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A Multi Objective Rule – Based Decision Support System of Marble Selection for Residential Buildings in Jordan

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Abstract. Selecting finishing building materials is a hard task to the architect due to the many variables affecting such process, as more than one dominating objective may arise, such as achieving sustainability, aesthetic, economic factors, social factors, environmental impact context and many other factors. This article will try to develop a multi objective rule-based system that enables the architect to select the most suitable marble type suitable to a specific project in relation to desired specific objectives. A multi layered data storage will be based upon the data collected from Jordanian market regarding, cost, environmental impact, maintenance, replacement period, installation expertise for each type of marble available in the market. The system will be based upon weighting factors technique that will compute the weighting of a list of decisions according to a preset objective being selected by the user. Also, the system will be able to recomputed weightings due to a change in the objectives accordingly. Data collection will include all the marble in the Jordanian market with all the physical, aesthetic, economic, and environmental characteristics, local or imported marbles. Data regarding the social environment of the residential sector will be reorganized so that the decision support system will be able to match users' objectives with the best marble alternative for any specific project.

Keywords: Multi Objective Rule Based Decision Support System, marble, residential buildings, Jordan

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INTRODUCTION

The growing population in Jordan is related to an increase of residential units in Jordan, where the number of single-family houses and apartment's blocks is also increasing. A considerable cost of such units is evident, and therefore the need for a certain quality of buildings finishes is of great importance. As for national policies regarding housing sector, it is greatly oriented towards sustainable and environmentally responsive designs. This creates a heavy burden upon architects, designers, and contractors to wisely ensure a certain quality that achieves both users' satisfaction and be environmentally responsive. One of the most important issues in this regard is materials selection; which an issue that must be considered in every project.

Materials selection is an important issue for both the designer and the user as well. Therefore, many variables and parameters do affect the strategy of materials selection. In this article the main focus will be on finishing materials selection and specifically on marble and Granite.

Floors and wall coverings in residential buildings are a costly procedure, though it consists of many items that in the end formula an interior environment supposed to be healthy and satisfying to the occupant, a durable finishing is an important condition that should be achieved in order to reduce maintenance costs and maintain durable use of the indoor environment. A simple finishing procedure and components is showed in the following diagram, figure 1.

One of the mast important items that must be considered is ground finishing, stairs finishing, kitchen counters and other floor grounds elsewhere in the house or the apartment. Given the taken for granted function of the house, many variables and influences faces the architect, the designer and the owner deciding the type of the floor.

The first variable that affects the decision about floor selection, kitchen counter, stairs selection is the concern about the aesthetics and the appearance of the final surface, the owner pays careful attention to the issue of beauty a surface will be, in addition to owner's considerations, there will be the opinion of the architect, the combined effect of both opinions of the owner and the architect are also influenced by many other variables like colour, cost, durability, and resistance. Considering the beauty of a specific finishing material is also influenced by the culture of the owner, this means that, how the owner considers a given material to be beautiful or not. External influences also may exist like the influences of colleagues, relatives, and friends; these influences may overcome the issue of the cost and durability, each variable has a weighting factor that should be considered when dealing with the issue of the final selection of the material.

The choice of materials will be impacted by the vast range of finishing materials that are offered in the neighborhood market as well as the finishing materials' rapid growth in the building materials market and industry. Time is therefore a crucial component that needs to be taken into account when choosing a certain piece of content.

