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Research Article

Modeling a Concentration Pattern on Critical Paths in Control of Project Delays

V. Rooholelm *, A. Sheikh Aboumasoudi †‡,

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Abstract

The passage of time always makes us aware of the issues around us. Time projects also reveal the hidden issues of the project. So the logical step is to include transparent points in the project. Stopping or slowing down the project process is necessary to apply these to the project, which will delay the projects. So project managers need to tightly control project risk with reasonable costs. Existence of delays is always an inseparable part of projects and subject of fundamental disagreements among their stakeholders in all countries. As delay in projects is equal to increased costs, thus, by having delay and spending too much cost out of the pre-planned cash flow, a project can even reach a point that it will get out of profit. In the present study the researchers believes that, risk of delays should be managed, minimized, shared, transferred or accepted, but it cannot be ignored. Therefore, it must be predicted, covered, managed and optimized. Now, the fact that any delay and prolongation of project time results in significant qualitative and quantitative costs more than the initial estimates shows importance and necessity of research in this area. By providing an innovative method with the help of the Work breakdown Structure, Baseline, Hierarchical Technique and Data Envelopment Analysis (DEA), the researchers will control the risk of projects and even prevent them from occurring.

Keywords : Delays Risk; Project Risk Management; Data Envelopment Analysis (DEA); Risk Coverage; Work breakdown Structure (WBS).

1 Introduction

Delay in projects is an inevitable reality and a common phenomenon even in advanced countries that is always considered one of the most challenging issues in projects [3]. According to the statistics gathered about problems existing in US projects, 69% of projects in this country have prolonged more than their time predicted time. In Iran also delay in projects is common such that according to the statistics published by Organization for Management and Planning of Islamic Republic of Iran in 2001, the average completion time of national projects of the country has been about 2.22 times their initial planned time [5]. Delays growth in UAE and Saudi Arabian projects is 39%. Research has shown that deciding on project delays is a very important

*Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
†Corresponding author. a_sh_edu@yahoo.com, Tel:+98(913)2676244.
‡Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran.

factor affecting business investors [1]. With regards to the many costs involved in carrying out projects, any kind of delay in doing them means not use of and inefficiency of large volumes of capitals for a long time. There is no doubt that this will lead to many economic losses for the community, and lack of planning to prevent these problems will be very harmful for the society. Certainly, delay in carrying out projects means inappropriate use of resources and capitals, so, a solution should be found to solve this problem. Hence, proposing an appropriate and efficient model as an essential strategy to prevent delays in projects is inevitable [8]. lack of attention to the necessity of controlling risk of delays from the beginning and during implementation of projects as well as lack of attention to importance degree of delayed activities in achieving final project outcome, firstly leads to increased delays in projects and, secondly, leads to obtaining unrealistic results in calculating share of failures and penalties for delays [9]. Although this study has been conducted in the field of construction project management, but its results and achievements can be used in many other social dimensions. The fact is that today, from the smallest social institutions such as family to the largest of them such as organizations, big companies, ministries, etc., all are engaged in planning and conducting various projects and activities considering the limitations of their own resources.

2 Research literature

It is very unlikely that you will find a project in the world without delays, the challenges of assigning it, determining its cause and determining the share of delays. Claims and, consequently, disputes have become inherent features in construction industry that many project stakeholders consider them to be one of the most destructive events in this industry. They believe that it is not possible to eliminate the probability of occurrence of claims by parties, but by optimizing current analysis methods and delay analysis, their occurrence can be prevented as much as possible and the share of stakeholders delays can be calculated [4].

Various factors may cause delay in a project. Since delay increases time duration of project implementation, so, it plays a significant role in increasing running costs of projects, lost opportunity cost, the reduction in credibility of project implementer, and the delay in return of the initial capital. Parties involved in a project are always seeking to analyze the delays and calculate the share of each party in creation of delays and, finally, to receive compensation from the other party [2].

According to the approaches used, these publications are grouped into five categories: classical DEMATEL, fuzzy DEMATEL, grey DEMATEL, analytical network process (ANP) DEMATEL, and other DEMATEL. All papers with respect to each category are summarized and analyzed, pointing out their implementing procedures, real applications, and crucial findings. This systematic and comprehensive review holds valuable insights for researchers and practitioners into using the DEMATEL in terms of indicating current research trends and potential directions for further research. Research showed: First, the literature review shows that a series of modified DEMATEL approaches have been developed, but no or few studies have been done to compare between the methods in the same or different groups. Second, to analyze the complicated interrelations between factors accurately, many computations are involved in the extended DEMATEL models, which limit their applications. Finally, future research could apply the DEMATEL methodology and its variants to other situations and broader fields that are not considered in the previous studies [12].

