Project Penalty Cost Management, Based on Activity Sensitivity Analysis (BASA)

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ABSTRACT

Existence of delays is always an inseparable part of projects and subject of fundamental disagreements among their stakeholders in all countries. Usually, changes to project-based indicators and decisions cause project delays. This is managed with the help of the change management process in the PMBOK standard. 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. The main purpose of the paper is project cost management with a focus on managing risk of changes and delays in project activities. Using a hierarchical, statistical, and data envelopment analysis tool, researchers have introduced innovative techniques that manage the likelihood of project changes and delays and minimize project overhead and project costs

Keywords:

Risk Management; Change Management; Delays Control; Cost Management; Risk Coverage; Data Envelopment Analysis (DEA); Project Management Body of Knowledge (PMBOK).

1. Introduction

Making changes to benchmarks is a major complication in projects. Any change requires time to make a decision and then to increase costs for action. Spending more time delays the project. It also delays other project activities. Project Delays In addition to contractual offenses, there are additional costs to the project, the most significant of which is presented below. The researchers in this paper presented an innovative technique to manage project changes and delays and manage project overhead costs. “Chou and Yang (2017)” In an article entitled “Preliminary Evaluation of BIM-based Approaches for Schedule” Delay Analysis 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. “Iranmanesh et al. (2009)” In an article entitled “Comparison of delay analysis methods for construction projects and implementation of the timing windows method for a real project” 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.

“Abdelhadi et al. (2019)” In an article “Factors influencing the selection of delay analysis methods in construction projects in UAE “Entitled Delays growth in UAE and Saudi Arabian projects is 39%. Research has shown that deciding on project delays is a very important factor affecting business investors. “Ramli M.Z., (2017)” In an article “Study of factors influencing construction delays at rural area in Malaysia, Journal of Physics “ 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.

“P. J. Keane & A. F. Caletka, (2015)” In their book “Delay Analysis in Construction Contracts, The Atrium, Southern Gate “ 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. 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. Literature Review

DEA[1] 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 (CRS)[2] models or (VRS)[3] 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 “AliNejad Alireza, Simiyari Kavous, (2013)”. 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[4] technique and obtaining the experts' opinions, the delay causes affecting the project are identified. The reason for choosing DEMATEL method: DEMATEL method is a popular method, which enables an analysis of cause-and-effect relationships. The potential of this method has also been noted in the context of determining weights of criteria “Baykasoglu A. et al., (2013)”. The numerical examples presented here show that the weights determined using the proposed approach exhibit high compatibility with weights determined using the commonly used AHP[5] method “Kobryń Andrzej, (2017)”. In the article a hybrid SD-DEMATEL[6] approach to develop a delay model for construction projects, purpose is to develop a model for complex interconnected structure of various factors interacting with delay in order to identify the most important factors influencing and influenced by delay based on their interrelations. According to the analysis, eight out of the 58 factors were identified as the most influencing factors on delay, and nine factors were found to be the most influenced factors by delay in the field of delay analysis. The study also concluded that factors related to labors are the most important and influential factors. In addition, factors related to client were the most influencing factors and external-related factors were the least important ones. At the end, some recommendations to reduce variation of delay in the construction projects are presented as well “Parchami Jalal Majid, Shahab Shoar, (2017)”.

According to the approaches used, these publications are grouped into five categories: classical DEMATEL, fuzzy DEMATEL, grey DEMATEL, (ANP)[7] 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 “Sheng-Li Si et al., 2019”. 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 “Chou Hui-Yu, Yang Jyh-Bin, 2017”. In an article entitled Exploring the Value of Risk Management for Projects Improving Capability through the Deployment of a Maturity Model, for any project, identification of the risk management goals before embarking on risk management and particularly the preparation of a maturity model is considered vital. This paper considers that a project’s PRM[8] goals dictate the activities to be implemented and the activities and barriers combined inform the competencies to be included in a PRM maturity model. Examination of the goals, activities and barriers has permitted the construction of a model which proposes 5 levels of maturity, 9 categories or ‘building blocks’ of effective risk management and a format for capturing risk competencies. In addition, through the application of the model during four live programmers, the paper draws the conclusion that there is a direct correlation between the use of the model and improvements in the effectiveness of project risk management. It also highlights that models are not deployed in a vacuum and that the circumstances of a project will influence the degree to which a model will aid the delivery of effective risk management. Possible avenues of further research are the application of the model on a large sample of live projects so that the appropriateness of the categories and competencies can be more rigorously assessed with the goal of determining a universally applicable model “James champman Robert, (2019)”.

