



Prioritization of Selection Criteria for Sustainable Materials and Equipment in Construction Projects by Managing Energy Consumption Using TOPSIS Method

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Abstract: The use of conventional construction methods and considering the new technologies in this regard as well as using sustainable materials and equipment are inevitable to strengthen the constructions, achieving sustainable development, and improving living conditions. Choosing a suitable construction system due to the high uncertainties in the decision-making process is very complex. On the other hand, the knowledge of very broad construction systems has a structured weakness, which includes a variety of specialties. Hence, choosing sustainable equipment and materials in construction projects is an essential solution for designing and implementing an appropriate construction system using Multiple Criteria Decision Making. This research aims to determine and facilitate a criterion for equipment and material selection based on sustainability and productivity management approach in energy consumption in construction projects. Then, some of the important factors, which affect the decisions of engineers and designers in the selection of materials for sustainable design and energy management, are characterized by analyzing the information. Modeling will be used to evaluate and choose the most appropriate materials, which aims to provide an analytical decision support tool for achieving the goals of sustainable design in TOPSIS.

Keywords: *Project Management, Equipment Selection, Sustainable Materials, Multi-Criteria Decision Making, Topsis.*

Introduction

In the current era, the environmental, human, and economic costs of disasters are irreversible in many times due to the use of sophisticated, inflexible, and expensive technologies. One of the consequences of these disasters is the irreversible degradation of the environment. The Rio Declaration, which contains a series of recommendations and legal principles in order to achieve sustainable development for developing countries, has defined the sustainable development as "Meet the needs of the present generation without wasting the ability of future generations to meet their needs". Some indicators are also considered for Sustainable Development.

The three main economic, environmental, and social indicators are proposed in this regard associated with the sub-indices. Sustainable development indicators show a range of progress, in which there is a relationship between economic prosperity, social welfare, and environmental protection in a strong or weak form. These indicators suggest a close relationship between the three sectors [1, 2, 3, 4]. The importance of optimal investment process in the construction of housing units and the proper utilization of massive national capitals reveal that about 40% of industrial investment is in the construction sector [5, 6].

Chan et al. presented some criteria in selecting of materials for the sustainable development [7,8] of construction projects that performance, technique, economy, and strategy are the most important of them [9].

Chamzini and Yakhchali have raised two categories of basic criteria for sustainable development in construction projects in the form of cost and performance [10]. Shen et al. have studied the key indicators of evaluating the sustainable development in massive construction projects and they suggested a pattern on this basis [11].

Lu and Kuei have stated that the most important managing principle of integration is quality in construction projects. They also have used the most important principles of sustainable development in data calibration in construction projects [12].

Choosing sustainable equipment and materials in construction projects in a construction system includes various specifications and diverse criteria, which selected using Multiple Criteria Decision Making [13]. The aim of this research is to provide an analytical decision-making model to achieve the goals of sustainable design using TOPSIS software.

Topsis Method and the Related Analysis

This model was proposed in 1981 by Hwang and Yoon, in which m option is surveyed by n indices. The underlying logic of this model defines the positive and negative ideal solutions. Ideal solution (positive) increases profit criterion and reduces the cost criterion.

The optimal option is the option that has the least distance from the ideal solution while having the furthest distance from the negative ideal solution [14]. In the ranking of options, the options that have the greatest similarity with the ideal solution earn higher grades. Here, A^+ and A^- are respectively positive ideal solution and negative ideal solution. A_1 has a shorter distance to the ideal solution and greater distance negative ideal solution than A_2 [15].

The prioritization parameters for sustainable materials and equipment selection have been shown in the form of 5 main criteria and 22 sub-criteria in Table 1 [16].

