of First Case Study

	Cost	Number of floors in the building	Building height	Type of used foundation on	Building area	Depth of foundation on	Type of structure	Effect of isolation materials	Size of shadow	MCDE
Precast Concrete wall	14	5	15	3	300	2.5	1	1	300	0.933254
Stone Wall	10	5	15	3	300	2.5	1	2	300	0.924312
Masonry Wall	7	5	15	3	300	2.5	1	2	300	0.892575
Pre-Panelized load Bearing Metal Stud Walls	7	5	15	3	300	2.5	1	1	300	0.859202
Engineering Brick Wall (115, 225 mm)	9	5	15	3	300	2.5	1	3	300	0.947106

Table 8. MCDM Results of Second Case Study

	Cost	Number of floors in the building	Building height	Type of used foundation on	Building area	Depth of foundation on	Type of structure	Effect of isolation materials	Size of shadow	MCDE
Precast Concrete wall	14	5	15	3	300	2.5	2	1	300	0.933254
Stone Wall	10	5	15	3	300	2	1	2	300	0.846527
Masonry Wall	7	5	15	3	300	1.5	1	2	300	0.794175
Pre-Panelized load Bearing Metal Stud Walls	7	5	15	3	300	1	1	1	300	0.740186
Engineering Brick Wall (115,225 mm)	9	5	15	3	300	1.5	1	3	300	0.848705

The permitted spending limit that you provide to a particular activity or work breakdown structure is referred to as the planned value (WBS). This budget doesn't contain a management reserve. Throughout the duration of the project, you will distribute the value that was intended in stages. Nevertheless, at a certain moment in time, the intended value describes the actual amount of labor that has been completed. The total PV may also be referred to as the performance measurement baseline (PMB), the budget at completion (BAC), or, more commonly, the Budgeted Cost of Work Scheduled (BCWS). Using the relation, you are able to determine the Planned Value (PV).

$$PV = BAC \times Planned \ \% \ of \ complete \tag{2}$$

The data showed a statistically significant relationship between time and cost estimation. As was already mentioned, testing the cost model serves the purpose of identifying not only whether or not the model generated was successful, but also whether or not the required degree of generality was attained. The process used to create the ideal model was guided by the advice that came before it and resulted in a model that could provide more accurate cost projections without sacrificing precision. As a result, the model could deliver more accurate cost projections without compromising its accuracy (Figures 5 and 6).

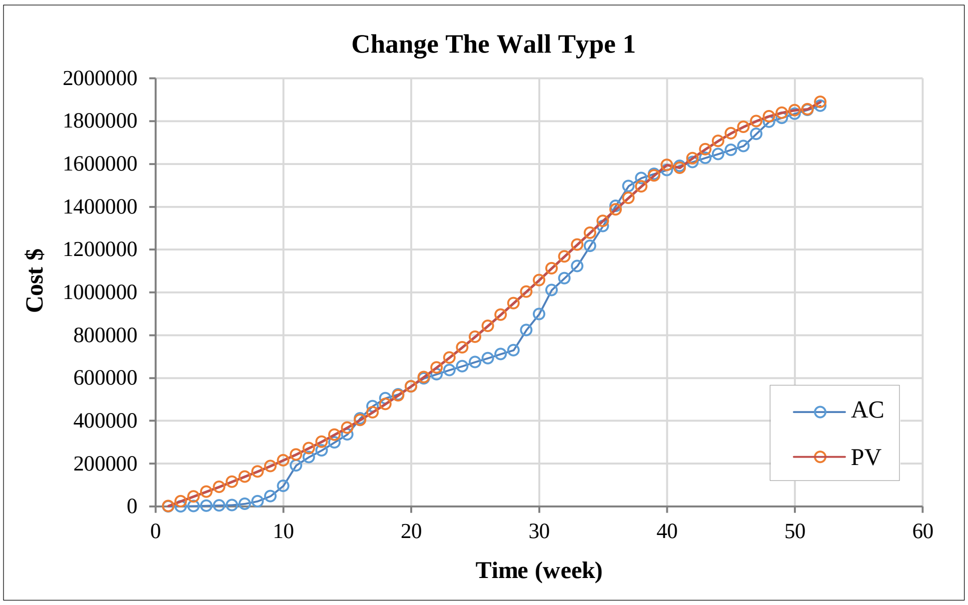

Figure 5. The Differences in (PV/AC) Results of MCDM Priority Result/ Wall Type 1