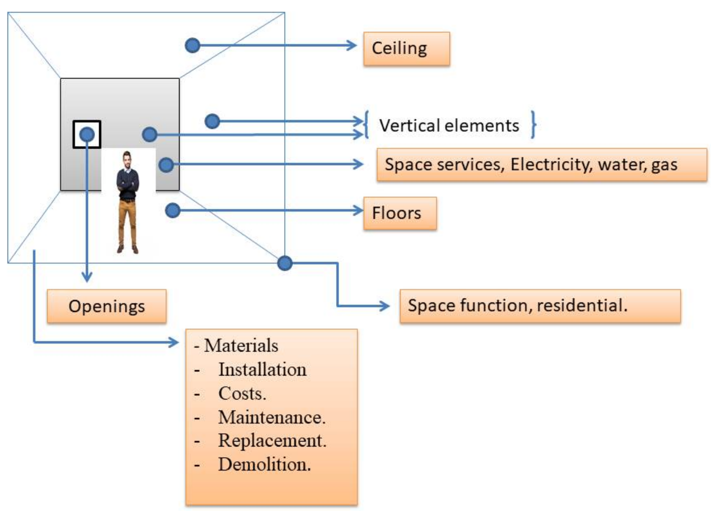


FIGURE 1. A schematic shows finishing items needed to create a habitable indoor environment.

In this article, the main objective will be to characterize the main factors affecting the selection of marble, ceramic, or porcelain as a finishing material in the residential sector in Jordan, based upon the items available in the Jordanian local market. The discussion will be restricted to ground, floor, stairs, and kitchen counter selection of the final finishing material.

Jordan is an open market regarding the availability of marble, ceramic, and porcelain as finishing materials. Part of the available items are manufactured locally, and the other part is imported from many other countries. The following table 1, shows the main countries from which marble is imported as well as other finishing materials, the table shows also the end use cost per unit area of each type at the time of writing these lines.

The choice of finishing material is dependent on a number of factors. Occasionally, poor material selection choices are made, which manifests as the need to replace the material over time, which raises maintenance costs, wastes time during maintenance procedures, and may cause confusion.

Decisions about material selection requires a systematic approach in order to help the designer and the owner to suitable select the most proper material according to an objective oriented strategy, the following section will show that.

TABLE 1. The most common marble and granite used in Jordan, just to mention. (Source: Author)

#	Type	Color	Source	Cost	Notes
1	Local Jordanian	Beige	Jordan	14-18	Lime stone
2	Gray marble	Gray	Egypt	35	Different dimensions
3	Pink granite	Pink	Egypt	22	Multi dimension
4	Granite Saudi	brown	Saudi Arabia	45	Different shapes
5	Marble Turkish	Gray to white	Turkiye	27	Crystal colours
6	White marble	white	Greece	42	Durable
7	Granite	Different colors	India	70	Durable
8	Marble	Beige, Gray	Italy	45	Durable, stiff.
9	Marble	Pink	Portugal	60	Multi dimension
10	Marble creamy marvel	Beige	Spain	80	Multi dimension
11	Onyx marble	Different colours	Pakistan	150	Multi-colour
12	Porcelain Indian	Different colours	India	10	Multi-colour
13	Ceramic Saudi	Different colours	Saudi Arabia	15	Multi shaped

WHAT IS DECISION SUPPORT SYSTEM?

Design process is a multi-variable process; in which human thought interact with physical variable, serving a specific purpose in the final product of a building. Thus, the designer might face design decisions that need a systematic approach to be able to make a decision regarding any design variable. The complex design variables make it a little bit problematic to arrive at a suitable decision. The decision support system is one of the many decision-making strategies that have been created to address this issue. It assists the designer in choosing the appropriate material in accordance with the objective priorities that are established throughout the design phase. In the paragraphs that follow, the development of decision support systems is briefly discussed.

To support managers' and other knowledge workers' decision-making in organizations, DSS is a class of information systems that integrates with other components of the total information system and draws on transaction processing systems (1). Interactive computer-based systems that assist users in using data, documents, knowledge, models, and computer communications to solve issues and make decisions are known as decision support systems (2). Applications for decision support systems are numerous and span a wide range of industries, including management, industry, social science, engineering, and architecture, as well as any discipline that calls for the solution of complicated and conflicting issues. When two presumptions seem reasonable—that is, when decision makers want computerized decision support and when good information is likely to improve decision making—decision support systems are better included. Research was a trailblazing implementation, specification, and research test of a model-based decision support system. The notion of decision support systems dates back to 1971 (1). Subsequent research applied behavioral theories of management and decision making along with management science methodologies to help build the Decision Support Systems (DSS) (1).

