Nigjeh and Amani
Journal of Engineering and Applied Science (2022) 69:48
https://doi.org/10.1186/s44147-022-00100-9

Journal of Engineering and Applied Science

RESEARCH

Open Access

Evaluation of influential value engineering factors on the function of interchanges: case studies in Iran

Mohsen Jafari Nigjeh[1] and Nima Amani[2*]

*Correspondence: nimaamani@iauc.ac.ir

[2] Department of Civil Engineering, Chalous Branch, Islamic Azad University, Chalous, Iran
Full list of author information is available at the end of the article

Abstract

In Iran, recently in large-scale projects, the science of value engineering has become very important and in order to show the significant impact of value engineering results in increasing efficiency and reducing the cost of projects, the reason for choosing this research. The experience of value engineering in the developed countries shows the significant effect of this method in the value optimization of plans and projects. This research, too, aims to evaluate the effects of value engineering on the performance of interchanges in Iran, so that with comparing their results, the most important qualitative parameters can be determined, and also to present a suitable model for cost reduction per each IRR of the value engineering study's expenses. The first part of this research will give a short introduction on value engineering and its job plan, and then, 8 value engineering studies of interchanges in the cities of Tehran, Karaj, Shiraz, and Mashhad will be qualitatively and quantitatively analyzed, and their results as a qualitative and quantitative evaluation (including construction cost, total value index, and relative value index) will be compared with the base plan of the projects and also with each other. Finally, the outcome of the research will show that among the evaluation parameters, the acquisition parameter plays a significant role in choosing the best design in value engineering, some part of which depends on the employer's view in this regard. In the next step, the best improvements were in reducing travel time and in increasing safety, and also the most neglected parameter in the value engineering analyzed here is environmental improvements, which demands especial attention. From this research, it can be concluded that per every one IRR of expenditure on performing value engineering studies, the total cost of interchange projects in Iran is reduced by 334 IRR.

Keywords: Value engineering, Interchanges, Case study, Cost reduction, Improving qualitative parameters

Introduction

Value engineering is a systematic attempt which aims to study and analyze all of the operations of a project from its conception up to the design stage and then initiation and utilization and is considered as one of the most effective and important economical methods in the engineering field [24]. In the framework of project management, value engineering is paying attention to all of the components of the design and at the same time not taking for granted any part of the project [1]. The goal in VE is reducing the time needed to reach initiation stage without increasing the cost or lessening the quality of the work [9]. Project management is planning and directing the project in a framework of specific time, cost, and quality constraints toward its specific results [6]. Standing (2001) considers VE as a project with minimum cost which includes due assessment and elimination of unnecessary costs without having detrimental effects on safety, quality, reliability, implementation method, and delivery [32]. In this paper, 8 VE case studies on Iranian interchanges are used, enabling this research to identify and analyze the benefits of the successful application of value engineering in enhancing the quality of interchange projects. The goal of this paper is the qualitative and quantitative measurement and evaluation of the effective factors of VE projects on interchanges and extracting the shared effects in order to increase quality, performance, and value index of such projects. This research will determine the amount saved for the cost of value engineering projects in Iranian interchanges. To conduct this research, extensive studies in this field have been conducted from various sources, and their impact and results have been used (Elhegazy H (2021) [13], Elzarka et al., (2016) [11], Chakraborty et al., (2020) [10], Chakraborty et al., (2016) [11], Dell'isola (2017) [12], Elmousalami [18], Kumar and Gururaj [22], Swei et al. [33], Elhegazy et al., (2020, 2021, 2022) [14–17], Wang et al., (2017) [36], Zhong et al., (2022) [37]).

Value engineering basics

Value engineering is a powerful methodology when it comes to problem-solving, cost reduction, and at the same time improving performance and quality, which by identifying and enhancing value indices, and applying creativity, increases client satisfaction and the value of investment.

