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Preliminary communication

Material Selection with Value Engineering Technique - A Case Study in Construction Industry

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Abstract: As a result of the rising level of competition in the construction industry, businesses strive to stay one step ahead of their rivals and overcome the most fundamental optimization challenge of balancing quality, time, and cost parameters. This is not always possible, however. Occasionally, the project may be completed late, the budget may be exceeded, or the desired quality cannot be attained. Various strategies have been developed to address these issues. The value engineering method is among these techniques. Taking into account quality, time, and cost, value engineering executes cost-saving projects without disregarding customer expectations. Value engineering seeks to increase value by concentrating on functions other than cost management. By conducting value studies on the products, value engineering can introduce new designs, develop the existing product, or provide value to the customer. This study employed value engineering to determine the thermal insulation material to be used in a building. First, the functions to be worked on were determined by considering user expectations, and then three alternative products that provide these functions were identified among the most preferred products. By developing alternative products, the advantages and disadvantages of the original products were revealed. The most valuable product was determined by calculating the product's value in relation to its benefits and costs. Thus, the optimal product was selected by weighing the user's expectations, the product's benefits, and its price.

Keywords: civil engineering; project management; value engineering

1 INTRODUCTION

Construction is currently one of the most competitive industries. Because of the growing population, the fact that it is a good earning area, and people choosing real estate as an investment, the construction industry has grown in popularity. New constructions and an increase in the number of construction companies have increased competition in the construction industry.

In this competitive environment, construction companies must make informed decisions regarding their future in the industry [1]. Today, construction companies should focus on three primary criteria in order to make the best decisions in this competitive environment, thereby increasing their popularity and financial gains. These three criteria are: quality, cost, and time [2, 3]. By meeting these criteria accurately, the business can distinguish itself from the competition [4]. Various techniques and strategies are employed to meet these requirements. The technique of value engineering is one of these methods. To meet the described criteria, thorough studies and analyses are conducted, information is generated, and the organization is supported to take the correct decisions using this strategy [5, 6]. In a market that is globally competitive, value engineering has been effectively applied to the process of creating new products. It is claimed that value engineering reduces producer and consumer purchasing costs by 15 to 25 percent. The performance of value engineering in creating customer-oriented value is impressive [7, 8]. Value engineering is a multi-step procedure that requires considerable time to complete. The value engineering team aims to increase the product's value in phases and acts accordingly. Value engineering studies may result in the introduction of modern designs, the improvement of existing products or systems, or the identification of the most valuable product.

2 THEORETICAL BACKGROUND

2.1 The Value Engineering

During World War II, General Electric Company engineer Lawrence D. Miles developed value engineering (the concept of value analysis) [9]. The primary objective of this investigation was to determine the most effective method for utilizing scarce funds and resources during the war years.

Miles has created a method that may require teamwork to examine each step - in order to reduce costs and completion time while increasing efficiency and performance in order to analyze functions based on the goals of the services, projects, or processes. General Electrics and Miles used the term "value analysis" rather than "value engineering". After World War II, the concept of value analysis was applied to all 55 General Electric factories in the United States [10].

Although it incorporates the concepts and techniques of the value analysis method, the United States has adopted General Electric's concept of "Value analysis" to reduce the cost of shipping and shipping-related equipment and renamed it "value engineering." The only distinction between value analysis and value engineering is that value analysis is performed on an existing system or product, whereas value engineering is performed during the design phase of the system or product. Nonetheless, it is evident that these two concepts are now used interchangeably [9, 11].

2.2 Definition of the Value Engineering Method

The term value, which comprises the value engineering concept, refers to the metric that determines the necessity and significance of something [12]. The value of a product or service is calculated by comparing its quality, cost, usefulness, performance, and the degree to which its derivatives with the same function possess superior properties to those with similar, desired conditions. On this basis, the value engineering method can be described as follows: It is the process of reducing costs by focusing on a product's functions while considering user preferences, quality, and time [13, 14]. The concept of function can be defined as the service's functional capacity or the product's inherent characteristics [14, 15]. Reducing

