Selecting an appropriate alternative for a major infrastructure project with regard to value engineering approach

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Abstract

Purpose – Road construction projects are one of the strategic industries in each country and their construction and development requires spending huge funds. Regarding the increased demand and resource constraints; a technique which reduces costs by maintaining and improving the functioning is of great importance for the authorities of each country. Value engineering is a comprehensive and coherent means based on innovation and team work which, in addition to maintaining the quality and improving the project function, reduces its cost and is not limited to the design and construction phase; however, it includes exploitation and maintenance as well. This study aims to present a practical model for the implementation and application of value engineering process in a construction project located in a special region (in terms of tourism, positioning in an economic growth path, and the East-West strategic axis of the region). In this regard, after reviewing the advisor's design, considering the interests of the project stakeholders, reviewing design criteria and assessment methods and with the use of value engineering techniques, a new option was presented which led to a significant reduction in costs and time and an increase of quality, safety, and environmental factors. Finally, including initial costs, repair, maintenance, income and expenses, the relative value index of this option, compared to the advisor's option, increased from 0.9 to 3.5. Based on the increased need for development of roads in the country, exploiting this model in similar projects can significantly improve the project value and the effectiveness of investments.

Design/methodology/approach – This research project was selected with regard to the extremely high credit of the project and its potential in terms of Value Engineering implementation. In this study, technical and financial information were first collected after forming a value engineering team including a value engineering expert who was responsible for coordinating the work, some representatives of the employer, designer, executor, and budget estimator. In functional analysis phase with the use of FAST graph, advantageous, costly, and risky functions were identified. In the creativity phase, ideas related to selected functions were created and investigated and developed in the evaluation phase. Finally, calculating the value index, two variants with higher value index than the baseline plan, were proposed and implemented.

Findings – Since the determining criteria of designing and implementation of road construction projects including increased safety, reduced travel time, user satisfaction, ease of implementation, cost of construction and maintenance and so on are almost similar in most projects, using this study results and implementing its practical framework in other construction projects can be beneficial. These parameters lead to an increase in quality, value, and safety of the project. With regard to done steps and resulted incomes, this essay can be known as a practical and theoretical model to promote the value of crucial projects especially in developing countries.

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Research limitations/implications – Sanandaj-Hamedan road with the length 176km connects central provinces of Iran. This study is regarding the first part of this route. Based on the specific topography of the region and the existing road limitations, selecting a good variance with all the features of an ideal road from geometric, economic, and safety aspects is a difficult task.

Originality/value – Employers and project sponsors are always looking for products with greater value and lower cost; therefore, present a practical model for the implementation and application of value engineering process in a construction project and providing a similar work experience can encourage the use of value engineering techniques and significantly improve the project value and the effectiveness of investments.

Keywords Value engineering, Road construction, Cost of construction, Functions analysis, Infrastructural projects, Value index

Paper type Case study

1. Introduction

Value Engineering (VE) is a management tool to achieve the essential functions of a product, service or project at the lowest cost (Xiaoyong and Wendi, 2012). Since its first adoption in the 1950s VE has become a standard practice for many government agencies and private engineering firms and contractors. It has been widely practiced in the construction industry and has become an integral part in the development of many civil infrastructure projects for reinforcing them.

However, the usage of VE (Value Engineering) in the project management of road construction definitely enhances the value of these types of projects. First, since the governments generally dedicate considerable amounts of financial resources to these projects, applying VE methods play a pivotal role in cutting costs without losing qualities. In addition, by reviewing basic plans in projects, using efficient methods can improve road construction in terms of safety and decrease the rate of road accidents. Because of the reasons mentioned, project managers consider VE a valuable tool for project management.

Hamadan-Sanandaj road axis with the length of 176 kilometers links the central provinces of Iran to each other and is located between Sanandaj- capital of Kurdistan province- and Hamadan – capital of Hamedan province- and connects the central provinces of Iran to the capital of the country, Tehran. This project is related to the first section of Sanandaj-Hamadan Road and examines the appropriate connection of this 4-lane highway to Sanandaj.

Based on the specific topography of the region and the existing road limitations, selecting a good variance with all the features of an ideal road, from geometric, economic, and safety aspects is an onerous task (Table I). The consultant of this plan evaluated and proposed the following as the table of various variant specifications. In addition, these variants are shown in Figure 1.

Generally, the cost of civil engineering plans including road projects are divided into two major types: initial investment costs and operational costs, and are periodic. According to the primary estimation by consultant (Table II), only the first part or the initial investment costs of plan is computed in terms of various variants and the other costs of operation are not considered. Based on this issue, technical and economic evaluation of choices are not conducted for the aim of achieving various evaluation indices, such as the internal rate of capital return and current net value. Based on the prediction by various effective recommendations on operational-periodic costs of the plan, such as maintenance costs, reduction of fuel consumption costs, improving safety, and reducing road accidents, the project manager needs to conduct economic and recalculating investment studies for various choices in the referred path.

Table I. Various variant specifications

Disadvantages	Advantages	Length of shadow (km)	Total length of bridge (m)	Total length of tunnel (m)	Maximum longitudinal slope (%)	Minimum radius (m)	Length reduction (km)	Variant name
Crossing gas line, lack of reduction of bottleneck, high distance from existing variant	Sunny, no barrier, low transversal slope, no need to temporary way	2	1,070	3,855	8.42	120	1.097	A
Far from the existing road, rocky nature of half of variant, high transversal slope of variant, snowy area	Being far from residential construction, not passing from agriculture fields, no barrier	11	1,150	8,185	6	120	4.953	B
The lack of reduction of bottleneck, difficult executive conditions, lack of variant length reduction	Maximum use of existing route	2	930	750	6	200	0.24	C1
Lack of U-turn execution	Maximum use of existing route, reduction bottleneck height, reduction of path length	2	230	2,500	6	200	3.01	C2
Lack of U-turn execution	Maximum use of existing route, reduction bottleneck height, reduction of path length	2	230	3,275	6	200	3.758	C3
Full elimination of a part of existing road, being far from Railway station	Reduction of bottleneck height, reduction of route length, sunny, lack of destruction of gardens and water well	5	–	2,510	6.2	200	3.452	D
Snowy, existence of gardens along variance, lack of reduction of bottleneck height, existence of water springs	Reduction of longitudinal slope, good view, lack of residential houses along variant	7	1,930	1,735	5.8	200	–	F
High length of tunnel, much costs and executive drawbacks	Shortening path of road, sunny region, reduction of bottleneck height, low volume	2	–	3,220	6	200	5.063	J
High length of tunnels in route, longitudinal slope more than standard level, lack of bottleneck height reduction	Reduction of path length	2	825	3,950	8.2	200	4.162	H