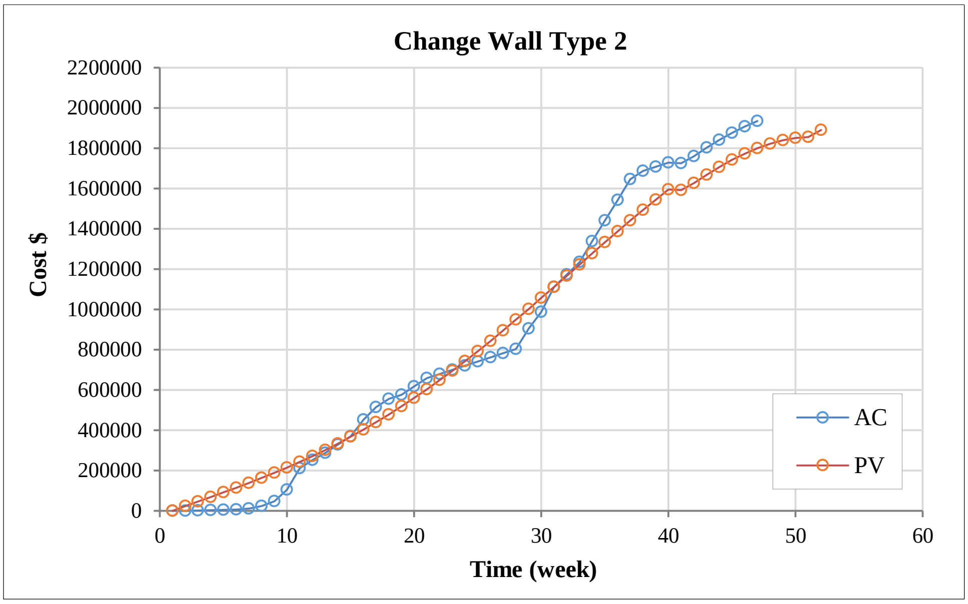

Figure 6. The Differences in PV/AC Results of MCDM Priority Result/ Wall Type 2

5.2. BIM Case Study Results

The descriptions of the materials used in their creation are probably related to the usage of BIM to define materials. These suggestions may be supplemented with any other safety measures that may be required. It's possible that more details pertaining to the item will be added. All of the drawings and other documents created with Revit are included in the Building Information Model (BIM). Revit is a program that may be used for designing various objects. The majority of architects and engineers should find that the program's fundamentals are familiar to them because they have previously obtained familiarity with other software that is comparable to Revit. The struggle to integrate your 2D and 3D ideas will be aided by the building information modelling (BIM) tool Revit. A single model, from which several drawings can be made, is all that is required for this; possessing this model is sufficient. The biggest difference between the two is that Revit is primarily designed for use in the architecture sector. Revit is a program that may be used to create digital and physical models for a variety of tasks. The design of the program now known as Autodesk Revit was inspired by the Building Information Model (BIM). The solution is as simple as it sounds: Revit is BIM compatible.

