JOIV : Int. J. Inform. Visualization, 8(1) - March 2024 289-298

INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

journal homepage : www.joiv.org/index.php/joiv

Modeling, Implementing, and Evaluating Decision Support System Used for Choosing the Best HVAC System in Buildings: A Case Study in Iraq

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***Abstract*— The life cycle cost of a building is affected by the heating, ventilation, and air conditioning (HVAC) system chosen by the Life Cycle Costs (LCC). Quality, constructability, appearance of the structure's interior and exterior, HVAC size and weight, and LCC are some of the criteria influencing the choice. Methods: To monitor a project's progress based on energy savings, standard measures such as cost variance (CV) and schedule variation have used an idea when tracking the performance of intelligent buildings. Also, as described in the article, this research compared the decision-making limits of Building Information Modelling (BIM) and (MCDM). Analysis: The conventional approach cannot reveal information regarding divergence from the expected level of performance. Based on the outcomes of the construction cost variables, the key finding was the observation of 12 efficient elements. Finding and Novelty: According to the R, a building's most valuable features are its (Energy Saving Features, Warranties, Budget, Protect Your Unit, SEER Ratings, and Home Square Footage). The findings of Actual value (AV) and planned value (PV) were significantly different, as noted by the Multi-Criteria Decision Maker (MCDM). The new method also makes it possible to track project costs and timetables more accurately. The paper will characterize the HVAC Decision Support System's architecture (HVACDSS). Also, a case study of action modeling is provided, and the preliminary findings are addressed. Six criteria characteristics are used by the HVACDSS technique by an analysis of building construction conducted using the WEKA mining tool (decision tree).**

***Keywords*— Data mining; multi-criteria decision maker; decision support system; building information modelling; HVACDSS.**

Manuscript received 4 Jul. 2023; revised 3 Nov. 2023; accepted 16 Dec. 2023. Date of publication 31 Mar. 2024.

I. Introduction

The building management must participate in a decision support system (DSS) to decide whether to carry out the advised action. The request for human involvement may seem like a device performing less well than an automated one. Still, it increases the building manager's awareness of the behavior of the building and may encourage the adoption of more successful actions [1]. Using the professional guidance provided by the DSS system based on gathered data, the building inspector can critically assess the trade-offs between energy use, comfort, cost, and performance as they become essential components of building management. Over the past few years, some decision support systems for managing energy consumption in buildings have been created [2].

The management of hybrid renewable energy systems was founded by [3], and subsequent publications concentrated on thermal mass control techniques. A study by [4] describes a DSS that uses intelligent criteria to ensure acceptable convenience and energy savings. A few decision-support systems have also recently been developed for a group of buildings instead of a single structure [5].

The second-largest industry in the world, construction manufacturing, has undergone a successful transformation during the past ten years. Construction is a critical problem since it is an industry with high capital intensity and variable turnover over time [6]. Due to the building industry's significant environmental impact, sustainability has permeated many aspects of society, particularly in the construction sector. Furthermore, how well a project is carried out ultimately determines its success—moreover, some prior research. A study by [7] looked at the efficiency of construction projects. Its performance has been evaluated based on the project's time, cost, and deliverables factors. Due to these factors, the project is of a high caliber, receives the backing of all its stakeholders, and is carried out successfully and efficiently [8].

A key objective in creating an ideal Air conditioning, ventilation, and heating (HVAC) system is to provide people with a comfortable atmosphere while using less energy [9]. However, the amount of heating and cooling required often varies depending on the outside climate as well as the needs of the users. To continue a reasonable quality of air and happiness under varying conditions, Systems for controlling HVAC must be used. Furthermore, if the system is maintained correctly, power consumption can be significantly reduced [10].

The original modeling technique used changeable time as an autonomous parameter to simulate physical situations. Most of the earlier simulation techniques were based on white-box or mathematics (physical) models, which are chosen over different models like the black-box and the gray-box systems because they are accessible for assessment even though they are more sophisticated [11].

The HVAC System's mathematical model. The lumped and dispersed parameters are two kinds of white boxes or mathematical models. The lumped parameter model's key benefit is that it is significantly more straightforward to solve than the scattered model. Mathematical models are particularly prevalent for describing signal processing in HVAC systems. The signals produced by the processes are built under physical and chemical conservation rules, such as the balance of components, mass, momentum, and energy [12] [13].

Many mathematical equations visibly reflect the relationship between the input and the output using these rules, which explain the relationship. Furthermore, by outlining the significant connections between the HVAC system's input and output, the mathematical model is a helpful tool for comprehending how the indoor environment behaves. In general, the modeling of HVAC systems produces models with very high order, pure lag time, unclear disturbance variables, high thermal inertia, and dynamic behavior [14].