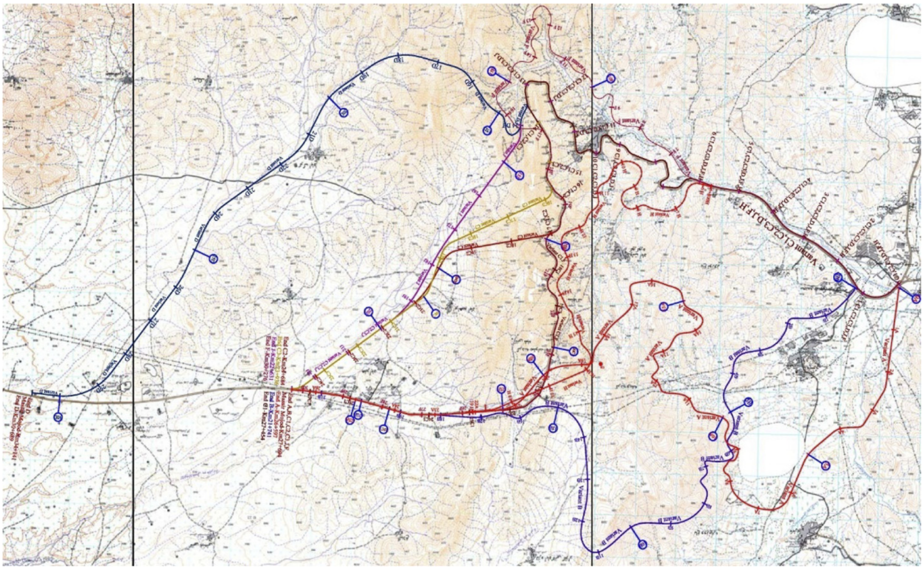


Figure 1.
The location of variants on the map

Table II.
The estimation of the cost of construction of various choices from the view of consultant

Explanation	Construction cost (billion rials)	Choice name
	1,390	A (construction as two roads beside each other and elimination of existing route)
	1,833	B(construction as two roads beside each other and elimination of existing route)
	504	C1(Construction as a road beside existing route attaching to it)
	454	C2(Construction as a road beside existing road or immediately after it)
	486	C3(Construction as a road beside existing road or immediately after it)
The end of this choice is not consistent with other choices	881	D(Construction as a road to kilometer 13-500 and then two roads besides each other and elimination of existing path from km 13 + 500)
2.582 km increase of length	787	F(Construction as a road beside existing road or immediately after it)
	506	J(Construction as a road beside existing road or immediately after it)
	632	H(Construction as a road beside existing road or immediately after it)

The applied method for evaluation of choices in this project considers various parameters hierarchy in which various choices are ranked based on disparate parameters and by normalization of the presented scores. According to the project's design consultant choice, C2 is selected as the best choice, from the technical and economic aspects (Table III, IV).

Applying value-engineering principles, in this research we can reduce the costs effectively, increase the project value, and offer another choice that has higher value index. Indeed, VE is not only an approach for cost cutting but also a systematic method to improve the value of goods or products and services by using an examination of functionality (Dell'Isola, 1997).

Moreover, as the definition of value engineering specifies, value engineering strengths, compared to other methods of minimizing costs and improving quality, focuses on tasks or projects and takes advantage of group creativity and their product to provide applicable solutions in the shortest time possible .

2. Literature review

VE started in the 1950s in the US and then it showed its impeccable role in increasing output and productivity in projects, particularly in the construction industry. The concepts of VE was used in the business industry in the 1990s for the first time in Iran and in practice, it was applied in the construction industry in the 2000s (Pourreza *et al.*, 2013). As regarding financial issues and projection of product quality, it has received much attention by academic and workshop researchers. The theory of VE is a systematic and continuous process of a work plan conducted by VE team to improve product value. Today, value engineering is based on better and common team activities as compared to individual activities, because group thinking is logically better than individual thinking (Cooke, 2014).

From an applied view, VE is an organized plan that uses logical composition and technological knowledge to find and eliminate unnecessary costs of a project. The aim of VE is to encourage the wider use of value analysis/engineering techniques throughout the industry (Value Engineering, 1969). In other words, the main aim of VE is increasing the value of products by cutting unnecessary costs and keeping quality or reinforcing it. VE is not a critical review, constructability review, nor a cost-cutting exercise. It is a problem-solving technique that bypasses learned responses to produce alternative solutions at less cost (Value engineering guidance handbook, No VE.1). On the other hand, VE is a systematic and low-cost approach to assess the value of a project. Typically, VE can be used on projects to gain the following benefits: cost reduction, time saving, quality improvement, and isolation of design deficiencies (Value Standard and Body of Knowledge, SAVE International, 2007).

According to Leung and Wong, performance of VE affects the organization and project efficiency directly. Moreover, Atabay and Galipogullari contend that the highest efficiency is achieved when the main goal is to increase the product value instead of cost reduction. (Atabay and Galipogullari, 2013). In addition, Chen *et al.* believed that VEW (Value Engineering Workshops) performance evaluation does not only lead to cost cutting, but also includes the impacts of various factors such as product value, quality, and safety (Chen *et al.*, 2010).

VE is a tool which can attenuate problems related to design and construction of highways by providing: cost reduction, process improvement and alternative means and materials for highway construction and maintenance. As referred to in PMBOK, value analysis and value engineering should be performed in the analysis of any product including road construction and transportation projects (PMBOK (Project Management

Table III. Scoring various choices by design consultant from technical and economic aspects

Sum of score	Construction cost	Access to existing road	Easy execution	Maximum application of	Sunny	Low bridge length	Low tunnel length	Low longitudinal slope	Suitable geometric plan	Length reduction	Choice name
55	8	7	1	7	1	5	6	5	8	7	A
56	9	7	6	4	4	6	8	2	8	2	B
30	3	1	4	1	1	4	1	2	5	8	C1
24	1	2	3	1	1	2	3	2	3	6	C2
27	2	3	5	1	1	2	5	2	2	4	C3
35	7	6	2	2	2	1	3	3	4	5	D
45	6	4	4	3	3	7	2	1	6	9	F
25	4	5	5	1	1	1	4	2	1	1	J
40	5	4	5	1	1	3	7	4	7	3	H

