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Research Article

Determination of exterior material in sustainable buildings by value engineering method according to LEED criteria

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ABSTRACT

Factors such as the rapid depletion of natural resources and environmental pollution enable us to understand the importance of sustainability better today. With the introduction of the concept of sustainability into the construction sector, the design of buildings according to the environmentally friendly "Green Building" approach has come to the forefront, and various certification systems have been developed. Due to these certification systems, various building materials must be used in buildings. However, since many materials are on the market, it is a problem which materials should be preferred according to the green building criteria. Although there are various approaches in this regard, the value engineering method is ideal as it considers both the criteria the materials must meet and their costs. Value Engineering is the teamwork to analyze the building properties, systems, equipment, and material selections while considering the costs to perform the necessary performance, quality, reliability, and essential functions. In this article, a method on how to choose a value-based, sustainable material was proposed, and as a case study, a product that can be used as an exterior cladding material of a building using LEED criteria, which is used for providing certification for sustainable green buildings, was selected. Initially, a value engineering team was formed. This team determined the product's qualities based on LEED criteria and the eight material alternatives that can meet these qualities. Subsequently, value analysis was conducted, and the highest-value exterior coating material was determined.

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1. INTRODUCTION

The construction industry produces structures by bringing together many stakeholders. Hundreds of stakeholders, from the designer to the manufacturer, from the equipment manufacturer to the end user, can work in great harmony to produce structures of the desired quality without exceeding the targeted budget and within the specified time [1]. However, this may not always be possible. When the aim is to reduce the cost, the quality often decreases with the cost. Similarly, when it is necessary to shorten the duration, the cost increases, or different risks arise. In addition, each stake-

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holder's expectation of the final product to be obtained may differ. The contractor will want to make more money, the engineer will want to obtain a safe and economic structure, the architect will want to make it look aesthetic, and the end user will want to live in a high-quality and comfortable living space. In this case, everyone will be satisfied if each stakeholder's request is fulfilled optimally. So how can this satisfaction be achieved? Today, many methods are used to achieve this goal. One of the most effective and practical of these methods is Value Engineering. Value Engineering is a systematic team effort to choose the lowest cost among the alternatives that can be solved to meet the stakeholders' demands and criteria for a product produced, a service provided, or an existing problem [2]. Team members are composed of people affected by the relevant problem and qualified to solve the problem.

The biggest problems experienced today are decreased resources and environmental pollution [3]. As in every field, similar problems are experienced in the construction sector [4–6]. In order to leave a habitable environment for the next generation, resources should be recycled and reused, and products should be obtained with the least amount of waste [7–9]. The construction sector is vital in deteriorating the ecological balance by using natural resources and energy consumption. Notably, 40% of the energy and 25% of the water consumed worldwide are spent on building construction or during their use [10]. In this context, sustainability has gained significant value in the construction sector, and various construction projects are built sustainably [11, 12]. Sustainable buildings, seen as green buildings in the construction sector, are evaluated with the criteria determined in advance by various global evaluators [13].

Sustainability can be described as the ability to be permanent. The concept of sustainability is used in many fields and sciences today. It is frequently used in ecological science. The global concept of sustainability introduced to the global public was formed thanks to the report "Our Common Future," published in 1987 by the World Commission on Environment and Development within the United Nations. This report defines sustainability as follows; "It is the ability to make development sustainable by providing the daily needs of nature without jeopardizing its ability to respond to the needs of future generations" [14]. Since the concept of sustainability is comprehensive, many people define it as per their understanding. However, they all have one common point in defining it: not using resources unlimitedly while creating a healthy environment and living spaces without harming the ecology.

Green buildings are environmentally friendly buildings designed for the most efficient use of natural resources. As a result of the measurements made, sustainability, green building, and environmental protection issues have become more critical, with the realization that the most significant share in the deterioration of global warming and environmental balance that causes climate changes in the world belongs to the construction sector. The building sector has developed green building projects that are compatible with nature, can use energy effectively, and aim to protect the health of people living and working in them with certification systems [15].