Following the creation of a theoretical framework to comprehend the problems involved in creating knowledge-oriented DSS, four key components of an effective DSS were found, which are outlined below:

1. A language system (LS) that lists all messages that a certain DSS is capable of accepting;
2. A PS for all communications that a DSS is capable of sending out;
3. A knowledge system (KS) that contains all of the DSS's knowledge; and
4. A problem-processing system (PPS), often known as the "software engine," which attempts to identify and resolve issues that arise when a certain DSS is being used (3).

Three primary features of a decision support system can be summed up as follows: First and foremost, decision support systems (DSS) ought to be able to swiftly adapt to the shifting requirements of decision makers, support decision making instead of automating it, and be specifically built to facilitate choice processes (4)(5).

Decision Support Systems and Architecture

A multitude of computer software packages were created to support architectural processes, including design, construction, management, and maintenance decisions. Decision Support Systems in architecture have seen numerous advancements and a broad range of uses. The literature is full of numerous research and instances demonstrating the high level of interest in this area. It is clear that decisions must be made in architecture, and computer systems are necessary to handle many complicated problems. Peter et al. (6) investigated the quick-and-cheap heuristics for making decisions in complicated and uncertain situations in the construction industry because they are task-specific strategies that are a part of a decision maker's toolkit of cognitive strategies for handling tasks involving judgment and decision-making. They created an adaptable toolkit of ecologically sound heuristics to improve decision-making in a range of building project scenarios (6). Jalaei et al. (7) suggested a model that combines building information modeling (BIM) and decision support systems (DSS) to assist designers in choosing the best sustainable building materials for a particular project. This will allow the design team to effectively optimize the selection of sustainable building components during the conceptual design phase by employing multiple criteria decision making (MCDM) techniques to help them choose the best kind of sustainable building components and design families (7). By creating a system dynamic model to study the environmental and financial benefits during the construction process and suggesting various materials, researchers attempted to identify and analyze the factors influencing material selection based on circular economy principles. One of their main goals was to propose a minimum amount of cement (8). Assistance with decisions According to Zong et al.'s research, systems also help with passive design tactics under uncertainty, the work of Zong et al. (9) is just an example for this. See the studies of Feng et al. as a method to integrate with life cycle evaluation of building materials Feng et al. (10) and Dsilva et al. (11). Schubert conducted a thorough investigation of the function of decision support systems in architecture, Schubert et al (12), where the writers examined the present goals and developments of these systems, underlining the difficulties these instruments continue to encounter and offering an outlook on how these systems can develop from reactive to proactive support in the future (12). DSS is also applied to energy sustainability in buildings (13), and sustainable building materials for building facades (14).

A Multi objective decision support system has been developed by Zhou et al (15) A multi-objective optimization methodology for the selection of sustainable materials was proposed. Though the suggested model lacked intangible aspects of building materials, which architects and designers considered important, tools and material data sheets included extensive information based on expert knowledge about cost, mechanical properties, process performance, and environmental impact throughout the life cycle. Espino et al (16) outlined the main techniques for applying multi-criteria decision-making techniques in the construction industry, including 22 distinct techniques that fall under this field (16).

Regarding aesthetic concerns in material selection, intangible material properties are not mapped out and described in the design models that are now in use, and no selection framework offers a paradigm for the parameters that Wastiels and Johnson have suggested (17).

In a different study, the focus was on choosing finishing materials for floors, walls, and ceilings while incorporating cost analysis into the decision-making process. However, the technique or standards for selecting information were not mentioned (18). Numerous other studies on a variety of relevant topics pertaining to the choice of materials can be found in the literature; Loh et al. stressed the need of carefully choosing sustainable materials and designing buildings before they are constructed (19); roofing materials selection (20); flooring systems selection (21).