the cost should not be equated with sacrificing concepts such as quality, performance, and dependability. By analyzing the functions, it is determined if they meet the customer's expectations and what the quality level is. As a result of research, functions that are deemed necessary or unnecessary by the analysis can be added or removed as needed to meet customer expectations. Products are manufactured to fulfill a particular need, and each product has its own unique functions to accomplish this. As needs change or new needs emerge, it may be necessary to develop or introduce new products in order to maintain the functionality of the products. At this point, value engineering works to achieve this development at the lowest cost without affecting the quality of the product. Functions are evaluated, and if there are unnecessary functions, they are removed because there is no need to waste time doing cost studies on unnecessary functions. It is necessary to consider the price of an existing product's modification. The cost of the proposed change should not exceed the product's benefit; otherwise, a situation will arise that is contrary to the goals of value engineering. Value Engineering is a method that has been used for many years to develop existing products, offer new products, analyze products, and attempt to reduce costs. It focuses on the concepts of products, processes, and functions. It would be incorrect to name a specific field or industry if we were to examine the application of value engineering. It can be applied to products, systems, and projects that produce and seek renewal and improvement. This may be a factory, a construction company, an automobile company, a textile workshop, a shoe company, etc. There may be numerous opportunities for improvement. Because value engineering serves a specific purpose, all industries that adopt this objective, i.e., want to advance in accordance with this objective, can benefit from it. According to [16] list, value engineering attempts to answer the following questions:

- What are the product's functions?
- In what manner are these functions essential?
- What is the cost of this product?
- What are the various products that perform the same function, and what are their prices?

Specifically, the objectives of value engineering are as follows:

- To increase the product's value.
- To provide affordable, high-quality services.
- To save time.
- To maximize the efficiency of the available resources.
- To be capable of developing the product manually in accordance with the desired conditions.
- To examine the product's functionality.
- To present the appropriate option to the user.
- In order to provide the above items, it is important to carry out some studies in advance.

Knowing the purpose of the project before beginning it, as well as certain project details such as the budget, materials, and steps to be taken during its execution, enables us to work more efficiently and achieve more accurate completion time, quality, and cost results. Value engineering is a team-based approach to product design that seeks to increase the value of the product [17]. In value engineering, there are two methods for increasing the value of a product. First, by maintaining the product's functions, it is possible to find new, lower-cost components to replace existing components and provide the same functionality at a lower price. In other words, the product is anticipated to retain the same functionality and features despite being cheaper. Consider the emergence of electric vehicles as an illustration. By reducing the cost of fuel in the vehicle, the same level of performance is maintained. The second strategy entails replacing existing components with those that perform better for the same price, while maintaining the product's price and enhancing its functionality. In other words, the product will be designed to deliver a higher level of performance at a lower price. The goal is to increase performance while keeping costs constant. This is exemplified by led light bulbs that provide more light for the same price. Value engineering is a time-consuming process that requires extensive research and analysis. Numerous phases of this process have distinct characteristics. Some of the characteristics required for this process include asking the right questions, having a creative mind, being able to brainstorm, employing correct working techniques, and avoiding erroneous thoughts [14, 18]. These features can only be provided through teamwork. However, effective teamwork and accurate analysis can lead to the desired outcomes. Seven distinct groups can be used to examine the general features of value engineering [16, 19].

1) This is a planned and organized endeavor.

The tasks and procedures to be performed are determined beforehand. It is executed according to a plan. The studies continue within the framework of a business plan.

2) It provides unity between diverse specializations.

The value engineering method consists of multiple phases. Each phase is completed by specialists in their respective fields. Experts may not know precisely how their work or decisions in their field will affect other fields; therefore, they must collaborate to achieve a common objective.

3) It examines function research using "function analysis"

The function analysis method is utilized by value engineering when conducting a functional analysis for product research. This method seeks to answer questions such as "What is the function of this element?" and "What is the fundamental function that this element seeks to fulfill?" It seeks to resolve issues by getting to their source.

4) It analyzes functions through the lens of the value concept.

In this section, the value of the system or product is attempted to be revealed. The cost and value of the function under consideration are determined and compared. The value index of the system or product is calculated.

5) The total cost includes both the cost of use and the cost of initial investment.

The cost of utilization includes personnel, maintenance, repair, and operation. The cost of the initial investment is sufficient to cover the production expenses. Total cost is the sum of the cost of use and the cost of the initial investment. Value engineering also accounts for total cost.

(6) Beginning early yields positive results.

As a result of cost analysis, value engineering enables the determination of necessary or unnecessary elements.

The ability to initiate this process early provides us with an advantage when implementing the necessary intervention.

7) It concentrates on the most pertinent target.

Rather than focusing on an element that is unimportant to the project or the product or that has little impact on the cost, it is preferable to concentrate on the important elements that have a substantial impact on the cost. Italian economist Pareto proposed that 80% of the nation's wealth is owned by 20% of the population [20]. Using this approach in value engineering, it has been determined that 20% of the project or application components influence 80% of the project's cost. In other words, the 20% of correctly determined and prioritized parts were more cost-effective than the remaining 80%.