Under the design program, the Developed Design coordinates structural design suggestions, building services systems, general specifications, financial data, and method statements (HVACDSS). The design process covered in the first six phases shows the selection of the primary design components; considering the client's requirements and the project's objectives, the planning and brief include HVAC systems. This initial choice is subsequently improved upon and periodically assessed considering project developments through the end of "Developed Design." The initial choices may be modified during this decision review process by the project's requirements and limits (HVACDSS) [15], [16].

The building manager must intervene in a DSS and decide whether to carry out the advised action. The request for human involvement may seem less effective than an automation system. Still, it increases the building manager's awareness of the behavior of the building and may encourage the adoption of more successful activities. Using the professional guidance provided by the DSS system based on gathered data, the building inspector can critically assess the trade-offs between energy use, comfort, cost, and performance as they become essential components of building management [17].

The following is a summary of this work's main contributions:

- Create a multi-criteria choice based on the chosen assessment standards for the HVAC System.
- Proposes a new way of assessment and decision-making for picking the best HVAC choice method based on Data mining algorithms (WEKA data mining tool and Decision Tree algorithm)
- Using the six primary classifications, assess the suggested decision-making methodology dataset of HVAC Systems for buildings.

The following is how this paper is structured: Section 2 Discuss the Material and Method. Section 3 describes the Results and Discussion of HVACDSS. Section 4 illustrates conclusions.

II. Material and Method

HVAC system scientists have used building and AHU modeling for years to help plan, construct, and operate HVAC systems. The building and HVAC system equipment sectors have never seen anything like the heat conduction equation model developed by [18]. The mathematical representation of intermittent circulation of heat through blocks, transparent material, and the temperature transmission between interior surfaces and the interior air was much enhanced by earlier simulations work in the design of buildings by [19] using the response factor approach. The invention of thermal balance processes made it possible to treat loads on buildings more rigorously [20].

A. The Mathematical Model of HVACDSS

Mathematical models have been widely used for some purposes, including fault diagnosis and inadequacy detection, control, prediction, and operator training, in sectors as diverse as engineering, economics, medicine, ecology, and agriculture. The building model is the most challenging model element in modeling HVAC systems. This is because, regardless of the building style, components such as roofs, walls, floor slabs, windows, and exterior shading must be depicted for building reasons. Moreover, internal loads like activity, tenant count, and heat gain from lighting must be modeled [21] [22].

B. Decision-Making for HVAC Systems Selection

The Smart (DMF) aims to analyze design options that a human team of developers has already developed, which contradicts this forward-reasoning technique Fig 1. Also available at the start of the process is the conventional, primarily in the form of architectural building information.

Building Information Models (BIMs) are initially linked to the relevant analysis data during the procedure. Models (BIMs) for problem-solving in decision-making are then used, along with information pertinent to analysis. As a result of the resolution of various issues, the design possibilities are nonetheless constrained in the context of a design competition [23].