In this study, while designing a sustainable building project, an exemplary application was made for selecting the building's exterior cladding material according to the LEED certification system criteria using the value engineering method. First, an experienced value engineering team consisting of all stakeholders who were relevant to the problem was formed. This team researched which criteria an external (façade) cladding material must meet according to the LEED certification system and subsequently determined the criteria. Then, by conducting market research, they determined the products that could meet these criteria and obtained the technical features that demonstrated in what capacity these products could meet the determined criteria. However, since the importance given by each stakeholder to each criterion will not be equal, the stakeholders have scored and ranked the criteria according to their expertise. As a result, the benefit of each product was calculated by performing a value analysis. The value was calculated by dividing the benefit values determined for each alternative product by the unit costs of the products, and the product with the highest value was determined as the solution to the problem.

2. INTERNATIONAL GREEN BUILDING CERTIFICATION SYSTEMS

It is known that residential buildings constitute the majority of the world's energy consumption. An important aspect that causes significant energy waste in these buildings is that they are produced with conventional construction technology and inefficient consumption habits. The construction sector, which has an essential role in increasing global warming, causing climate changes, and leading to the reduction of energy resources in the world, has started to develop an innovative understanding of the concept of green building, which is a product of the construction concept that is compatible with nature, sustainable, environmentally friendly, and can use natural resources efficiently in order to reduce these adverse effects. Certification systems based on specific criteria have been developed for buildings to have green building characteristics. The most common certification systems developed and implemented by different countries are BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen e.V.), IISBE (International Initiative for Sustainable Built Environment), Greenstar (Environmental Rating System for Buildings), Casbee (Comprehensive Assessment System for Built Environment Efficiency) [16].

In this study, especially the features of this certification system will be mentioned since the exterior coating material will be selected in line with the LEED certification system criteria as an application.

2.1. LEED (Leadership in Energy and Environmental Design)

LEED certification can be used for all types of buildings, including existing buildings, commercial interiors, schools and homes, new buildings under construction, and buildings that have undergone significant renovations. Studies of LEED systems in a neighborhood, retail, and health system are in the pilot phase. To date, 41.8 million square meters of construction area have dealt with the LEED system. LEED is a points-based system, and each building project earns LEED points to meet specific green building criteria. Projects in the seven LEED credit categories must meet specific prerequisites and earn points. It has three grades: silver, gold, and platinum. Regional loans are another feature of the LEED Certification system and recognize the importance of local conditions in determining the best environmental design and construction practices. The distribution of scores is based on strategies to increase energy efficiency and reduce CO_2 [17].

3. VALUE ENGINEERING METHOD

The perception that the concept of value creates in most people is the price, which is the monetary equivalent of the product. However, value is not a concept that can only be measured by cost and price. The highest value is the value that can safely perform the desired functions at the desired time and place and meet the basic quality need with the minimum possible total cost. The actual value of a product comes only from comparing its quality and cost with another product that performs the same functions. Value Engineering (VE) is the technique of generating cost-cutting ideas by focusing on the functions of products without compromising the characteristics of a product desired by the customer and prolonging the product development process. Analyzing the functions determines whether the product or service provides the desired quality level and compliance with customer expectations. In order to meet customer expectations, if necessary, functions deemed not to be needed as a result of function analysis can be removed from the process, or new functions can be added. Value, which is the criterion for customer selection, is a phenomenon that becomes evident due to the quality of the product. A product or service designed and produced to expectations is found valuable and high quality by the customer [18].