If a general value engineering assessment is conducted based on the characteristics because functions are the most effective way for us to save money, reduce costs, and increase efficiency, then it is evident that one of the most important issues is accurately analyzing the product or system's functions.

2.3 Functional Analysis Method

In the 1960s, Charles developed the Functional Analysis Systems Technique (FAST) for functional examination [21]. This method is used to disassemble, examine, precisely comprehend, and identify the functions of a product, system, or process. By performing value analysis within the framework of functional analysis, what should be for the client? The question's answers are sought. In other words, it is essential that the functions satisfy these needs in accordance with the needs and preferences of the customer. Additionally, functional analysis answers the following questions [15, 16]:

1) What is the topic or opportunity being discussed?

Here, the problem and its corresponding solution are identified.

2) Why is this a problem or an opportunity?

The factors to consider when deciding whether something is a problem or an opportunity are discussed.

3) Why is the solution necessary?

It is debatable what problems the identified problem causes and how to solve them.

In response to these questions, the functional analysis method's objectives can be explained as follows:

- To evaluate the technical functions performed by the product or system's components.

Examine the interrelationships between the components that comprise the product or system.

- To define what the customer expects from the product.
- To direct the design process to produce the most cost-effective product in terms of price and quality.

After examining and analyzing the product or system's functions using the functional analysis method, the results should be evaluated to determine if it meets customer expectations and if it can be improved in terms of cost or function. Comparing the characteristics such as performance, physical appearance, cost, and durability to those of a product with the same or similar function as the one being developed allows for evaluation of the results. The results can indicate whether the product is adequate.

In performing functional analysis:

- System engineering
- Software engineering
- Quality function development and system diagrams are used.

The functional analysis technique can be considered the core of value engineering. At this stage, it is essential to conduct precise analyses. When analyzing the functions of a product or system, it is necessary to correctly define the functions and determine the relationship between the components, as the data obtained at this stage determine the solutions that will increase the product's or system's value. These data are incorporated into a value account that reveals the product's value.

In value engineering, functional evaluation of a product or system is followed by value analysis for alternatives that can increase the product's value by determining the system's value. The option with the highest value is identified and proposed for use. Here is how the value account can handle headlines that reveal a product's value:

Economic value: The sum of all costs incurred, such as labor, in the production of a good or service is its economic value.

Exchange value: The monetary equivalent of the qualities that make one prefer one good or service over another is known as exchange value.

Impressive value: Impressive value is the value assigned to characteristics, such as the appearance, that make a product or system desirable and entice the recipient to purchase it. When purchasing a product, consumers want to be pleased with both its appearance and its primary functions.

Usage value: The value assigned to the product or system's functions. The greater the product's performance for its intended purpose, the greater its value. Because value engineering works by focusing on the functions of the product, it is possible to say that the value engineering title emphasizes use-value in its studies.

The value of a product can be shown as a formula as follows [22]:

$$\textbf{\textit{Value}} = Functionality/Cost$$

$$\textbf{\textit{Value}} = Functionality/Cost \times Velocity$$

$$\textbf{\textit{Value}} = Function/Cost$$

$$\textbf{\textit{Value}} = User\ satisfaction/Cost$$

According to the preceding formulas, the functionality of the product or service offered to the customer determines its value. The product's value increases as its functionality is expanded while the price remains constant. While enhancing a product's functionality, the intended use should not be overlooked. The formula demonstrates that the value can increase when the functionality is fixed and the cost is reduced. From a different perspective, increased functionality will please the user, leading to an increase in user satisfaction. When viewed in this manner, it is evident that the user satisfaction/cost ratio can indirectly lead to the value result. The objective of value engineering is to increase the product or system's value. The concept of increasing value should not be interpreted as directly

increasing the profit rate because increasing the profit rate can only be accomplished by lowering the product's cost, which can compromise the product's functional properties [23]. This perception is contrary to the concept of value engineering, as value engineering always increases the value of the product by maintaining or enhancing the product's or system's essential functional characteristics.

Cost, time, and function are the most significant factors in enhancing a product's value. Regarding the significance of the concept of value, one of the conditions for a company's success in a competitive industry is the ability to provide the customer with the highest value at an affordable price. In this type of competition, businesses compete by attempting to design customer-centric products or projects. They believe that in order to win this competition, they must provide the most value for the lowest price.