Table IV. Normalized scoring of various choices from technical and economic aspects by design consultan

Sum of score	Construction cost	Access to existing road	Easy execution	Maximum application of	Sunny	Low bridge length	Low tunnel length	Low longitudinal slope	Suitable geometric plan	Length reduction	Choice name
7.55	0.89	1	0.17	1	0.25	0.71	0.75	1	1	0.78	A
8.34	1	1	1	0.86	1	0.86	1	0.40	1	0.22	B
4.15	0.33	0.14	0.67	0.14	0.25	0.57	0.13	0.40	0.63	0.89	C1
3.56	0.11	0.29	0.50	0.29	0.25	0.29	0.38	0.40	0.38	0.67	C2
4.17	0.22	0.43	0.83	0.43	0.25	0.29	0.63	0.40	0.25	0.44	C3
4.97	0.78	0.86	0.33	0.57	0.50	0.14	0.38	0.60	0.25	0.56	D
6.57	0.67	0.57	0.67	0.71	0.75	1	0.25	0.20	0.75	1	F
4.08	0.44	0.71	0.83	0.57	0.25	0.14	0.50	0.40	0.13	0.11	J
6.24	0.56	0.57	0.83	0.71	0.25	0.43	0.88	0.80	0.88	0.33	H

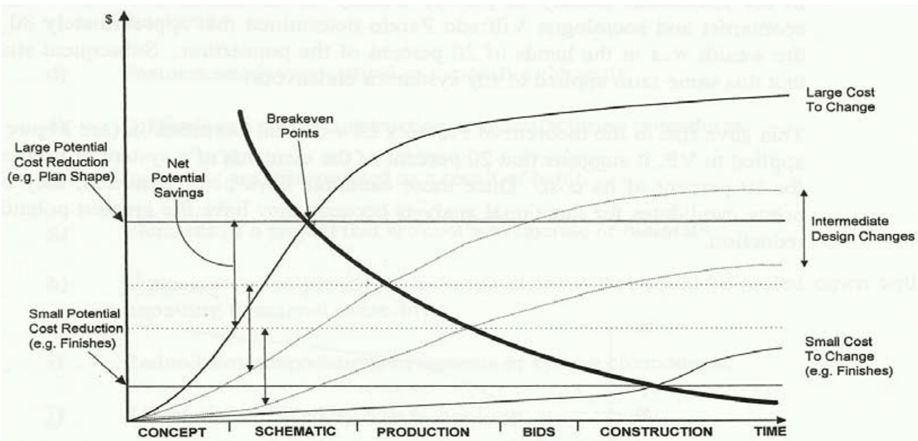
Body of Knowledge), Project Management Institute, 2008). Since road construction projects need a huge amount of money and resources, Therefore, applying VE methods in these projects has reasonable justification and the value-engineering workshop can be used in the management of these projects, including financial analysis, innovation, costs to value ratio, and the systematic application of techniques (Chen *et al.*, 2010).

In terms of the best time for applying VE, it is stated that, although VE can be used throughout the entire project's life, the more the VE is used in the early stages of a project, namely in the design phase, the higher is its output (Figure 2) (Value Engineering Handbook, 2000).

Mansfield and Udo-Inyang believe while the term VE is often used, the majority of today's construction industry members do not understand the true concept of VE. Furthermore, the performance of VE studies with an independent facilitator in the private construction industry is rare and the industry is confusing cost saving measures with VE (Mansfield and Udo-Inyang, 2006).

Ismail *et al.* achieved the new model of VE in Main Road Construction (VEMRC), which leads to decrease in time and cost, and increase the quality in projects. Their results indicate that VE techniques are very useful in construction of main roads, and such techniques are inclined to work not only in the stage of design but in all stages of projects (Ismail *et al.*, 2010). In the other research Kolla and Eng examined the relation between the application of Highway design standards and VE. Then, they demonstrated that there is a synergy between highway design standards and VE (Kolla and Eng, 1997). In addition, to overcome the problem of geographical location and contract issues Ch. Mitchell suggested that construction/civil engineering VE should focus on functional analysis of components and TCQ (Time, Cost, Quality analysis) of elements. Thereupon, the researcher offers a method for both client(s) and contractor(s) to undertake VE proposals (Mitchell and Jessup, 2013).

Although many studies have been conducted in VE theoretically both in business and construction industry, its role in road construction projects especially in terms of investigating value index and its practical framework in such projects are less considered. In fact, the existence of a viable framework, which the project managers and value engineers



Source: Value Engineering Handbook, 2000

Figure 2.
Application of value engineering in life cycle of project

can apply for other projects pertaining to road construction, has been ignored in the past researches.

3. Methodology

This paper evaluates a road construction project as a case study, and with the usage of value-engineering techniques, a new option is presented which leads to significant reduction in cost and time and increase in quality, safety and environmental factors.

This research project was selected with regard to the extremely high validity of its potential in terms of Value Engineering implementation (reducing costs while maintaining quality and standards and thus increasing the value index).

After completing the examination of the consultant's proposed plan with the aim of improving the project value to reduce the bottleneck height and shorten the path length, the research studied the project scope and identified suitable, costly, and highly risky functions in the function analysis phase by utilizing FAST (Function Analysis Technique System). FAST is defined as a form of function analysis expressed in diagrammatic form to show the relationship between functions and the means of achieving them. A FAST diagram is limited by two vertical lines that delimit the scope of the problem and on the left of the line is to be found the 'higher level' function, which is in fact the general need. The chart and ideas of selected functions went through the creativity and evaluation phases.

4. Value engineering study

In this study, technical and financial information were first collected after forming a value engineering team including a value-engineering expert who was responsible for coordinating the work, some representatives of the employer, the designer, the project executor, and the budget estimator. In addition, the results of the seminars held in the form of value engineering, field visits of the project sites, and modeling data were collected. Then, after a thorough review of the plan proposed by the consultant and holding value-engineering workshops aiming at improving the value of the project, the scope of the project was discussed. In functional analysis phase with the use of FAST graph, the advantageous, and costly and risky functions were identified. In the creativity phase, ideas related to selected functions were created, investigated, and developed in the evaluation phase. Finally, calculating the value index, two variants with higher value index than the baseline plan, were proposed and implemented. In Figure 3, the implementation of this framework is shown:

In the final development of the study and based on the initial development of 30 ideas and their evaluation, seven main choices are formed. These 7 choices can be divided into three main groups. The first group contains the choices proposing a new path different from the basic plan, or a major part of the path is changed; variant DOA, S, and Snail Bridge (SC1) have these features. Major changes are observed in the lower part of the bottleneck and in Sanandaj.