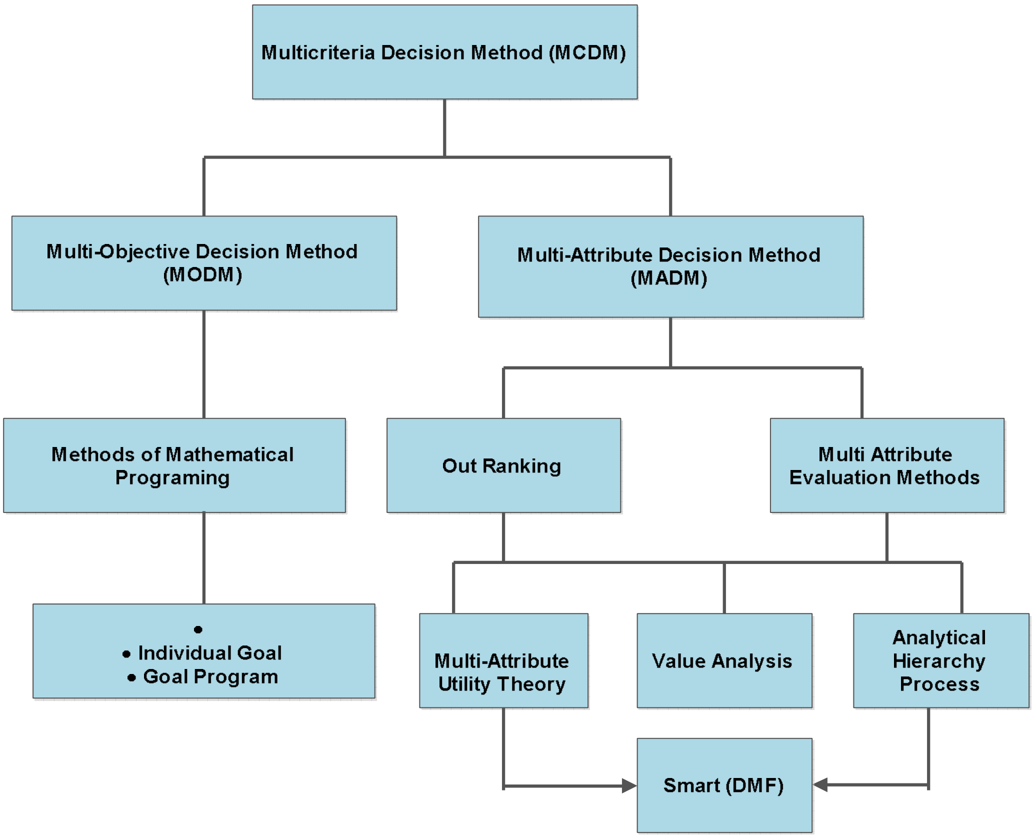

Fig. 1 Multi-Criteria Decision Methods

C. Purpose and General Description of the HVACDSS

The HVACDSS is a tool designed to help city officials make decisions. It is directed towards them. Using a set of suggested measures that help manage the criteria while keeping a sufficient level of comfort, the HVACDSS aims to choose an appropriate HVAC system as the energy use, budget, protect your unit, SEER Ratings, home square footage, and warranty emissions in public buildings. Primarily applicable activities are recommended. Controlling the utilization of buildings and administrating the HVAC technical systems are used to categorize the actions [24]. The HVACDSS bases the recommended course of action on logic inference rules and prediction models. The building may be divided according to several criteria following this technical standard (Table 1).

D. Architecture of the HVACDSS

The HVACDSS is fed with constructing and context data, both static and dynamic. Sensors mainly obtain dynamic data, whereas static data comprises the structure's features and technological systems (either already existing in the BEMS or newly installed). The HVACDSS can interface with some currently installed construction monitoring systems [25]. Raw data are gathered and placed through pre-processing modules for each monitored variable, as shown in Figure 2. The HVACDSS user's first outputs, as shown in the initial results, are the detected indications of the HVACDSS. Before taking the advised actions, they are intended to quantify the building's performance. The DSS supports the creation of artificial indices using data mining techniques [26].

The first ones originate directly from forecasting components. In contrast, the latter results from data mining techniques used in elaboration and an intelligent rules procedure used in data correlation. They are founded on a series of logical assertions, including premises (including the result hypothetical) and parameters. A valid argument is one in which the validity of every premise entails the truth of the conclusion. The data mining process is anticipated to be fed by the actions resulting from procedures to interpret inferences with the other variables [27].