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Although many attempts and studies at project management level have been done to control project delays, but it seems that the main problem of project delays is not primarily related to the nature of projects themselves, but rather it must be considered from a higher level, namely, through comprehensive strategic planning. In fact, if there is a suitable decision-making model for controlling projects, delays of their individual activities can be prevented to a large extent [6]. Two definitions have been presented about risk management: a) Increased probability and impact of positive risks and reduced probability and impact of negative risks to optimize chances of success in achieving the desired goal [9]; b) Uncertainty and unawareness about the result of an act [7]. Financial source is one of the most important and effective sources of projects and occurrence of delays always cause increase in project costs. These surplus costs (which are probable) in the first step, cause that many companies at the time of tendering bidding documents, because of the overestimating risk coefficients, face the problem of discovering a high price and will not win the bidding, or during project implementation, cause full bankruptcy of stakeholders and the project becoming economically not profitable for the employer. The most important costs resulted from delay in projects are as follows:

- Costs for getting expensive of non-renewable resources (equipment and materials to be purchased
- Increased cost of renewable or working resources (human force and machinery)
- Costs of continued design and engineering services
- Headquarters overhead costs (rental of office, salary and mission, office equipment of the headquarters, etc.)
- Efficiency cost, opportunity cost or lost profit
- Utilization delay cost or lost profits
- Costs for project inspection during the unauthorized delay time
- Costs for maintaining current facilities during the unauthorized delay time
- Costs for extension of licenses and agreements
- Supply cost and cost of interest capital expenditures
- Interest cost arising from project financing (loans, borrowing)
- Loss due to losing competition market
- Becoming the uneconomic project
- Lack of employment in the country
- Reduced government revenue and social welfare of people
- Escalation costs [9].

In the article Causes of delay in Iranian oil and gas projects: a root cause analysis, the reports highlight the delay as a recurring problem, thereby, more in-depth investigation to find out the main contributing causes is needed. Based on RCA procedure; Pareto analysis showed that 84.7% of the delay is because: the radar chart indicated no difference in perception of the participants regarding the importance of the root causes, correlation analysis suggested strong relationship among the participants and the cause-and-effect diagram emphasized more on operational, human and equipment categories, which in total account for 51.86% of the delay [13].

3 Research method

Due to the destructive nature of the delays in the projects and the high global statistics on the many delays in most of the projects in the world, this research is presented to control the risk of project delays. The researcher attempted to minimize the risk of project delays by identifying historical factors such as delays and waste methodology and data envelopment analysis.
The present study is scientific-applied-developmental in terms of purpose, descriptive and comparative analysis in terms of importance, cross-sectional survey in terms of data collection method and qualitative-quantitative in terms of nature of the data. Data collection methods include combinative, field study (researcher-made questionnaire and interview) and library method. The scale for measuring research variables in the questionnaire is Likert scale; the researcher in this study applies his technique on an actual project with EPC nature titled Oxygen production unit project and analyzes its results. This technique contains one special and coupled innovation as follows: Ability to identify delay causes, predict probability of their occurrence and control risk of delays in projects.

Step 1: Formation of a team of experts.
Selection of a team of academic and industrial experts.

Step 2: Identification of delays incidence factors (initial).
Study historical records of about 110 projects and identify the important factors of their delays and has presented them in the form of Table1.

Table 1: Delay factors

Index code	Index Name	Index code	Index Name
1	Flexibility	26	Difficulty in doing activities
2	Remained progress percentage	27	Access limitations in the project
3	Novelty of project type	28	Allocation of appropriate adjustment
4	Access to resources	29	Prolongation of examining the agendas
5	Economic stability	30	Prolongation of examining new prices
6	Contractual clarity	31	Prolongation of contract announcement
7	Timely decisions	32	Prolongation of contract affirmation
8	Opening of working fronts	33	Problems in private conditions of contract
9	Accuracy in initial estimation of project time	34	Problems in bidding documents
10	Accuracy in initial estimation of project cost	35	Adding new tasks to the project
11	Changes in contract domain	36	Delay in extension of contract
12	Timely responding to correspondences	37	Changes in laws
13	Observance standards and common tech. language	38	Delay in prepayment
14	Accuracy in initial identification of project activities	39	Delay in presentation of initial information
15	Access to mechanism	40	Delay in opening of LC
16	Ability to finance the project	41	Prolongation of acquiring legal allowances
17	Inappropriate organizational structure	42	Prolongation of situation statement confirmation
18	Land conditions	43	Problems in building the equipment
19	Project complexity	44	Changes in plan
20	Contract amount	45	Delay in confirmation of documents
21	Foreign dependence	46	Working interference
22	Technological level of project	47	Outdated working methods
23	Project revenue	48	Changes in place of project implementation
24	Penalties for contractual delays	49	Delay in supply of items committed by the employer
25	Economic restrictions	50	Problems in engineering maps