The second group includes choices proposed in the consultant's studies and with a few changes is evaluated to obtain the opinion of the value team about them. Modified H, J, and C1 are some examples. The third group includes the modified C2 as a basis plan.

Based on the items and by calculation of value index, beside the proposal to modify variant C2, using two choices of DOA and S as the choices with high value index compared to the basic plan, are proposed to the employer for decision-making.

The assessment process to achieve a chosen option is according to the following phases:

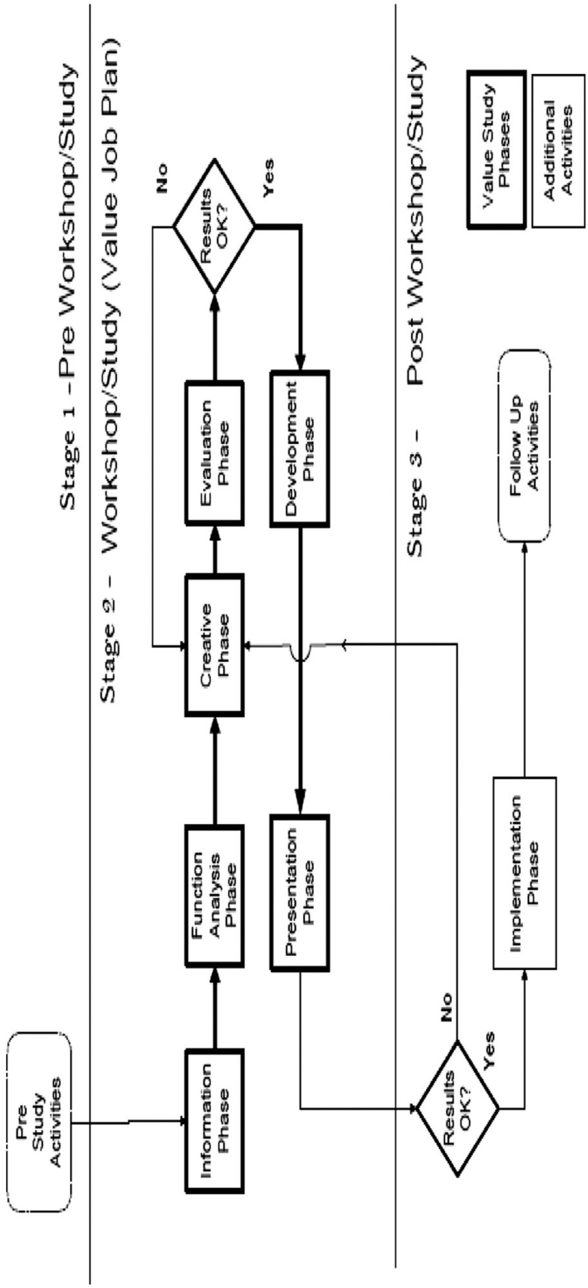


Figure 3.
Applying framework to implement main steps of value engineering

4.1 Information phase

The study basics include the study proposal, study scope, underlying limitations, evaluation criteria, problems and opportunities, and finally, identification of beneficiaries. The details of the above project study are summarized in Table V.

The importance of the evaluation criteria is different when it is based on the conditions or on the expectations, or on the needs. Determining the priority and quantification of the criteria are summarized by the AHP method in Table VI.

In this method, a table is provided and the criteria are placed in horizontal and vertical rows. Then, in the interaction point of two factors (a horizontal row and a vertical row in the table), the more important criterion and its priority to the second criterion is respectively written. The importance is sometimes measured from 3 and sometimes from 5. A more accurate scoring method for each criterion is comparison. The total score of each comparison is usually 10. At the end, the total scores of each idea are added up and divided by the sum of the scores. People usually complete each of these tables individually and at the end, the weights of criteria are calculated based on their comments.

4.2. Function analysis phase

This phase transforms project components to functions, analyses, and selects potential areas in order to improve the project's condition.

No	Title	Items	
1	Project goals	Social and economic development of region Improvement of communication of Kordestan province with neighboring provinces and center of country Increasing service level of Sanandaj-Hamedan road	
2	Value engineering goals	Improvement of project value	
3	Employer expectations		
4	Study scope	Sanandaj to the end of Salavatabad	
5	Project opportunities and problems	Opportunities Touristic region The existence of road The existence of tunnels of existing path Mountain materials Proximity to province center Considering various variants Four lines of surrounding roads	Problems: High height difference Credits limitation Limitation of work season Border free Running water Low mines, shortage of water and transportation distance Security problems of region Facilitation in operation
6	Beneficiaries of plan	The construction and development of transportation infrastructures company	Railway (cargo and passenger)
		Main road office of region resident province	Tourists and passengers
			Drivers Traffic
7	Evaluation criteria	Increasing safety	Easy execution
		Reduction of trip time	Facilitation of operation and maintenance
		Users satisfaction	Improving geometric features of plan
		Maximum use of existing facilities	Facilitation of operation

Table V.
Project information

4.3. Function of the project's components

First, the project is divided into several components (tunnel, bridge, the body of road villages, Salavatabad mountain pass, service complexes, C2 choice, infrastructural installations, border and intersection), then the relevant functions are extracted.

Table VII shows four components of the project (C2 choice, infrastructural installations, border, intersections), and the other components are extracted in the same way.

4.4. Project's fast diagram

After the extraction of functions, the study team in a group activity defined the systematic form of the project in the form of a function analysis chart. Then, six potential areas in functions were identified to increase the value. These functions will finally reach the project's components i.e., it shows how you can gain high-level functions by low-level functions.

4.5. Determining opportune, costly, and risky functions

Generally, value engineering focuses on potential areas for augmenting value. These areas include characteristics such as high cost, risk, and opportunities for promoting the amount of value. In this study, six functions (Figure 4) are specified and selected to increase the value.