VE does not take the objectives of the contractor, owner, or user involved in the construction process individually as an objective. By balancing all these, the goals to be determined work to achieve the whole. The impact of each component to be included in the process, such as the project's objectives, cost limitations, construction technique, materials, and equipment, should be estimated by collecting the necessary information in advance. The more information we have before starting the project, the more chance we have to be in control of goals, cost, quality, and completion date. DM objectives can be itemized as follows [19]:

- Avoiding unnecessary costs
- Using money, materials, and human resources efficiently and effectively
- Reducing construction time by using time effectively
- Improving quality
- Ensuring construction safety
- Ensuring the longevity of the structure
- Revealing staff skills through psychological techniques such as teamwork, creativity, and adaptation
- Identifying functions that contain and do not contain a value for the customer, adding the necessary (valuable) ones to the process, removing the unnecessary (worthless) ones from the process

Value engineering is used to solve many different problems. In the Croatian highway project where the method was applied, a total of $43,000,000 and 12 months of time savings were obtained from value engineering studies. Thus, 6% financial savings and a 17% reduction in project duration were achieved for the contractor company [20]. In the study by Mahdi et al. [21], value engineering was used to apply the four most frequently used techniques: soil replacement, preloading, vertical drains, and the construction of dikes to rehabilitate soft clay existing on highways under construction in Egypt. In the study conducted by Brahmane and Bachhav [22], value engineering was used to shorten the construction time of construction projects. In his publication, Atabay [23] applied value engineering to select the filling material between the shoring wall and the structure. In a study prepared by Taher and Elbeltagi [24], they developed a model to choose the best alternative among sustainable building designs with various criteria they determined, using Building Information Modeling (BIM) and Value Engineering. This model is based on developing a 5-D BIM model that examines the energy efficiency of a building design. In a study conducted by Gunarathne et al. [25], a model integrating the concepts of Value Engineering and sustainability was developed to improve project values in constructions built in Sri Lanka. Both quantitative and qualitative research approaches were used in the study. Albarbary et al. [26] used sustainability and value engineering integration for environmentally friendly concrete production in their study. Suliyanto [27] determined the criteria necessary to build a green bridge and applied value engineering in green bridge construction with the help of these criteria. Abdulaziz Almarzooq et al. [28] applied the value engineering method to the project to reduce the cost of energy use while building a new hospital building.

3.1 Job Plan in Value Engineering

One of the most critical differences distinguishing value engineering from traditional cost reduction methods is its application within the framework of a Job Plan. A Value Engineering Team is created for and implements this job plan. The application of Value Engineering starts with determining the scope and content of the project being worked on, then alternatives are produced to solve the identified problem, the alternatives produced are evaluated, and a solution is proposed at the end. The method used to do all these, that is, to implement value engineering, is known as a job plan. The job plan ensures that all the elements that will play a role in the realization of the project work together, and the team strives to meet the project owner's requirements at the optimum cost. The Job Plan consists of 5 steps, and each step has questions that need to be answered [29]:

Step 1: Information Gathering
- What functions should be provided?
- What are the costs of these functions?
- What are the values of these functions?
- Which functions must be performed?

Step 2: Creativity and Idea Development
- What else can this function do?
- How else can this function be performed?

Step 3: Evaluation
- Can each new idea perform functions?
- How can every idea be changed to provide the function?

Step 4: Developing Recommendations
- How to implement new ideas?
- Can all needs be met?
- What would the cost be?
- Does it contribute to value in terms of cost of use?

Step 5: Presentation/Completion
- What are the better features of the new idea than the old one?
- What are the pros and cons of the existing suggestions?
- What is needed to implement the proposal?

The Value Engineering Team completes the job plan by seeking answers to these questions, and thus the problems are solved from a value-based perspective.

3.2. Functional Analysis

The functional analysis seeks answers to the following questions [30]:
- What is it? In the analysis of complex products or processes, explaining the connection of each part to the whole can provide advantages in practice.
- What does it do? Functional identification of the product is made.
- How much does it cost? Information about the cost of each part/component must be available. High-cost elements can be analyzed first.
- What is the value of the basic functionality provided? It is aimed to fulfill the function with minimum cost.
- How is the primary function provided as an alternative? The ideas put forward should be evaluated together with their costs.
- What is the cost of the alternative? The alternatives decided are evaluated in terms of cost. Evaluation can be completed by:
  - o Comparison with a standard that provides a similar function
  - o Comparison to a similar physical-looking product
  - o Comparison with a product with similar processes in its production
  - o Dividing into functional areas that are simple enough to be comparable to commercial products that can perform similar functions
  - o Determining the quantity and cost of the material required to perform the function
  - o Destruction, creation, and perfection
  - o First, realize creative thinking and identify costs for new ideas