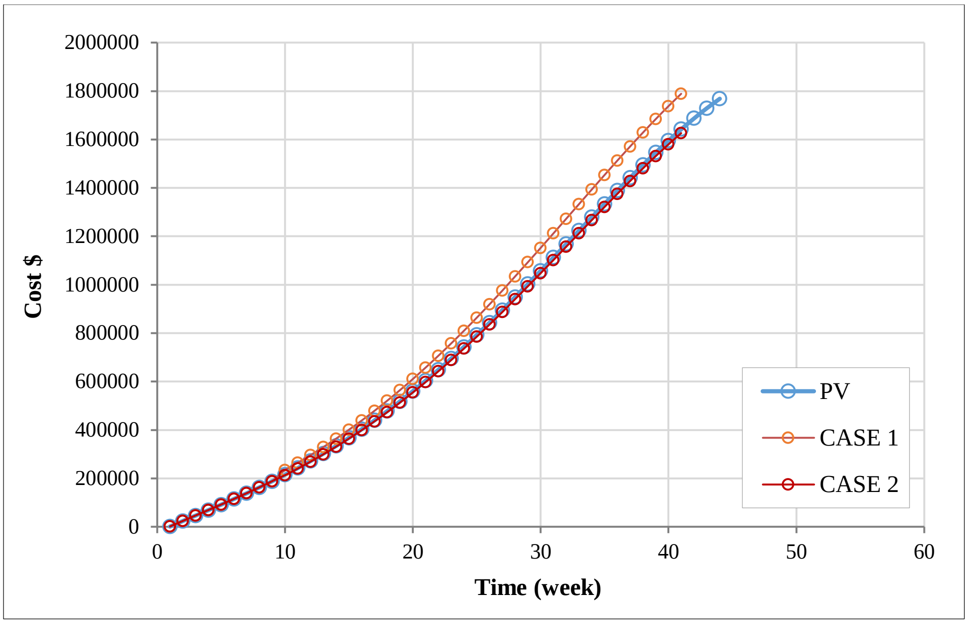

Figure 7. Results of the Case BIM Study

6. Discussion

(MCDM) has involved making optimal choices over optimal solution alternatives that are distinguished by some attributes that remain typically conflicting. Furthermore, it can be worked with mixed INFO as well as can enables both qualitative which is associated with quantitative INFO towards being incorporated [52, 53]. Moreover, Pavlovskis et al. [54], have observed the implementation of (MCDM), which is associated with (BIM) methods based on integrated information management, when evaluating old manufacturer construction building regeneration strategies with a focus on sustainability. In this research study, the researcher has addressed the issue of sustainability as well as MCDM and BIM efficiency in different building designs according to an optimal solution and decision-making according to some main factors through different methods. In the same way, different conventional approaches have been utilized to assist the main point of decision-making, which has included probability theory, fuzzy logic, as well as a utility function. Therefore, each of these methods has provided a way to incorporate the different criteria as well as select an optimal alternative solution. As declared by Bank et al. [55], BIM has been adopted in the low-carbon building selection towards improving efficiency based on optimal decision-making. Similarly, Chen et al. [56] have explored the BIM-integrated fuzzy (MCDM) model for selecting low-carbon building measures. Therefore, the analysis deduced from the utilized model has presented that both technologies have provided the same final ranking for low-carbon building measures. However, as announced by Carbonari et al. [51], which have developed a BIM-based decision support framework for the management of large building stocks by utilizing an approach based on a Bayesian Network (BN) the outcome has been reliable.

7. Conclusions

The study focuses on Iraq's building industry in particular. Detailed explanations of the measures used to attain this aim are provided after the list of actions. Through a study and conversations with industry experts, the most cost-effective features for building projects were selected.

- Choosing the right application for MCDM modeling and estimating cost as well as time were done using the MATLAB application;
- The validation phase shows that using the MCDM system's effective factors results in a meaningful cost model. An additional benefit of the MCDM technique was that it provided accurate project cost estimates;
- RII and MCDM cost models were required to be associated, and numerous aspects had to be considered;
- Building material quantities are computed using the BIM system, and a model is then used to calculate the cost and time variances based on priority variables;
- System review shows that the prediction results are very positive and the performance is very accurate.

8. Declarations

8.1. Author Contributions

Conceptualization, S.A. and S.N.; methodology, S.A.; software, S.A.; validation, S.A., S.N., and S.Al.; formal analysis, S.Al.; investigation, S.N.; resources, S.Al.; data curation, S.A.; writing—original draft preparation, S.Al.; writing—review and editing, S.Al.; visualization, S.A.; supervision, S.N.; project administration, S.A., S.N., and S.Al. All authors have read and agreed to the published version of the manuscript.

8.2. Data Availability Statement

The data presented in this study are available in the article.

8.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

8.4. Conflicts of Interest

The authors declare no conflict of interest.

9. References

[1] Wilson, M. T. (2004). Technology advancement in intelligent buildings: a through preplanning process pertaining to long-term maintainability. PhD Thesis, Georgia Institute of Technology, Atlanta, United States.

[2] Omar, O. (2018). Intelligent building, definitions, factors and evaluation criteria of selection. Alexandria Engineering Journal, 57(4), 2903–2910. doi:10.1016/j.aej.2018.07.004.

[3] Belani, D., Makwana, A. H., Pitroda, J., & Vyas, C. M. (2014). Intelligent building new era of today's world. Trends and Challenges of Civil Engineering in Today‟s Transforming World, March, 1–16. doi:10.13140/RG.2.1.1723.4965.