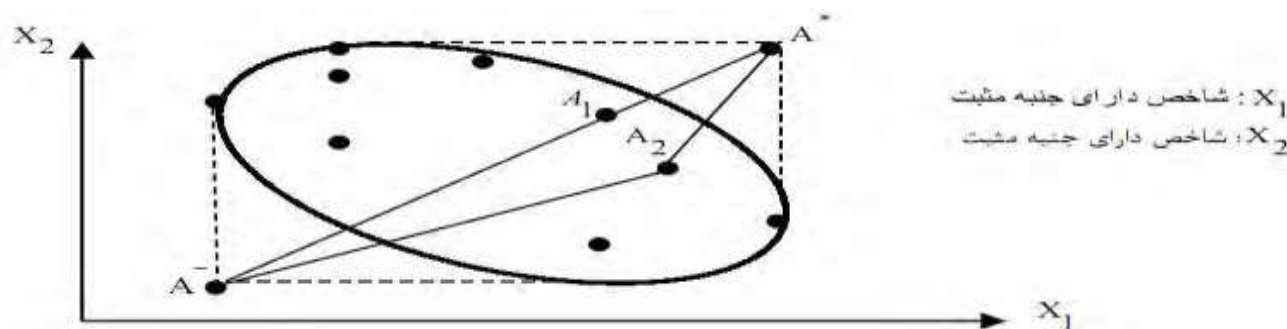


Figure 1: The target space between the two criteria in TOPSIS technique

Table 1: Selection factors of sustainable materials and equipment in construction projects

No.	criteria	No.	Sub-criteria
1	Environmental impact	1	Legal Compliance of Environment
2		2	Ozone depletion
3		3	Minimization of pollution
4		4	The impact on air quality
5		5	Recycling and reuse
6	Life cycle cost	1	Initial cost
7		2	Maintenance cost
8		3	Disposal cost
9	Resource efficiency	1	Raw material extraction
10		2	Loss in utilization
11		3	Energy saving
12		4	The environmental impact of harvest
13	Functional capacity	1	Fire resistance
14		2	Rot resistance
15		3	Energy saving and thermal insulation
16		4	Greater life and durability

17	Social benefit	5	Ease of construction
18		6	Maintainability
19		1	The use of local materials
20		2	Aesthetics
21		3	Health and Safety
22		4	Availability of materials

This technique is based on the notion that every selective factor must have the minimum distance from the positive ideal factor (most important) and the maximum distance from the negative ideal factor (the least important factor). In other words, in this way, the distance of a factor was measured with the positive and negative ideal factor. This itself is a prioritization criterion for factors. The steps in this method are:

The First Step: Creating a Decision-Making Matrix

A matrix will be formed in this step, in which options are in the rows and indices are in the columns. The weight of each index is given in the last row. The intersection of rows and columns shows the importance of each response to each of the options in accordance with the relevant index (Table 2 and 3).

Table 2: Decision-making matrix (N)

Index Options	C1	C2	...	Cn
A1	r11	r12	...	r1n
A2	R21	R22	...	R2n
.	.	.	.	.
Am	Rm1	Rm2	...	rmn
Wj	W1	W2	...	Wn

r_{ij} is the score of the i th option in the j th index and W_j is the weight of the j th index. In this research,

Table 3: Decision-making matrix (N)

	C1	C2	C3	C4	C5
Index type	Positive	Positive	Positive	Positive	Positive
A1	7.667	5.333	5	4.667	7
A2	7	5.667	5	4.333	6.667
A3	7.333	5.667	5.667	5	7
A4	7.333	6.333	6.333	5.333	7.667
A5	8.667	7	6.667	6.333	8
A6	5.667	7.667	5	4.667	6.333
A7	5.333	8.333	5	4.667	6.333
A8	6.333	8.333	6.333	5.667	7
A9	7	6.333	8	6.333	6.667
A10	7.667	7	8	6.333	6.667
A11	8.333	7	9	6.667	8.333
A12	9	6.333	8	6.333	6.667
A13	6.667	5.667	6	8	6.333
A14	6.333	6	6	8.333	7.333
A15	7.333	7	7	9	7.667
A16	6	6.667	6.333	8.333	8
A17	6.333	7	7.333	8.333	7.333
A18	6.333	7.333	6.333	8.333	7
A19	7	6.333	7	7.333	8.667
A20	5.333	5.333	5	6	8.333
A21	6.667	7.667	7	8	9
A22	7	7.333	7.333	8	9
Weight	0.2	0.2	0.2	0.2	0.2

It should be noted that the decision-making matrix (Table 3) is the arithmetic average of all experts' views.