3.3. Value Calculation

In value engineering, the value of a product can be formulated in the following ways [31]:

Value = Entitlement/Cost (1)

Value = Customer Satisfaction/Cost (2)

Value = (User's Initial Impact + Benefit from the product)/(Initial Cost + Life-cycle costing) (3)

Value Analysis (VA) of each alternative is performed by determining the values of the products, processes, and services after the functional evaluation. The high-value alternative is determined as the product, process/service that can be applied and used.

4. SELECTION OF EXTERIOR CLADDING MATERIAL IN SUSTAINABLE BUILDING

The material should be preferred for coating the exterior of a building designed according to LEED certification criteria. Many coating materials on the market are available for this purpose. It was decided to make a value-oriented selection on which of these should be used. For this purpose, a team of four people with material, application, value analysis information, and also the end-user was formed. The members of the value engineering team consist of a civil engineer with 13 years of application experience working in a company that provides sustainable building design and consultancy services, an architect with 15 years of projecting experience working in the same company, a contractor, as well as a project owner who receives services from this company. A team of four stakeholders was sufficient for this study. However, the types and numbers of stakeholders will vary if the problem is more complex and involves different specializations. There may be additional members who are not directly involved in the team but provide support from outside for the calculations that need to be made. The team first determined the qualifications the materials should fulfill in line with the essential criteria specified in the LEED certification, considering the customer's requests.

The value calculation will determine the selection of the building material to be used as an exterior coating. The value shall be defined as the ratio of a product's suitability (benefit) to the economic burden it imposes on the user.

Value = Benefit (Suitability for use)/Economic burden (4)

Suitability for use (Benefit) = Importance x Satisfaction level (5)

Importance; is the value obtained by distributing the 100 total points or perceived by the customer to the qualifications specified in the product specification.

Satisfaction level; is a value that indicates how satisfied the customer is with the specified qualities of each product. It is found by digitizing between 1 and 10.

4.1. Determination of the Qualifications of Materials

The qualifications of the materials determined by the value engineering team are as follows:

- Use of local materials
- Recycling/Reusability
- Material life
- Energy efficiency
- Cost

The cost criterion will not be used in the benefit (function) calculation but will be used in the value calculation. The value engineering team has researched accessible exterior cladding materials that can meet these criteria, and eight alternatives have been determined with the help of brainstorming methods, etc.

4.2. Determination of Exterior Cladding Material Alternatives

- Aluminum: It is an accessible substance to find and access. It is about three times lighter than iron and is almost as durable as steel. Its pure form is much softer. It is non-magnetic and has high electrical and thermal conductivity. It can be quickly processed as hot and cold. It can be drawn and beaten well. It is non-toxic, non-flammable, and can be used without paint. It resists weather conditions, food, chemical liquids, and gases. It is much more active with hydrochloric acid and alkalis [32].
- PVC (Polyvinyl chloride): PVC is a polymer produced from oil (natural gas) and salt in petrochemical plants. PVC has good thermal insulation. The ignition temperature is high. It has a good insulation feature, and it is recyclable. It also prevents cutting trees and thus helps global sustainability [33].
- Glass: Provides heat and sound insulation and a wide field of view in buildings. Resistant to climatic conditions. It is stylish and aesthetic [34].
- Wood: It is a natural building material suitable for health. It provides heat and sound insulation. Moreover, it is 100% recyclable. Lightweight, aesthetic, additional treatments are required to protect from pests such as sun and insects. It is earthquake resistant [35].
- Fiber-cement: The word meaning in the literature is fiber-reinforced cemented board. Thanks to its flexible structure, it is environmentally and human-friendly, suitable for various architectural plans and textures, can be used in various climatic conditions and can be easily applied [36].
- Ceramic: It is unaffected by weather conditions, suitable for energy efficiency conditions, fire resistant, integrated, safe in earthquakes, has high application speed, and is functional and practical [37].
- Precast: It is very resistant to external factors. Its heat and good permeability are low and comply with fire regulations. Since the casting is done in the factory environment, the product quality and artistry can be controlled productively. Since precast equipment can be reused hundreds or even thousands of times, the time and equipment required for the mold are saved [38].
- Siding: It is resistant to heat and water. Fuel savings can be achieved as it provides pretty good insulation. It does not require paint, does not rot, and does not get insects. It is aesthetic and washable [39].