Evaluation criterion	Specification	Precedence
Increasing safety	A	1
Reduction of trip time	B	2
Satisfaction of users	C	3
Satisfaction of path area residents	D	4
Maximum use of existing condition	E	5
Easy use	F	6
Facilitation of operation and maintenance	G	7
Improvement of plan geometric features	H	8
Facilitation of operation	I	9

Table VI. Weighting the evaluation by AHP method

Intersections	Border	Infrastructural installations	C2 choice
Reduction of safety	Increasing safety	Passing facilitation	Improving features
Increasing access	Creating limitation	Creating barrier	Increasing capacity
Increasing costs	Creating social issues	Difficult execution	Increasing safety
Passing disturbance	Delay in operation	Cost increase	Development of region
Delay in trip	Increasing environmental problems	Safety increase	Development of region
Residents satisfaction		Safety reduction	Social development
Providing relation		Increasing public welfare	Economic development
		Tourism development	Easy access
		Cultural development	Communication improvement
		Increasing public level	Increasing welfare
		Sustainable development of region	Reducing welfare

Table VII. Some functions of project components

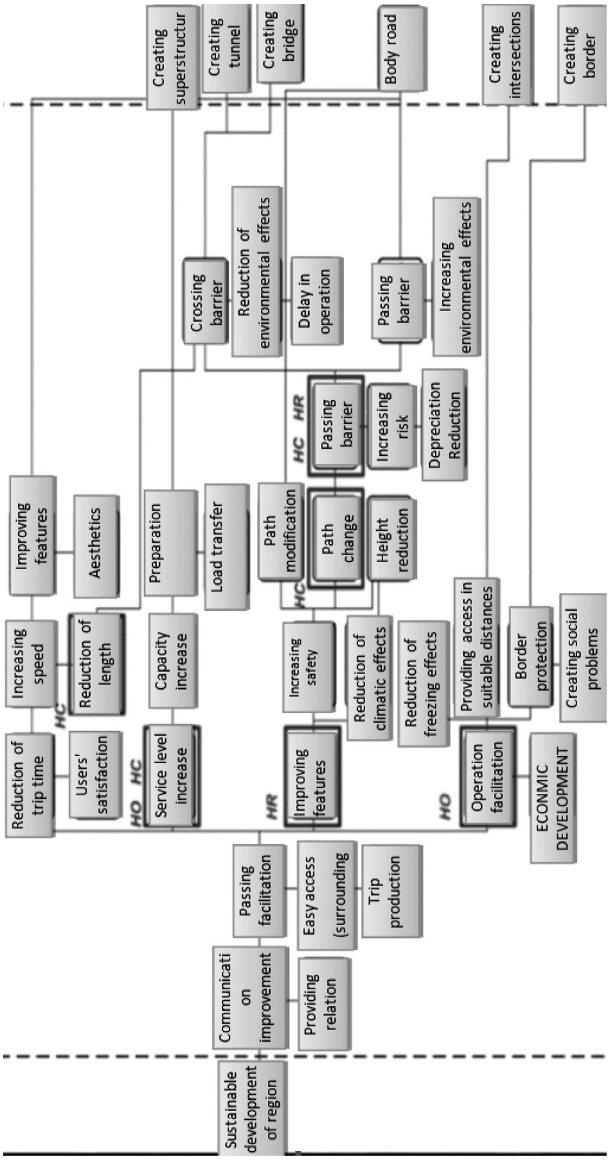


Figure 4.
Selected function sin function analysis systematic chart

5. Creativity phase

Hosts of ideas are generated in this phase for reaching the chosen functions without any criticism and challenge for being feasible. Here, brain storming and other innovation techniques are used:

- Gourdone;
- Shorthand;
- Related lists;
- Making a matrix;
- Morphology; and
- Checklist, etc.

In this phase, six selected functions are processed separately. Generally, the ideas in the creativity phase are about 350 ideas in various aspects to increase the plan value.

6. Evaluation phase

In this section, by the full assessment of ideas and investigation of strengths and weakness of each idea, the initial evaluation for the development of the idea or determining ideas to potential functions is provided. These ideas are classified according to the table below (Table VIII):

The results of evaluations show that 35 ideas are scored, and 30 ideas with a score above 5 are proposed for development. The results of the idea evaluation is shown in Table IX.

7. Development phase

In this phase, the selected ideas based on the results of the evaluation phase are completed by the collaboration of the development teams. Then, a combination of developed ideas of scenarios and choices are formed.

In the final development of the study and based on the initial development of 30 ideas and their evaluation, seven main choices are formed. These seven choices can be divided into three main groups. The first group contains the choices proposing a new path different from the basic plan, or a major part of the path is changed: Variant DOA, S, and Snail Bridge (SC1) have these features. The major changes are observed in the lower part of the mountain pass and in Sanandaj. These variants are shown in Table X.

Summary mark	Idea explanation
OF	Potential ideas related to Facilitate of operation
LR	Potential ideas related to Length Reduction
SI	Potential ideas related to Increasing Safety
OP	Potential ideas related to Pass over Obstacle
IL	Potential ideas related to Increasing in Level of services
CV	Potential ideas related to Change road
OS	Potential ideas related to Out of Scope

Table VIII.
Clasification of ideas

No.	Function	Idea code	Idea title	Mean score
1	Increase the level of service	OP37	To eliminate specific bridge in the 14-kilometer length of the tunnel	856
2	Redirects	CV3+CV4	Variants c1	8.56
3	Increase the level of service	OP10	Predicted ventilation and lighting safety review options	850
4	Redirects	Cv43	Correction curve for the design speed of 60 km	833
5	Increase the level of service	Lr16	Remove long trenches into the tunnel	820
6	Increase the level of service	Lr5	J variant is applied instead of C2	818
7	Increase the level of service	OP42 + 25	Consolidation and strengthening of trenches and rock tours	79
8	Redirects	CV8	Verify j, C3, C2, C1 and combined with 10 and 11	778
9	Facilitate of operation	OF45	Compare valley bridge option C1 with C2	767
10	Redirects	CV2	Integration variants h and C2 and creation variant S	744
11	Redirects	CV7	J variant due to a significant reduction in the length of the tunnel	722
12	Increase the level of service	IL48,49	Construction of retaining walls and guarantor of C1	711
13	Redirects	CV16	Construction tardy band at 5 km beginning of the path	689
14	Increase the level of service	OP32	Construction of hanging bridges (the establishment of special bridges)	656
15	Facilitate of operation	OF13	Change the direction of tunnel than wind	65
16	Increase the level of service	SI31	Identify the unstable points	65
17	Redirects	CV54	Increase Longitudinal gradient of the tunnel to 2.5% for S option	644
18	Increase the level of service	IL24,28	Adjustment slope of the first tunnel in c2	633
19	Increase the level of service	SI61	Provide safety index for all variants	627
20	Redirects	CV20	Modifying C2 to use most of the existing four-lane	6.22
21	Operation facilitation	Of37	Creating path C1 in two different levels	6.1
22	Increasing service level	Lr23	Repair of old road by passive defense budget	6
23	facilitation of operation	Of19	Displacement of tunnel entrance in C2	5.6
24	Route change	Cv49	Calculation of total existing 4-lines	5.56
25	Increasing service level	Si19	The identification and providing the plan for disaster -stricken areas	5.55
26	Route change	Cv12	Tunnel between high arcs in C1 in km 18	5.44
27	Increasing service level	Op12	Updating icc of all choices by considering the elimination of infrastructure benefits	5.4
28	Increasing service level	Il34	Establishing choice H by exact investigations	5.25
29	Increasing service level	Lr6	Using big trenches	5.1
30	Route change	Cv40	Comparison of total path costs as two roundtrip bands	5