2.4 Business Plan in Value Engineering

In order to obtain the results of value engineering studies, certain steps must be followed. The value engineering study begins with the determination of the project's or system's scope and content. After generating solutions to a predetermined problem, solutions are presented by evaluating all production options. To achieve all of this, certain measures must be taken. A business plan is a method that reveals these steps, i.e., the method utilized for value engineering work. The business plan ensures that all components of the project will function cohesively.

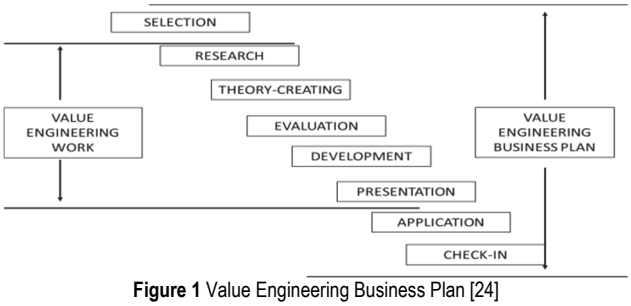

Figure 1 Value Engineering Business Plan [24]

The value engineering business plan consists of eight phases, but only five phases cover the value engineering studies.

2.4.1 Research-Information Collection Phase

Research is one of the most crucial phases of the value engineering business plan. At this point, all information regarding the ongoing project is collected. The purpose of information gathering is to determine the functions, value, and cost of the project. The most important factor at this stage is having accurate information, as it is crucial to collect accurate information at the outset so that subsequent stages can proceed correctly and the best solution can be identified. During this phase, the project's documentation and design are reviewed, and functional analysis is conducted to determine how and to what extent customer expectations will be met. Although functional analysis is listed as a separate phase in some sources, it is actually a component of the information collection phase.

2.4.2 Theory-Creativity Phase

This phase entails generating alternative concepts to meet the basic requirements established in the previous phase. Brainstorming is one of the best ways to generate alternative ideas. Using this method, the Value Engineering team examines each function individually and records all suggestions that arise in response to that function. It is essential to generate as many options as possible.

At this stage, the following questions can be answered:
- What other tasks can this function perform?
- In what other manner could this function occur?

2.4.3 Evaluation Phase

The primary purpose of the evaluation phase is to assess the alternative concepts presented in the theory phase. First, unfavorable ideas that cannot be definitively accepted are eliminated, followed by a discussion and evaluation of the positive and negative aspects of the remaining alternatives. Some factors may be considered when evaluating alternatives.

These factors are:
- Cost of alternative ideas
- To meet the expectations of the user
- Facility of design
- Security impact
- Materials needed
- Compliance with standards.

2.4.4 Development Phase

The alternatives selected during the preceding evaluation phase are examined in greater detail. The level of applicability is evaluated, and cost analyses are conducted. This is the phase in which the necessary modifications are made to the final application. At this point, the following actions are possible:
- Additional information sources are identified.
- Technical viability of the selected alternative is demonstrated.
- Advice from experts and experienced individuals is sought.
- Determine the economic viability of the alternatives.
- Implementation plan must be developed while incorporating suggestions for change and existing information.

2.4.5 Presentation Phase

The purpose of the presentation phase is to make the project owner and design team appreciate the alternatives chosen during the previous phase of development. For this reason, the selected alternatives should be presented with convincing evidence.

The value engineering team completes its work in accordance with these stages in a step-by-step, methodical manner. The error to be made at any stage of the business plan may affect other stages and lead us to the incorrect conclusion, but the problem addressed by the proper implementation of the business plan is resolved from an expert's standpoint.

3 MATERİAL AND METHOD

3.1 Value Engineering Study for the Selection of Wall Insulation Material in the Buildings

Thermal insulation materials are used to insulate buildings, which is one of the most important building features today. Thermal insulation materials are intended to minimize heat loss to the exterior, thereby protecting and conserving heat in the environment. In this section, insulation materials for wall thermal insulation will undergo value engineering, and the material values will be calculated.

3.2 Defining the Problem and the Methodology

In order to insulate the walls of a construction project, thermal material will be chosen. To determine which material to use, a value analysis calculation, as well as the benefit and cost of the product to the user, will be performed.

Value = *Benefit/Cost*

Benefit = *Satisfaction level* × *Importance*

Importance: It refers to the importance of the product's features that the user will work on. The importance of the products is distributed across a 100-point percentage scale.

Satisfaction Level: It indicates the extent to which the user is satisfied with the product's features for the specified products. On the scale, it is a number between 1 and 10 points.