4.3. Limit Values of the Qualifications of the Materials

The limit values for the determined qualification criteria of the materials were found by investigating the technical characteristics of the selected exterior coating material types (Table 1). The determined alternative products are produced and applied by many different companies in the market. As far as possible, the technical features of the relevant products on the web pages of these companies were examined. Since the product features of some companies could not be accessed from the web pages, various communication tools were utilized, interviews were conducted, and information about their products was obtained. As a result of all this research, it has been found that although the material life, heat transfer coefficients, and reusability properties of alternative facade coating products specified in the technical specifications of each company are close to each other, they differ. Since some companies reinforce their products with various additives, differences have been observed in the product characteristics of each company. In order to avoid being based on a single brand, the average value of the relevant characteristics of each product was taken and is shown in Table 1.

Similarly, through research, it was determined whether the products were locally made. Since the application prepared here is a sample study, such a method was followed to not depend on a particular company. However, the products/brands intended to be selected and implemented in an actual project should be identified when an actual application occurs. Thus, the technical characteristics of that product are used in the problem as exact values. The cost values were taken from the 2022 Construction and Installation Unit Prices list published by the T.R. Ministry of Environment, Urbanization, and Climate Change [40]. The prices in the table are the

Table 1. Limit values of the qualifications of the materials

Qualification / Material	Material life (average year)	Energy efficiency (heat transfer coefficient) (w/mK)	Local material	Recycling/reusability	Cost (TL/m²)
Aluminum	130	0.16	50%	70%	1.277,23
PVC	30	0.23	60%	80%	714.90
Glass	200	0.04	100%	100%	6.176,87
Wood	80	0.20	100%	90%	880,00
Fiber-cement	40	0.18	50%	90%	605,01
Ceramic	180	0.96	80%	100%	260,25
Precast	60	0.44	60%	70%	2.824.82
Siding	20	0.22	60%	60%	963,19

Table 2. Determination of the order of importance of materials with nominal group technique

Value engineering team / Qualification	Architect	Civil engineer	Contractor	End user	Total	Sequence no
Energy efficiency	4	4	4	4	16	1
Material life	3	3	2	3	11	2
Recycling/reusability	2	2	3	2	9	3
Local material	1	1	1	1	4	4

Table 3. Importance ranks and percentages of qualifications with the priority matrix method

	Energy efficiency	Material life	Recycling/reusability	Local material	Total	%	Sequence no
Energy efficiency		1	1	1	3+1	40	1
Material life	0		1	1	2+1	30	2
Recycling/reusability	0	0		1	1+1	20	3
Local material	0	0	0		0+1	10	4
					10	**100**	

finished costs of each exterior cladding material, including 1 m^2 of craft. Life cycle repair costs are not taken into account in this example. The life span of the buildings varies depending on their quality, but it is around 50–60 years on average. It can be seen that some of the exterior cladding materials discussed have a longer life than the building's life. These features are not limited to the life of the building, and it is assumed that its longevity will contribute to its usability in recycling.

4.4. Order of Importance and Percentages of Qualifications

In Value Engineering, customer requests and demands are prioritized as much as possible. Customers' requests constitute the qualities that the solution to the problem must meet. However, the importance and priority of these qualities may vary according to customer expectations. Before proceeding to value analysis, different methods can be used to determine the customers' and value engineering team's ideas and priorities. This study used Nominal Group Technique and Priority Matrix Methods for this purpose.

