Vol. 12(1), pp. 1-6, January-June, 2021
DOI: 10.5897/JCECT2020.0544
Article Number: B860FB065923
ISSN 2141-2634

http://www.academicjournals.org/JCECT

Journal of Civil Engineering and Construction Technology

Full Length Research Paper

Evaluation and selection of the quality of internal doors for buildings using building information modeling building information modeling (BIM)

Ibrahim Al-Hammad and Zaidan Ahmed Zanklo

Department of Civil Engineering, King Saud University, Riyadh, Saudi Arabia.

Received 13 June, 2020; Accepted 9 October, 2020

The selection of building materials from various available alternatives is a critical process affected by many complicated factors. Every single element in a building has a specific function to perform. This necessitates a proper selection of material from the various available alternatives, which generally differ in their quality, performance, and cost. To make the most practical choice, the owner wants the building's function to perform with maximum quality at the minimum possible cost, and this is the principle of value engineering. Therefore, a determination has been made to identify the criteria impacting selecting each element and how close it is to achieving the project's goal. Each alternative has been evaluated, and its quality, and cost scores have been calculated. Implementing a value engineering process is challenging, and it needs much effort and many brainstorming sessions to be achieved. Therefore, this study has proposed a framework to automate the value engineering process and integrate it into selecting building materials. Moreover, this process was accelerated and facilitated by using innovative computer technology such as building information modeling (BIM) that has been widely used in the architecture, engineering, and construction industry. The scientific paper touched on determining the evaluation of the elements of choosing the doors and determining the criteria affecting their quality by conducting a field survey with specialized engineers in the Kingdom of Saudi Arabia to know the factors affecting the selection of doors. The scientific paper also reviewed the case study of a hospital buildingwhere the elements of the building's internal doors are chosen from among eight alternatives using the proposed evaluation processes. And then, chose the building information model as a database that facilitates information entry and selected from the available alternatives. The results were shown automatically and gave a summary of them. The research results showed the six most important criteria affecting the process of selecting interior doors for buildings: fire resistance, acoustic insulation, humidity resistance, aesthetic, durability, and maintenance. Based on this study, the best alternative for interior doors to buildings will be chosen from among the eight available alternatives. This methodology will make it easier for the decision-maker to choose the appropriate section according to the previous criteria.

Key words: Alternatives, factors, criteria, value engineering, BIM, fire resistance, acoustic insulation, humidity resistance, aesthetic, durability, maintenance.

INTRODUCTION

The construction industry is considered the second biggest industry in Saudi Arabia, contributing to the development of a country where billions of dollars are being spent on different types of projects, including residential, commercial, educational, administrative, industrial, and sports buildings (Assaf et al., 2013).

A substantial part of the construction project cost depends on building materials. The specified materials and the proposed construction details have a significant bearing on the project (Cunningham, 2013).

It is a very complex task related to how to manage and verify successful material selection in building construction due to the vast number of materials available. Besides, current construction trends require a more comprehensive range of evaluation criteria, which further complicate the material selection process (Jorge et al., 2009).

Therefore, the design engineer should always be confident about the design he proposes and the ideal choice he makes to make the most practical choice. The owner desires to perform the function with the maximum quality and reduce the cost to the minimum. Hence, the value ratio will be the maximum value ratio (Dell 'Isola, 1997).

$$\text{Value} = \frac{\text{Function} + \text{Quality}}{\text{Cost}} \tag{1}$$

For the cost factor, in most projects and designs, we find it is easy to compare the figures to calculate the cost, but it is not easy for the quality factor. Quality standards should be determined and weighed. The calculation method must be developed to facilitate the work and data input BIM can be adopted and output. This is the focus of the current research. A conceptual framework was proposed; a case study was reported that hospital building were evaluated for the construction of internal building elements to indicate that Autodesk Revit is the most available tool among commercially available BIM tools. Accordingly, Autodesk Revit is well known and widely used by architects, designers, engineers, and contractors. BIM is truly advantageous due to its smart functionality to share and distribute the technical data between several stakeholders during all stages of a project, ranging from the design phase to the operation phase. Furthermore, depending on the database, various BIM approach dimensions can be distinguished, 3D, 4D, 5D, … nD. Each dimension refers to a specific type of data (Cost, Scheduling, and Sustainability). These extension dimensions were used to enhance the model's full automation during the project life cycle of the project. This research can be developed to establish a new BIM dimension related to the value engineering. This paper will be of practical value to the design engineer who seeks to select and identify building materials. It will also be an essential step towards determining the overall quality of the building.

LITERATURE REVIEW

A comprehensive literature review was presented, which deals with the material evaluation methods and stages and previous studies related to Multiple Criteria Decision Making (MCDM).

