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**VALUE ENGINEERING IN CONSTRUCTION PROJECTS USING ELECTRE III
MODEL**

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ABSTRACT

Every year, a major part of Iran's budget is allocated to civil projects. Among major reasons for delays in the implementation of civil projects are failure to properly manage the expenses as well as complexities underwent in the course of construction process. By now, decision-makers are able to go through some of such challenges and complexities using value engineering techniques. In fact, value engineering is an executive managerial methodology to enhance values within the projects with its objective being to eliminate or modify those factors imposing unnecessary costs to the project, without imposing any adverse side effect on the main functions of the system. Addressed in this paper is the importance of value engineering in construction projects and the role it plays in reducing construction costs. One of the effective approaches toward implementing value engineering in the construction projects is what is referred to as ELECTRE III model; it is introduced in this model. The objective of the presented model is to enhance the efficiency of the decision-making process on the alternatives. This model can be used to propose proper solutions in terms of construction cost management.

**Keywords: Value Engineering, Project Management, Construction Costs, ELECTRE III
Model**

1. INTRODUCTION

Every year in Iran, large sums are paid for construction projects implemented in the form of civil, non-civil or private plans. One of the major reasons for delays in the implementation of civil projects is failure to properly manage the expenses. Project's cost management is an activity involving prediction, planning, control, cost evaluation, analysis and assessment. Managerial techniques for cost reduction can be utilized to reduce these costs considerably. In fact, value engineering is an executive managerial methodology to enhance values within the projects with its objective being to eliminate or modify those factors which impose unnecessary costs to the project or industrial plan, without imposing any damage into the main functions of the system.

Today, the outcomes of value engineering performed on numerous civil projects indicates it to be not only an approach toward reduced construction cost with the quality maintained, but also a way to shorten the delivery time along with enhanced delivery quality of the civil projects [1].

During the past three decades, along with value engineering, project management processes have witnessed significant advancements together with major evolutions. The main evolutions underwent

within the field of project management have been the change from traditional to the modern insight into the management of projects. Lack of resources, large and complex structure of such projects, ever increasing dimension of projects, formation of giant companies to implement giant projects, and unique nature of such projects are among the reasons suggesting the use of modern project management methodologies. As such, top managers of organizations have approached to project construction via decisions based on multiple attribute decision-making.

Rather than other types of projects, such evolutions are more pronounced in construction projects. One of the major evolutions in terms of the management of construction projects is seen to be the application of value engineering. Investigating the evolutions of value engineering during the recent years suggests that the value engineering process have not undertook significant changes in terms of contents, techniques and application method; it does, however, considerably evolved in terms of utilization circumstances, development of the required legal basis, and elimination of barriers in the course of implantation in construction projects.

Formation of firms is providing the value engineering services, issuing certifications of professional activity in the field of value engineering, and establishment of binding and incentive legislations, especially for those projects utilizing public budgets in various societies, are among the achievements obtained during the recent years [1]. One of the efficient techniques that can be used in the course of value engineering process within construction projects is what is referred to as ELECTRE III decision-making model. It is an efficient approach when dealing with uncertain data of low accuracy or even wrong data, so that considering the nature of construction projects, it seems to be a suitable model for such projects.

In this research, we start with an introduction on the value engineering and its background history followed by a discussion on the important role it plays in construction projects. In the next step, ELECTRE III decision-making model is introduced together with a piece of explanation on the way it is applied. Finally, application of the proposed model in value engineering context within construction projects is discussed via a case study.

2. Background of value engineering

Formation of value engineering roots back to WWII. When due to increased rate of consumption, the problem of raw material shortage was arisen in manufacturing sector. Being an electrical engineer in the department of purchasing electrical devices Lawrence D. Miles was looking for a work around for the problem of raw material shortage in electrical devices manufacturing. To overcome this limitation, he focused on those functions launched and tested by different alternatives to achieve the same functions for each product without any quality downgrade [1].

Although cost reduction was not the main concern, it was, however, considered as a sub-objective. First designated by Lawrence D. Miles, value analysis designed a plan to enhance the value. The principle hypothesis in this plan was to stick with the main objectives of the manufacturing process while enhancing the level of value. This principle hypothesis is still supporting current concepts of value analysis, value engineering, and value management [1]. In 1963, value engineering techniques in construction activities were admitted by USA Navy and Corps of Engineers, through the acceptance of incentive provisions in construction contracts [2].

Shortly, other public USA agencies such as Department of Transportation and the General Services Administration went for implementing this technique. Outside United States, in 1970s, the value engineering along with its application was introduced in Japan, Italy, Australia and Canada. Furthermore, construction value engineers found jobs in India, South Africa, England, France, Sweden, and Germany [3]. A number of successful applications of value engineering techniques are reported for many construction projects [4]. Nowadays, in order to better analyze the discussions on value engineering, a set of other tools such as work plan, Functional Analysis System Technique (FAST), and even creative thinking methods such as Delphi are utilized.