In an article entitled, Schedule Risk Analysis using a Proposed Modified Variance and Mean of the Original Program Evaluation and Review Technique Model, the mean error rate for all the cases, was computed for both the original PERT[9] model and the proposed modified PERT model. It was shown that the proposed modified PERT model had a better mean error rate of 2.46% as compared to 3.31% of the original PERT model. This suggests that the proposed modified PERT model performs approximately 0.85 percentage points or 25.7% better than the original PERT model. Comparing with the simulation results, the error in both models can be attributed to the fact that the PERT model only considers one path to be critical in the network. However, through verification using simulation, other paths compete to be on the critical path and the probability of any non-critical activity becoming critical effects the project completion time. Thus, the study has shown that the proposed modified PERT model can more accurately estimate the probability of completion than the original PERT model. Nevertheless, as the proposed modified model was based on certain assumptions, it is difficult to conclude with certainty that it is better than the original PERT model. However, as it yields a better result at this stage, it is hoped that using the proposed modified PERT model would aid the improvement of analysis of schedule risk in projects. The study also identifies the critical path as a high-risk path, but does not identify the critical path and tries to reduce its risks in a number of ways “Sackey and Kim (2019)”.

In an article entitled From Risk Matrices to Risk Networks in Construction Projects, There is a way to control risk. But There are a few limitations of this paper. The entire risk management process was not covered including the risk mitigation and risk monitoring stages. Risks were modeled using discrete states rather than continuous functions. The risk matrix used in the study contained discrete partitions. This study can be developed along different lines of inquiry. The efficacy of different risk mitigation strategies could be evaluated using risk matrices associated with the reimplementation and post implementation of the strategies. Risks could be modeled using continuous functions and other features of risk, including detectability, controllability, and manageability of risk could be explored within the proposed framework. Other risk metrics could be developed and integrated into the framework to better project the impact of different risk scenarios. A comprehensive project risk management process could be developed and a suitable decision support system be designed to prioritize risks and risk mitigation strategies. Although the proposed method can be applied to all kinds of projects, the risk network depicted in this paper is application specific, thus cannot be generalized. Case studies could be conducted to establish the challenges involved in implementing the proposed framework “Qazi Abroon, Dikmen Irem, (2019)”. In an article entitled A Risk-Oriented Buffer Allocation Model Based on Critical Chain Project Management, the comparative results of the novel buffer sizing method gave evidence for the efficiency of the robust multi-attribute buffer sizing method presented in the real world project. Finally, some of the strengths and the limitations of the buffer sizing approach proposed were discussed. It was verified that the size of the time buffers determined by the method proposed is more reasonable and economical, demonstrating its capability to manage project planning under uncertainties. The ventures for the proposed multi-attribute CC/PM[10] approach to be accepted by the construction industry are encouraging as a result of a number of motives. First, the risk mitigation approach is based on further realistic expectations than existing buffer sizing methods such as the flexibility of the framework to include different user criteria. Second, the proposed buffer sizing model is acquainted with different resource usages and the risk preference, which are better descriptions of managerial observes and allows for more flexible adjustments of project schedules when disruptions happen. Third, the proposed buffer sizing model was extended on the basis of CC/PM which is a well-known approach in project management discipline Thus, the time and effort required to train the users and risk managers are really reduced by the model application “Ghoddousi et al. (2016)”.