Accordingly, the various methods were compared for selecting the perfect method, which is appropriate to meet this research. Consequently, it dealt with the interior doors of buildings and the various criteria affecting selecting the materials. Finally, an overview of Building Information Modeling (BIM) was provided and these were the most tangible benefits. Furthermore, its relevance to the research topic was presented.

Evaluation process for material selection

It is an over-complicated task to manage and verify the successful material selection process in building construction because of the massive number of available materials.

Besides that, the current construction trends require a broader scope of evaluation criteria, which increases the complexity of the material selection process (Jorge et al., 2009). Many researchers have deeply talked about this issue of material selection decision through many approaches in the literature. Rao and Davim (2008) have proposed an intelligent synthesis of conjoining the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) with Analytic Hierarchy Process (AHP) to the right selection materials. After all, this method implies many comparisons that become those methods impractical to solve problems with a large number of alternatives and criteria usually found in the construction industry.

Evaluation criteria for material selection

Some researchers restrict themselves to evaluating the material alternatives according to the cost and environmental criteria (Dutil and Rousse, 2012; Castro et al., 2009; Lee, 2013). Other studies focused on evaluating energy criterion versus cost criterion in comparing alternatives (Nemova et al., 2015). On the other hand, some researchers evaluate material alternatives according to different criteria, including quality, performance, durability and cost (Al-Hammad et al., 2014). The ranking takes into consideration how each alternative compare with the criteria. The rankings were multiplied by the weight corresponding to the criteria.

*Corresponding author. E-mail: 437107176@student.ksu.edu.sa

Building information modeling (BIM)

To evaluate the building materials, a wide range of data must be collected and analyzed, such as material specifications, prices, and quantities. Hence, BIM can be adopted to facilitate and automate the process. BIM is defined as a model-based technology linked with a database of project information that can be accessed, manipulated, and retrieved for construction estimation, scheduling, and project management. This building design approach can enhance higher productivity and improved quality, securing project delivery time at minimum cost (Azhar et al., 2008).

The broad scope of BIM usage incorporates data management from the initial design and throughout a building's lifecycle. In fact, through a BIM model, the user can take out the geometric data and other relevant necessary data for design enhancement, such as procurement, fabrication, construction, maintenance, plus any other activities and technical tasks related to the building during its lifecycle (Eastman et al., 2011). It is necessary to indicate that Autodesk Revit is the most available tool among commercially available BIM tools. Accordingly, Autodesk Revit is well known and widely used by architects, designers, engineers, and contractors.

Objectives

The main goal of this paper is to propose a framework that will help calculate quality scores for material alternatives for building interior elements, then defining the quality criteria of building internal elements with its relative weights, and finally linking the database and the proposed process with a BIM model to facilitate data input and outputs, and to show the impact of the total cost as per the selected materials.

METHODOLOGY

The research methodology is proposed to achieve the research objective (Figure 1). In the beginning, the quality criteria for the doors were studied. The weights for these criteria are calculated based on the results of the questionnaire that was studied. The ranks were determined to evaluate the quality of each material.

Then the price was added to these doors to produce our value, and the more excellent value in the results indicates the best material chosen in this research. These theoretical results in building information systems were linked to facilitate selection processes in another scientific paper explaining this environment's application.

Material types

All material types that can perform the selected building element's function elements function must be stated in this step. Sources include manufacturer's information, manuals, catalogs, information available from contractors, subcontractors, specialized consultants, and other literature (CSI, 2011). In this paper, eight types of doors standard using the internal doors for buildings as per the American Society for Testing and Materials ASTM and Saudi Standards, Metrology and Quality Organization SASO were selected (Table 1).

Evaluation criteria

In this step, quality and performance criteria that affect the process of evaluating and selecting various types of material must be plainly stated. Besides, the literature review and the investigations of professional engineers may be used. Cost-related criteria will not be stated in this step, since the total score of material will be compared with the cost criteria, including initial and life cycle cost. Criteria that have no importance, or minor importance level, should be eliminated to lessen their number before proceeding with a more detailed analysis and evaluation. For example, if we are selecting door types, the criterion (Resistance of wind load) will not be that important, so that it will be eliminated. Criteria must be evaluated through a survey soliciting the opinions of professional engineers/ architects.

Types of criteria

Selecting the appropriate evaluation criteria will help ensure that the proposed range of alternative mitigation measures will be evaluated to reflect the values best. Once these criteria have been applied, officials should have a better idea of which alternatives are the most meritorious and desirable. In this paper, we selected the six most important criteria affecting the process of selecting interior doors for buildings: fire resistance, acoustic insulation, humidity resistance, aesthetic, durability, and maintenance.