[4] Tih-Ju, C., An-Pi, C., Chao-Lung, H., & Jyh-Dong, L. (2014). Intelligent Green Buildings Project Scope Definition Using Project Definition Rating Index (PDRI). Procedia Economics and Finance, 18(14), 17–24. doi:10.1016/s2212-5671(14)00908-3.

[5] Froufe, M. M., Chinelli, C. K., Guedes, A. L. A., Haddad, A. N., Hammad, A. W. A., & Soares, C. A. P. (2020). Smart buildings: Systems and drivers. Buildings, 10(9), 1–20. doi:10.3390/buildings10090153.

[6] Moses, T., Heesom, D., & Oloke, D. (2015). The Impact of Building Information Modelling (BIM) for Contractor Costing in Offsite Construction Projects in the UK. Modular and Offsite Construction (MOC) Summit Proceedings, 331–338. doi:10.29173/mocs191.

[7] Aljohani, A. (2017). Construction Projects Cost Overrun: What Does the Literature Tell Us? International Journal of Innovation, Management and Technology, 8(2), 137–143. doi:10.18178/ijimt.2017.8.2.717.

[8] Silvius, A. J. G., & Schipper, R. P. J. (2014). Sustainability in Project Management Competencies: Analyzing the Competence Gap of Project Managers. Journal of Human Resource and Sustainability Studies, 02(02), 40–58. doi:10.4236/jhrss.2014.22005.

[9] Silvius, A. J. G., & Schipper, R. P. J. (2014). Sustainability in project management: A literature review and impact analysis. Social Business, 4(1), 63–96. doi:10.1362/204440814x13948909253866.

[10] Misopoulos, F., Michaelides, R., Salehuddin, M. A., Manthou, V., & Michaelides, Z. (2018). Addressing organisational pressures as drivers towards sustainability in manufacturing projects and project management methodologies. Sustainability (Switzerland), 10(6). doi:10.3390/su10062098.

[11] Padickakudy, M. (2019). Evaluating the Importance of Sustainability in the Project Management Process. Master Thesis, Coventry University, Coventry, United Kingdom.

[12] Silvius, G. (2016). Considering Sustainability in Project Management Processes. Project Management, 1927–1951. doi:10.4018/978-1-5225-0196-1.ch096.

[13] Marcelino-Sádaba, S., González-Jaen, L. F., & Pérez-Ezcurdia, A. (2015). Using project management as a way to sustainability. from a comprehensive review to a framework definition. Journal of Cleaner Production, 99, 1–16. doi:10.1016/j.jclepro.2015.03.020.

[14] Persson, U., Landin, A., Olander, S., & Persson, M. H. (2008). Sustainable construction management at a project level: A modified environmental management system structure. In World sustainable building conference. doi:10.13140/2.1.3223.5840.

[15] Salleh, R. (2009). Critical success factors of project management for Brunei construction projects: improving project performance. PhD Thesis, Queensland University of Technology, Brisbane City, Australia.

[16] de la Cruz López, M. P., Cartelle Barros, J. J., Del Caño Gochi, A., & Lara Coira, M. (2021). New approach for managing sustainability in projects. Sustainability (Switzerland), 13(13), 1–27. doi:10.3390/su13137037.

[17] Hui, S. C. M. (2004). Sustainable design and operation of construction site offices. Proceeding of the Shenyang-Hong Kong Joint Symposium 2004, 29-30 July, 2004, Shenyang, China.

[18] Pocock, J., Steckler, C., & Hanzalova, B. (2016). Improving Socially Sustainable Design and Construction in Developing Countries. Procedia Engineering, 145, 288–295. doi:10.1016/j.proeng.2016.04.076.

[19] Himanen, M. (2004). The intelligence of intelligent buildings. Intelligent Buildings: Design, Management and Operation, 25-52, Thomas Telford, London, united Kingdom.

[20] Wollos, K. G., Mui, K., Pershing, J., & Oetjen, E. (2011). Enhancing energy efficiency and green building design in section 202 and section 811 programs. Office of Policy Development and Research, US Department of Housing and Urban Development, Washington, United States.

[21] Górecki, J., & Núñez-Cacho, P. (2022). Decision-Making Problems in Construction Projects Executed under the Principles of Sustainable Development—Bridge Construction Case. Applied Sciences (Switzerland), 12(12), 6132. doi:10.3390/app12126132.

