Vol.4, No.1 Special Issue on New Dimensions in Economics, Accounting and Management
ISSN 1805-3602

Effectiveness of Value Engineering in Reducing Delay in Urban Projects

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Abstract

Because of misappropriate design, technology complications, excessive number of organizations and involving people in the project, variation of needed qualifications and extensive number of activities, development projects don't execute within primary determined cost and time constraint. Therefore presence of a regular system for optimizing investment in development and urban plans is needed. Optimization methods causing project implementation within primary cost and time constraint work are effective to eliminate negative effects of mentioned factors. The objective of this research is to investigate the effect of using value engineering in order to eliminate causes of delays in the urban projects of country. Regarding the results of this research, the most and least effect of value engineering are in order to eliminate delay causes arising from integration and human resource mismanagement. Moreover, value engineering must be employed for refinement and optimization of processes before and during project execution in order to decline time delay and costs and to increase value of projects. Value engineering studies, specifically whenever strategic decisions should be taken, could affect positively on the project execution. Finally, employing value engineering technique and compounding these methods to project management science can increase the value index of urban projects.

Keywords: value engineering, urban projects, causes of delay, project management.

Introduction

The construction and development projects are the essence and prerequisites for industrialization in developing countries. The annual budget deficit, high inflation, improper program during the operation, not reaching the final goals of the project, lack of influential consultation and contraction companies, lack of modern technology, and leaving the projects unfinished impose completion costs of projects twice or three times of the predicted cost. Lack of efficient management in allocation of construction budgets and inappropriate implementation of the project leads to heavy costs after implementation (operation period) and reduces the quality and efficiency of the project. These factors create negative cycles which amplify each other and threaten development process of the countries.

Nowadays, the executers and designers of construction projects throughout the country, Iran, encounter many problems in their way to achieve project objectives due to inefficient design, technical complexities, variety of the required specialties, huge load of activities, and large number of involved organizations and people. Thus, these projects do not achieve their goals in the defined deadline. The necessity of a well-organized system for investment optimization in construction projects is obvious in the country, Iran. So, the optimization methods, which facilitate project execution in the initially defined cost and time framework, could be of a great assistance for dealing with the negative consequences of the mentioned factors causing project delays. In this regard, there are various project management methods and techniques; among which, value engineering is a

comprehensive method. During the life cycle of the project, the design and construction phases are considered as appropriate beds for value engineering studies. The main question of the present study is how value engineering can be applied for reducing the time delays in construction projects. In this study; first, literature review is presented and then the field study is conducted based on the research method and statistical population, and, finally, the results and findings are presented.

Literature review and research background

Value engineering is a managerial tool for achieving the necessary functions for producing commodities and services as well as project implantation with minimum cost. Ever since value engineering emerged in 1950; this technique has been used as a major approach in public institutes and private corporations for minimizing the time required for projects. This approach is broadly applied in construction industry and is considered as an inseparable component of construction and development projects [Zhang, 2009, pp 777-789]. Value engineering or value management is among the important instruments in project management that can be applied as a systematic effort for analyzing the main needs of systems, equipment, facilities, and programs by spending the minimum cost [Ismail, 2010, pp 699-703]. The 14th meeting of American Society of Value Engineering, held in 1973, explained the achievements of value engineering and reported that per each USD invested in value engineering about 4.53 USD had saved in operational costs. As since applying the value engineering in USA in 1973, about 1.8 billion USD is economized. The output of value engineering from 1973 to 1995 for each invested USD was from 15 to 30 USD. Value engineering in construction projects of USA saved 35 billion USD from 1996 to 2000 and reduced 55 billion USD of costs. Table (1) shows application of value engineering in different industries of the world and their percentages [Sedigh, 2009, pp 129-152].

Table 1: percentages of value engineering application in various industries

Application percentage	Field
79.9	Power and electronic
91.3	Transportation (road and traffic engineering)
90	Equipment production
84.5	Machinery and automobile manufactory
50	Chemical industries
39	Construction industries
37.5	Food industries

The first application of value engineering in Iran was in 1975; however, it had no progress for many years. After a long respite, the article c of principle 61 of the third economic, social, and cultural development program clarified that the operational systems are obliged to revise their construction programs by applying value engineering standards for programs facilitation and acceleration. Indeed, the legal requirements as well as some activities on 1999 and 2000 finally resulted in reapplication of managerial engineering technique in Iran and, afterward, establishment of Value Engineering Association in 2001 [Ghamarnia, 2008].