4.4.1. Nominal Group Technique

The process of scoring the qualities, determined by brainstorming or another method by the value engineering team, in order of importance and ranking the values obtained by adding these scores is called the nominal group technique. Thus, the importance given by each stakeholder to the qualities is taken into account (Table 2).

4.4.2. Priority Matrix Method

In the Priority Matrix Method, the value engineering team compares qualifications with each other in pairs, and 1 point is given to the more critical and 0 points to the less important. The score of each qualification is summed and expressed as a percentage (Table 3).

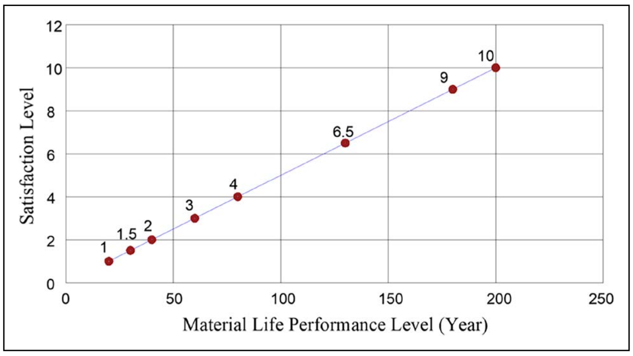

Figure 1. Material life performance – Satisfaction level graphic.

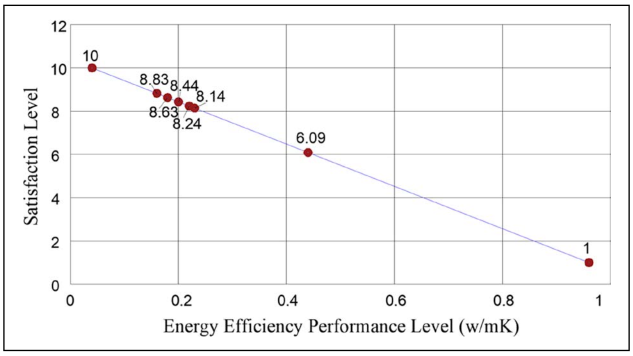

Figure 2. Energy efficiency performance – Satisfaction level graphic.

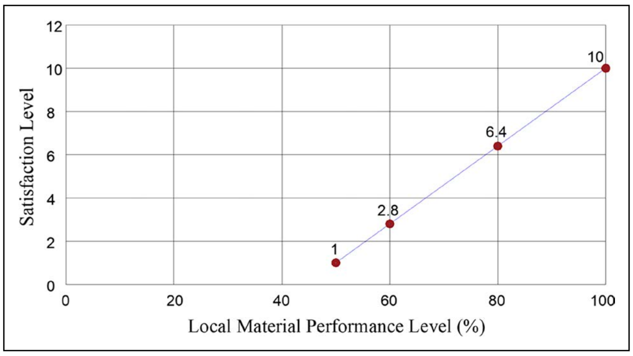

Figure 3. Local material performance – Satisfaction level graphic.

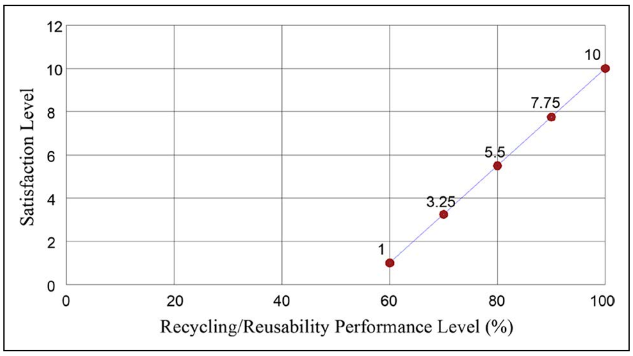

Figure 4. Recycling/Reusability performance – Satisfaction level graphic.