[22] Schreyer, M., Benning, P., Ryd, N., Tulke, J., Jaeger, J., & Brandt, T. (2010). A Smart Decision Making Framework for Building Information Models. European Commission, Brussels, Belgium.

[23] Mashayekhi, A., & Heravi, G. (2020). A decision-making framework opted for smart building's equipment based on energy consumption and cost trade-off using BIM and MIS. Journal of Building Engineering, 32, 101653. doi:10.1016/j.jobe.2020.101653.

[24] Vijayan, D. S., Rose, A. L., Arvindan, S., Revathy, J., & Amuthadevi, C. (2020). Automation systems in smart buildings: a review. Journal of Ambient Intelligence and Humanized Computing, 1–13. doi:10.1007/s12652-020-02666-9.

[25] Tabatabaee, S., Mahdiyar, A., & Ismail, S. (2021). Towards the success of Building Information Modelling implementation: A fuzzy-based MCDM risk assessment tool. Journal of Building Engineering, 43, 103117. doi:10.1016/j.jobe.2021.103117.

[26] Hsu, H. C., Chang, S., Chen, C. C., & Wu, I. C. (2020). Knowledge-based system for resolving design clashes in building information models. Automation in Construction, 110, 103001 103001. doi:10.1016/j.autcon.2019.103001.

[27] Muller, M. F., Esmanioto, F., Huber, N., Loures, E. R., & Canciglieri, O. (2019). A systematic literature review of interoperability in the green Building Information Modeling lifecycle. Journal of Cleaner Production, 223, 397–412. doi:10.1016/j.jclepro.2019.03.114.

[28] Fu, F. (2018). Design and analysis of tall and complex structures. Butterworth-Heinemann, Oxford, United Kingdom. doi:10.1016/c2015-0-06071-3.

[29] Heaton, J., Parlikad, A. K., & Schooling, J. (2019). A Building Information Modelling approach to the alignment of organisational objectives to Asset Information Requirements. Automation in Construction, 104, 14–26. doi:10.1016/j.autcon.2019.03.022.

[30] Changsaar, C., Abidin, N. I., Khoso, A. R., Luenhui, L., Yaoli, X., & Hunchuen, G. (2022). Optimising energy performance of an Eco-Home using Building Information Modelling (BIM). Innovative Infrastructure Solutions, 7(2), 1-14. doi:10.1007/s41062-022-00747-6.

[31] Yin, X., Liu, H., Chen, Y., & Al-Hussein, M. (2019). Building information modelling for off-site construction: Review and future directions. Automation in Construction, 101, 72–91. doi:10.1016/j.autcon.2019.01.010.

[32] Charef, R., & Emmitt, S. (2021). Uses of building information modelling for overcoming barriers to a circular economy. Journal of Cleaner Production, 285, 124854. doi:10.1016/j.jclepro.2020.124854.

[33] Seyis, S. (2020). Mixed method review for integrating building information modeling and life-cycle assessments. Building and Environment, 173, 106703. doi:10.1016/j.buildenv.2020.106703.

[34] Sadeghifam, A. N., Meynagh, M. M., Tabatabaee, S., Mahdiyar, A., Memari, A., & Ismail, S. (2019). Assessment of the building components in the energy efficient design of tropical residential buildings: An application of BIM and statistical Taguchi method. Energy, 188, 116080. doi:10.1016/j.energy.2019.116080.

[35] Zolfani, H. S., Pourhossein, M., Yazdani, M., & Zavadskas, E. K. (2018). Evaluating construction projects of hotels based on environmental sustainability with MCDM framework. Alexandria Engineering Journal, 57(1), 357–365. doi:10.1016/j.aej.2016.11.002.

[36] Ghosh, S., & Das, A. (2019). Urban expansion induced vulnerability assessment of East Kolkata Wetland using Fuzzy MCDM method. Remote Sensing Applications: Society and Environment, 13, 191–203. doi:10.1016/j.rsase.2018.10.014.

[37] Zhao, S., Zhang, P., & Li, W. (2021). A study on evaluation of influencing factors for sustainable development of smart construction enterprises: Case study from china. Buildings, 11(6), 221. doi:10.3390/buildings11060221.