Criteria weight evaluation

Multi-criteria problems require expert knowledge from the side of decision-makers to assign a weight to each criterion. Some of the selection criteria are subjective, as a result of which the decision must be made under the consensus of a group of decision-makers who typically demonstrate various views. However, the criteria believed to be objective may prove hard to be evaluated. For example, the door fire resistance criterion seems easy to measure and can be obtained from its factory or as per performance tests. On the other hand, the door's esthetic is perceived as a problematic criterion because it cannot be measured straightforwardly (Figure 2).

Analytic Hierarchy Process (AHP) is one of the Multi-Criteria decision-making methods initially developed by Prof. Thomas L. Saaty. In summary, it is an ideal way to derive ratio measures from double comparisons. Entries can be obtained from actual measurements such as price, weight, etc., or personal opinions such as contentment, feelings, and preference. AHP allows some small inconsistencies in judgments because humans are not always harmonic.

The questionnaire that seeks professional engineers/ architects who work in Saudi Arabia has been done. The question was of the listed criteria that influence the quality of internal doors for buildings. Seventy persons received the questionnaire. The questionnaire shows that these criteria are related to selecting the material in general, so that all criteria will be considered in this paper. The weight for each criterion will be different as per the function of the project.

Ranks evaluation for each material type

These material alternatives in consultation with a design

Figure 1. Research Methodology Process.

Table 1. Table of doors type.

Doors type							
Wooden doors				**Steel doors**		**Glass doors**	**Aluminum doors**
Hollow core with air space	Hollow core with rock wall	Hollow core with chip board	Solid wood	Hollow core with air space	Hollow core with rock wall	Tempered glass	With glass

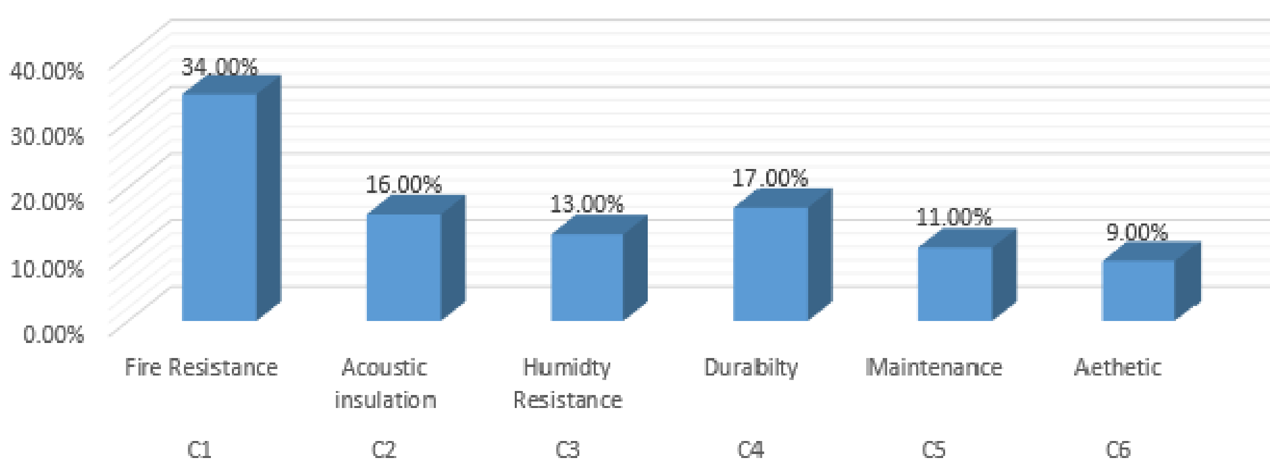

Figure 2. The questionnaire results.

Table 2. Table of quality standards for the alternative doors.

Criteria		Weights (%)	Doors Quality							
			Wooden Doors				Steel Doors		Glass Doors	Aluminum Doors
			Hollow Core with Air Space	Hollow Core with Rock Wall	Hollow Core with Chip Board	Solid Wood	Hollow Core with Air Space	Hollow Core with Rock Wall	Tempered Glass	with Glass
C1	Fire resistance	34	4.5	3.9	3.6	4	3.8	3.2	4	2
C2	Acoustic insulation	16	3.5	3.4	3.2	3	3	3.5	1	2.5
C3	Humidity resistance	13	3.7	3.5	3	2.2	2	3	3.5	4
C4	Durability	17	2.5	2	2.5	2.5	3.5	3.5	2	3.5
C5	Maintenance	11	3.2	1.5	3	3	3.2	3.4	2.5	4
C6	Aesthetic	9	3	2.5	3	4.5	2	2.5	3.5	3
Q=W*R			3.618	3.055	3.151	3.286	3.159	3.232	2.095	2.095

professional as per standard practice in the market were evaluated. The ranking takes into consideration how each alternative compares with the criteria. Ranks are as follows: excellent (5); very good (4); good (3); fair (2), poor (1). For example, if we evaluate the resistance of three different material types, we find that the resistance values are: (300, 500 and 100 KN/ m^2). Ranks will be scaled to be (5) for 500 KN/ m^2, and (1) to 100 KN/ m^2, because these are the maximum and the minimum values.