Research contributes towards identification of critical risk factors causing delays in the construction projects being implemented in Islamabad and Rawalpindi. Detailed literature review and interviews with experts from construction industry were conducted, on the basis of which a total of 29 risks from 5 major categories (financial, technical, design, labor and external risks) were identified. To find out the relationship between these risk factors and project delay, a quantitative questionnaire survey was conducted. A result of this survey design risks were ranked first, external risks at second, technical and labor risks were ranked third while financial risks were ranked forth. Recommendations were made considering the study findings “Rao Aamir Khan; Warda Gul, (2017)”.

In an article entitled, the Use of a Multiple Risk Level Model to Tackle the Duration of Risk for Construction Activity, proposes a (MRL)[11] model that improves a traditional PERT in determining the durations of risk for an activity by evaluating the constraints that are associated with the environmental effect and different construction resources, including spatial, environmental, man, machine, material, method and monetary constraints. A Risk-based Critical Path Scheduling Method, namely R-CPSM, is proposed for developing the schedule for a construction project using the MRL activity durations. An interior construction project from the literature is used as a case study to demonstrate the proposed method. In this study, he considers the critical path a risky path and tries to reduce its risks in a number of ways “Chang et al. (2019)”. 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 “Sweis Rateb et al., (2019)”. 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 “AliNejad Alireza, Simiyari Kavous, 2013”.

Existence of delay in projects is inevitable due to their particular complexity, such that studies show that most construction projects in the world face more than 45% increase in time that has numerous consequences such as increased completion time of the project, increased direct and indirect costs, lack of project’s achievement of predetermined goals in pre-planned time, and creation of lost opportunity cost. On the other hand, delay in projects can also affect their quality objectives, such that project implementers, in order to avoid penalties for unauthorized delays and completion of the project in due time, speed up implementation process of the project over a time period which dramatically reduces quality of project implementation “Faroughi Hiva et al., (2018)”. In the article Causes of delays in construction industry and comparative delay analysis techniques with SCL[12] protocol, They sought to discover the root causes of project delays with the help of the SCL Protocol and the International Association for the Development of Value Engineering (AACEI). They used questionnaire and RII method and SPSS software in their research and identified 78 factors of delay, divided into 7 groups including 58 contractors, 55 consultants, 62 employers. The result is that 10 important factors are identified and 3 are the most effective: 1) Delays in outsourcing activities. 2) Poor site management and monitoring. 3) Problems in financing the project by the contractor "Shahsavand Parvaneh et al., (2017)".

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 "Golabchi Mahmoud et al., (2014)". 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 "Bazi hamidreza, Mirsaeidi shahrokh, (2013)". 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 "Momeni Abolfazl, Kheirkhah Amir Saman, (2006)". 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 "P. J. Keane & A. F. Caletka, (2015)"; b) Uncertainty and unawareness about the result of an act "Rahnama Roodposhti Fereydoun, Rooholelm Vahid, (2016)". 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
- 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 "P. J. Keane & A. F. Caletka, 2015".

To use the innovative technique introduced in this research, the existence of historical information, accuracy of information, selection of expert team with sufficient expertise and background, selection of appropriate statistical methods, selection of analytical method and professional analysts and project control and cost control experts Certification is required.

3. Methodology

Budgeting and budgeting for projects are some of the basics for getting started. Then the amount of costs based on the approved cash flow is the key to the success of the project. Any factor that increases the cost of a project budget is a project risk. It seems that not all project activities can be controlled equally to manage costs. Project activities need to be managed by targeted grouping and categorization to avoid excessive costs at minimal cost. For example, researchers believe that even critical path activities should not be given equal importance and cost the same to control them. This has challenged, halted, or derailed major projects in the world. 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.

Step 1: Formation of a team of experts

Selection of a team of academic and industrial experts. The team of experts is made up of all elements of the project including employer, consultant, contractor, mechanical, electrical, structural, contract and management specialties. Experts collaborate with researchers at each stage of the project as needed (to explain) to develop and complete the questionnaires.