3. Associated definitions and concepts with value engineering in construction projects

Value engineering is a systematic method with its objective being to optimize value index of the project. Due to differences in the nature of the projects, different approaches may be followed toward incorporation the value engineering into different projects. Value engineering plans are used to enhance the value obtained from the lifecycle of manufacturing assets. This is, as a process related to the projects performance, quality and costs, considered in the course of

determining optimum construction solutions. In construction industry, value engineering is seen to be an organized effort to design challenges and plans for projects' construction, in which the following objectives are followed to provide the required facilities [3]:

1. Minimum total cost,
2. Compatibility with executive requirements,
3. High reliability, and
4. High maintainability.

Requiring an extensive effort, value engineering studies involve gathering a group of such individuals together as one can reliably suggest that they can work together and investigate and review, as a team, every aspect of the projects. These individuals work as a group headed by a value engineering facilitator with the facilitator's task being to guide the individuals within the framework of value engineering work plan. Each expert considers project's context aligned with his/her expertise before providing his/her comments [7]. Application of value engineering causes project's issues to be investigated from different perspectives, so that no expertise would be independent from the others. On the other hand, sometimes some initial ideas and amending ideas are provided by those with

no expertise in the corresponding discipline. Such ideas have the chance to be analyzed in the group, so as to be evolved into comprehensive solutions. Accordingly, the project's intellectual capacity will be increased via utilizing different ideas and non-similar insights.

4. Importance of value engineering in construction projects

The nature of value engineering makes it applicable to many projects such as construction projects and water treatment plans. It can be developed to be applied to various industries. In addition, value engineering is expected to be further incorporated into companies and systematic contexts. The advantages of value engineering are usually beyond temporal optimizations, cost reduction, and creative solutions, as it leads to enhanced efficiency and communications among the shareholders. In many cases, whether to incorporate value engineering in a construction largely depends on the projects' dimensions. Such researchers as Akiyama, Cooper, and Slagmolder have stipulated the contribution of implementing value engineering within giant construction corporations. In the long run, to be able to use value engineering in a competitive environment, construction companies need to extend their competitive capabilities which

are referred to value engineering by some practitioners. The key subject in terms of accepting the border thinking approach is necessarily lied on the development of value engineering technique [5, 6].

5. An introduction on ELECTRE III model

Proposed in this paper is a tool to utilize value engineering techniques in construction projects. ELECTRE III model is a method for ranking different alternatives and evaluating the facilities they provide. ELECTRE model provides a comprehensive approach toward decision-making problems in which many shortages associated with decision-making methods are eliminated [8-11]. Various versions of ELECTRE model are presented; they include:

Although being all based on the same fundamental concept, they are different in terms of operations they involve and the type of decision-making problem they apply to. Generally speaking, ELECTRE I is used for selection problems, ELECTRE TRI is applied to assignment problems, and ELCTRE II, III, and IV are utilized when one deals with ranking problems. Being applied to a variety of cases, ELECTRE III is more commonly used, than other approaches, when uncertain data of low accuracy or even wrong data is concerned [12, 13].

In the approach followed by this model, for each attribute j , the following three thresholds are defined:

1. Indifference threshold (q),
2. Priority (p), and
3. Veto (v).

a) Equation (1) should be satisfied for indifference (q), priority (p), and veto (v) thresholds:

$$(1)$$

b) For each attribute j , the significance rate should be determined by w_j .

These three thresholds determine ranking relationships for a set of uncertain data. Main steps of the ranking process using ELECTRE III model are illustrated in Figure 1 [14]. Following parameters should be determined for each and every attribute so as to be able to implement ELECTRE III:

Explained in the following is how to determine required parameters for ELECTRE III model.

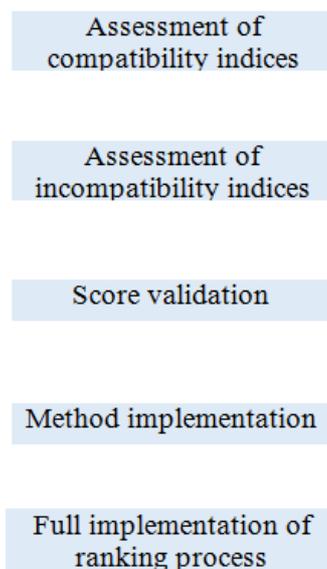


Figure1. Main steps in the ranking process using ELECTRE III.