Table IX. Idea evaluation results

The second group includes the choices in the consultant's studies and is evaluated with a few changes to achieve the opinion of the value team about them. Modified H, J, and C1 are some examples. The third group includes the modified C2 as basis plan.

7.1 Practical comparison between options

In this section, firstly, the research will investigate and compare the functions of various choices. As mentioned, nine criteria are determined to evaluate the function by the team. These criteria for each choice have a score ranging from 1 to10. A score above five shows improvement and a score lower than five indicates its weakness for the choice. Besides scoring each criterion for options, each option is given a general score. The team's generic choices are variants S and DOA. In this scoring, variant S is in better condition than variant DOA.

Variant C2 is modified and J is improved too. Other variants show a decrease in their functions. The scoring comparisons are shown in the figure below (Figure 5).

Table X. New variants specifications

demerits	merits	Maximum linear slope (%)	Minimum radius (m)	Decreasing length (km)	variant
To Separate going and coming road about 13km, don't using of 1km from road at the start	Building a toll house instead of two toll house for monitoring traffic, being sunshiny, possibility for performing emergency exit with low cost, the better plane characteristic, decreasing in cross fall, decreasing in road length about 3km, go upping in speed of plan about 10km/hr., minimizing time trip and technical structures, facilitating in operating and maintenance	6	175	3/185	DOA
Absence of accessing to existent road from 6km to 20km, rising in time performing of project, don't using from existent road	Decreasing length of road, performing road without disordering traffic, minimizing the height of stem about 150m, don't passing over rural area, falling performing costs	6	200	7	S
Increasing length of road, declining safety, difficulty in operating and maintenance, difficulty in performing plan	Attenuating the environment destruction, beautifying, new exercise of road building	45	200	−2	SC1

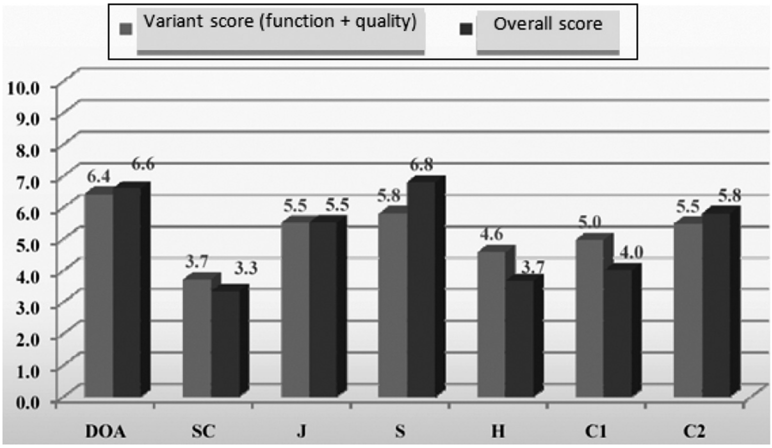


Figure 5.
Chart of comparison between generic score and variant score base on criteria

Figure 6 shows the scores of various criteria for all choices (Figure 6). Generally, this figure shows a high improvement in the criterion of reduction in travel time, users' satisfaction, and maximum use of existing conditions, improvement of plan, geometric features, and finally, the increasing safety and satisfaction of native residents. On the other hand, the three criteria of easy implementation, rapid operation, and facilitation in maintenance have the lowest score.

7.2 Calculation of construction costs

The VE team relied on cost analysis that the Consultant Company announced for variant C2, so they calculated the costs of variants DOA, S, and SC1. In addition, the authors considered some coefficients for extending the tunnels (executive operation, ventilation, and lighting costs) in order to pore over the calculations, which have been carried out (Figure 7). Table XI illustrates a comparison between estimating different variants with and without considering coefficients.

According to the chart (Figure 8), variant DOA contains less cost. In addition, variants C1, C2, H, C3, and S are situated systematically. Another part of cost calculation pertains to the incomes of three of the main components that are illustrated in the below chart.