The second step: normalizing the decision-making matrix (normalization)

In order to be comparable, the decision-making matrix is converted to a normalized

matrix or a scaleless matrix (N1) using the following equation.

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^m r_{ij}^2}} \quad (1)$$

Table 4: Scaleless matrix (N1)

	C1	C2	C3	C4	C5
A1	0.234	0.168	0.162	0.146	0.201
A2	0.214	0.179	0.162	0.136	0.192
A3	0.224	0.179	0.184	0.157	0.201
A4	0.2244	0.2	0.206	0.167	0.22
A5	0.264	0.221	0.217	0.199	0.23
A6	0.173	0.242	0.162	0.146	0.182
A7	0.163	0.263	0.162	0.146	0.182
A8	0.193	0.263	0.206	0.178	0.201
A9	0.214	0.2	0.26	0.199	0.192
A10	0.234	0.221	0.26	0.199	0.192
A11	0.254	0.221	0.292	0.209	0.24
A12	0.275	0.2	0.26	0.199	0.192
A13	0.203	0.179	0.195	0.251	0.182
A14	0.193	0.189	0.195	0.262	0.182
A15	0.224	0.221	0.227	0.282	0.22
A16	0.183	0.21	0.206	0.262	0.23
A17	0.193	0.221	0.206	0.262	0.211
A18	0.193	0.232	0.206	0.262	0.201
A19	0.214	0.2	0.227	0.23	0.249
A20	0.163	0.168	0.162	0.188	0.24
A21	0.203	0.242	0.227	0.251	0.259
A22	0.214	0.232	0.238	0.251	0.259

The third step: obtaining the weighted Scaleless matrix

To obtain weighted scaleless matrix (V), we multiply the obtained scaleless matrix (from the second step) by a square matrix ($w_{n \times n}$) whose main diagonal elements are the weights of indices and the other elements are zero.

$$V = N_1 \times w_{n \times n} \quad (2)$$

The fourth step: Determining the positive and negative ideal factors

At this stage, the options that are determined as the most important and least important factors by respondents should be identified. In other words, the largest amount of v is the positive ideal for the positive indices and the smallest amount of v is negative ideal for the negative indices.

Table 5: Weighted scale less matrix (V)

	C1	C2	C3	C4	C5
A1	0.047	0.034	0.032	0.029	0.04
A2	0.043	0.036	0.032	0.027	0.038
A3	0.045	0.036	0.037	0.031	0.04
A4	0.045	0.04	0.041	0.033	0.044
A5	0.053	0.044	0.043	0.04	0.046
A6	0.035	0.048	0.032	0.029	0.036
A7	0.033	0.053	0.032	0.029	0.036
A8	0.039	0.053	0.041	0.036	0.04
A9	0.043	0.04	0.052	0.04	0.038
A10	0.047	0.044	0.052	0.04	0.038
A11	0.051	0.044	0.058	0.042	0.048
A12	0.055	0.04	0.052	0.04	0.038
A13	0.041	0.036	0.039	0.05	0.036
A14	0.039	0.038	0.039	0.052	0.036
A15	0.045	0.044	0.045	0.056	0.044
A16	0.037	0.042	0.041	0.052	0.046
A17	0.039	0.044	0.041	0.052	0.042
A18	0.039	0.046	0.041	0.052	0.04
A19	0.043	0.04	0.045	0.046	0.05
A20	0.033	0.034	0.032	0.046	0.048
A21	0.041	0.048	0.045	0.05	0.052
A22	0.043	0.046	0.048	0.05	0.052