5.1. Compatibility index

For each pair of alternatives a and b , the compatibility index $c(a, b)$ is assessed based on a general comparison over alternative's performance; this is done for all attributes. Compatibility index is a number between 0

and 1. The zero value indicates that the alternative a is, in terms of all attributes, worse than the alternative b . Compatibility index is calculated based on a harmonic comparison of single attributes $c_j(a, b)$ using Equation (2):

$$C(a, b) = \frac{1}{W} \sum_{i=1}^n w_j c_j(a, b) \quad (2)$$

$$W = \sum_{j=1}^n w_j \quad (3)$$

Depending on the problem conditions, each attribute is independently calculated via one of the following equations:

$$c_j(a, b) = \begin{cases} 1 & \text{if : } g_j(a) + q_j(g_j(a)) \geq g_j(b) \\ 0 & \text{if : } g_j(a) + p_j(g_j(a)) \leq g_j(b) \end{cases} \quad (4)$$

When none of above conditions is met, each attribute is calculated via the following relationship:

$$c_j(a, b) = \frac{g_j(a) - g_j(b) + p_j(g_j(a))}{p_j(g_j(a)) - q_j(g_j(a))} \quad (5)$$

5.2. Incompatibility index

In order to define incompatibility within a set of ranked relationships, a veto threshold is assigned to each attribute. Incompatibility index demonstrates the superior rank of b over a . Such a superiority can be rejected if there is an attribute for the alternative b in

$$g_j(b) \geq g_j(a) + v_j(g_j(a)) \quad (6)$$

Therefore, if the alternative a is superior over the alternative b , there may be a number of (or even one) attributes in which the attribute a is worse than b . Incompatibility $D_j(a, b)$ index is used for those attributes with such

which the alternative a outperforms b within the veto threshold. Even if other attributes of the ranking alternative b are better than those of a , the alternative b will remain to be rejected; the following relationship expresses such a situation:

conditions. Once more, the value of incompatibility index is some number between 0 and 1. Incompatibility index can be calculated by the following equations:

$$D_j(a, b) = \begin{cases} 0 & \text{if : } g_j(b) \leq g_j(a) + p_j(g_j(a)) \\ 1 & \text{if : } g_j(b) \geq g_j(a) + v_j(g_j(a)) \end{cases} \quad (7)$$

The following equation would be applied to calculate incompatibility index when none of the above conditions are satisfied:

$$D_j(a, b) = \frac{g_j(b) - g_j(a) - p_j(g_j(a))}{v_j(g_j(a)) - p_j(g_j(a))} \quad (8)$$

5.3. Score validation

Based on the compatibility and incompatibility indices, ranking validity grade is calculated via the following methods:

$$S(a, b) = C(a, b) \text{ if : } D_j(a, b) \leq C(a, b) \quad (9)$$

b) Ranking grade is equal to the compatibility index minus a quantity referred to as

$$S(a, b) = C(a, b) \prod_{j \in \Psi(a, b)} \frac{1 - D_j(a, b)}{1 - C(a, b)} \quad (10)$$

where $\Psi(a, b)$ denotes a set of attributes in which we have $D_j(a, b) \geq c_j(a, b)$.

5.4. Method implementation

Alternatives are ranked based on two previously presented orders. With the first order, the alternatives are sorted in a descending order with the worst alternative on top of the list and the best one at its very end. With the second order, however, the

$$\lambda_0 = \max_{a, b \in A} S(a, b) \quad (11)$$

Step 2) Cutoff level of ranking (λ_1) is defined as the maximum ranking score which is lower than the maximum ranking score

$$\lambda_1 = \max_{\{S(a, b) < \lambda_0 - s(\lambda_0)\} \in A} S(a, b) \quad (12)$$

a) If there is no incompatible attribute, i.e. no veto threshold is employed; the ranking grade is equal to the corresponding compatibility index.

incompatibility enhancement at a threshold.

alternatives are sorted in an ascending order with the best alternative on top of the list and the worst one at its very end. Adjusted based on the score each alternative achieves, the previous orders are implemented as follows:
Step 1) Set λ_0 to the maximum value $S(a, b)$ within the matrix A .

minus discrimination threshold with $S(\lambda_0)$ being the discrimination threshold at the maximum ranking level λ_0 .

At the initial cutoff level, if $S(a, b)$ is greater than the cutoff level and $S(a, b)$ and $S(b, a)$ are higher than the discrimination threshold,

$$S(\lambda) = 0.3 - 0.15\lambda \tag{13}$$

$$a \succ b \quad \text{if: } S(a, b) > \lambda_1, \tag{14}$$
$$S(a, b) - S(b, a) > S(\lambda)$$

Step 3) Whenever a is superior over b , a +1 score (denoting the strength) is assigned to a while a -1 score (denoting the weakness) is assigned to b . At the end, the strengths and weaknesses are summed for each alternative, so as a final qualification score can be obtained for each alternative.

Step 4) In the descending order, the alternative with the highest qualification score is assigned a rank before being removed from the process. Then the process is repeated until all alternatives are removed.