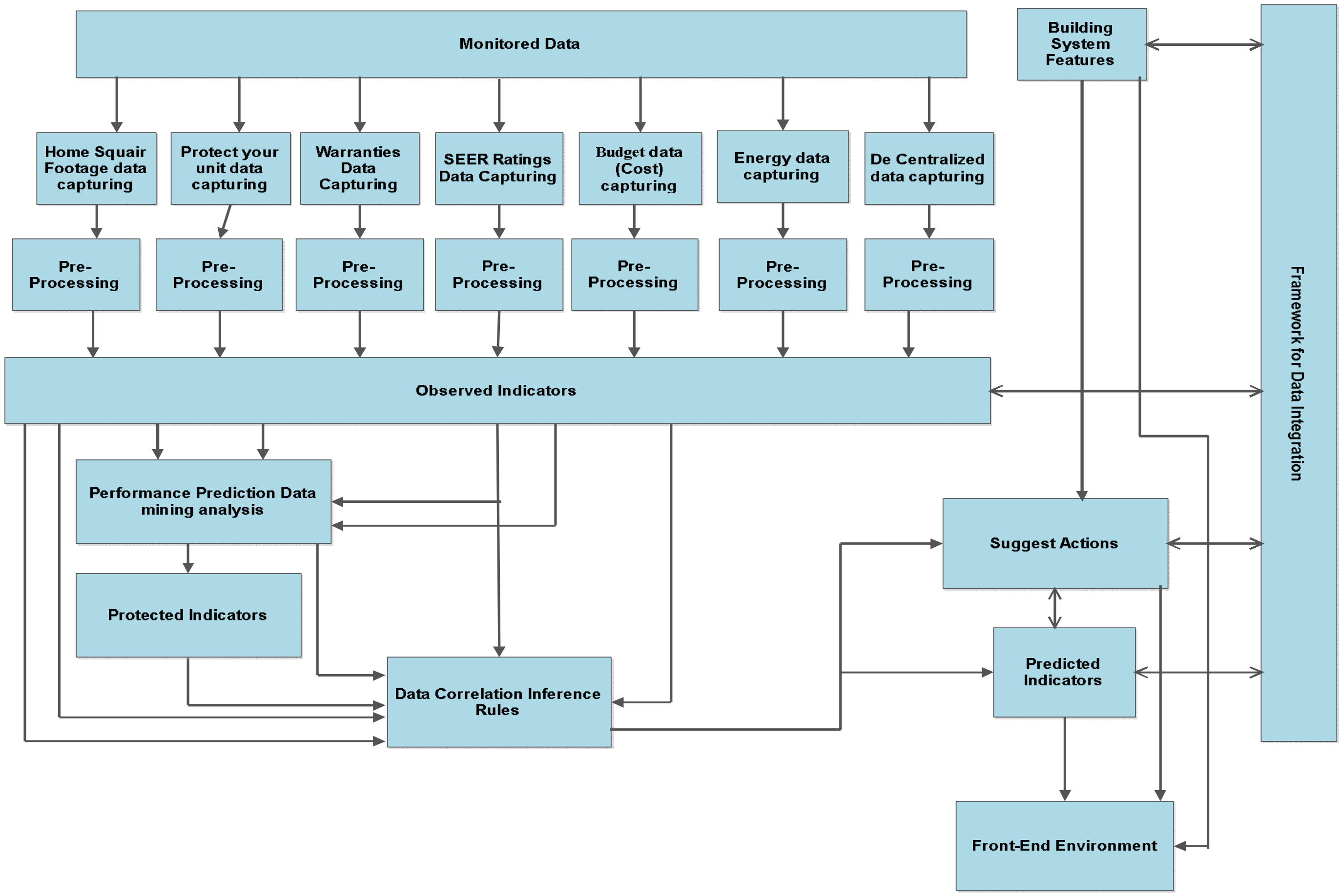

Fig. 2 The workflow of HVACDSS

Structure and design of technology for information systems: the overall structure of the HVACDSS system is depicted in Figure 2, where both the user interface and analytical components and the data gathering modules are represented. The HVACDSS receives and saves all the information gathered by the capture modules in a semantic data store [28].

TABLE I
THE CRITERIA OF HVAC [29]

No.	Criteria of HVAC Systems Types	Energy Saving Features	Warranties	Budget	Protect Your Unit	SEER Ratings	Home Square Footage
1	Central Air Conditioners	Energy use CO2 emissions Thermal comfort	Ease of maintenance occupied space	Operating cost	Perimeter partition flexibility	Noise level of quietness	Required lifetime ceiling space
2	Mini-Split Air Conditioners	convenient for managing air quality inside	Low upkeep in the Implementation challenges	Maintenance cost	Module integration	Individual zone control	Required space
3	Window Units	Available energy sources	Concentration	Insurance cost	User satisfaction	Temperature control	Kind of building Schedule of operations
4	Portable Units	Energy source flexibility	Total heat efficiency	Investment cost	Vendor viability and ongoing support availability	Humidity control	Building size
5	Hybrid Air Conditioner	Implementation difficulties	Reliability	The cheapest choice is a window or portable air conditioner that cools a single room. Of course, this is the least efficient choice as well. It won't do much more than adequately cool the room, akin to a good room fan.	Level of compatibility with perhaps higher load needs	Cooling density	Indoor/outdoor design conditions

No.	Criteria of HVAC Systems Types	Energy Saving Features	Warranties	Budget	Protect Your Unit	SEER Ratings	Home Square Footage
6	Geothermal Heating and Cooling	System complexity	Maturity	A ductless system might be an excellent financial choice if you need to chill a few rooms. If you install a ductless system throughout your house, costs can soon rise.	Efficiency	Cooling capacity	Your home has central air conditioners ranging from 1.5 tons to 5 tons.
7	Wall-Mounted AC Units	Simplicity Time required for repair	Disruption to occupants during maintenance	While a central air conditioner is more expensive than a portable or window unit, it is also more efficient and will last longer.	Economic, social footprint	Refrigeration coefficient	Typically, a 1,600-square-foot home needs a 3-ton air conditioner
8	Floor Mounted Air Conditioners	Lead time	Floor space encroachment	A geothermal unit is the most expensive option, but it might last you almost your entire lifetime.	Economic uncertainty	seasonal energy efficiency ratio	A light commercial HVAC unit usually is one that weighs above 5 tons.
9	Spot Coolers for Boats, Ships	Future flexibility	Loss of usable floor space	Fresh air	Contribution to net zero energy	estimate of the energy required to cool a home with an air conditioner	
10	Ceiling Type of Air Conditioner	Variable speed motors	cover the cost of labor	Clean lines	Water consumption	The SEER range for central air conditioners is 13 to 24.	
11	Stand-Alone AC Units	Automatic fan delay switch	cover labor-related expenses during the first year	LCC	Buy the best unit for your space	Those who reside in hot, humid conditions choose air conditioners with a minimum SEER of 15	
12	Split-System AC units	Thermal expansion valves			Have it professionally installed	Changing to a SEER 15 model from an older system with a SEER of 10 could significantly lower your air conditioner's energy costs.	