Value engineering job plan

A value engineering job plan is comprised of three stages (Iyer, 2009) [20]:

1. Pre-study
2. Value engineering or value analysis workshop

Table 1 The order of value engineering steps

Pre-workshop steps	VE workshop steps	After-workshop steps
Project coordination	Information	Final report
Information preparation	Function analysis	Implementation
Preparation of models	Creation	Follow-up
Team members (1 to 3 persons)	Evaluation	Team members (1 to 3 persons)
Working days (2 to 5 days)	Development	Working days (2 to 5 days)
	Presentation	
	Team members (5 to 12 persons)	
	Working days (1 to 5 days)	

Table 2 Value engineering methodologies

1	Information stage	Gathering and completing information, delimiting the study
2	Function analysis stage	Definition of functions, categorization of function, making function models, determining the value of functions, calculating the cost of functions, calculating value index, choosing functions to continue the study
3	Creation stage	A number of alternative ideas for each function are generated
4	Evaluation stage	Ranking and weighing the proposed ideas, choosing suitable ideas for development
5	Development stage	Efficacy analysis, completion of technical information, preparing implementation design plans, preparing final proposal
6	Presentation stage	Composition and presentation of the oral report and the written one

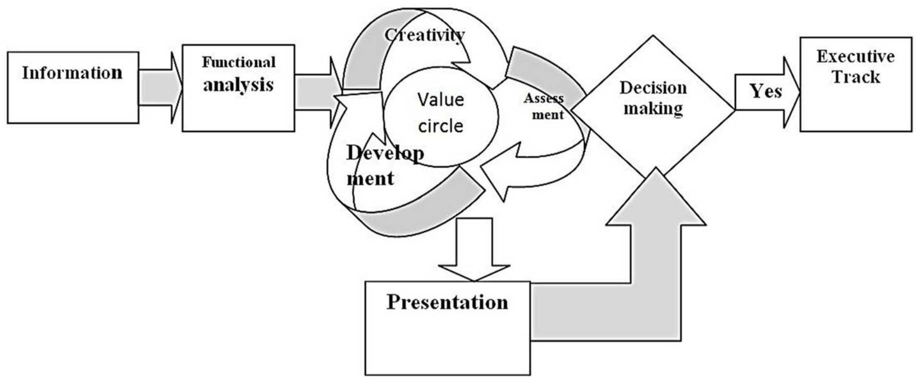

Fig. 1 The schematic of the value analysis process in VE workshop

3. After study

Each stage having a job plan as is shown in Table 1 [8].

Value analysis plan includes operational implementation steps of value methodology [23]. In fact, that which Miles and the people coming before him were doing was the application of this key stage. The second stage has 6 steps which are applied in order as depicted below. The International Society of American Value Engineers (SAVE) has proposed the job plan depicted in Table 2 for the value engineering workshop (SAVE international, 2017 [31]; Kolano & Eta, 2015 [21];) (second stage).

The International Society of American Value Engineers (SAVE) has proposed the following procedure (Fig. 1) for the steps mentioned in Table 2 [21, 31].

International experiences regarding value engineering interchanges

The experience of value engineering in the developed and developing countries demonstrates the significant effect that this method has on improving the value of designs and projects. International experience shows that, in a period of 8 years, 2700 value engineering studies have been carried out in the transportation sector of the USA, for which the ratio of cost reduction (with preserving or improving quality and function) to the study costs has been 113 dollars to 1 [9]. In the US road sector alone in 2008, 382 value studies were carried out. Twelve billion dollars were spent conducting these studies. The approximate total cost of these projects was roughly 30,000 billion dollars. The amount of cost reduction produced as proposals in value engineering workshops was 6500 billion dollars from which 2530 billion was approved. This reported and approved saving shows that for every 1 dollar spent on value engineering, 205 dollars have been saved [32]. The statistics given here are from the value-engineered projects funded through federal government's budget, and if we were to include the projects value engineered by private sector contractors, the figures would have been higher. The results produced in the USA illustrate a number of pivotal points:

1. The strength and accuracy of the base plan (the initial design by the consultant) not only do not preclude value engineering, but it paves the way for presenting new ideas and increasing the value of the project.
2. Not every value engineering proposal is necessarily approved. In most cases, only 50% of them gets approval.
3. The reported savings only include construction costs, and if the costs accumulating in the life span of the project were included, the figures would have been significantly higher [2, 32].

A well-designed methodological research presents the administrators and engineers of road projects, including interchanges, with the most effective approaches for solving many of the problems they encounter. Although, the growth rate of highway transportation brings more complex problems with itself, which demands special attention on the part of decision makers. All selected projects are among the major and very important projects in Iran, which have been designed and implemented by the most prominent and well-known consultants and contractors, and these projects are among the highest projects in terms of price and cost of work.