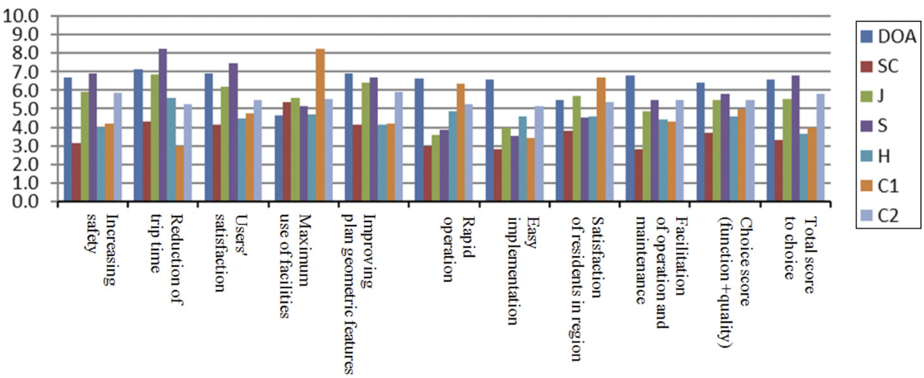


Figure 6.
Score of evaluation criteria in various choices

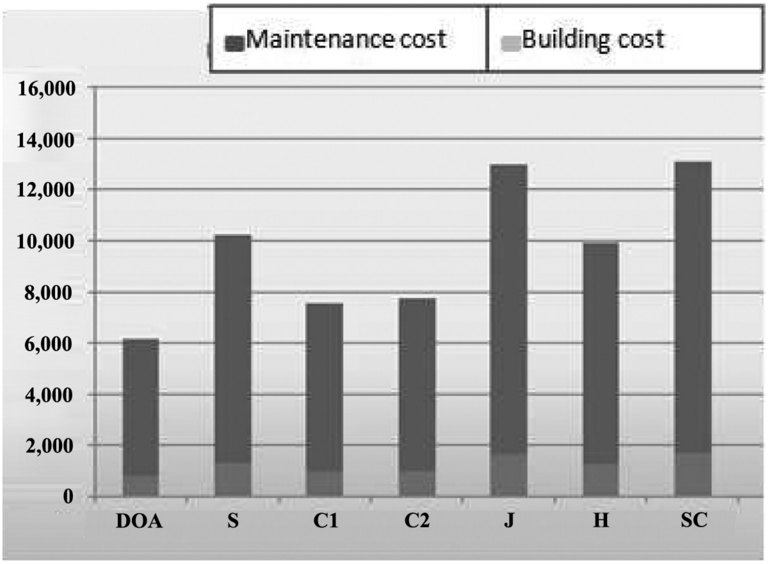


Figure 7.
Costs of construction and maintenance of various choices (cost over kilometers)

Table XI.
Construction cost of various choices from design consultant (milliard rials)

Estimating cost according to consultant with considering coefficients	Estimating cost according to consultant	variant	No
541	504	C1	1
555	454	C2	2
720	486	C3	3
714	787	F	4
931	506	J	5
713	632	H	6

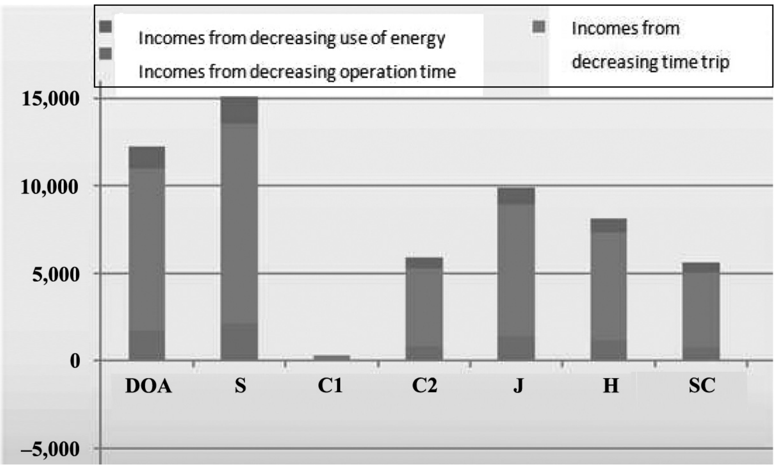


Figure 8.
Suggesting variants incomes

In further scrutiny, according to the chart (Figure 9), an amount of NPV (Net Present Value) for each of the different variants shows that variant S and DOA excel financially more than other variants, and only these two options have a positive net present value. Figure 10 reveals NPV beside profits and costs for all variants. Hence, financially, the value engineering team recognizes variant DOA as the best variant in this project. The chart states that the highest income belongs to variant S followed by DOA. Variant F leads to a decreased income by extending the road.

7.3 Options value index

After examining the function of choices, based on the score of evaluation criteria and the assessment of various choices, the authors investigated the value index deficiency. Value index is used to determine the improvements achieved through value engineering in a project and to compare the rate of improvement of various projects through value engineering. In order to quantify this index, the improvement resulted from changes are calculated and the index becomes the value in the case of reduction. The project's or the product's cost is also

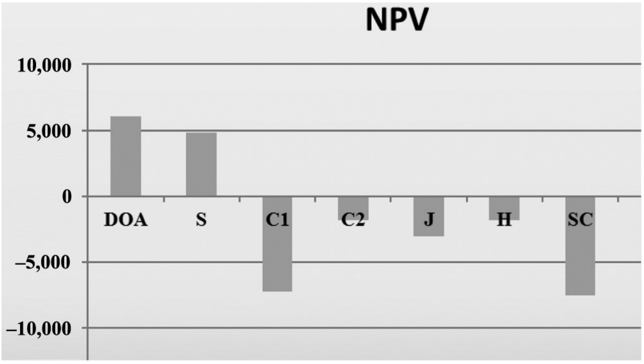


Figure 9. Comparison of NPV between different variants

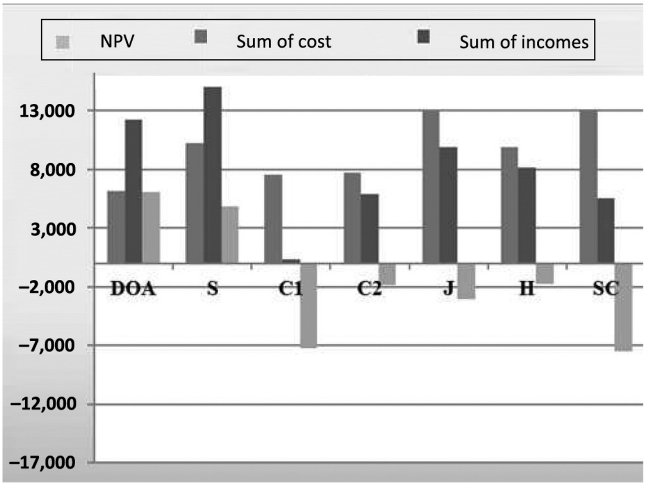


Figure 10. Incomes, costs, and NPV for all variants

calculated after applying the changes and is the denominator of the fraction. The quotient of these two values forms the value index. Evidently, the higher this index is, the more improvement will be observed in the project or the product [Equation (1)]:

$$\text{Value Index} = \frac{\text{Relative Important}}{\text{Relative Cost}} \tag{1}$$

Relative Importance and not Relative Important (in the above equation).

At first, by considering the costs of the project life cycle, it can be estimated that the value index is relative and absolute. The results show the suitable condition of DOA, then the C1, C2, and S choices. The income and savings of the various choices implemented are not mentioned in the index calculations. Thus, from the economic aspect, the DOA variance is the preferred variant in this study.

Entering incomes and savings over the variants including DOA, S, C2, H and finally J, the best conditions in terms of value index is observed in the following chart (Figure 11).

8. Conclusion

Employers and project sponsors are always looking for products with greater value and lower costs; therefore, providing a similar work experience can encourage them to use value-engineering techniques.

This research proposed the final options after conducting value-engineering workshops during the development phase. Then, these seven selected options were divided into three basic categories:

(1) *The first category*: Options proposing a new direction different from the basic plan with a change in a significant part of the direction (DOA variant and the variant S and SC) according to Table X.