E. Important Index in HVACDSS

An acceptable cost barrier must be established early in the project to make the best decisions practical. The project's cost policy must specify the acceptable cost level. The degree of cost depends on how much a decision-maker is ready to accept a particular cost [30].

$$R=\Sigma(PiUi)/Nn \tag{1}$$

where N is the total number of survey respondents, R is the relative importance index, Pi is each respondent's assessment of the cost, Ui is the total number of respondents who gave each cost the same weight or rating, and n is the most incredible score that may be provided for each cost.

F. MCDM Design

The stated purpose is the hierarchy's top and second levels, although it comprises the six pertinent project selection criteria. While assessing the hierarchy depicted in Figure 3, there are numerous more cultural factors to consider.

G. Collecting Data

The responder is questioned for as much information as is practical in this type of research. Compared to less personal surveys, this research process provides the most precise and comprehensive knowledge about the research. Although data collection is not possible with this approach, researchers can nevertheless assess the preferences and goals of the interviewee. The investigator took notes as the researcher asked questions.

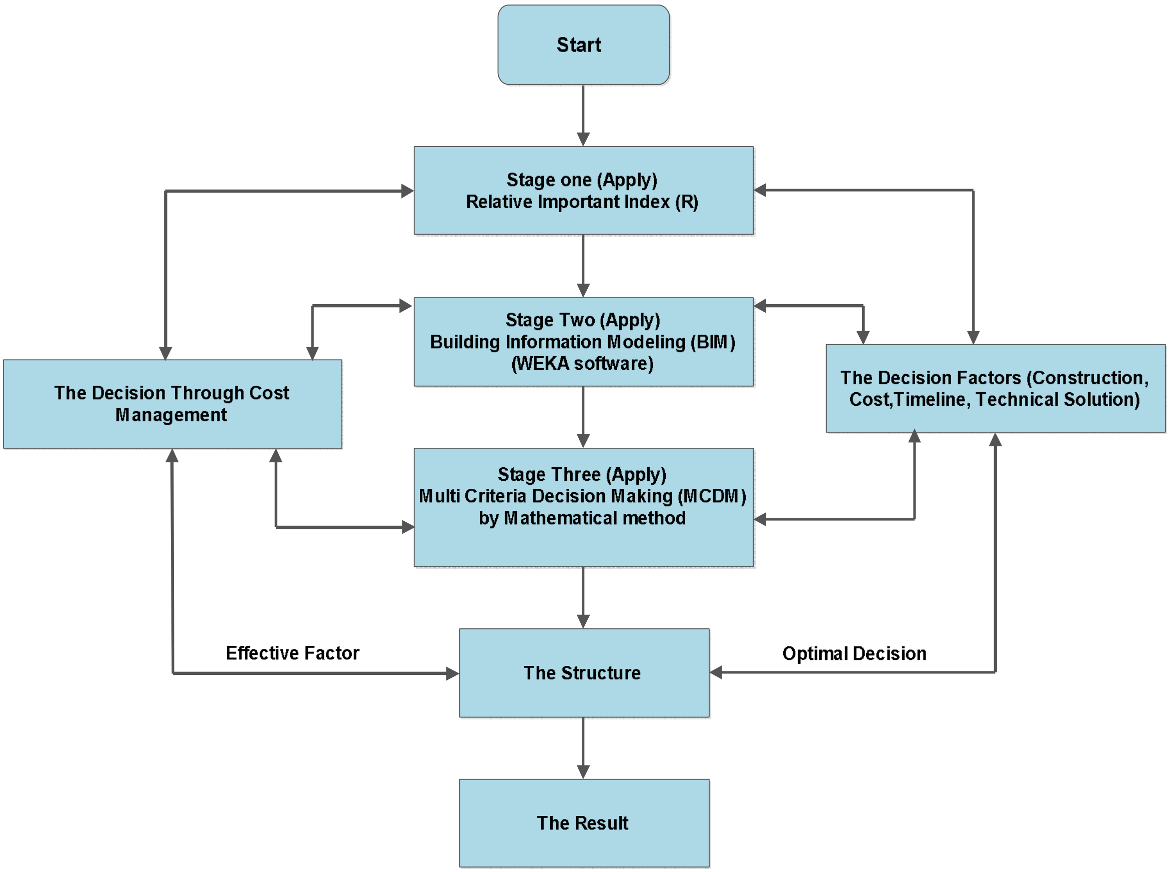

Fig. 3 The research method

III. Results and Discussion

Considering how well monitoring and analysis work could decide a project's success or failure, many academics are working to improve this process. Cost variance (CV) and schedule variation are typical measures for gauging project success using conventional methods (SV). Conversely, the traditional approach cannot offer departure details from anticipated effectiveness. Project expenses and timeframes may be tracked more precisely with the current system. The information from a genuine construction project served as the basis for the performance rating in this study. Actual data should be used to verify that the PV indexes are standard. For illustration, construction control performance monitoring utilizes process models or standard operating data. A primary statistical analysis was given to calculate the project's predicted performance. The ability to supervise construction projects makes the existing system better.