Methods

For all selected projects, the value engineering discussion has been done extensively and separately by the country's leading expert consulting engineers, and it has not been possible to provide all the details for each project separately. Therefore, the statistics and results obtained from value engineering, which is completely accurate and specialized, have been used to conduct research, and the results obtained from the value engineering of projects have been transferred and used without any change in the analysis of relevant research data.

At first, in this research, all civil, traffic, construction, economic, value, base plan, and value engineering design studies, were gathered from their respective consulting firms for analysis. The general specifications of the projects and the consulting firms of the base plans and value are presented in Table 3. The total cost of the base plan is comprise of the construction costs, repair and maintenance, utilization, and land acquisition [3–5, 7, 19, 25–30, 34, 35]. In the next stage, all of the parameters will be qualitatively and quantitatively analyzed.

Table 3 General specifications of the projects analyzed

Interchange name	Project location	Base total cost (IRR)*	VE project cost (IRR)*	Project's consulting firm	VE consulting firm
Simon Bolivar-Yadegar-e-Emam	Tehran	3,445,590,000,000	2,155,609,000,000	Ardam	Imen Taghatoe
Chamran-Jalal Al-e-Ahmad	Tehran	614,377,000,000	352,460,000,000	Rahan Sazeh	Imen Taghatoe & Rahab
Shahed-jadeh ghouchan	Mashhad	245,502,000,000	148,084,760,000	Rah Avar	Tarh Rah-e-Abrisham
Rezvan-koneh bist	Mashhad	346,000,000,000	135,000,000,000	Abadgaran-e-shargh	Tarh Rah-e-Abrisham
Khawrazmi	Karaj	186,612,437,500	120,859,360,000	Arces pol & Behin taradod-e-pars	Tarh Rah-e-Abrisham & Rahab
Sepah Square	Karaj	375,383,589,610	202,194,986,465	Metra	Rahab
Jomhouri Square	Karaj	72,225,429,629	33,802,131,792	Etehad Rah	Rahab
Rezvan-rahmat	Shiraz	256,300,000,000	138,700,000,000	Gueno	Behin Taradod-e-Pars

*In the year of the research (2017), each Iranian rial (IRR) was equal to $0.00003

Results

All selected research projects are among the large and very important and well-known projects in Iran in which value engineering is very important, and in general, it can be said that value engineering reduces costs. A total of 10 to 40% in these projects and due to the budget deficit of many construction projects in Iran, cost reduction is the most important factor in value engineering in this country.

Qualitative analysis

Considering the forms sent to all beneficiary parties of the interchange projects, the parameters deemed important by the beneficiaries and team experts were gathered, integrated, and extracted as is presented here [7, 19, 27–30, 34, 35].

-Reducing problems in construction and traffic detour	-Pedestrian passage facilitation
-Increased safety	-Securing pedestrian and cyclist access
-Enhancing urban landscape	-Project's flexibility
-Improving local access	-Increasing the level of service of the highway
-Reducing construction time	-Improving traffic performance
-Accelerating construction and utilization	-Maintenance and utilization facility
-Travel time reduction	-Reducing social problems
-Acquisition facility	-Improving public and quasi-public transportation
-Reducing environmental degradation	

Based on the project value studies of the projects under analysis done by the consulting firms (named in Table 3), the evaluated qualitative parameters of the projects are presented in Table 4.

The value engineering team in each project, noting the location, type, and the particular conditions of that project, compares the qualitative parameters using binary AHP method. Then, for each parameter, a numerical score is calculated, and finally,