(2) *The second category*: There are also options that were in the consultant's studies and are re-evaluated with a few changes (Option H, J and modified C1).

(3) *The third category*: Consultant's proposed option (option C2).

Ranking of various criteria was performed in Figure 5. (Reduction of travel time, user satisfaction, maximized use of existing conditions, improved geometric design, increasing the safety of region's residents' satisfaction, ease of implementation, accelerating the exploitation, and facilitation of operation and maintenance, were investigated). Then, two options (S with a score of 6.8 and DOA with a score of 6.6) were selected as the best options.

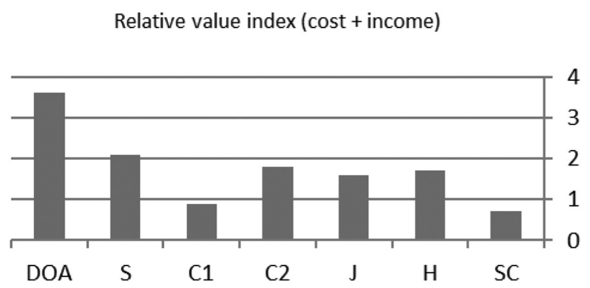


Figure 11. Relative value index by considering initial costs and maintenance costs and income and saving

Then, considering the fact that the cost estimated by the consultant was limited to construction cost, the consultant designer modified the estimated costs. (Traffic coefficient for interfering with the existing traffic, the tunnel length coefficient, and costs related to tunnel ventilation and lighting was added). Maintenance costs were also calculated for each option. As it is shown in Figure 7, DOA that is bulging with the costs of construction and maintenance to about 6,000 billion Rials has the lowest cost, followed by C1, C2, H, C3 and S. Then, the project revenues during exploitation period (of reduced energy consumption, reduced travel time and reduced exploitation time) were also added to the economic analysis. According to Figure 8, the option S with 15,000 billion Rials and the option DOA with 12,000 billion Rials have the highest incomes, respectively. Finally, using the present value of options along with the total costs and incomes of each option (Figure 10), the following results are obtained:

Value index of the different options represents the improved function of two options, S and DOA; however, the decreased function of the SC and the increasing cost totally reject this option. Regarding H and J options, the option H is also an appropriate function. However, it has no significant difference with the primary plan in terms of cost. Improved functioning of the option J is more significant than that of the option H, though, its cost is relatively high and exposes the value index of the option to stagnation.

At the end, DOA was selected as the first and second priority in which not only the numerator value index increased but also there was a considerable reduction in costs as well as an increase in interest. On the other hand, calculating the relative value index of the options in Figure 11, the growth of this index from 0.9 in the variant C1, which is the consultant's proposed variant, to 3.5 in the variant DOA and to 2 in the variant S, which are the proposed options of value engineering team, can be observed.

Since the determining criteria of designing and implementation of road construction projects including increased safety, reduced travel time, user satisfaction, ease of implementation, cost of construction and maintenance, [. . .] are almost similar in most projects, therefore, utilizing the results of this study and implementing its practical framework in other construction projects will be beneficial.

These parameters lead to an increase in quality, value, and safety of the project. With regard to the steps taken and resulted incomes, this essay can be referred to as a practical and theoretical model to promote the value of crucial projects especially in the developing countries.

References

Atabay, S. and Galipogullari, N. (2013), "Application of value engineering in construction projects", *Journal of Traffic and Transportation Engineering*, Vol. 1 No. 1, pp. 39-48.

Chen, W.T., Chang, P.Y. and Huang, Y.H. (2010), "Assessing the overall performance of value engineering workshops for construction projects", *International Journal of Project Management*, Vol. 28 No. 5, pp. 514-527.

Cooke, J. (2014), "Improving the value of products and processes by combining value analysis techniques and lean methods with TRIZ" *TRIZ FUTURE CONFERENCE – Global Innovation Convention*, p. 2.

Dell'Isola, A. (1997), *Value Engineering: Practical Applications for Design Construction, Maintenance & Operations*, John Wiley & Sons, New Jersey NJ, p. 22.

Ismail, R., Aminzadeh, A. and Aram Arshad, I. (2010), "Using of value engineering in main road construction", *Journal of Applied Sciences*, Vol. 10 No. 22, pp. 2950-2953.

Kolla, E.J. and Eng, P. (1997), "Highway design standards and value engineering – a synthesis" *Save International Conference Proceedings*, p. 317.

Mansfield, S. and Udo-Inyang, P. (2006), "Application of value engineering within the construction industry", *ASC Proceedings of the 42nd Annual Conference*, *Colorado State University Fort Collins*, *Colorado CO*, *April 20-22, 2006*.

Mitchell, C. and Jessup, S. (2013), "Developing a standard approach to the value engineering process for the civil engineering industry: a theoretical, case study and industry perspective" *CEEC General Assembly Brussels*, 25-27 April, 2013.

Pourreza, M., Zonnorian, M. and Atri, A. (2013), *Knowing Value Engineering*, Knowledge Resource in Value Engineering, Tehran, p. 17.

Project Management Institute (2008), "Project scope management", *A Guide to the Project Management Body of Knowledge*, 4th ed., Chapter 5, Project Management Institute.

Value Engineering (1969), *Society of American Value Engineers (SAVE)*, Vol. 1 No. 6, p. 321.

Value Engineering Handbook (2000), *Value Engineering Handbook*, Bechtel Corporation, London Execution Units, London, p. 10.

Value Standard and Body of Knowledge SAVE International (2007), *The Value Society*, Northbrook, IL.

Xiaoyong, L. and Wendi, M. (2012), "Appraisal of value engineering application to construction industry in China", in Zhang, Y. (Ed.), *Future Wireless Networks and Information Systems, Lecture Notes in Electrical Engineering*, Springer, Berlin, Heidelberg, Vol. 144.

Further reading

Leung, M.Y. and Wong, K.M. (2002), "Value elevation by the evaluation of behavioral facilitation skills" *Proceedings of SAVE International 42nd Conference*, *Colorado CO*, May 5–8, pp. 139-145.

United States Dept. of the Interior (2011), *Value Engineering Guidance Handbook*, Department of the Interior.

Xueqing, Z., Xiaoming, M. and Abourizk, S.M. (2009), "Developing a knowledge management system for improved value engineering practices in the construction industry", *in Automation in Construction*, Vol. 18 No. 6, pp. 777-789.

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