Step 3: Selection of ultimate effective causes of occurrence of delays.
According to the above table, the researcher faced a wide range of causes of delay that they required to be more limited in order to develop a more objective strategy. For this purpose, using DEMATEL technique and obtaining the experts opinions, the delay causes affecting the project are identified.
The reason for choosing DEMATEL method is its superiority over other methods, decision making based on paired comparisons and acceptance of feedback of its relationships, as in the hierarchical structure resulted from it, each element can affect all elements of similar level and be affected by every one of them. Acceptance of transferrable relationships and the ability to display all possible feedbacks are also other reasons for its superiority over other similar methods. Accordingly, the researcher collected the experts opinions about intensity of the impact of relationships between delay causes with a 5 point scale (0 to 4) and by questionnaire method, and entered them into DEMATEL method final influential delay factors of the project were extracted as is shown in Figure 1 and Table 2.

Step 4:Preparation of a structure for failure of activities and scheduling plan of

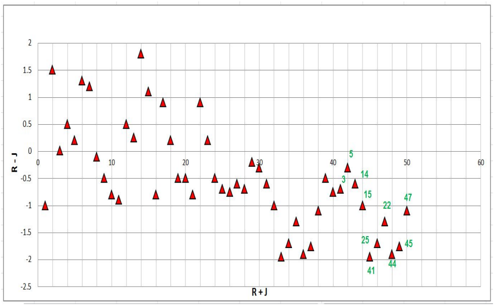
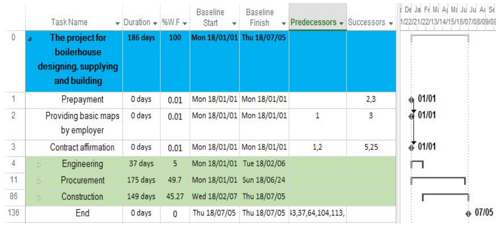


Figure 1: Final selected influential causes of delay

Table 2: Final selected influential causes of delay

Index Name	Index code
Novelty of project type	3
Economic stability	5
Accuracy in initial identification of project activities	14
Access to mechanism	15
Technological level of project	22
Economic restrictions	25
Prolongation of acquiring legal allowances	41
Changes in plan	44
Delay in confirmation of documents	45
Outdated working methods	47

project.
At this stage, experts of various engineering departments study the contract and determine the major and minor activities required to realize working scope of the contract for each engineering department. The researcher enters those activities into failure structure of MSP software (Microsoft Project). It should be noted to realistically and in operational terms, determine milestones, control points, time duration of activity, start and end dates of the base plan, weight factor, prerequisites and subsequent requirements of activities and floating and not to forget any activity. In the present study the researcher has chosen a real project called Oxygen production unit project as EPC. He has prepares this project in the form of 136 activities and sub-activities in the project. Figure2 shows a view of Level 2 of the four-level scheduling plan which is the basis of this research. Information about other levels will be introduced in the related steps.



	Task Name	Duration	%W.F	Baseline Start	Baseline Finish	Predecessors	Successors
0	The project for boilerhouse designing, supplying and building	186 days	100	Mon 18/01/01	Thu 18/07/05		
1	Prepayment	0 days	0.01	Mon 18/01/01	Mon 18/01/01		2,3
2	Providing basic maps by employer	0 days	0.01	Mon 18/01/01	Mon 18/01/01	1	3
3	Contract affirmation	0 days	0.01	Mon 18/01/01	Mon 18/01/01	1,2	5,25
4	Engineering	37 days	5	Mon 18/01/01	Tue 18/02/06		
11	Procurement	175 days	49.7	Mon 18/01/01	Sun 18/06/24		
86	Construction	149 days	45.27	Wed 18/02/07	Thu 18/07/05		
136	End	0 days	0	Thu 18/07/05	Thu 18/07/05	3,37,64,104,113,	