RESIDENTIAL BUILDINGS IN JORDAN

The demand for residential units in Jordan is rising in all of the country's cities and can be categorized into three categories: single-family homes, apartment buildings, and owned and rented apartments. The first category includes single-family homes. Since Jordan's building materials market offers the construction industry a wide variety of finishing materials that are in turn subject to accelerating growth, all residential units in Jordan share common finishing materials and practices. The designer is in charge of choosing the flooring materials for the inside kitchen, walls, and floors. Typically, they have a conceptual framework in place for making these kinds of decisions.

However, in many instances, the owner's ardent desire to choose a certain kind of flooring material has no bearing on the designer. The issue with this method is that the owner chooses flooring only based on aesthetics and price, ignoring a wide range of other factors including the environment, the economy, life cycle concerns, and routine maintenance, for example.

Due to frequent replacements and alterations of various flooring finishes in a brief amount of time, field observation reveals the issue of inconvenient choices for wall, floor, bathroom, and kitchen finishes. This observation is typical in many apartment buildings in Amman city, as well as naturally in single-family homes.

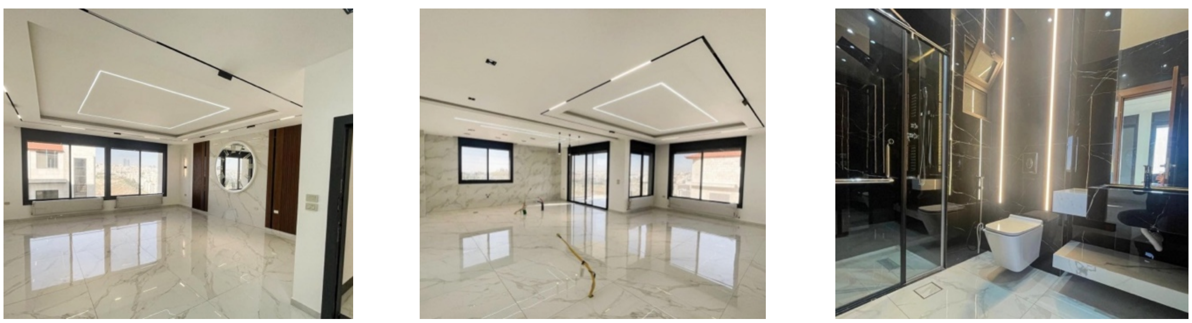
This is a result of the seeming necessity to replace less attractive flooring with more modern, thriving flooring materials, regardless of how long-lasting and low-maintenance they are—and, frequently, because of financial concerns. A new flooring layer is frequently applied using adhesive materials, which doubles the expense of the original floor finishing, It places a significant strain on the apartment owner. In this instance, there is no increase in value just a minor change in the floor's appearance.

Issues such as subfloor drainage and water pipe systems may necessitate replacement; in this scenario, new flooring finishing may be necessary, providing the owner with the chance to change the flooring material.

A parametric framework is necessary for the easy selection of flooring materials in all the scenarios that an owner may encounter during construction or house occupation.

The goal of this article is to create a methodical, multi-objective rule-based decision support system that could assist designers and owners in choosing the right flooring material for a given residential apartment space while optimizing other variables in order to meet predetermined goals.

A thorough framework for choosing materials will be presented in the next section. This will assist designers, architects, and owners in addressing the issue of making the right choice while taking into account a number of intangible factors that are invisible to the human sight.



(1) Living room (2) Kitchen (3) Bathroom

FIGURE 2. An example of floorings in modern apartments in Amman City, Jordan.

DECISION SUPPORT SYSTEM DEVELOPMENT

In order to arrive at an ideal material selection, a systematic methodology or technique is required, as the objective-oriented material selection procedure is primarily controlled by numerous variables and characteristics. There are various goals in the core model; the following lists the primary goals: First, define the primary aim or target, which should contain the primary task to be carried out. The second step is to identify the collection of all potential materials on the market; we may refer to this as the "materials library."

Thirdly, there is a subroutine loop that allows the system to filter out materials that are obviously unsuitable for the intended application from the library. For instance, if the element being considered is a kitchen counter, then all materials used for indoor and outdoor flooring must be disregarded. Instead, the system needs to include the set of materials that satisfy specific requirements, such as adhering to standard kitchen desktop functionality.