A large number of studies have been recently conducted about value engineering. For example, Tiri applied value engineering concept in project management process and suggested a customer-based approach for better control of the project quality. This approach involves many techniques employed in construction projects. He proposed some techniques for making these approaches as useful as possible for staffs, project managers, and project team. He concluded that to obtain the maximum benefit from value engineering, organizations should apply value engineering in both strategic and tactical levels [Thiry, 1996]. Applying value engineering techniques, Glass et al

examined innovations in England construction industries; particularly, in concrete technology and indicated that these industries can achieve further strategic innovations in research and development section by employing value engineering techniques [Glass, 2001]. Gershenson investigates application of value engineering in revision and improvement of the educational programs and indicates that employing such techniques is very beneficial in many engineering programs and enables colleges to improve innovation [Gershenson, 2002]. Utilizing their experiences of executive management in construction and industrial projects, Jabal Ameli and Mir Mohammad Sadeghi studied value engineering process in construction and industrial engineering programs and defined the optimum time for application of value engineering and proposed a model for employing value engineering in management process of the development projects [Jabal Ameli, 2004, pp115-122]. Using fuzzy logic, Sabt et al extended delay analysis techniques by approving analysis of weather delays. Their results indicated that the presented model is in accordance with practical experiences in weather delay duration except in some circumstances that can be divided into the separated parts. It also advances the use of fuzzy logic in delay analysis procedures and becomes it more systematic special for weather delays [Sebt, 2007]. Ismail et al studied application of value engineering in highway construction projects and found that value engineering plays a key role in improvement of highway construction projects in terms of cost and time minimization and improving the quality of highway construction [Ismail, 2010, pp 699-703]. Salahshur et al reported that applying value engineering caused about 18913 million USD economization, time save of several months for each project phase, and reduction of the environmental problems during the great siphon construction project of Karkhe Dam [Selahshur, 2006]. Mahjubi et al reported that application of value engineering in drain project of Hendijan, located in SW of Khuzestan Province, prevented ruin of the farming lands which were not involved in the project, as well as reduction in the project execution length, exploitation and environmental problems, and operation costs about 6750 million Rials [Mahjubi, 2006]. Using value engineering based on the international job plan of the SAVE (Society of American Value Engineering), Tavakoli Moghadam et al proposed various alternatives to improve upon the performance of Customer Services of Water and Sewage Co. The results indicate possible savings of about 714 Million Rials for the water authority in the city of Sari and 4860 Million Rials across Mazandaran Province [Tavakoli Moghadam, 2007]. Mahab Ghods Consultant Engineers reported that application of value engineering techniques in irrigation and drainage network of Tajan 4 in Mazandaran Province through removal or combining some basins in the route of main channel and change of project line for minimizing the fillings volume in the main channel has resulted in a 2850 million Rials financial save [Mahab Ghods Consultant Engineering., 2007]. Amini applied value engineering technique for selecting the optimum dam type alternatives among 8 options in Raeis Ali Delvari Dam by considering factors including cost, life, time need for their construction and selected the double arch concrete dam with concrete pad as the optimum choice [Amini, 2008]. Ghamarnia et al studied advantages of value engineering in Baba Hadi Irrigation and Drainage Project in Kermanshah Province and reported that application of value engineering can result in a significant cut in cost and time of the operational projects as well as optimum facility use [Ghamarnia, 2008].

Methodology

In the present work, desk study (by books, texts and papers) and survey research (using the questionnaires and semi-structured interviews) were employed for data collection. The questionnaire, as the main tool for data collection, was prepared by using the theoretical studies. To enhance validity and content reliability of the work, not only the available studies and literature review was used, but also the questionnaires and questions available through the national and

international work and consultation with experts were utilized. The statistical population of the present work includes all professionals and experts of value engineering active in construction and development projects. The common characteristic of statistical population members is their specialty: value engineering. The sample of the present research involves 40 experts of value engineering from Tehran who are active in construction and development projects.

In this research, the main factors of delay in urban projects were detected by studying the documents available in municipalities, interview with experts and authorities of the urban projects, and filling the first questionnaire. Besides, the share of each factor in the delay was determined in the main framework of the project management discipline and, finally, the findings of the first questionnaire were used as the initial information for designing the second questionnaire. The first questionnaire was developed by using 38 contracts of the contractor and engineering procurement corporations of the urban projects and the main causes of delay in urban projects were determined in the project management body of knowledge (Table.2).