Step 2: Identification of delays incidence factors (initial)

Study historical records of about 255 projects and identify the important factors of their delays and has presented them in the form of Table 1.

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 Diagram 1 and Table 2.

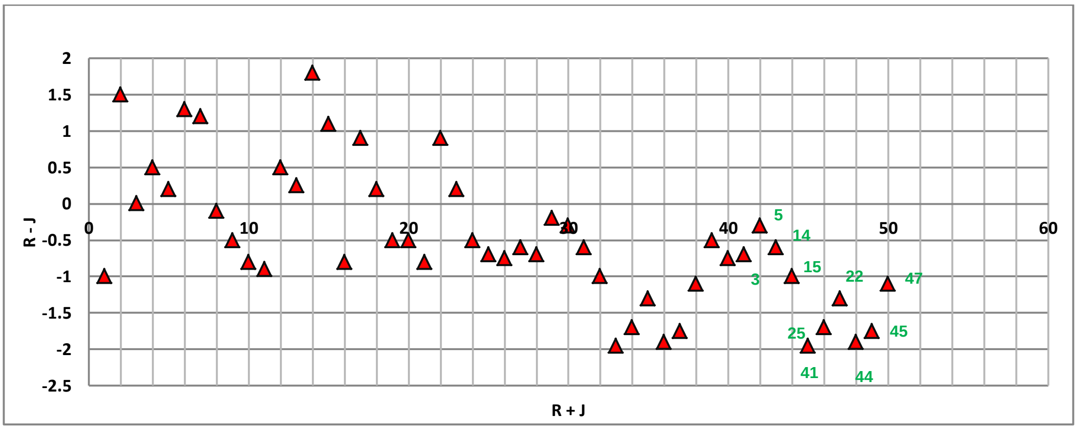


Diagram 1: Final selected influential causes of delay

Table 2: Final selected influential causes of delay

Index Code	Index Name
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

Step 4: Preparation of a structure for failure of activities and scheduling plan of 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[13] software. 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[14]. He has prepares this project in the form of 136 activities and sub-activities in the project. Table 3 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.

Table 3: Level 2 of the base scheduling plan

	Task Name	Duration	%W.F	Baseline Start	Baseline Finish	Predecessors	Successors
0	The project for boilerhouse designing, supplying and building	186 days	100	18/01/01	18/07/05		
1	Prepayment	0 days	0.01	18/01/01	18/01/01		2,3
2	Providing basic maps by employer	0 days	0.01	18/01/01	18/01/01	1	3
3	Contract affirmation	0 days	0.01	18/01/01	18/01/01	1,2	5,25
4	Engineering	37 days	5	18/01/01	18/02/06		
11	Procurement	175 days	49.7	18/01/01	18/06/24		
86	Construction	149 days	45.27	18/02/07	18/07/05		
136	End	0 days	0	18/07/05	18/07/05	135,49,40,43,37,64,104,113,120,127,22	

Step 5: Identification and selection of activities with high risk of delays incidence from WBS[15]

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)[16] in Data Envelopment Analysis (DEA) technique in order to control risk of project delays. The mentioned activities are listed in Table 4.

Table 4: Selected activities of WBS to identify DMUs

Weight factor(%)	Task name	Activity code	Weight factor(%)	Task name	Activity code
1.1	Roll sheet of the tank	Ac 16	1.2	Boiler room designing	Ac 1
1.1	Providing tank lenses	Ac 17	1	Tank room designing	Ac 2
0.7	Pre-assembly and initial welding of the tank	Ac 18	0.7	Guard room and restroom designing	Ac 3
1	Machine excavation and soil handling	Ac 19	0.7	Designing of mechanical installations system	Ac 4
1.2	Concreting of floor and columns	Ac 20	1	Power supply system designing	Ac 5
3.4	Concreting of ceiling	Ac 21	1.1	Receiving and examination of boiler's technical maps	Ac 6
2.8	Piping for compressed air	Ac 22	1	Providing and confirmation of boiler's raw materials	Ac 7
1	Piping for drinkable water and industrial water	Ac 23	0.9	Steam Drum	Ac 8
1.5	Piping for drainage	Ac 24	0.6	Sealing Fan	Ac 9
2.7	Delicate work	Ac 25	0.8	Attemprator Desuper Heat	Ac 10
1	Plastering white cement of walls	Ac 26	0.7	Flame Scanner	Ac 11
0.7	whitening of ceiling	Ac 27	1.5	Stack	Ac 12
1.93	Testing tank leak	Ac 28	0.5	Transportation of boiler to the site	Ac 13
1.9	Testing boiler's pressure	Ac 29	1.4	Purchasing electrical panel	Ac 14
1.34	commissioning	Ac 30	1.2	Assembly of electrical panel's internal electrical parts	Ac 15