Step four involves evaluating the remaining options. To do this, feasible options are compared to a predefined model, which allows the system to rank options based on how important the material is for the intended use. This can be done by using a sub categorical procedure like the one below: The steps involved are as follows: a) weigh decision variables, or attributes; b) compute attribute values; c) inter-dynamical purification of weighted attributes; and d) create rankings. Reassess the options' ranking in step five; choose an option based on that ranking in step six; and make the ultimate decision in step seven. The selection process is flowcharted in Figure 3 below.

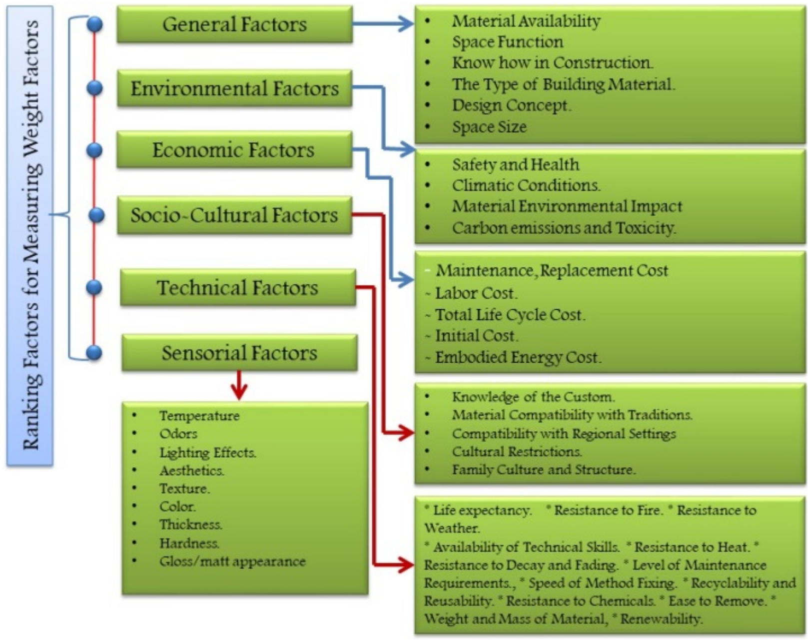


FIGURE 3. General description of the selection framework and variables for flooring materials.

Following the creation of the selection framework, the overall structure for the rule-based decision system must be constructed. The eleven steps of the suggested rule-based decision support system will be covered in detail in their own sections as needed. The following could be used to sum up the system:

Step 1: Identify the problem. In this case, the difficulty is pairing marble type with the previously developed corresponding selection framework. Step2: Give the system a name. Depending on the programmer or designer, the system may be called "MARBLE SELECTOR" in this instance. Step 3: Compose the opening statement. For example, "This program helps you selecting the type of marble for your residence" may be the opening statement. Step 4: Choose the right coding, or how to handle an ambiguous circumstance, by employing a scoring system to allow the system to make a judgment based on several objective factors that best suits the user's preferences.

Step 5: Choose any additional inferencing parameters that the processor has set. These are guidelines to help the decision-making process reach the most convenient conclusion. These guidelines can be in the form of rules, such as "use all the rules," "use some of the rules," or "set threshold levels." Insert a "concluding note" in step six. Step 7: Make a list of the possible options. For example, you could write "marble type that matches lowest cost," "marble type that matches lowest cost and long-life cycle," or "marble type of lowest carbon emissions and moderate cost and acceptable aesthetic appearance." You could also pull a list of matches from Figure 3, which could result in a very long list of options.

Step 8: Become familiar with the many types of marble and their purposes; this can involve compiling a list of all the marble, granite, terrazzo, ceramic, and porcelain options that are available. Step 9: Create a knowledge map by consulting a human specialist and organizing the facts and focuses in a tabular format. Step 10: Create the basic set of rules. This is done by creating what are referred to as "quantifiers." And all they are is inquiries meant to extract information. Step 11: Gather more cases and rules and improve the rules. Step 12: Create a feedback subroutine that allows the system to mimic a human expert's decision-making process in order to reach an expert system level that is comparable to that of a human expert. Figure 4 summarizes the process's schematic flow chart.