RESULTS

Total quality scores calculation

In this section, scores were calculated for each criterion. The ranks were multiplied by the weight corresponding to the standard. The resulting overall quality score were assigned to each material alternative (Table 2).

Material scores comparing with cost

The perfect choice will be the material which has the maximum score and the least life cycle cost. Then, the initial and maintenance cost of each material must be given by factories or contractors. The initial cost must include material and installation costs. Then, the material that has the maxi-mum cost will be considered as 100% cost percentage. The other materials cost percentage was calculated correspondingly. Finally, each alternative's value ratio is the ratio of the material score percentage to the cost percentage (Table 3).

$$V = Q/C \tag{2}$$

Where V=Value ratio, Q = Quality scores, C = Cost percentage.

Linking evaluation process with the BIM model

BIM model, which includes the studied elements, was the locale to process data as per the proposed methodology. All studied material types with their properties and criteria values were embedded. Once a material type is selected, it will automatically calculate the criteria scores, the quantity, and the total cost. This will help the decision-maker to note the impact of their choices instantly. To achieve the calculation process, all criteria were defined as parameters. The parameters in Revit can be assigned to any category. They allow the user to transfer any data, and they can be linked with each other by a specified formula. The application of BIM will be implemented in future work.

Conclusion

According to Table 3, it will be noted that the highest value is 12.060. This is the best materials after applying the value engineering for the element comparison with quality and cost. To better understand the evaluation process and validate it, a case study of a commercial building will be reported in future work. Besides, eight types of materials from each classification of internal doors will be studied and evaluated using the study methodology. The calculation and output charts will be outlined to help the decision-maker to select the material type that secures the best value.

Table 3. Table of values of the materials.

Values of the materials	Wooden Doors				Steel Doors		Glass Doors	Aluminum Doors
	Hollow Core with Air Space	Hollow Core with Rock Wall	Hollow Core with Chip Board	Solid Wood	Hollow Core with Air Space	Hollow Core with Rock Wall	Tempered Glass	with Glass
Q=Material Quality Score	3.618	3.055	3.151	3.286	3.159	3.232	2.905	2.905
C= Material Cost	30%	45%	50%	70%	55%	60%	45%	40%
V=Material Value	12.060	6.789	6.302	4.694	5.744	5.387	6.456	7.263

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Al-Hammad AM, Hassanain M, Juaim M (2014). Evaluation and selection of curtain wall systems for medium-high rise building construction. Emerald Group Publishing Limited, 299-314.

Assaf S, Omar S, Hassanain M (2013). Causes of failure of small contractors in Saudi Arabia. International Journal of Construction Management 13(4):1-10.

Azhar S, Nadeem A, Mok J, Leung B (2008). Building Information Modeling (BIM): A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects. Conference: First International Conference on Construction in Developing Countries (ICCIDC–I), At Karachi, Pakistan pp. 435-446.

Castro D, Sefair JA, Flórez L, Medaglia A (2009). Optimization model for the selection of materials using a LEED-based green building rating system in Colombia. Building and Environment 44(6):1162-1170.

CSI (2011). The CSI Construction Contract Administration Practice Guide. John Wiley & Sons.

Cunningham T (2013). Factors Affecting the Cost of Building Work-An Overview. Dublin Institute of Technology.

Dell 'Isola A (1997). Value Engineering, Practical Applications, for Design, Construction, Maintenance and Operations. RSMeans.

Dutil Y, Rousse D (2012). Energy Costs of Energy Savings in Buildings. Sustainability 4(8):1711-1732.

Eastman C, Teicholz P, Sacks R, Liston K (2011). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors (2nd ed.). Wiley.

Jorge S, Daniel CL, Andres M (2009). Material Selection In Building Construction Using Optimal Scoring Method (OSM). Construction Research Congress.

Jorge S, Daniel CL, Andres M (2009). Material Selection In Building Construction Using Optimal Scoring Method (OSM). Construction Research Congress.

Lee S (2013). A Financing Model to Solve Financial Barriers for Implementing Green Building Projects. The Scientific World Journal.

Nemova D, Reich E, Subbotina S, Khayrutdinova F (2015). Comparison of different types of transparent structures for high-risebuildings with a fully glazed facade. In Applied Mechanics and Materials 725:26-33. Trans Tech Publications Ltd.

Rao RV, Davim JP (2008). A decision-making framework model for material selection using a combined multiple attribute decision-making method. International Journal of Advanced Manufacturing Technology 35(7-8):751-760.