3.3 Determination of Material Functions

The value engineer has determined the properties of the insulation material to be used in the building, taking into account the user's preferences. The identified characteristics are as follows:

- Thermal conductivity value
- Burning degree
- Water absorption value by volume
- Cost.

Thermal conductivity value: Thermal insulation products are distinguished from other products primarily by their thermal conductivity value. The lower a product's thermal conductivity, the greater its ability to insulate.

Burning degree: This value represents the maximum temperature the thermal insulation material can withstand. In the event of a fire, the thermal insulation material's high level of combustibility is advantageous because it limits the extent of the damage.

Volumetric coefficient of water absorption: The ability of thermal insulation materials to absorb water is not a positive characteristic. In terms of insulation, the material with a low water absorption value is of superior quality. Over the specified functions of the product, concepts of importance and satisfaction will be calculated. As the cost is not a function, it will not be considered when determining the significance and level of satisfaction. Cost will not be factored into the calculation of value until the final stage.

3.4 Defining the Alternatives of Isolation Materials

As a result, researchers selected three isolation materials from the value engineering team's most frequently used materials. Fig. 2 depicts a breakdown of isolation materials.

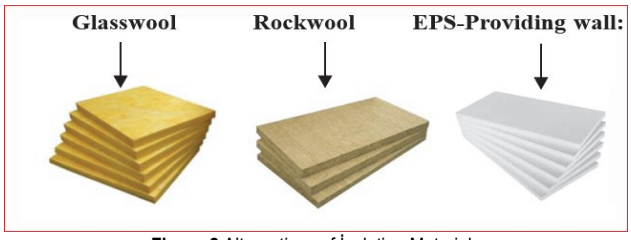

Figure 2 Alternatives of İsolation Materials

Glasswool: Glasswool provides thermal and acoustic insulation for the wall, with 5 cm thick boards positioned between two walls with no gaps. The average thermal conductivity of glass wool is 0.04 W/mK. Thermal insulation relies primarily on the extremely low thermal conductivity of gases [25].

Rockwool: The average thermal conductivity of rockwool is 0.03 W/mK. Mineral wool's thermal conductivity varies with temperature, moisture content, and mass density [25].

EPS-Providing Wall: In the construction industry, EPS boards are used primarily as insulation for external walls, roofs, ceilings, floors, and heating and cooling devices. The average thermal conductivity of EPS-Providing walls is 0.03 W/mK [25].

3.5 Limit Values of Functions

The products listed above have limited thermal conductivity, combustion, water absorption by volume, and cost values. These values will be incorporated into subsequent calculations. Each insulation material has its own set of limitations. The limit values for the identified insulation materials are listed in Tab. 1 below.

Table 1 Function Limit Values [25, 26]

Product / Function	Glass wool	Rock wool	EPS
Thermal conductivity value	0.040 W/mK	0.036 W/mK	0.033 W/mK
Combustion value	250 °C	750 °C	80 °C
Water absorption value by volume	6% = 0.06	6.5% = 0.065	3% = 0.03
Cost	1.28 USD/m^2	0.75 USD/m^2	1.65 USD/m^2

3.6 Determination of Importance Orders and Percentage of Functions

The method of value engineering is defined as cost-optimizing studies conducted by concentrating on the functions of a product while taking into account user requests, quality, and time. According to this definition, one of the most important aspects of value engineering is meeting user needs. Previously, the functions that need to be worked on have been identified in consideration of the customer's request; however, it should be determined which of these functions is more important and should be weighed more heavily based on the customer's request. The significance of the functions may vary by user. Therefore,

in order to determine the importance order and percentage of the functions, it is necessary to employ methods that allow the value engineer and the users to express their opinions and jointly determine the importance level. This study employed the Priority Matrix technique and the Nominal Group Technique.

3.6.1 Nominal Group Technique

This technique will enable the value engineer and the value engineering team of the users to jointly determine the importance ranking. In this method, each member of the value engineering team is awarded points equal to the number of functions that was determined beforehand. Each person assigns the highest score to the function he believes to be the most essential. It continues scoring by subtracting one point for the subsequent function [27].

3.6.2 Priority Matrix Method

This method permits the ranking of functions, similar to the nominal group technique. In this method, functions are compared against one another. During comparisons, the function deemed to be more important by the value engineering team receives one point, while the other function receives zero points. After completing the comparisons, the points earned by the functions are tallied and the order is determined. Based on the collected points, importance percentages can also be calculated using this method. Using the Nominal Group Technique in Tab. 2 and the Priority Matrix Method in Tab. 3, the value engineering team calculated the importance rankings and importance percentages of the functions listed below.