Moreover, each group of causes of delay introduced in questionnaire 1 is placed in project management body of knowledge; so that, the delay is defined as an index; while, the project management body of knowledge are considered as variables. Then, each variable is analyzed by Friedman test. The variables are as: 1) inattention to the integration management, 2) inattention to the scope management, 3) inattention to the time management, 4) inattention to the cost management, 5) inattention to the quality management, 6) inattention to the human resource management, 7) inattention to the communication management, and 8) inattention to the procurement management.

Table 2: the main causes of delay in project management body of knowledge

project management body of knowledge	Number of repetitions	Repetition percentage	Ranking
Project integration management	42	16.67	2
Project scope management	12	4.76	9
Project time management	41	16.27	3
Project cost management	45	17.86	1
Project quality management	21	8.33	5
Project human resource management	19	7.54	6
Project communication management	8	3.17	10
Project risk management	13	5.16	8
Project commodities and materials management	33	13.10	4
Uncontrollable factors	18	7.14	7

Here, we face to the question that whether there is a difference between the mentioned 8 variables from the viewpoint of effect of value engineering on dealing with cause of the delay. In other words, we wonder whether it is possible to categorize the variables in terms of their affectability from value engineering. To reply this question, Friedman test was used. This test generally is used where statistical data are ordinal and can be classified in at least two side categories. The Freidman test statistic ($\chi 2$) is defined as (eq.1):

$$\chi^2 = \frac{12}{nk(k+1)} \sum_{j=1}^{k} R_j^2 - 3n(k+1) \quad (1)$$

Where, n is number of interviewees; k is number of classified variables; and Rj is the rank assigned by the interviewees to variable jth.

The sum of ranks assigned to jth variable is calculated as (eq.2):

$$\sum_{j=1}^{k} R_j = \frac{n(k)(k+1)}{2} \quad (2)$$

This test is used to examine significance of ranking of the variable [Salehi Ghadiani, 2009].

The approximation of $\chi 2$, introduced in eq.1, is adequate just when the number of subjects (interviewees) is quite high. However if $k > 4$ and $n > 10$, this test would be adequate [Human, 2010]. Therefore, our hypotheses are expressed as:

- Null Hypothesis (H0): there is no significant difference among the variables.
- Alternative Hypothesis (H1): there is significant difference among the variables.

The lower the validity of the measurement instrument is, the higher measurement errors occur. Validity of the research was tested by the validity analysis; through which; first, different variables are considered and then the variables closer together are detected and the irrelevant ones are dismissed. To this end, Cronbach alpha (α) method, as a common validity measurement tool, was used. This method works based on internal consistency of the variables. When the obtained α coefficient is greater than 0.7, the questionnaire meets the required validity [Sarmad, 2004].

In this work, Cronbach α coefficient of the questionnaire and the validity test were performed in SPSS software. The first questionnaire contains 31 questions and was distributed among 20 subjects. After collecting the questionnaires, the obtained α coefficient of the questionnaire was measured as 0.926 and since it had adequate validity ($\alpha > 0.7$) it was used as the final questionnaire. Therefore, in the present research, we apply the qualitative-quantitative method, as one of the most common research approaches for studying social and human phenomena; particularly, in project management.

Data analysis

According to the documents available in municipalities and information extracted from interviews with experts and authorities of the urban projects as well as data of the first questionnaire, an initial model was designed to determine the main causes of delays in urban projects in the main scopes of project management body of knowledge which is selected as an instrument for designing second questionnaire. To design the second questionnaire, considering the research literature, comments of the paper authors, and results of the non-structured interviews conducted with several experts and professionals in value engineering, we determined the main causes for the delays in urban projects with regard to their effectiveness for each main scope of project management body of knowledge (Table.3).