Step 5) In the ascending order, the alternative with the lowest qualification score is assigned a rank before being removed from the process. Then the process is repeated until all alternatives are removed.

5.5. Completing the ranking process

The results obtained from ascending and descending orders are combined to form a complete ranking scheme in which the common values in these two orders are selected.

then a is said to be superior over b , so that we will have:

6. Case study

Provided in this section is an example of application of ELECTRE III model in the course of value engineering in construction projects. Consider a building in its final construction phase when heating equipment is to be installed. The problem is what equipment to choose for the installation. Here we have 5 alternatives which can be evaluated via 4 effective attributes: product price, budget, appearance, and easy installation. Table 5 shows the 5 alternatives along with the value of each attribute.

Two scenarios are considered in this example. In the first scenario, different weights are assumed for the selected attributes. The second scenario, however, is based on the same weight for all of the selected attributes. Reported in Table 2 are the values of indifference threshold (q), priority (p), and veto (v) for both scenarios.

Thresholds are defined as a performance function in the form of $[\alpha * g_i(a) + \beta]$ where α and β are 0.05 and 0, respectively.

Based on the above data, the corresponding matrix to the model is drawn (see Table 3).

It is worth mentioning that when an alternative is compared to itself, the value of ... is set to 1. Then, ascending and descending orders methods are considered

for each scenario (see Figure 2). As can be seen, alternative 5 is selected as the best alternative under scenario 1, while alternatives 4 and 5 are seen to be the best alternatives under scenario 2.

Table1: Attribute values for each of five alternatives.

Attribute ID	Attribute	First Scenario Weight	Second Scenario Weight	Unit	Alternatives				
					1	2	3	4	5
g ₁	product price	0.333	0.25	\$	60000	75000	100000	75000	75000
g ₂	budget	0.286	0.25	\$	0	7600	15200	7600	11400
g ₃	appearance	0.143	0.25	%	20	40	40	70	60
g ₄	easy installation	0.238	0.25	%	100	70	40	70	70

Table 2: Threshold values for both scenarios.

Thresholds	Indifference threshold (q)	Priority (p)	Veto (v)
Values	0.05g _i (a)	0.05g _i (a)	Unused

Table 3: Attributes estimation matrix.

Alternatives	Scenario 1					Scenario 2				
	1	2	3	4	5	1	2	3	4	5
1	1	0.57	0.57	0.57	0.57	0.5	0.5	0.75	0.5	0.5
2	0.43	1	0.71	0.86	0.57	0.5	1	0.75	0.75	0.5
3	0.43	0.43	1	0.29	0.29	0.5	0.5	1	0.25	0.25
4	0.43	1	0.71	1	0.71	0.5	1	0.75	1	0.75
5	0.43	1	0.71	0.9	1	0.5	1	0.75	0.83	1

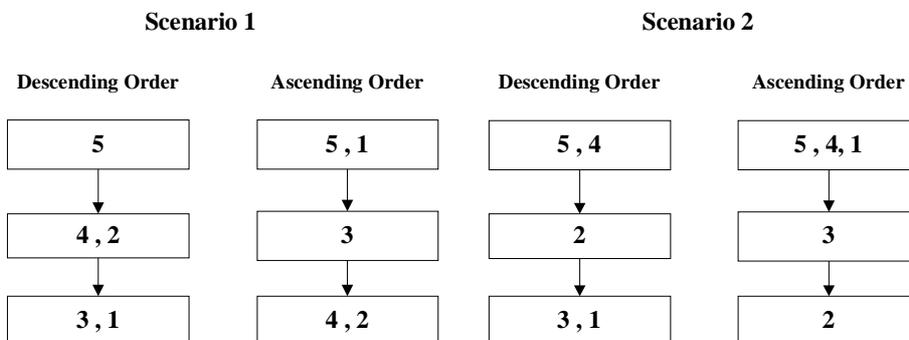


Figure 2: Method implementation output

6. CONCLUSION

Implementation of value engineering in construction is highly dependent on the project's dimensions. By providing optimum solution for projects, value engineering deals with cost and quality. This paper presented

ELECTRE III model as a ranking model used for value engineering in construction projects. Various steps followed in ELECTRE III model and described in this paper were: assessment of compatibility indices, assessment of incompatibility

indices, assessment of credit score, applying the method to achieve a full rank of alternatives. Further used in this model were p and q thresholds which are dependent on the decision-maker's preferences in terms of attributes. Based on the introduced relationships one can choose the alternative with the highest efficiency in terms of enhanced project values when dealt with cases where it is difficult to make a decision. The above approach is highly efficient for cases with uncertain data of low accuracy or even wrong data. Considering the nature of construction projects, the above model seems to be a suitable workaround. On the other hand, when incorporated into software, the presented model can help the decision-maker making the best decisions for multiple attribute engineering problems.

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