[38] Harmon, E. Y., & Gillen, R. W. (2022). Comparison of the Brief Interview of Mental Status (BIMS) and Montreal Cognitive Assessment (MoCA) for Identifying Cognitive Impairments and Predicting Rehabilitation Outcomes in an Inpatient Rehabilitation Facility. PM&R. doi:10.1002/pmrj.12908.

[39] Dias, P. D. R., & Ergan, S. (2020). Owner requirements in as-built BIM deliverables and a system architecture for FM-specific BIM representation. Canadian Journal of Civil Engineering, 47(2), 215–227. doi:10.1139/cjce-2018-0703.

[40] Shrivastava, H., & Akhtar, S. (2019). Development of a building information modeling tool for green sustainable building design: A review. AIP Conference Proceedings, 2158(1), 20026. doi:10.1063/1.5127150.

[41] Zahedi, A., Abualdenien, J., Petzold, F., & Borrmann, A. (2022). Bim-Based Design Decisions Documentation Using Design Episodes, Explanation Tags, and Constraints. Journal of Information Technology in Construction, 27, 756–780. doi:10.36680/j.itcon.2022.037.

[42] Jang, R., & Collinge, W. (2020). Improving BIM asset and facilities management processes: A Mechanical and Electrical (M&E) contractor perspective. Journal of Building Engineering, 32, 101540. doi:10.1016/j.jobe.2020.101540.

[43] Ma, G., & Wu, Z. (2020). BIM-based building fire emergency management: Combining building users' behavior decisions. Automation in Construction, 109, 102975. doi:10.1016/j.autcon.2019.102975.

[44] Xu, J., Shi, Y., Xie, Y., & Zhao, S. (2019). A BIM-Based construction and demolition waste information management system for greenhouse gas quantification and reduction. Journal of Cleaner Production, 229, 308–324. doi:10.1016/j.jclepro.2019.04.158.

[45] Wu, Z., & Ma, G. (2022). NLP-Based Approach for Automated Safety Requirements Information Retrieval from Project Documents. SSRN, 4242757.

[46] Onososen, A., & Musonda, I. (2022). Barriers to BIM-Based Life Cycle Sustainability Assessment for Buildings: An Interpretive Structural Modelling Approach. Buildings, 12(3), 324. doi:10.3390/buildings12030324.

[47] Huzaimi Abd Jamil, A., & Syazli Fathi, M. (2019). Contractual issues for Building Information Modelling (BIM)-based construction projects: An exploratory case study. IOP Conference Series: Materials Science and Engineering, 513(1), 12035. doi:10.1088/1757-899X/513/1/012035.

[48] Schiavi, B., Havard, V., Beddiar, K., & Baudry, D. (2022). BIM data flow architecture with AR/VR technologies: Use cases in architecture, engineering and construction. Automation in Construction, 134, 104054. doi:10.1016/j.autcon.2021.104054.

[49] Tan, T., Mills, G., Papadonikolaki, E., & Liu, Z. (2021). Combining multi-criteria decision making (MCDM) methods with building information modelling (BIM): A review. Automation in Construction, 121, 103451. doi:10.1016/j.autcon.2020.103451.

[50] Haruna, A., Shafiq, N., & Montasir, O. A. (2021). Building information modelling application for developing sustainable building (Multi criteria decision making approach). Ain Shams Engineering Journal, 12(1), 293–302. doi:10.1016/j.asej.2020.06.006.

[51] Carbonari, A., Corneli, A., Di Giuda, G., Ridolfi, L., & Villa, V. (2018). BIM-Based Decision Support System for the Mangement of Large Building Stocks. Proceedings of the 35th International Symposium on Automation and Robotics in Construction (ISARC). doi:10.22260/isarc2018/0049.

[52] Chen, L., & Pan, W. (2015). A BIM-integrated Fuzzy Multi-criteria Decision Making Model for Selecting Low-Carbon Building Measures. Procedia Engineering, 118, 606–613. doi:10.1016/j.proeng.2015.08.490.

[53] Mendoza, G.A., & Prabhu, R. (2000). Multiple criteria decision making approaches to assessing forest sustainability using criteria and indicators: A case study. Forest Ecology and Management, 131(1–3), 107–126. doi:10.1016/S0378-1127(99)00204-2.