Table 4 Qualitative parameters analyzed in each project

Reducing problems in construction and traffic detour	Pedestrian passage facilitation
Increased safety	Securing pedestrian and cyclist access
Enhancing urban landscape	Project's flexibility
Improving local access	Increasing the level of service of the highway
Reducing construction time	Improving traffic performance
Accelerating construction and utilization	Maintenance and utilization facility
Travel time reduction	Reducing social problems
Acquisition facility	Improving public and quasi-public transportation
Reducing environmental degradation	

the parameters having the highest score are chosen for analysis and proceeding with the value engineering process. The scoring is done by binary comparison of the parameters and giving each one a score ranging from 0 to 10, where the sum of score for both of the parameters is 10. The priority and importance of the parameter determine the score it receives, that is, the higher its priority and importance, the higher the score it receives. In such manner, using the binary method, all of the parameters are separately compared, their individual score is calculated, and finally those having a score higher than 5 are chosen. After comparing the parameters using AHP, based on the score they received by the value engineering team of each project being studied, the chosen qualitative parameters were analyzed. Then, all the qualitative parameters of each project were analyzed (according to the Table 4), and those parameters which were shared by at least 50% (i.e., 4) of these projects and were among the important qualitative factors were extracted. In the following Table 5, points (rates) of qualitative parameters in each project can be seen.

In the next stage, we calculated the average score of each parameter for these projects. Table 6 shows the average for the influential parameters determined in the previous stage.

Keeping in mind that the base plan score is evaluated as 5, therefore, by calculating the ratio of the base plan score to that of the calculated average scores from Table 6, the optimization rates of the qualitative parameters, as shown in Table 7, are obtained.

Therefore, it can be concluded that the priority of qualitative parameters of interchanges in Iran (according to the conducted case study) and their optimization rate is as shown in Table 8.

Based on the conducted research, it can be concluded that in Iran, when constructing interchanges, among the qualitative parameters, the acquisition facility has an especial importance for the employer (in most cases the government), as it has the highest optimization rate among the qualitative parameters leaving them behind with a significant margin. It is worth mentioning that in analyzing each project separately, acquisition facility had the highest optimization rate compared to other parameters. This goes to demonstrate that in many of the value-engineered projects, considering the high cost of land and buildings in Iran, the employers in choosing the best option among the value-engineered options, put forward by the value consulting firm, go for

Table 5 The scores of the qualitative parameters analyzed in each project

	The Case Studies							
	Khawrazmi	Rezvan-koneh bist	Jomhouri square	Sepah square	Rezvan-rahmat	Simon Bolivar-Yadegar-e-Emam	Shahed-jadeh ghouchan	Chamran-Jalal Al-e-Ahmad
Qualitative Outcomes	Reducing problems in construction and traffic detour	Construction and execution facility	Reducing problems in construction – improving traffic detour	Reducing problems in construction – improving traffic detour	Construction facility	Construction facility	Construction facility _ improving traffic detour	Reducing problems in construction – improving traffic detour
	Increased safety of the path	Increased safety	Increased safety – Pedestrian passage and movement	Increased safety – Pedestrian passage and movement	Increased Utilization saftey	Increased safety	Increased safety	Increased safety – project's structure
	Enhancing urban landscape		Enhancing urban landscape	Enhancing urban landscape	Preserving urban landscape and image	Enhancing urban landscape	Enhancing urban landscape	Enhancing urban landscape
	Improving local access	Improving access for periphery usage			Providing Adequate local access	Improving local access	local access facility	Improving local access
	Reducing construction time, the possibility of quickly starting and completing the project		Reducing construction time	Reducing construction time	Accelerating Construction and Utilization		Accelerating the construction	Accelerating Utilization
	Travel time reduction		Travel time reduction	Travel time reduction	Travel time reduction			Travel time reduction and Smooth traffic flow
		Acquisition facility			Acquisition facility	Reducing claims and acquisition facility	Acquisition facility	Acquisition reduction
			Enhancing environment and urban green space	Enhancing environment and urban green space		Reducing environmental degradation		
	Increasing traffic capacity		Improving Public and quasi-public transportation	Improving Public and quasi-public transportation				Increasing the integrity of transportation system
		Enhancing geometrical characteristics	Enhancing geometrical characteristics	Enhancing geometrical characteristics				
	Reducing social problems	Reducing social dangers					Reducing social problems	
	Table Legends: Identical colors are the parameters shared by the projects.							

Identical colors are the parameters shared by the projects

the one with no or the fewest number of acquisitions or ultimately the one having the highest acquisition facility.

The other point worthy of attention in this research is that reducing environmental degradation occupies the last place (i.e., it has the least priority) among the important and influential qualitative parameters with an optimization rate of zero. Unlike other countries which place a significant importance on preserving and improving the environment, unfortunately, in Iran, this issue is neglected especially by the governmental employers, which requires reconsideration and more attention.