4.5. Satisfaction Levels of Materials

The level of satisfaction is a value for each product that indicates how satisfied the customer is with the specified qualities. It is determined by scaling from 1 to 10. When determining the satisfaction level, a graph shows the performance level of the materials on the horizontal axis and the satisfaction level on the vertical axis. The satisfaction level of the material with the lowest performance is taken as 1, the satisfaction level of the highest material is taken as ten, and a line is drawn. The satisfaction levels of other materials are determined according to their performance levels from this graph. This graph is drawn again for each qualification value. Satisfaction levels were determined for Material Life in Figure 1, Energy Efficiency in Figure 2, Local Material in Figure 3, and Recycling/Reusability performance levels in Figure 4.

4.6. Importance of Qualifications

The importance of exterior cladding materials is found by distributing the previously calculated importance percentages of each quality at the rate that the materials meet the performance of that quality.

For example, if the importance of aluminum for material life quality value is calculated;

Material Life quality value of aluminum: 130 years

Percentage of importance determined by the value engineering team for Material Life qualification value: 30%

Total Material Life qualification values of all materials: 130+30+200+80+40+180+60+20=740

In this case, the significance value corresponding to the ratio of aluminum to meet the total Material Life is calculated as 30x(130/740) =5.27.

All other Significances are calculated similarly. While it is more important that all other qualities are of high value except for the Energy Efficiency qualification value, it is more important that the energy efficiency qualification value is lower. Therefore, the importance of Energy Efficiency should be found with the inverse ratio when calculating the importance.

4.7. Qualification/Function Matrix

The Qualification/Function matrix was used to calculate the benefits of the qualifications of each exterior cladding material (Table 4). The importance and satisfaction levels corresponding to the qualification values for each exterior coating material were previously determined. After these are written in their places in Table 4;

Benefit = Importance x Satisfaction Level (5)

The benefits of all materials regarding qualification values are calculated with this formula. By adding these benefit values, each material has a total benefit. If desired, Function Benefit can also be obtained by adding the benefits of each qualification value for all materials.

Table 4. Qualification/function matrix

Material	Qualification	Energy efficiency	Material life	Recycling/reusability	Local material	Total
Aluminum	Importance	5.27	7.24	0.89	2.12	15.52
	Satisfaction level	6.5	8.83	1	3.25	19.58
	Benefit	34.26	63.93	0.89	6.89	**105.96**
PVC	Importance	1.22	2.96	1.07	2.43	8.51
	Satisfaction level	1.5	8.14	2.8	5.5	17.94
	Benefit	1.83	29.09	3.00	13.37	**47.29**
Glass	Importance	8.11	15.80	1.79	3.03	28.73
	Satisfaction level	10	10	10	10	40
	Benefit	81.11	158	17.9	30.30	**287.31**
Wood	Importance	3.24	3.62	1.79	2.73	11.38
	Satisfaction level	4	8.44	10	7.75	30.19
	Benefit	12.96	30.55	17.90	21.16	**82.57**
Fiber-cement	Importance	1.62	3.79	0.89	2.73	9.03
	Satisfaction level	2	8.63	1	7.75	19.38
	Benefit	3.24	32.71	0.89	21.16	**58**
Ceramic	Importance	7.30	0.66	1.43	3.03	12.42
	Satisfaction level	9	1	6.4	10	26.4
	Benefit	65.7	0.66	9.15	30.30	**105.81**
Precast	Importance	2.43	2.64	1.07	2.12	8.26
	Satisfaction level	3	6.09	2.8	3.25	15.14
	Benefit	7.29	16.08	3.00	6.89	**33.26**
Siding	Importance	0.81	3.29	1.07	1.82	6.99
	Satisfaction level	1	8.24	2.8	1	13.04
	Benefit	0.81	27.11	3.00	1.82	**32.74**
	Function's benefit	**207.20**	**358.13**	**55.73**	**131.89**	**752.95**

4.8. Value Calculation

Value of each exterior cladding material alternative;

Value = Benefit (Suitability for use)/Cost

formula, and thus it was determined which material was suitable for use in terms of value engineering (Table 5)

As a result of the value calculation, it was concluded that it would be appropriate to use the "Ceramic" material with the highest value (0.407) among the alternative exterior coating materials discussed.