In addition, the smallest amount of v is the positive ideal for the positive indices and the

largest amount of v is negative ideal for the negative indices. The following equation expresses this subject:

$$A+ = \{(MaxV_{ij}|j \in J), (MinV_{ij}|j \in J')|i = 1, 2, \dots, m\} = \{V_1^+, V_2^+, \dots, V_j^+\}$$

$$A- = \{(MinV_{ij}|j \in J), (MaxV_{ij}|j \in J')|i = 1, 2, \dots, m\} = \{V_1^-, V_2^-, \dots, V_j^-\}$$

In these equations, J is the positive index and J' is the negative index (the related calculation are in Table 6).

Table 6: positive and negative ideals of each index

Criteria	Positive ideal	Negative ideal
C1	0.055	0.033
C2	0.053	0.034
C3	0.058	0.032
C4	0.056	0.027
C5	0.052	0.036

The fifth step: Calculating the distance from the positive and negative ideals

In this level, the distance of each option from the positive and negative ideal is determined according to the following equation.

$$d_j^+ = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^+)^2} \text{ for } i=1, 2, \dots, m \quad (5)$$

$$d_j^- = \sqrt{\sum_{j=1}^n (V_{ij} - V_j^-)^2} \text{ for } i=1, 2, \dots, m \quad (6)$$

The distance of each of the options from the positive and negative Table 7.

The sixth step: Calculating the proximity of each factor to the positive and negative ideal

At this stage, the proximity of each option from the positive and negative ideal (CL) can be obtained according to the following equation.

$$CL_i^* = \frac{d_i^-}{d_i^- + d_i^+} \text{ for } i=1, 2, \dots, m \quad (7)$$

Table 7: Ranking the options CL

No.	Options	Distance to the positive ideal	Distance to the negative ideal	CL	Ranking
1	A1	0.044	0.015	0.251	20
2	A2	0.046	0.011	0.186	22
3	A3	0.04	0.014	0.262	19
4	A4	0.034	0.019	0.359	16
5	A5	0.025	0.03	0.546	6
6	A6	0.046	0.015	0.248	21
7	A7	0.046	0.019	0.291	17
8	A8	0.034	0.024	0.412	15
9	A9	0.028	0.026	0.479	12
10	A10	0.025	0.029	0.536	8
11	A11	0.018	0.038	0.683	1
12	A12	0.026	0.033	0.561	5
13	A13	0.034	0.025	0.429	14
14	A14	0.033	0.027	0.447	13
15	A15	0.02	0.037	0.647	3
16	A16	0.028	0.03	0.513	11
17	A17	0.027	0.03	0.522	10
18	A18	0.027	0.03	0.524	9
19	A19	0.024	0.029	0.545	7
20	A20	0.044	0.016	0.263	18
21	A21	0.021	0.035	0.628	4
22	A22	0.019	0.035	0.656	2

The seventh step: Ranking the options

At this stage, the options are ranked based on CL. In other words, each option that has a higher CL will gain a better ranking (Table 7).

Conclusion

The purpose of this research is to provide an analytical decision support tool for achieving

the goals of sustainable design and energy management in the decision process of construction projects. For this purpose, according to the qualitative and quantitative evaluations by experts' views, the main criteria given the priority of 1) Resource efficiency, 2) Performance capacity, 3) public interest, 4) environmental impacts, 5) Cost and sub-criteria were determined for

selecting sustainable materials and equipment. In addition, by analyzing the sub-criteria through TOPSIS method, the most important options were 1) Energy saving, 2) Availability of materials, 3) Thermal insulation, 4) Health and Safety, 5) Environmental impact of harvesting, 6) Recycling and reuse, 7) Loss in utilization, 8) maintainability, 9) ease of construction,

and 10) Greater life and durability. According to the results, it can be observed that energy saving, health and safety, and environmental impact of recycling and reuse are the top priorities in both analytical modes. Therefore, more attention to them can have a positive impact on the final selection of materials.

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