The results of the relative index investigation are shown in the tables below (Table 2), one for each category. According to these rankings, risks scored highly in examining the consequences of cost overruns in building projects.

TABLE II
The Main Factors in HVAC Suitable System Types

No	Factor	R-Value	No	Factor	R-Value
1	Central Air Conditioners	0.817	7	Wall-Mounted AC Units	0.528
2	Mini-Split Air Conditioners	0.673	8	Floor Mounted Air Conditioners	0.568
3	Window Units	0.723	9	Spot Coolers for Boats, Ships	0.584
4	Portable Units	0.747	10	Ceiling Type of Air Conditioner	0.594
5	Hybrid Air Conditioner	0.739	11	Stand-Alone AC Units	0.576
6	Geothermal Heating and Cooling	0.534	12	Split-System AC units	0.683

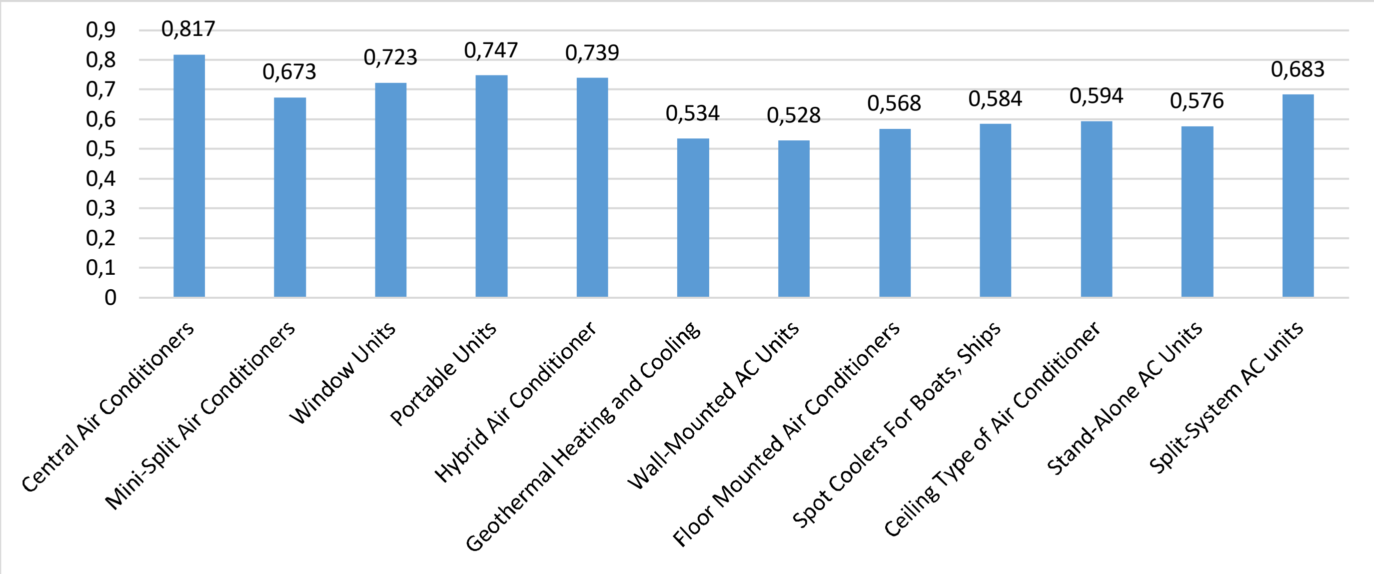

Fig. 4 The variations in the factors' R Rank results

The outcomes of interpreting the fully customizable for each category have been compiled and displayed in Table 3. According to these rankings, the HVAC system types included in Table 1 were highly regarded in evaluating the costs associated with building efforts conducted on their effects Fig 4.

TABLE III
THE MAIN FACTORS IN HVAC SUITABLE SYSTEM TYPES IN THE PRESENT STUDY

No.	Factor	R-Value	Rank
1	Energy Saving Features	0.737	1
2	Warranties	0.682	3
3	Budget	0.664	5
4	Protect Your Unit	0.642	6
5	SEER Ratings	0.676	4
6	Home Square Footage	0.721	2

The decision to install an energy-efficient HVAC system in the building has the most impact. Using energy analysis, a designer can evaluate the quantity of energy access to various building design components. While creating new structures or renovating old ones, it is crucial to consider the present and the future. Zoning regulations often require shadowing a mentor to demonstrate how a new construction would impact the current circumstance. Each project had a data sheet to collect all the information needed. We examined most Iraqi colleges and universities that provide building engineering degrees.