The second questionnaire contain 6 demographic questions, 31 closed questions for measuring the indexes and variables, considered by the research, and one open question in each page for examining the effect of value engineering in dealing with the delay causes in urban projects. The questions, which are about different scopes, include:

1. Complexity of the equipment and lack of design experience; frequent changes in design and engineering during the project operation; 2. Poor project planning; 3. Lack of remedial actions for delay compensation; 4. Lack of accurate and systematic feasibility study and feasibility study of the changes; 5. Slow decision making process by the authorities; 6. Discrepancy in the feasibility study and potential study with reality; 7.Inattention to service scope and scope control; 8. Unclear duties of the contractor; 9. Unreasonable insistence of the client on shortening the time and early start of the project; 10. Unclear elaborate scheduling of the construction process; 11. Lengthy period of design; 12. Unreasonable estimated time; 13. Delay in payments; 14. Inaccurate cost estimation; 15. Lack of financial plan, budgeting, and cost control; 16. Lack of pricing system; 17. EP liquidity shortage; 18. Incomplete initial design of the project; 19. Problems in construction engineering unit; 20. Inadequate training offered to the human force; 21. Lack of productivity increasing rewarding

system for motivation of the staffs; 22. Inadequate planning of the human force; 23. Unclear duties of the people; 24. Shortage in efficient and expert human force; 25. Inappropriate communication between EP and material suppliers; 26. Inadequate information for providing plots; 27. Delay in material supply; 28. Unclear contracts; 29. Poor material planning; 30. Lack of motivational systems in the contracts; and 31. Lack of a distinguishing system and unpunctual remedial actions.

Table 3: the main causes of delay with regard to the effectiveness of value engineering on them

Main scopes of causes	Cause of delay
Integration project management	Complexity of the equipment and lack of design experience
	Frequent changes in design and engineering during the project operation
	Poor project planning
	Lack of remedial actions for delay compensation
	Lack of accurate and systematic feasibility study, and lack of feasibility study of the changes
	Slow decision making process by the authorities
	Discrepancy of feasibility study and potential study with reality
Project management time	Inattention to service scope and scope control
	Unclear duties of the contractor
time management of the project	Unreasonable insistence of the client on shortening the time and early start of the project
	Unclear elaborate scheduling of the construction process
	Lengthy period of design
	Unreasonable estimated time
Cost management of the project	Delay in payments
	Inaccurate cost estimation
	Lack of financial plan, budgeting, and cost control
	Lack of pricing system
	EP liquidity shortage
Quality management of the project	imperfect initial design of the project
	Problems in construction engineering unit
Human resource management of the project	Inadequate training offered to the human force
	Lack of productivity increasing rewarding system for motivation of the staffs
	Inadequate planning of the human force
	Unclear duties of the personnel
	Shortage in efficient and expert human force
Communication management of project	Inappropriate communication between EP and material suppliers
	Inadequate information for providing plots
Procurement management of the project	Delay in material supply
	Unclear contracts
	Poor material planning
	Lack of motivational systems in the contracts

The second questionnaire was distributed among the experts and professionals of value engineering involved in construction and development projects. The instrument used in the second questionnaire was a 5-choice Lickert scale; in which, the choices are scored from 1 (very low) to 5 (very high). The second questionnaire contains 3 parts. The first part is for measuring demographic

specifications of the statistical society of this research and contains 6 questions. These questions are about characteristics such as job, professional/academic certificate and their issue source, education level, familiarity with value engineering, engagement level in urban projects, and the type of urban project contracts the individual engaged in. Second part contains 31 closed questions and 1 open question in every page and is designed for finding the research question. These questions (indices) are designed to measure 8 variables. It is notable that each group of delay causes in urban projects is placed in main scopes of project management body of knowledge. Here, delay causes are considered as a criterion and the scopes of project management body of knowledge are defined as variables. Effect of value engineering on reducing the delays in urban projects was determined based on the conducted field studies. Figure 1 presents the mean scores for each question (index) based on the conducted field studies. As shown in figure 1, the mean scores assigned for the questions of questionnaire 2 are higher than the mean score (3). Besides, based on the standard deviation of the questions (which are 0.8 to 1.3), that interviewees' comments were almost close to each other.