Quantitative analysis

All of the information and documentations related to the base plan and value engineering studies of the aforementioned projects were analyzed and studied, and the data including the construction cost of the base plan, the construction cost of the top value engineering plan, the total cost of the base plan (comprising of the construction costs, repair and maintenance, utilization, and land acquisition), and the total cost of the value plan of the projects were extracted and are represented here in Table 9.

Table 6 The average score for the qualitative parameters

Interchange name	Construction facility	Increasing safety	Enhancing urban landscape	Improving local access	Travel time reduction	Reducing construction time	Acquisition facility	Reducing environmental degradation	Improving public transportation
Khawrazmi	5	6.2	6.3	5.2	4.3	5.5			5.7
Rezvan-rahmat	7.2	7	6	4.8	5.3	6.4	9		
Chamran- Jalal Al-e-Ahmad	6	6.25	5.6	5.6	5.5	6.1	7.6		5.2
Shahed-jadeh ghouchan	6.25	6	5	5		6.5	5		
Simon Bolivar- Yade-gar-e-Emam	5	4	6	5.5			6	6	
Sepah Square	3.5	6.25	4		7	4		4.5	5.5
Jomhouri Square	5	5	5		7	4.5		4.5	5
Rezvan-koneh bist	6	4		5.5			7		

Table 7 Optimization rate for qualitative parameters

Construction facility	Increasing safety	Enhancing urban landscape	Improving local access	Travel time reduction	Reducing construction time	Acquisition facility	Reducing environmental degradation	Improving public transportation
5.49	5.59	5.41	5.27	5.82	5.5	6.92	5	5.35

Table 8 Priority of qualitative parameters rates

	Construction facility	Increasing safety	Enhancing urban landscape	Improving local access	Travel time reduction	Reducing construction time	Acquisition facility	Reducing environmental degradation	Improving public transportation
Optimization rate (to base plan)	1.10	1.12	1.08	1.05	1.16	1.10	1.38	1	1.07
The percentage of optimization rate of qualitative parameters	10%	12%	8%	5%	16%	10%	38%	0%	7%

Table 9 Construction and total costs of the projects

Qualitative parameter	Optimization percentage after value analysis
Acquisition facility	38%
Travel time reduction	16%
Increasing safety	12%
Reducing construction time, construction facility	10%
Enhancing urban landscape	8%
Improving public transportation	7%
Improving local access	5%
Reducing environmental degradation	0%

Table 10 The amount of the construction cost reduction of the projects (IRR)

Name and location of the interchange	Base plan's construction cost (IRR)*	Value plan's construction cost (IRR)*	Base plan's total cost (IRR)*	Value plan's total cost (IRR)*
Khawrazmi (karaj)	186,612,437,500	120,859,360,000	186,612,437,500	120,859,360,000
Rezvan-rahmat (shiraz)	133,000,000,000	118,000,000,000	256,300,000,000	138,700,000,000
Chamran-Jalal Al-e-Ahmad (Tehran)	256,606,000,000	293,717,000,000	614,377,000,000	352,460,000,000
Shahed-jadeh ghou-chan (mashhad)	245,502,000,000	148,084,760,000	245,502,000,000	148,084,760,000
Simon Bolivar-Yade-gar-e-Emam (Tehran)	512,185,000,000	677,449,000,000	3,445,590,000,000	2,155,609,000,000
Sepah Square (karaj)	261,554,898,000	140,882,794,360	375,383,589,610	202,194,986,465
Jomhouri Square (karaj)	50,324,296,000	23,552,210,000	72,225,429,629	33,802,131,792
Rezvan-koneh bist (mashhad)	225,000,000,000	135,000,000,000	346,000,000,000	135,000,000,000

*In the year of the research (2017), each Iranian rial (IRR) was equal to $0.00003

For each project, the construction cost reduction is calculated by finding the difference between value plan's construction cost and construction cost from base plan. Also, the total cost reduction is the result of subtracting the total cost of value plan from the total cost of the base plan (in Table 10).