The amount of concrete and reinforcing steel that must be utilized, which depends on the building's intended function, also influences the project's final cost. For instance, table 4 has "University, Hospital, Mall, Hotel," and "School." The construction completion method can significantly affect its price. Tiles are a frequent and essential architectural component in many buildings in Iraq, including homes and schools.

The fundamental benefit of decision-making using many criteria (MCDM) is its ability to minimize and confirm expert disagreement. The initial stage is identifying significant value differences; the various cost components can then be ranked in order of relevance. This conclusion, shown in Table 5, was reached after multiple surveys and conversations with Iraqi engineers and management.

TABLE IV
THE RESULTS OF R VALUE FOR COMPONENTS OF VARIOUS CONSTRUCTION KINDS

No.	Factor	R-Value				
		University	Hospital	Mall	Hotel	School
1	Energy Saving Features	0.684	0.672	0.816	0.686	0.588
2	Warranties	0.724	0.514	0.712	0.826	0.727
3	Budget	0.676	0.649	0.648	0.646	0.694
4	Protect Your Unit	0.639	0.736	0.688	0.719	0.681
5	SEER Ratings	0.618	0.813	0.418	0.674	0.646
6	Home Square Footage	0.658	0.682	0.718	0.715	0.828

TABLE V
THE WEIGHT FACTORS OF MCDM FOR DIFFERENT TYPES OF BUILDING

No.	Factor	University	Hospital	Mall	Hotel	School
1	Energy Saving Features	0.12	0.11	0.13	0.11	0.11
2	Warranties	0.16	0.17	0.16	0.15	0.16
3	Budget	0.15	0.14	0.15	0.13	0.15
4	Protect Your Unit	0.11	0.12	0.10	0.11	0.12
5	SEER Ratings	0.10	0.10	0.11	0.11	0.10
6	Home Square Footage	0.13	0.14	0.13	0.13	0.15

Table 6 and an external questionnaire design. a format for an internal questionnaire. Throughout the comparison process, Decision makers rely on their assessments of the potential value of the various factors. The problem is identified, and the degree of expertise needed to solve it is determined as the first stage in the MCDM process. Considering the comparisons' outcomes, the priorities at the level below were weighted. For this, the priorities that emerged from the comparisons were used. The researcher then employed the MCDM approach to ascertain what impact that cost had on the total project expenses. Finding a way to manage the massive volumes of data involved in this endeavor is likely the most challenging hurdle. The results of the MCDM study will be presented in the sections that follow this one. The research's findings about every MCDM result from the case study are reported in Tables (5,6). (Figure 5,6). In addition, the selected expenses have been acknowledged based on their cost-effectiveness as being of considerable priority in the study of project costs; the discoveries determined by the outcomes of this evaluation have been provided in the investigation's conclusions.

TABLE VI
THE RESULTS OF MCDM FOR CASE STUDY

No.	Factor	Energy Saving Features	Warranties	Budget	Protect Your Unit	SEER Ratings	Home Square Footage	MCDE
1	Central Air Conditioners	4	5	14	3	15	300	0.9435644
2	Mini-Split Air Conditioners	4	5	13	3	15	300	0.9634213
3	Window Units	4	5	11	3	15	300	0.8645217
4	Portable Units	4	5	9	3	15	300	0.9743218
5	Hybrid Air Conditioner	4	5	8	3	15	300	0.7674631
6	Geothermal Heating and Cooling	4	5	12	3	15	300	0.9832468
7	Wall-Mounted AC Units	4	5	10	3	15	300	0.8468735
8	Floor Mounted Air Conditioners	4	5	16	3	15	300	0.8743278
9	Spot Coolers For Boats, Ships	4	5	7	3	15	300	0.9436577
10	Ceiling Type of Air Conditioner	4	5	12	3	15	300	0.8924846
11	Stand-Alone AC Units	4	5	10	3	15	300	0.9727543
12	Split-System AC units	4	5	9	3	15	300	0.7654321

The intended value is the allowable spending cap that you assign to a specific work breakdown framework for activities (WBS). There isn't a management reserve in this budget. You will gradually spread the value that was planned across the course of the project. The budget at completion (BAC), the performance measurement baseline (PMB), or, more frequently, the anticipated work's estimated cost are other names for the total PV (BCWS). You may calculate the Intended Value using the relation (PV).