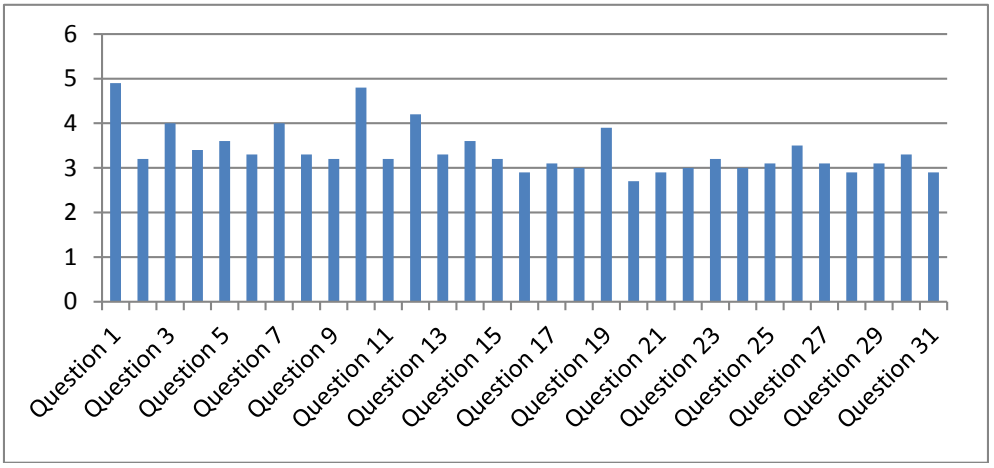

Figure 1: average effect of value engineering on each index

It is remarkable that each group of causes addressed in questionnaire 1 is placed in scopes of the project management body of knowledge which are defined in questionnaire 2 as the criterion and main scopes of project management body of knowledge. Then, the data related to each variable was averaged. The data obtained for each variable is shown in table 4.

Table 4: effect of value engineering on decreasing the project delay

Role of value engineering in dealing with the delay caused by:	Mean	S. D
Lack of integrated management	3.6484	0.51827
Lack of scope management	3.2297	1.02466
Lack of time management	3.6250	0.71365
Lack of cost management	3.0803	0.97326
Quality management of the project	3.5526	0.85258
Lack of quality management	3.0013	0.92769
Lack of Human resource management of the project	3.2568	0.93260
Lack of communication manager	3.0541	0.89197
Lack of procurement management	3.6484	0.51827

The mean score of the variables can be obtained by averaging the data of indices of each variable. As shown in table 4, the obtained mean values are medium to high (score of 3 and greater), implying that the experts believe that the role of value engineering in dealing with causes of delay

emerged in questionnaire 2 is evaluated as medium to high and very high. For instance effect of value engineering on dealing with the delay caused by lack of project integration was measured as 3.64, indicating its high effect on dealing with the delay caused by this factor. The statistical Hypothesis is defined as:

Null Hypothesis(H0): According to the experts' views, the mean of effect of value engineering in dealing with causes of delay in urban projects is less or equal to the mean value (H1: $\mu \leq 3$).

Alternative Hypothesis (H1): According to experts' views, mean of value engineering effect on dealing with causes of delay in urban projects is greater than medium (H1: $\mu > 3$).

The statistics of the single-sample t-test and test value for the medium level are presented in table 5 and 6, respectively. The significance level in the software output is less than 0.05 implying rejection of the Null Hypothesis and proving the Hypothesis that the effect of mean value engineering in dealing with causes of delays in urban projects is greater than the claimed value (3). Since the mean value (3) implies the medium effect of value engineering on dealing with delay causes, it can be concluded that value engineering is highly effective in dealing with delay causes. So, application of this technique can reduce the time delay and cost changes in urban projects.

Table 5: statistics of the single sample t test

	N	Mean	Standard deviation	Mean standard error
Average	39	3.31	0.62	0.991

Table 6: test value for medium level

	Test value = 3					
	t	Degree of freedom	Significance (two-sided testing)	Mean difference	Confidence interval at 95% level	
					Lower level	Upper level
Average	3.2	38	0.003	0.32	0.12	0.52

Results

The findings of this research can be summarized as:

a) About effect of value engineering on dealing with delay causes in urban engineering projects, the following items have highest effects.

Table 7: Ordinal mean of Friedman test

Effect of value engineering on dealing with delay cause of each variable	Ordinal mean
Integration management	5.83
Scope management	4.28
Time management	5.5
Cost management	3.71
Quality management	5.32
Human resource management	3.24
Communication management	4.21
Procurement management	3.71

- Unreasonable insistence of the client on shortening the time and early start of the project (mean = 4.11)
- Discrepancy in the feasibility study and potential study with reality (mean = 4)
- Lack of accurate and systematic feasibility study (3.97)
- Incomplete initial design of the project (3.89)
- Frequent changes in design and engineering during the project operation (3.81).