A decision support system is distinguished by the criteria that motivate the processing unit to reach a conclusion. The system's knowledge units are rules, with a fine degree of granularity; rules and hierarchies make up the knowledge acquisition units; backtracking of rule firings serves as the explanation mechanism; the characteristic output is an answer and a confidence measure; backtracking results in high knowledge transfer across problems, whereas deterministic results in low knowledge transfer; speed as a function of knowledge base size is exponential in backtracking and linear in deterministic scenarios; A strong set of inference rules, a small number of rules or rules that apply sequentially, and a domain that largely complies with rules are among the prerequisites for a domain (2).

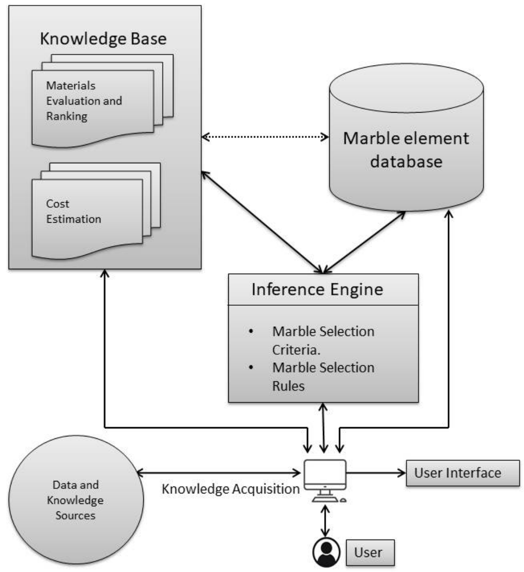


FIGURE 4. Schematic flowchart summarizes the general framework of the system procedure.

Production of Rules

In a particular decision support system, condition-action pairs, or "production rules," are used to represent rule production. A certain action (or outcome, conclusion, or consequence) will (or should) occur IF condition (premise or antecedent) is met. For instance, a marble from the green color family will be chosen if the room under consideration is the "Kitchen" and the interior color scheme is "green." A knowledge base's production rules each implement a separate body of knowledge that may be added to or changed without affecting other rules. The collection of rules acts in concert when input into the inference engine.

Producing outcomes that are superior to the total of the outcomes of the individual rules. Knowledge-based rules are not autonomous; rather, they rapidly become extremely interdependent due to the possibility of conflicts when introducing new rules or the need to change existing characteristics or rules. One way to think of rules is as a simulation of how human experts think. Rules are a model of real human behavior rather than just a tidy formalism for knowledge representation in computers (2).

Rules can have many different forms, one of which is "IF..., THEN..." Numerous Ifs can be found on a rule's IF side. There may also be multiple components on the THEN side. Palopoli and Torlone provide an explanation of the application of production rules in deductive and active databases (22).

AI typically uses two kinds of rules: knowledge and inference. Declarative rules, also known as knowledge rules, lay forth all the details and connections surrounding a given issue. Procedural rules, also known as inference rules, provide guidance on issue solving when specific facts are known. Knowledge guidelines could resemble the following:

- RULE 1: IF marble A is scarce
  THEN the price of marble A will rise.

Inference or procedural rules may look like the following:

- RULE 1: IF the data needed are not in the system
  THEN request them from the user.
- RULE 2: IF more than one rule applies
  THEN deactivate any rules that add no new data.

Rules regarding rules are contained in inference rules. Since they apply to other rules or even to themselves, these kinds of rules are sometimes known as Meta rules. While inference rules are integrated into the inference engine, knowledge rules are stored in the knowledge base.

Rules have benefits and drawbacks. They are particularly useful when a course of action needs to be recommended in response to observable events. Table (2) below lists the main benefits and drawbacks of rules.