Table 2 Determination of order of importance using the nominal group technique

	Field Expert 1	Field Expert 2	Field Expert 3	Field Expert 4	Total Value	Sequence of Importance
Thermal conductivity value	3	3	3	3	12	1
Combustion value	1	1	2	1	5	3
Water absorption value by volume	2	2	1	2	7	2

Table 3 Finding the order of importance using the priority matrix method

	Thermal conductivity value	Combustion value	Water absorption value by volume	Total	Percentage	Sequence of Importance
Thermal conductivity value		1	1	2 + 1	50	1
Combustion value	0		0	0 + 1	17	3
Water absorption value by volume	0	1		1 + 1	33	2
				6	100	

The order of importance was established based on the points collected by the functions, and the thermal conductivity value ranked first according to the value engineering team's scoring.

Using the method of the priority matrix, importance rankings and percentages were calculated. Since a function cannot be compared to itself, the matching functions are painted black and awarded a single point. Both approaches have produced the same result.

The order of importance is as follows:

1) Thermal conductivity value
2) Water absorption value by volume
3) Combustion value.

3.7 Determination of Material Satisfaction Levels

The Benefit/Cost formula will be used to calculate the value. In this regard, the satisfaction levels of the materials must also be known in order to calculate the benefit. In situations where the level of satisfaction is unknown, it is possible to determine it by constructing a utility curve. The utility curve is a chart with two axes. On the vertical axis are the satisfaction levels of materials from 1 to 10, and on the horizontal axis are the performance levels corresponding to the specified functions of materials. For each function, a distinct graph is produced. The value with the worst performance is plotted with a satisfaction level of 1, while the value with the best performance is plotted with a satisfaction level of 10, and the two points are added. On this chart, the performance level corresponds to the satisfaction level of all products in between.

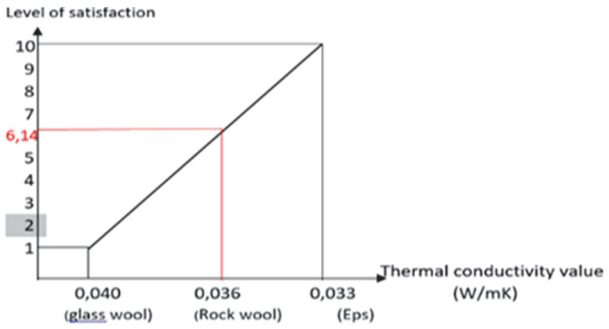

Figure 3 Satisfaction level for thermal conductivity value

The level of satisfaction with thermal insulation materials is depicted in Fig. 3 above. The lowest conduction coefficient is assigned a 10-point satisfaction level, while the highest conduction coefficient is assigned a 1-point satisfaction level, because the material with the lowest thermal conductivity value provides the best insulation. Therefore, the level of satisfaction with the value in the middle (rock wool) was calculated to be 6.14.

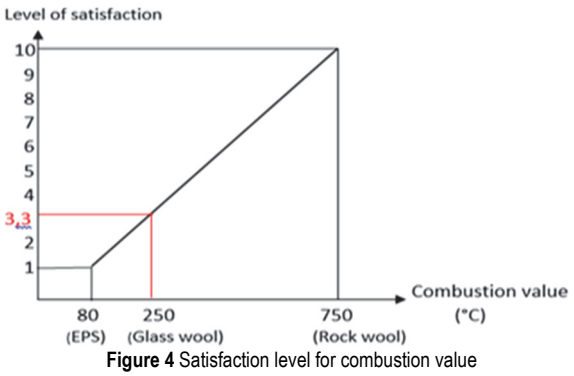

Figure 4 Satisfaction level for combustion value

The level of contentment with the combustion value is determined by Fig. 4. Since the material with a high combustion value will be more useful, as the degree of combustion increases, so will the level of satisfaction. The material with the highest burning value has a 10-point satisfaction level, while the material with the lowest burning value has a 1-point satisfaction level. Accordingly, a 3.3% satisfaction level was calculated for the median value (Glasswool).