As significance level is less than 0.05 in Friedman test, Null Hypothesis can be rejected. As shown in table 7, the ordinal mean of the research variables have significant difference. The interviews believe that value engineering is effective in dealing with delay causes including integration management, time management, quality management, scope management, communication management, cost management, procurement management, and human resource management, respectively. In addition, the $\chi 2$ coefficient shown in table 8 indicates that Friedman test proves the significance difference among the research variables.

Table 8: ordinal Friedman test

Number of samples	39
Chi-square ($\chi 2$)	37.611
Degree of freedom	7
Significance level	0.0005

b) About the effect of value engineering on dealing with delay cause in urban projects, the majority of response (65 %) had the medium to higher than medium score implying the high effect of value engineering in dealing with these causes in experts' view. Additionally, the standard deviation of the responses is in the limited range of 0.8 to 1.3, implying that the participants had mostly similar ideas.

c) The mean of effect of value engineering in dealing with delays caused by inattention to the scopes of project management body of knowledge is also greater than the medium level (mean≥3). Here, the maximum effect of value engineering in dealing with delay caused by lack of integration management which involves the following cases:

- Frequent changes in design and engineering during the project execution
- Lack of proper audit system and unpunctual remedial actions
- Lack of accurate and systematic feasibility study, and feasibility study of the changes
- Complexity of the equipment and lack of design experience
- Slow decision making process by the authorities (multiple decision making authorities)
- Poor project planning process
- Discrepancy in the feasibility study and potential study with reality

Besides, the least effect of this technique was for dealing with delays caused by lack of human resource management which includes the following items:

Lack of efficient and expert human force

Unclear duty of the personnel

Lack of productivity increasing rewarding system for motivation of the staffs

Inadequate planning of the human force.

d) The standard deviation of value engineering in dealing with delay caused by lack of integrated management was much more than that of other factors, which is because of the consensus among the interviewees about this factor.

e) Independent single-sample t-test at significance level of 5 % reveals that the experts and professionals believe the effect of value engineering in dealing the delay causes mentioned in this paper is high.

f) Based on results of Friedman test, there is a significant difference between delay causes classified as main scopes of project management body of knowledge from the viewpoint of effect of value engineering in their removal and they can be ranked. We can rank such causes of delay based on the effect of value engineering respectively: lack of integration management, time management,

quality management, scope management, communication management, cost management, procurement management (the two last factors are equal), and human resource management.

Conclusion

According to the findings of the present study, the most important effect of value engineering in dealing with delay causes in urban management belongs to integration management, which involves the processes required for guaranteeing the coordination and integration among different components of a project in a proper way. The main task of integration management in a project is the maximum coordination between the needs and expectations of the beneficiaries through aligning the goals and operational opportunities of the project with each other. The main processes of integration management include preparation of project program, execution of project program and integrated control of the changes. Thus, application of value engineering in improvement and optimization of these processes, before and during the project, can significantly reduce the time delays and cost changes and increase value of a given project.

The results indicate that value engineering studies in different phases of the urban projects, particularly when it is required to take strategic decisions about the project, can significantly affect project optimization; as these studies can eliminate or reduce many delay causes in urban projects. Particularly, in the following phases performing a value engineering study is recommended:

a) Economic, technical and environmental Analysis of the urban projects
b) Preparing the financial sources of the urban projects
c) Contraction arrangement and defining the relationship between parties in urban projects
d) Selecting the method of execution of urban projects (conventional method, design and construction, BOT, etc.)
e) Risk transferring in the urban projects

Suggestions

Based on the results of this research, to apply value engineering in the national urban and construction projects, the following strategies are proposed:

a) Refinement and removal of the ambiguities in the rules related to the value engineering for motivating the national project towards applying value engineering and defining some rules for participation of project consultant in benefits and economization obtained through application of value engineering.
b) Defining some standards for qualification of individuals and corporations volunteer to apply value engineering.
c) Application of the contraction methods which are more matched to value engineering
d) To familiarize the project authorities to value engineering and the benefits achieved by application of it.
e) Creation of specialized value engineering units in organizations associated to the projects execution.
f) Increase the skill of labor through the train courses such as seminars, educational workshops, and short courses of value engineering and risk management by the related institutes.
g) Learning the value engineering in majors associated to construction projects at universities.
h) Acculturation and domestication of the value engineering method in national construction and development projects.

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