Afterwards, using the value engineering contracts of each project, the cost of value engineering was extracted, and the total sum of the cost of value engineering studies was obtained, and next, the total sum of cost reduction was calculated. To calculate the profit gained for every IRR spent on value engineering (saved amount), the sum of total cost reduction must be divided by the sum of value engineering costs. The resulting figure represents the amount saved for every IRR of value engineering cost (in Table 11).

As it can be observed in the table above (Table 9), in value engineering interchanges in Iran for every IRR of the cost of value engineering studies, 586 IRR is saved from the total cost. But in order to improve the accuracy of the research,

Table 11 The amount of total cost reduction and value study costs of the projects (IRR)

Name and location of the interchange	Construction cost reduction (IRR)*	Total cost reduction (IRR)*
Khawrazmi (karaj)	−65,753,077,500	−65,753,077,500
Rezvan-rahmat (shiraz)	−15,000,000,000	−117,600,000,000
Chamran-Jalal Al-e-Ahmad (Tehran)	37,111,000,000	−261,917,000,000
Shahed-jadeh ghouchan (mashhad)	−97,417,240,000	−97,417,240,000
Simon Bolivar-Yadegar-e-Emam (Tehran)	165,264,000,000	−1,289,981,000,000
Sepah Square (karaj)	−120,672,103,640	−173,188,603,145
Jomhouri Square (karaj)	−26,772,086,000	−38,423,297,837
Rezvan-koneh bist (mashhad)	−90,000,000,000	−211,000,000,000

*In the year of the research (2017), each Iranian rial (IRR) was equal to $0.00003

taking into consideration that the initial construction cost of these interchange projects are not identical, and also the size of the projects, a range must be chosen so that the figures obtained can be realistic and credible. To do so, a variance and a standard deviation were calculated using formula 1, so that the intended range could be calculated using formula 2. Then eliminating the data outside of that range, the figure given above was fine-tuned.

$$\sigma \ Standard \ Deviation = \sqrt{\left(\sum (x_m - x_i)^2 \div n\right)} \tag{1}$$

X_m: Total average of saving for every IRR of the cost of value engineering studies of the projects

X_i: The amount saved for every IRR of the cost of value engineering study of each project

n: the number of projects

$$\begin{gathered} \rightarrow \sigma \ Standard \ Deviation = \sqrt{(472308 \div 8\ )} = 6\,8\,7 \\ \text{Average} - \text{standard deviation} \leq \text{the range being studied} \leq \text{average} - \text{standard deviation} \\ \rightarrow 102 \leq \text{the range being studied} \leq 1273 \end{gathered} \tag{2}$$

Obtaining the range of the research, it is determined that one of the projects is located outside of the domain, therefore, leaving the numbers for the said project out of the calculations, the amount saved is recalculated as follows (formula 3).

$$\begin{aligned} &\mathrm{X}_m = \left(\textstyle\sum_i^n x_m\right)/n \\ &\rightarrow \text{Saving} = 2340 \div 7 = 334 \end{aligned} \tag{3}$$

The total saving of the projects located inside the obtained range is 2340 IRR, which if it is divided by the number of projects located inside the range, on average, the saving would be 334 IRR for each project. Consequently, it is revealed that for every IRR cost of the value engineering studies conducted for these interchange projects, 334 IRR is saved from the total cost of interchange project in Iran. Accordingly, it can be deduced that for the interchange project in Iran, on average, for every IRR spent on value engineering, 334 is saved from the total cost of these kind of projects, which testifies as to the necessity of value engineering and its tangible effects on interchange projects in Iran. The international experience shows that in federal highway projects, the amount saved for every dollar of the cost of value studies in the year 2009 has been 99 dollars; 2010, 146 dollars; 2011, 80 dollars; 2012, 96 dollars; and in the year 2013, 118 [32]. In the US road sector alone in 2008, 382 value studies were carried out. Twelve billion dollars was spent conducting these studies. The approximate total cost of these projects was roughly 30,000 billion dollars. The amount of cost reduction produced as proposals in value engineering workshops was 6500 billion dollars, from which 2530 billion was approved. This reported and approved saving shows that for every 1 dollar spent on value engineering, 205 dollars have been saved [32].