Figure 2: Level 2 of the base scheduling plan

Step 5: Identification and selection of activities with high risk of delays incidence from Work Breakdown Structure (WBS)
The researcher, after providing the base scheduling plan selects 30 activities (based on the need stated in the eighth step) that are located on the critical path or, based on the results of brainstorming of experts, have a high risk of delay, and ranks them as Decision Making Units (DMUs) in Data Envelopment Analysis (DEA) technique in order to control risk of project delays. The mentioned activities are listed in Table 3.
Step 6: Ranking selected activities of WBS (having potential high risk of delay)
In order to rank project activities in terms of efficiency and inefficiency in occurrence of risk of delays, the researcher has used DEA technique and DEA Frontier software. The reasons for using this technique according to the researcher are as follows:

- Converting qualitative factors to quantitative ones in numerical measurement
- Weighting and ranking decision making units and selecting the best scenarios
- Comparing inefficient scenarios with efficient ones and identifying causes of inefficiency in order to eliminate them
- Considering decision units as Black Box and evaluating them regardless of their internal performance
- Considering decision units as White Box and evaluating them according to their internal performance
- Ranking positive ideal decision units according to the related weights [11].

Table 3: Final selected influential causes of delay

W.F.(%)	Task name	Act code	W.F.(%)	Task name	Act code
1.1	Roll sheet of the tank	Ac16	1.2	Boiler room designing	Ac1
1.1	Providing tank lenses	Ac17	1	Tank room designing	Ac2
0.7	Pre-assembly and initial welding of the tank	Ac18	0.7	Guard room and restroom designing	Ac3
1	Machine excavation and soil handling	Ac19	0.7	Designing of mechanical installations system	Ac4
1.2	Concreting of floor and columns	Ac20	1	Power supply system designing	Ac5
3.4	Concreting of ceiling	Ac21	1.1	Receiving and examination of boiler's technical maps	Ac6
2.8	Piping for compressed air	Ac 22	1	Providing and confirmation of boiler's raw materials	Ac7
1	Piping for drinkable water and industrial water	Ac23	0.9	Steam Drum	Ac8
1.5	Piping for drainage	Ac24	0.6	Sealing Fan	Ac9
2.7	Delicate work	Ac25	0.8	Attemprator Desirer Heat	Ac10
1	Plastering white cement of walls	Ac26	0.7	Flame Scanner	Ac 11
0.7	whitening of ceiling	Ac27	1.5	Stack	Ac12
1.93	Testing tank leak	Ac28	0.5	Transportation of boiler to the site	Ac13
1.9	Testing boiler's pressure	Ac29	1.4	Purchasing electrical panel	Ac14
1.34	commissioning	Ac30	1.2	Assembly of electrical panel's internal electrical parts	Ac15

Table 4: Data entry in DEA Frontier software

	Delay Factors Main Effectiv									
	1	2	3	4	5	6	7	8	9	10
	Input (v)				Output (u)					
activity code	Economic stability	Accuracy in initial identification of proj. activities	Access to mechanism	Technological level of project	Changes in plan	Economic restrictions	Delay in confirmation of maps	Prolongation of acquiring legal allowances	Outdated working methods	Novelty of project type
	v1(1∼4)	v2(1∼4)	v3(1∼4)	v7(1∼4)	u1(1∼10)	u1(1∼10)	u2(1∼10)	u3(1∼10)	u4(1∼10)	u5(1∼10)
Ac1	3	4	4	2	6	5	7	1	5	6
Ac2	3	4	4	3	7	6	7	2	5	6
Ac3	2	4	3	3	7	6	7	2	5	7
Ac4	2	4	2	2	8	6	7	2	6	7
Ac5	2	4	2	1	8	7	7	2	2	7
Ac6	2	2	2	1	8	9	6	7	9	10
Ac7	2	4	2	2	7	6	6	2	2	6
Ac8	1	3	2	2	8	8	7	6	7	8
Ac9	1	2	1	1	9	10	10	5	8	8
Ac10	1	3	1	1	8	9	10	5	7	9
Ac11	1	2	2	1	9	8	7	7	8	9
Ac12	1	3	1	2	7	8	7	5	6	7
Ac13	4	4	2	2	2	2	2	10	3	2
Ac14	2	2	2	2	5	7	6	2	7	7
Ac15	1	2	2	1	8	9	9	5	9	10
Ac16	4	4	1	2	7	2	4	2	4	4
Ac17	2	2	1	1	6	8	7	7	10	8
Ac18	3	1	1	2	5	5	5	10	8	7
Ac19	4	3	1	4	5	2	5	7	4	4
Ac20	2	3	2	3	10	7	10	9	6	6
Ac21	2	3	2	3	5	5	5	4	5	1
Ac22	2	4	2	2	9	7	7	3	7	7
Ac23	1	1	1	2	6	10	8	5	10	10
Ac24	4	4	1	2	6	1	1	1	8	8
Ac25	2	2	1	2	4	6	3	6	6	7
Ac26	3	3	1	2	6	5	1	7	8	8
Ac27	2	2	1	2	8	9	8	9	9	9
Ac28	3	4	2	1	5	7	3	5	9	9
Ac29	3	4	2	1	4	6	2	4	5	6
Ac30	2	2	1	1	1	6	2	6	7	7