TABLE 2. Advantages and limitations of rules in a rule-based decision support system (2).

Advantages	Limitations
Rules are simple to comprehend. Because they are a natural kind of knowledge, they may be communicated.	Thousands of rules are needed to handle complex knowledge, which can make maintaining and operating the system challenging.
It is easy to draw conclusions and provide explanations.	Rather than searching for more fitting representations, builders prefer rules and attempt to impose all knowledge into their frameworks.
Maintenance and modifications are comparatively simple.	Systems having a lot of rules could have a control program search restriction. Certain programs struggle with assessing rule-based systems and drawing conclusions. .
Rules can be easily mixed with uncertainty. Most of the time, no rule affects another.	

A rule-based decision support system relies on probability ratios. Probabilities are the likelihood that a specific event will occur, and they are calculated as follows. Probabilities can be used to represent the degree of confidence in a premise or a conclusion as follow:

$$F(X) = \text{Number of outcomes favouring the occurrence of X} / \text{Total number of outcomes} \quad (1)$$

X: the probability of X to occur.
F(X): the ratio of the number of times X occurs to the total number of events that take place.

METHODOLOGY

In the methodology section, the main elements of the system are explained and these include the main variables of the system.

User

Potential users include architects, designers, quantity surveyors, and anyone else involved in the decision-making process when it comes to choosing flooring materials for walls or floors as well as specific coverings for residential spaces. Owners may also be involved in the selection process when it comes to the design stage. Architects and quantity surveyors with the necessary expertise in building design specifications and material selection make up the expert forum.

Database

All accessible data regarding wall coverings and flooring finishes related to the performance factors taken into account when choosing materials, such as sustainability, initial cost, upkeep cost, and durability, is stored in databases for wall coverings and flooring finishes. Information is gathered from manufacturing catalogs, local resources, designers, architects, and contractors. Examples of such extended data sheets include price guides, text books, environmental effects, and aesthetic considerations. The system is capable of accepting additional and future modifications based on market dynamics and newly manufactured materials that are either domestically or imported.

Knowledge Base

The procedures for material selection and cost estimation make up a knowledge base. The MARBLE SELECTOR is incorporated to answer decision-making problems for all those related to multi-criteria decision-making procedures.

(23). Building codes, specifications, installation guidelines, and other selection criteria that could influence the choice of material or technology are all included in the knowledge base. It consists of a decision support shell that may help choose the best material by employing MARBLE SELECTOR to make decisions. For example, hard marble or granite is the preferred flooring material as a first priority when there is severe exposure to the category of extensive users movements and when space use exceeds 10 hours of occupation.

Inference Engine

As previously demonstrated in the section on rule creation, the system searches create decision rules for choosing the proper material combinations based on the knowledge base and the database by utilizing the IF-THEN production process in conjunction with a forward-chaining reasoning mechanism. These guidelines direct the system to focus the database's search space; more justifications are provided in the preceding section.

User Interface

This component of the system allows user interaction with data inputs, processes, and windows for individual preferences. It takes user inputs and initiates operations to provide output for the users.

Scores and Weights

A kind of ranking based on weightings and scores is required so that the system can prioritize choices. This is derived from human expertise, whereby each variable is given a categorical weight and score that corresponds to its relative relevance. For instance, when choosing a floor covering, aesthetics might be a crucial factor. Selection criteria of each ground or wall element have been considered based upon the importance weights given by the domain experts. Since this is a subjective variable, it is removed from the list of criteria, or if the user is to take this criterion into consideration, a subroutine with carefully scored aesthetic considerations must be inserted.

Since it is generally acknowledged that language qualitative variables are helpful in describing traditional quantitative expressions, Table 3 displays linguistic descriptions of variables that are regarded as qualitative. A scoring correspondence is used to translate qualitative concepts into quantitative ones (24).

TABLE 3. Linguistic variable ranking matched with numerical value assignment.