Conclusions

The outcome of this research demonstrates that among the evaluation parameters, the acquisition parameter in interchange projects plays a significant role in choosing the top value engineering plan. As it was mentioned, this partially depends on the views that the employers hold. The highest improvements accomplished were in reducing travel time and increasing safety. The most neglected parameter in the value engineering plans evaluated was improving the environment which demands especial attention. Also, from this research, it can be concluded that for every IRR spent on conducting value engineering studies, 334 IRRs are saved from the total cost of interchange projects in Iran.

The value engineering study should be started in the design stage of interchange projects.

Abbreviations

AHP: The analytic hierarchy process; USD: United States dollar; $: Dollar; VE: Value engineering; IRR: Iranian rial.

Acknowledgements

Not applicable

Authors' contributions

MJ carried out the research methodology, developed the computational technique and performed the investigation and validation of the analytical work, and wrote the manuscript draft. NA performed the conceptualization of the research idea, participated in the interpretation of the results, reviewed the edited manuscript, and supervised the whole project. Also, he contributed to the discussion of the results and visualization of the final manuscript. The author(s) read and approved the final manuscript.

Funding

No specific funding has to be declared for this work.

Availability of data and materials

The datasets used and/or analyzed during the current paper are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

The consulted firms and/or beneficiaries approve that data pertaining to them will be published.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Construction Management, Department of Civil Engineering, Chalous Branch, Islamic Azad University, Chalous, Mazandaran Province, Iran. [2]Department of Civil Engineering, Chalous Branch, Islamic Azad University, Chalous, Iran.

Received: 17 February 2022 Accepted: 28 April 2022
Published online: 02 June 2022