DEA technique is a nonparametric model for estimating efficiency level and ranking. DEA models can be input-based or output-based, and they also exist as Constant Return to Scale (CRS) models or Variable Return to Scale (VRS) models. The output-based models maximize output according to values of input factors; and input-based models minimize input factors according to the given output level [10].

The researcher has considered 10 final selected influential causes of delay obtained from the fourth step as the inputs (v) and outputs (u) of DEA technique. In this regard, considering that CCR coverage output-based computation method is going to be used for ranking, the factors that their reduction will increase risk of project delays are considered as inputs, and the factors that their increase will increase risk of project delays are considered as output. Results of the seventh step, which are 30 selected activities of the base scheduling plan, were assumed as the DMUs of the researcher-made technique and ranked using DEA technique. In order to enter this stage the researcher, in accordance with the designed questionnaire, obtained the experts opinions for input data (v) with a 4-point scale and for output data (u) with a 10-point scale, according to the following categories and entered them into DEA Frontier software as can be seen in Table 4.

After software solution, results of ranking for

Table 5: Ranking of efficient and inefficient decision making units

DMU No	DMU Name	Output-Oriented CRS Efficiency	DMU No	DMU Name	Output-Oriented CRS Efficiency
1	Ac1	2.80000	16	Ac16	2.57143
2	Ac2	2.90476	17*	Ac17	1.00000
3	Ac3	2.50000	18*	Ac18	1.00000
4	Ac4	2.25000	19	Ac19	2.69231
5	Ac5	1.12500	20*	Ac20	1.00000
6*	Ac6	1.00000	21	Ac21	3.40000
7	Ac7	2.57143	22	Ac22	2.00000
8	Ac8	1.08333	23*	Ac23	1.00000
9*	Ac 9	1.00000	24	Ac24	1.18182
10*	Ac10	1.00000	25	Ac25	2.47059
11*	Ac11	1.00000	26	Ac26	1.15385
12	Ac12	1.20930	27*	Ac27	1.00000
13	Ac13	1.40000	28	Ac28	1.03704
14	Ac14	1.80952	29	Ac29	3.00000
15*	Ac15	1.00000	30	Ac30	2.04902

Table 6: Benchmark of inefficient projects

DMU No	DMU Name	Output-Oriented CRS Efficiency	Benchmarks		
1	Ac1	2.80000	Ac9	Ac15	
2	Ac2	2.90476	Ac9	Ac11	Ac27
3	Ac3	2.50000	Ac9	Ac11	Ac15
4	Ac4	2.25000	Ac9		
5	Ac5	1.12500	Ac9		
7	Ac7	2.57143	Ac9		
8	Ac8	1.08333	Ac6	Ac9	Ac11
12	Ac12	1.20930	Ac9	Ac23	Ac27
13	Ac13	1.40000	Ac17		
14	Ac14	1.80952	Ac6	Ac9	Ac15 Ac17 Ac23
16	Ac16	2.57143	Ac9		
19	Ac19	2.69231	Ac18	Ac27	
21	Ac21	3.40000	Ac9	Ac27	
22	Ac22	2.00000	Ac9		
24	Ac24	1.18182	Ac23	Ac27	
25	Ac25	2.47059	Ac17	Ac23	Ac27
26	Ac26	1.15385	Ac23	Ac27	
28	Ac28	1.03704	Ac6	Ac17	
29	Ac29	3.00000	Ac6	Ac9	Ac15 Ac17
30	Ac30	2.04902	Ac6	Ac17	Ac23 Ac27

30 DMUs were extracted according to Table 5, in which 10 DMUs were announced as efficient (*) and 20 remaining DMUs were announced as inefficient.