Table 5. Value calculation for material selection

Material	Benefit	Cost (TL/m^2)	Value
Aluminum	105.96	1.277,23	0.083
PVC	47.29	714.90	0.066
Glass	287.31	6.176,87	0.047
Wood	82.57	880,00	0.094
Fiber-cement	58	605,01	0.096
Ceramic	105.81	260,25	**0.407**
Precast	33.26	2.824.82	0.012
Siding	32.74	963,19	0.034

5. CONCLUSION AND RECOMMENDATION

In this study, the exterior cladding material was determined using the Value Engineering method based on the LEED criteria in line with the sustainability principle of the structure to be built.

First, the problem was clearly revealed, and then a four-person Value Engineering Team consisting of people who may be interested in solving the problem was formed. In line with the LEED certificate, this team conducted a study on what the expectations may be from a product that can be the exterior coating material of a sustainable structure by brainstorming and other methods; hence, expectations, which are the criteria, were determined from the products. Subsequently, the alternative products that could meet these criteria were investigated, and eight products were determined. In order to determine to what extent these products could meet the determined criteria, their technical characteristics were researched, and these characteristics were digitized in the form of a scale.

Value Engineering tries to fulfill the wishes of the customers and all stakeholders involved in solving the problem at the optimum rate. For this reason, the criteria determined by the team were scored, and thus the ranking of importance and percentages of each criterion was identified. In order to perform Value Analysis, each product's satisfaction levels and importance were calculated, and its benefits were defined. The values of each product were estimated with the help of benefit and unit costs, and thus the material with the highest value was determined. Value Engineering chooses the alternative with the highest value as the solution to the problem. This study selected "ceramic" as the most valuable product.

Ceramic facade coating system is a vital coating material preferred in interior and exterior facades due to its features such as being easy to install, resistant to impacts and abrasions and all weather conditions, low water absorption, stain-free, having a large number of colors and size options and low maintenance-repair cost as a result of all these factors (although not taken into account in this application). Ceramic cladding systems prevent moisture formation due to the continuous air circulation within themselves. Joint gaps between the panels provide natural ventilation behind the facade. It is a natural material that complies with energy efficiency requirements, is fire-resistant, is safe from earthquakes, and has a high application rate [41].

Despite all these features, ceramic exterior cladding material cannot be claimed as the most environmentally friendly product. If the aim were to determine only the most environmentally friendly product, only the technical characteristics of the products would be considered, and the product that met the most desired criteria would be selected directly. Value engineering may require a product to meet different requirements, as well as the primary purpose, among the criteria it must meet when selecting a product. In addition, since the team members prioritize these criteria, each criterion contributes to the problem to a certain extent. In value engineering, the goal is to choose the least costly of the alternatives that can solve a problem. If the chosen alternative does not satisfy the selected team due to the calculations, it should not be involved in the problem from the beginning. In the study conducted here, there may be a more environmentally friendly product than ceramic. However, the value obtained when the benefit of each product is calculated by taking into account the determined criteria such as importance, satisfaction levels, etc., and divided by its unit cost, has led to choosing the "ceramic" coating material, which is among the alternative solutions, assuming that it is also among the environmentally friendly products. In other words, an optimization has been made.

Value Engineering does not offer the lowest-cost product as a solution. The goal is not just to cut costs; customer and stakeholder requests are also significant. Therefore, it proposes a value-based solution, not a cost-based one. The Value Engineering Method can be used to evaluate projects on a macroscale or to solve a problem related to the minor function of a project.

One of the essential things to remember is that the solution to this type of problem is not always the same. The fact that the Value Engineering team consists of different specializations, criteria, and preferred alternatives will also change the solution.

As a result, this study was prepared as an example for similar choices to be made. Only the construction costs were considered in this example, but also considering the life cycle costs would be ideal. For those who want to do similar studies later, it is also recommended to consider the life cycle costs.

ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declare that they have no conflict of interest.

FINANCIAL DISCLOSURE

The author declared that this study has received no financial support.

PEER-REVIEW

Externally peer-reviewed.

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