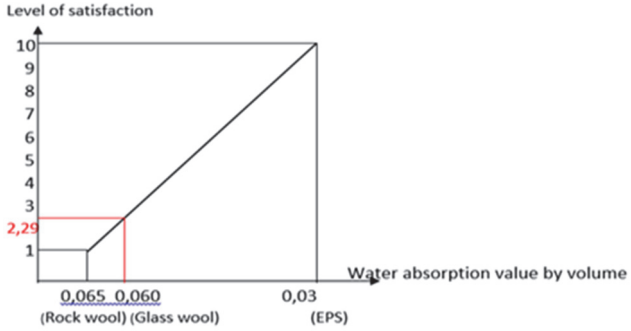

Figure 5 Satisfaction level for water absorption value

In Fig. 5, the level of satisfaction for the water absorption value by volume is calculated. Since water absorption is undesirable for thermal insulation materials, the calculated level of satisfaction for the material with the lowest water absorption value is 10 points and for the material with the highest water absorption value is 1 point. Accordingly, 2.29 was determined to be the satisfaction level for the in-between (glass wool).

Satisfaction levels of the studied thermal insulation materials for the specified functions have been calculated. Satisfaction levels will be used to calculate benefits at a later stage. The levels of satisfaction found in the graphs above are more clearly expressed in Tab. 4 below.

Table 4 Satisfaction level values

	Glass wool	Rock wool	EPS
Thermal conductivity value level of satisfaction	1	6.14	10
Combustion value level of satisfaction	3.3	10	1
Water absorption value by volume level of satisfaction	2.29	1	10

3.8 Utilizing the Feature-Function Matrix Method for Utility Calculation

The Benefit / Cost formula will be used to calculate the value of thermal insulation materials. Utilizing the Feature-Function matrix method, the utility of each material will be determined. In this method, importance percentages and satisfaction levels determined in earlier steps will be utilized. In the quality function matrix method, the benefit score is obtained by multiplying the importance and satisfaction level. Prior to calculating importance, the importance percentages of materials corresponding to functions should be distributed according to the materials' performance for that function [17].

Calculation of thermal conductivity value's significance:

Glass wool: Percentage of importance 50%, thermal conductivity value 0.040 W/mK.

Total thermal conductivity value of all products:

$0.040 + 0.036 + 0.033 = 0.109$

Significance corresponding to the total thermal conductivity ratio for glass wool:

$50 \times (0.040/0.109) =$ **18.35**

Rock wool: Percentage of importance 50%, thermal conductivity value 0.036 W /mK.

Total thermal conductivity value of all products:

$0.040 + 0.036 + 0.033 = 0.109$

For rock wool, its significance corresponding to the total thermal conductivity ratio:

$50 \times (0.036 / 0.109) =$ **16.51**

EPS: Percentage of importance 50%, thermal conductivity value 0.033 W /mK.

Total thermal conductivity value of all products:

$0.040 + 0.036 + 0.033 = 0.109$

Significance for EPS corresponding to the total thermal conductivity ratio:

$50 \times (0.033/0.109) =$ **15.14**

Calculation of combustion value significance:

Glass wool: Percentage of importance 17%, burning value 250 °C.

Total combustion value of all products:

$80 + 250 + 750 = 1080$ °C

The significance corresponding to the total combustion value ratio for glass wool:

$17 \times (250/1080) =$ **3.94**

Rock wool: Percentage of importance 17%, burning value 750 °C.

Total combustion value of all products:

$80 + 250 + 750 = 1080$ °C

For rock wool, its significance corresponding to the total combustion value ratio:

$17 \times (750/1080) =$ **11.8**

EPS: Percentage of importance 17%, burning value 80 °C.

Total combustion value of all products:

$80 + 250 + 750 = 1080$ °C

Significance corresponding to the total combustion value ratio for EPS:

$17 \times (80/1080) =$ **1.26**

Calculation of combustion value significance:

Glass wool: Percentage of importance 33%, water absorption value by volume 0.06.

Total combustion value of all products:

0.06 + 0.065 + 0.03 = 0.155

For glass wool, its significance corresponding to the ratio of total water absorption value by volume:

33 × (0.06/0.155) = **12.78**

Rock wool: Percentage of importance 33%, water absorption value by volume 0.065.

Total combustion value of all products:

0.06 + 0.065 + 0.03 = 0.155

For stone wool, its significance corresponding to the ratio of total water absorption value by volume:

33 × (0.065/0.155) = **13.83**

EPS: Percentage of importance 33%, volume water absorption 0.03

Total combustion value of all products:

0.06 + 0.065 + 0.03 = 0.155

For EPS, its significance corresponding to the ratio of total water absorption value by volume:

33 × (0.03/0.155) = **6.39**

Table 5 Calculation of the benefit using the property function matrix method

		The Value of Thermal Conductivity	Combustion Temperature	Water Absorption Value by Volume	Total
Glass wool	Importance	18.35	3.94	12.78	35.07
	Satisfaction Level	1	3.3	2.29	6.59
	Benefit	18.35	13.002	29.27	**60.62**
Rock wool	Importance	16.51	11.8	13.83	42.14
	Satisfaction Level	6.14	10	1	17.14
	Benefit	101.37	118	13.83	**233.2**
EPS	Importance	15.14	1.26	6.39	22.79
	Satisfaction Level	10	1	10	21
	Benefit	151.4	1.26	63.9	**216.56**
	Function Benefit	271.12	132.26	107	

The significance value associated with each function and material has been calculated previously. To verify the accuracy of this calculation, it can be determined whether the sum of all significance values calculated equals 100. The sum of the account's values has reached 100.