[54] Pavlovskis, M., Antucheviciene, J., & Migilinskas, D. (2016). Application of MCDM and BIM for evaluation of asset redevelopment solutions. Studies in Informatics and Control, 25(3), 293–302. doi:10.24846/v25i3y201603.

[55] Bank, L. C., McCarthy, M., Thompson, B. P., & Menassa, C. C. (2010). Integrating BIM with system dynamics as a decision-making framework for sustainable building design and operation. Proceedings of the first international conference on sustainable urbanization (ICSU), 15-17 December, 2010, Hong Kong, China.

[56] Chen, G., Yan, Z., Chen, J., & Li, Q. (2022). Building information modeling (BIM) outsourcing decisions of contractors in the construction industry: Constructing and validating a conceptual model. Developments in the Built Environment, 12, 100090. doi:10.1016/j.dibe.2022.100090.

Appendix I

Table A-1. An external questionnaire designs

Factors	Opportunity	Threat
Politics	1. How beneficial the preferential policies for enterprise residences remain towards the construction building on a competitive advantage 18. What development opportunities offered via the "new infrastructure" policies 19. What development opportunities offered via the "smart city" as well as "smart building" policies 20. What development opportunities offered via national and local smart building development plans	27. How detrimental macro policy volatility and universality remain towards the construction building on a competitive advantage
Economy	21. How beneficial the prospect of smart building development remains towards the construction building on a competitive advantage 22. How beneficial the rate of market demand growth remains towards the construction building on a competitive advantage	29. How detrimental the macro-economic situation remains to the construction of competitive advantage 30. How detrimental the low level of economic development of the enterprise premises remains towards the construction of competitive advantage
Society	24. How beneficial social recognition of smart buildings remains towards the construction building on a competitive advantage	32. How detrimental the outbreak towards the construction building based on competitive advantage of a competitive advantage
Techy	25. How beneficial the development level of smart building techy remains towards the construction of a competitive advantage 26. How beneficial the level of smart construction processes remains towards the construction building of a competitive advantage	35. How detrimental the low level of product standardization remains towards the construction of a competitive advantage
Entrant		28. How detrimental the weakened entry barriers for potential entrants remain towards the construction building based on a competitive advantage
Supplier	23. How detrimental the supplier dependence remains to the construction building based on a competitive advantage	
Customer	2. How beneficial government purchases remain towards the construction building based on a competitive advantage	33. How detrimental difficulties in expanding new customers remain the construction building on a competitive advantage 34. How detrimental the increased bargaining power of major customers remains the construction building on a competitive advantage
Competitor		31. How detrimental the competition intensity of enterprises in the industry towards the construction building on a competitive advantage
Materials of building		17. How detrimental the substitutes remain the construction building on a competitive advantage

Table A-2. An internal questionnaire designs

Factors	Strength	Weakness
Construction building qualification		10. How detrimental architectural building qualifications remains towards the construction based on a competitive advantage
Human resources	15. How detrimental construction building insufficient talent pool remains towards the construction building based on a competitive advantage	
Brand and marketing	5. How beneficial construction building based on manufacturing social as well as business relationships remain the construction of its competitive advantage	13. How detrimental construction building based on manufacturing position remains the construction building of its competitive advantage 14. How detrimental construction building based on manufacturing brand reputation remains the construction of its competitive advantage
Techy	9. How beneficial construction building based on manufacturing core techies remain the construction of its competitive advantage	6. How detrimental construction building based on manufacturing weak reserves of patents and software copyrights are to the construction building based on manufacturing competitive advantage

Finance		12. How detrimental construction building based on manufacturing capital scale is detrimental towards the construction remains a competitive advantage
Marketing	4. How beneficial construction building based on manufacturing business diversification remains the construction of its competitive advantage 6. How beneficial the customer service quality of construction building based on manufacturing remains the construction building based on manufacturing competitive advantage	
Research as well as development	8. How beneficial construction building based on manufacturing remains techy and product innovation capabilities remain towards the construction building based on a competitive advantage	
Organization	3. How beneficial construction building based on manufacturing remains relationship with its parent company remains the construction building based on manufacturing remains competitive advantage	11. How detrimental construction building based on manufacturing remains imperfect management system remains the construction building based on manufacturing remains competitive advantage
Culture		7. How detrimental construction building based on manufacturing remains weak cultural attractiveness remains the construction building based on manufacturing remains competitive advantage