In order to identify the DMUs causing inefficiency of other DMUs, benchmarks of each one are presented in Table 6, which shows that through which one of efficient DMU or DMUs, each of these inefficient DMUs has become inefficient. This capability of ranking along with calculation of efficiency of each DMU makes it possible to have the required information to control the risk of not converting or converting inefficient cause of delay into efficient one and vice versa.

Step 7: Sensitivity analysis of efficiency delay factors

Given that the researcher-made delay analysis technique has the ability to identify and control risk of project delays incidence too, it is necessary to calculate the risk of conversion of activities prone to delays (efficient) into inefficient activities as well as the risk of conversion of activities non-prone to delay (inefficient) into efficient activities or control the risk of remaining of efficient activities in efficiency state (with cost management attitude), and take it into account in prediction of risk of project delays incidence. For this purpose the researcher, using Super Efficiency capability in DEA Frontier software has obtained sensitivity analysis of efficient DMUs (high-risk activities) and has calculated efficiency and inefficiency rate of activities having risk of delay based on efficiency boundary of the existing data and has ranked its results according to Table 7. In this table, efficient DMUs are marked with (*) and ranked 1 to 10 and inefficient DMUs are ranked from 11 to 30.

Table 7: Benchmark of inefficient projects

Rank	DMU Name	Activity name	Output-Oriented CCR Super Efficiency
1	*Ac27	whitening of ceiling	0.60458
2	*Ac17	Providing tank lenses	0.73913
3	*Ac9	Sealing Fan	0.74561
4	*Ac11	Flame Scanner	0.74641
5	*Ac20	Concreting of floor and columns	0.84252
6	*Ac15	Assembly of electrical panel's internal electrical parts	0.87179
7	*Ac10	Attemprator Desirer Heater	0.88889
8	*Ac23	Piping for drinkable water and industrial water	0.9
9	*Ac18	Pre-assembly and initial welding of the tank	0.9
10	*Ac6	Receiving and examination of boiler's technical maps	0.92157
11	Ac28	Testing tank leak	1.03704
12	Ac8	Steam Drum	1.08333
13	Ac5	Power supply system designing	1.125
14	Ac26	Plastering white cement of walls	1.15385
15	Ac24	Piping for drainage	1.18182
16	Ac12	Stack	1.2093
17	Ac13	Transportation of boiler to the site	1.4
18	Ac14	Purchasing electrical panel	1.80952
19	Ac22	Piping for compressed air	2
20	Ac30	commissioning	2.04902
21	Ac4	Designing of mechanical installations system	2.25
22	Ac25	Delicate work	2.47059
23	Ac3	Guard room and restroom designing	2.5
24	Ac16	Roll sheet of the tank	2.57143
25	Ac7	Providing and confirmation of boiler's raw materials	2.57143
26	Ac19	Machine excavation and soil handling	2.69231
27	Ac1	Boiler room designing	2.8
28	Ac2	Tank room designing	2.90476
29	Ac29	Testing boiler's pressure	3
30	Ac21	Concreting of ceiling	3.4

4 Conclusion

Given the fact that project risk control puts a lot of costs on the stakeholders, the high number of indicators required to control causes a significant increase in costs in the project. So, the researcher-made technique, by focusing on the failure structure, the project's critical path, and the method of the DEMATEL, has tried to reduce the number of risk indicators necessary to control and, using the data envelopment analysis technique, indexes are ranked and sensitized. In this way, for each risk-sensitive item, the risk is spent on the project in its own right. Also, the risk of becoming an inefficient (risk-free) indicator is identified as effective (risk) and vice versa throughout the project, and is deliberately made policy and decision in relation to them. In this regard, the cost control module in the PMBOK standard will be implemented correctly.

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Dr. Vahid Rooholelm is PhD in Industrial Engineering (Project Management), Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Najafabad Iran. university lecturer, senior manager of Iran's steel industry and senior consultant for large construction projects. His areas of interest include project management, claim management, risk management, delay analysis, and data envelopment analysis. He has published numerous articles in international journals in this field. He is a member of the Iranian Elite Association and a member of the International Industrial Engineering Festival.

Dr. Abbas Sheikh Aboumasoudi is a university professor at university about 35 years out of 43 years of his work experience in industry and university. He received his PhD in Industrial Engineering from Iran university of Science and Technology, Tehran. His research interests include in four areas: Industrial engineering, Management, Economic analysis and financial analysis.