In Table 5, the benefit is computed for the thermal insulation materials, and the benefit values are displayed in the table. As a result of the calculation, it was determined that rock wool was the most advantageous material, while glass wool was the least advantageous.

However, benefit and value should not be confused, the material with the highest benefit should not be interpreted as the most valuable material. In order to find value, the last step, the benefit, must be proportionate to the cost.

3.9 Value Calculation

By rationing the benefit values in Tab. 5 to the unit cost, the value account will be discovered. The best option for use in construction projects will be the insulation material with the highest ratio value. The value calculation for insulation materials is shown in Tab. 6 below.

Table 6 Value calculation for materials

	Glass wool	Rock wool	EPS
Benefit	60.62	233.2	216.56
Cost	1.28 USD/m^2	0.75 USD/m^2	1.65 USD/m^2
Value*	47.35	**310.93**	131.24

* Value = Benefit/Cost

Based on the value calculation in Tab. 6, it was determined that, among these three materials, rock wool is the most suitable thermal insulation material for use in specific construction projects.

4 FINDINGS

In this study, the value engineering methodology was applied to three thermal insulation materials slated for use in the selected construction project's wall insulation. During the study, actual materials and their actual values were taken into account. Using techniques such as the priority matrix, nominal group technique, and utility curve, the order of importance, the significance of percentages, and the level of satisfaction of materials have been determined. As a result of all of these studies, the benefit was initially computed. The value was then computed utilizing the benefit/cost formula. Due to its high utility value and low cost, rock wool was determined to be the optimal material for wall insulation in the construction project. The following is the value ranking of the materials as determined by the study:

1) *Rock wool* = **310.93**

2) *EPS* = 131.24

3) *Glass wool* = 47.35

5 CONCLUSIONS AND RECOMMENDATIONS

Value engineering, which aims to design new products or improve existing ones while considering quality, time, and cost, is crucial in the increasingly competitive construction industry of today. Value engineering is a

value-based approach that satisfies expectations and generates new alternatives by taking into account budget, time, and quality as key factors. By acting within a specific business plan with a team of knowledgeable experts in their respective fields, solutions are sought from a unique perspective. The value engineering method is superior to other approaches because it emphasizes originality. Value engineering focuses not only on reducing costs but also on increasing value from a creative standpoint. It is inconceivable to sacrifice quality to reduce costs. Value engineering prioritizes user requirements and project specifications. A successful value engineering study satisfies the customers by meeting their expectations and enables the contractor to generate a profit by avoiding poor decisions and unnecessary expenses. Although value engineering provides substantial benefits and profits to both the national economy and businesses, it is uncommon in the construction sector. To ensure that this method is implemented in businesses, training must be provided, the volume of work must be increased, and engineers must be informed.

The purpose of this study is to determine the thermal insulation material that will be used in a construction project by employing the value engineering method. On the market, there are numerous thermal insulation materials. Modern construction materials are typically selected based on their cost rather than their properties, but this is not the most intelligent method. As well as the material's intended use and cost-effectiveness, it is necessary to meet the expectations of the customer. This will be a more precise method of selection. In the study, the Value Engineering Team's primary method for ensuring the correct selection was determined, and as a result, the product's intended functions were determined. As a result of this research, three functional thermal insulation materials have been discussed. By determining the order of importance, the significance of the percentages, and the level of satisfaction of the determined functions, a value analysis was performed on the benefit values, and a product that satisfies expectations and is cost-effective was chosen. Therefore, rockwool was chosen as it provided the highest benefit-to-cost ratio.

The product selected using the value analysis method is the preferred product in terms of its benefits and cost-effectiveness, as well as its widespread use, availability, and access to the construction project's elements. As a result of this study, the selected product was determined based on the functions determined by the work team, the significance of the functions determined, and the insulation material alternatives selected. The product selected at the conclusion of the study may vary based on the various functions determined by the work team, the relative importance of the functions, or the identification of alternative materials.

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