$$PV = BAC \times Planned\ \%\ of\ complete \quad (2)$$

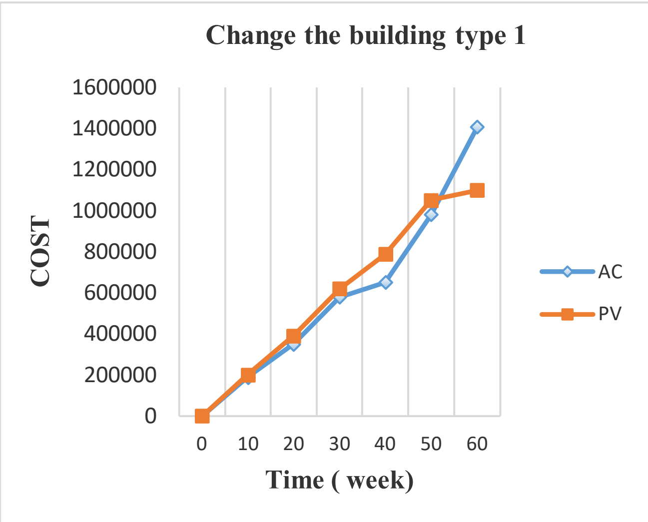

Fig. 5 The difference in (PV/AC) Result of MCDM (Building type 1)

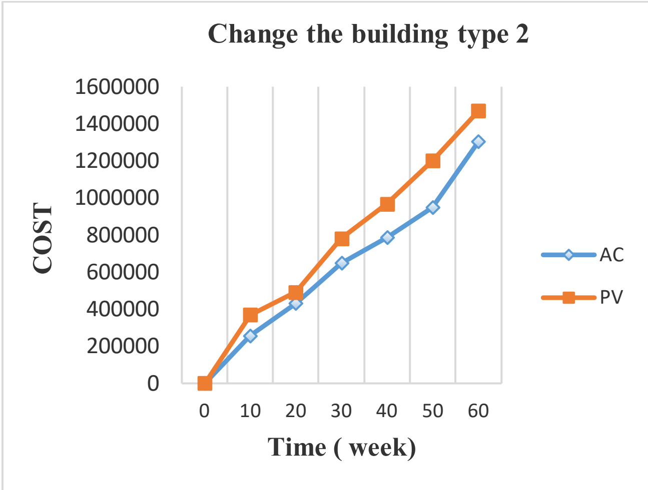

Fig. 6 The difference in (PV/AC) Result of MCDM (Building type 2)

An association between time and cost prediction that is statically important was seen in the data. Testing the cost modeling is used with the objective of determining both whether the design developed was adequate and whether the necessary level of generality was obtained, as was already mentioned. The guidance given before helped to direct the process used to create the optimum model, which led to a potential framework delivering more precise cost forecasts without sacrificing accuracy. As a result, without sacrificing accuracy, the model could give more precise cost forecasts (Figs. 5 and 6).

The definition of materials using BIM is probably connected to the descriptions of the materials used in their fabrication. The Building Information Model contains every drawing produced by WEKA (BIM). Data pre-processing, categorization, regression, collection, association rules, and visualization tools are all included in WEKA. The building information modeling (BIM) tool WEKA will help in the battle to combine your ideas. All that is needed for this is one model from which multiple drawings can be produced; having this model is sufficient Fig 7.

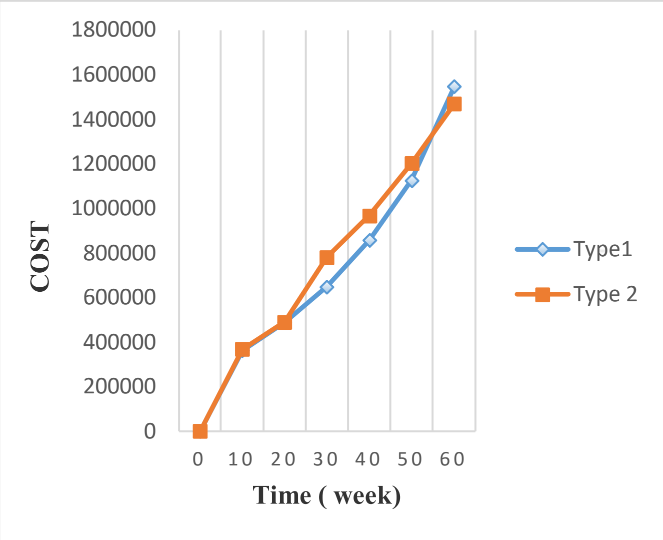

Fig. 7 The Result of Case Study BIM

IV. Conclusion

The study specifically focuses on the construction sector in Iraq. After the list of actions, there is a detailed description of how the steps were taken to achieve this goal. Decision support systems are evolving into cutting-edge technologies that assist decision-makers in making decisions by helping them better understand how well a building or set of buildings performs in terms of comfort, energy efficiency, cost savings, etc. The HVACDSS's potentialities and initial stage of development have been discussed in this competition. The architecture of the information system and energy-related factors have both been considered. Employing predictive models with real-time data capture is the primary novelty of the created HVACDSS. Furthermore, a framework is used to process the data after it has been collected from multiple sources. The HVACDSS's overall architecture has been designed with an eye on information technology and the relevant requirements.

Acknowledgment

We thank Baghdad University, College of Nursing, Department of Basic Sciences and Middle Technical University, Technical Institute-Suwaira, and Department of Computer Systems for their support during this work.

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