References

1. Amani N, Alipour M (2021) Managing operational strategies to standardize contractors'decisions in construction projects. J Struct Construct Eng 8(8). https://doi.org/10.22065/jsce.2020.232383.2148
2. Amani N, Derafshi M (2021) Optimal implementation of claim management framework on rubber dam projects with price list contract. J Struct Construct Eng 8(7). https://doi.org/10.22065/jsce.2020.232819.2152
3. Amani N, Nasly MA, Mohammed AH, Samat RA (2013a) Maintenance and management of wastewater system components using the condition index system, prediction process, and cost estimation. Eksploatacja i Niezawodność 15:161–168
4. Amani N, Nasly MA, Mohammed AH, Samat RA (2013b) Optimization of time and cost of building component maintenance: a case-study in a five star hotel in Iran. Malaysian J Civil Eng 25:1–8
5. Amani N, Nasly MA, Hosseini SM (2011) Building component maintenance/repair management: an economic analysis simulation. Appl Mechanic Materials 94-96:2134–2137
6. Amani N, Safarzadeh K (2022) Project risk management in Iranian small construction firms. J Eng Appl Sci 69(7):1–14
7. Behin Taradod Pars Engineers Consulting Firm Co (2010) Pre-study reports and main and final workshop for reforming the intersection of Rezvan and Rahmat. Shiraz, Iran
8. Bolton JD (2003) Value methodology: a pocket guide to reduce cost and improve value through function analysis. Revaluation Books, Exeter
9. Boroujerdi M, Ekram Jafari MJ, Jafarpour A, Hashemi SH (2008) "A road map to value engnineering." 3th National Conference on Value Enginee*ring*, Tehran, Iran. (in Perisian)
10. Chakraborty D, Elhegazy H, Elzarka H, Gutierrez L (2020) A novel construction cost prediction model using hybrid natural and light gradient boosting. Adv Eng Inform 6. https://doi.org/10.1016/j.aei.2020.101201
11. Chakraborty D, Elzarka H, Bhatnagar R (2016) Generation of accurate weather files using a hybrid machine learning methodology for design and analysis of sustainable and resilient buildings. Sustainable Cities Soc 24:33–41
12. Dell'isola AJ (1997) Value Engineering: Practical Applications for Design, Construction, Maintenance & Operations. Wiley
13. Elhegazy H (2021) State-of-the-art review on benefits of applying value engineering for multi-story buildings. Intelligent Buildings Int. https://doi.org/10.1080/17508975.2020.1806019
14. Elhegazy H, Ebid AM, Mahdi IM, Aboul Haggag S, Abdel Rashid I (2020) Selecting optimum structural system for R.C. multi-story buildings considering direct cost. Structures 24:296–303. https://doi.org/10.1016/j.istruc.2020.01.039(1)
15. Elhegazy H, Chakraborty D, Elzarka H, Ebid AM, Mahdi IM, Aboul Haggag SY, Abdel Rashid I (2022b) Artificial intelligence for developing accurate preliminary cost estimates for composite flooring systems of multi-storey buildings. J Asian Architect Building Eng 21(1):120–132. https://doi.org/10.1080/13467581.2020.1838288
16. Elhegazy H, Badra N, Aboul Haggag S, Abdel Rashid I (2022a) Implementation of the neural networks for improving the project's performance of steel structures projects. J Industrial Integration Management. https://doi.org/10.1142/S2424862221500251
17. Elhegazy H, Ebid A, Mahdi I, Haggag S, Abdul-Rashied I (2021) Implementing QFD in decision making for selecting the optimal structural system for buildings. Construction Innovation 21(2):345–360. https://doi.org/10.1108/CI-12-2019-0149
18. Elmousalami HH (2019) Intelligent methodology for project conceptual cost prediction. Heliyon 5. Retrieved from. https://doi.org/10.1016/j.heliyon.2019.e01625
19. Imen Taghatoe Engineers Consulting Firm Co (2013) Pre-study reports and main and final workshop for reforming the intersection of Yadegar Imam and Simon Bolivar, Tehran
20. Iyer SS (2009) *Value Engineering: A How to Manual,* 3rd, Management Consultant and Certified Value Engineering Specialist (CVS)
21. Kolano F, Sprague R, Woodhead R (2015) Value methodology standard and body of knowledge, 2nd edn. Save International, Washington, DC
22. Kumar P, Gururaj S (2019) Conceptual cost modelling for sustainable construction project planning— a Levenberg-Marquardt neural network approach. Appl Math Inform Sci 13(2):201–208
23. Miles LD (1989) Techniques of Value Analysis and Engineering, 3th ed. Mc Graw-Hill Co, New York
24. Mudge AE (2004) Value Engineering: A Systematic Approach. McGraw-Hill, New York, p c1971
25. Nasly MA, Amani N, Mohammed AH (2012) Prediction simulation process for controlling in maintenance time in the material department. Adv Sci Letters 13:654–657
26. Nasly MA, Amani N, Samat RA (2011) Developing a framework of economic model for building component lifecycle repair. Adv Mater Res 255-260:3893–3897
27. Rahab Engineers Consulting Firm Co (2014a) Pre-study reports and main and final workshop for reforming the Chamran and Jalae Ale-ahmad highways intersection, Tehran
28. Rahab Engineers Consulting Firm Co (2015) Pre-study reports and main and final workshop for reforming Khawrazmi square, Karaj
29. Rahab Engineers Consulting Firm Co (2014b) Pre-study reports and main and final workshop for reforming Sepah Square, Karaj
30. Rahab Engineers Consulting Firm Co (2014c) Pre-study reports and main and final workshop for reforming Jomhuri square, Karaj
31. SAVE International (2017) The Power of Value Engineering, website: http://www.value-eng.org
32. Stasiak BR (2015) Value engineering application in the American transportation industry. Period Polytech Transport Eng 43(4):206–210

33. Swei O, Gregory J, Kirchain R (2017) Construction cost estimation: a parametric approach for better estimates of expected cost and variation. Transportation Research Part B 101:295–305
34. Tarhe Rah-e-Abrisham Engineers Consulting Firm Co (2014a) Pre-study reports and main and final workshop for reforming the intersection of 75 meter Razavi and Kane bist. Mashad, Iran
35. Tarhe Rah-e-Abrisham Engineers Consulting Firm Co (2014b) Pre-study reports and main and final workshop for reforming the intersection of Shahed and Gouchan road. Mashad, Iran
36. Wang W-C, Bilozerov T, Dzeng R-J, Hsiao F-Y, Wang K-C (2017) Conceptual cost estimations using neuro-fuzzy and multi-factor evaluation methods for building projects. J Civil Eng Manage 23(1):1–14
37. Zhong S, Elhegazy H, Elzarka H (2022) Key factors affecting the decision-making process for building projects in Egypt. Ain Shams Eng J 13(3):101597. https://doi.org/10.1016/j.asej.2021.09.024

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.