Linguistic variable ranking	Values (arbitrary assigned scale)•
Over Estimated	10
Very High	8
High	6
Medium	5
Low	3
Very Low	1
Not Applicable	0

- This is meant to express different scale intervals; for example: scale a:[0-1], [1-10], or [0-100].

Information Structure

To feed databases, all the material information gathered from various sources, including technical manuals, textbooks, and catalogs, is arranged in Microsoft Excel's Comma Separated Values (CSV) format. Cost, individual preferences, and environmental factors are noted and recorded for manufacturing regulations to regulate material choices. Excel (CSV) files are used to organize cost concerns and other relevant data.

System Testing

The Oracle database management system is being used in conjunction with the Microsoft Windows Platform in the continued development of the system. Oracle Developer Suite 10 is used to develop the processes and user interface. A schematic data flow diagram for the "MARBLE SELECTOR" system is shown in Figure 5 below.

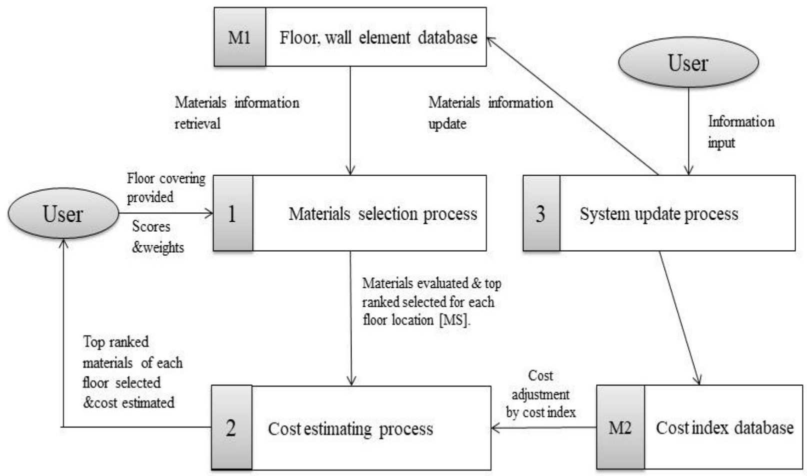


FIGURE 5. Schematic data flow diagram for MARBLE SELECTOR [MS] program.

CONCLUSION

In summary, the developed system represents a significant advancement in Jordanian construction technology. The literature review indicates that the DSS system "MARBLE SELECTOR" [MS] is the country's first rule-based decision support system, despite significant advancements in other regions. The system presents a fantastic opportunity to create a database of Jordanian materials that are available for wall and floor coverings, with the goal of optimizing selection based on connected, either objective or subjective objectives.

Further developments including more design elements like roofs, decorations, sustainable concrete, and soft landscapes will result from the project's continuous work. Field findings highlighting the numerous reasons for floor repair and upkeep greatly support the initiative "MARBLE SELECTOR" [MS]. Interviews with occupants, owners, and designers revealed several reasons, which were divided into two groups: the first group was the need to change the color regardless of the cost; the second group consisted of floor parts that broke because the material was weak or the floor material was chosen incorrectly for the purpose for which it was intended.

Domain specialists for the [MS] are selected from pricing catalogues, owners, designers, and architects. Data that is required is gathered from catalogs and entered into a database. It is vital to note that an interview stage was created in order to determine the necessity of this kind of DSS system as well as the key variables. To identify issues beyond wall covering and floor replacements, a quick statistical survey has been carried out. Cost concerns and individual aesthetic preferences were identified.

Making decisions based on several criteria is a useful method for choosing the best and most practical wall and floor coverings for various household uses.

As a final piece of advice, Jordan needs to create a database on building materials so that architects and designers can use DSS models for sustainability considerations and design purposes. This is especially important when it comes to adhering to national energy and environmental policies, as the government has proposed national policies that aim to achieve maximum comfort and an environmentally healthy environment while also minimizing environmental harm.

In future work, this system will be developed and updated to cover more building components and a panoramic profile of different materials which will be an excellent guide and application tool for the designer, architect, and the owner; and to include different building types and functions.

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