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.
- 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 "Sheikh Aboumasoudi, Abbas, (2016)".

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 "Rooholelm Vahid, Shiroyezad Hadi, (2017)". 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[17] 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 5.

Table 5: Data entry in DEA Frontier software

Activity Code	Delay Factors Main Effective									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Input (v)				**Output (u)**					
	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)
Ac 1	3	4	4	2	6	5	7	1	5	6
Ac 2	3	4	4	3	7	6	7	2	5	6
Ac 3	2	4	3	3	7	6	7	2	5	7
Ac 4	2	4	2	2	8	6	7	2	6	7
Ac 5	2	4	2	1	8	7	7	2	2	7
Ac 6	2	2	2	1	8	9	6	7	9	10
Ac 7	2	4	2	2	7	6	6	2	2	6
Ac 8	1	3	2	2	8	8	7	6	7	8
Ac 9	1	2	1	1	9	10	10	5	8	8
Ac 10	1	3	1	1	8	9	10	5	7	9
Ac 11	1	2	2	1	9	8	7	7	8	9
Ac 12	1	3	1	2	7	8	7	5	6	7
Ac 13	4	4	2	2	2	2	2	10	3	2
Ac 14	2	2	2	2	5	7	6	2	7	7
Ac 15	1	2	2	1	8	9	9	5	9	10
Ac 16	4	4	1	2	7	2	4	2	4	4
Ac 17	2	2	1	1	6	8	7	7	10	8
Ac 18	3	1	1	2	5	5	5	10	8	7
Ac 19	4	3	1	4	5	2	5	7	4	4
Ac 20	2	3	2	3	10	7	10	9	6	6
Ac 21	2	3	2	3	5	5	5	4	5	1
Ac 22	2	4	2	2	9	7	7	3	7	7
Ac 23	1	1	1	2	6	10	8	5	10	10
Ac 24	4	4	1	2	6	1	1	1	8	8
Ac 25	2	2	1	2	4	6	3	6	6	7
Ac 26	3	3	1	2	6	5	1	7	8	8
Ac 27	2	2	1	2	8	9	8	9	9	9
Ac 28	3	4	2	1	5	7	3	5	9	9
Ac 29	3	4	2	1	4	6	2	4	5	6
Ac 30	2	2	1	1	1	6	2	6	7	7

After software solution, results of ranking for 30 DMUs were extracted according to Table 6, in which 10 DMUs were announced as efficient (*) and 20 remaining DMUs were announced as inefficient.

Table 6: 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	Ac 1	2.80000	16	Ac 16	2.57143
2	Ac 2	2.90476	17*	Ac 17	1.00000
3	Ac 3	2.50000	18*	Ac 18	1.00000
4	Ac 4	2.25000	19	Ac 19	2.69231
5	Ac 5	1.12500	20*	Ac 20	1.00000
6*	Ac 6	1.00000	21	Ac 21	3.40000
7	Ac 7	2.57143	22	Ac 22	2.00000
8	Ac 8	1.08333	23*	Ac 23	1.00000
9*	Ac 9	1.00000	24	Ac 24	1.18182
10*	Ac 10	1.00000	25	Ac 25	2.47059
11*	Ac 11	1.00000	26	Ac 26	1.15385
12	Ac 12	1.20930	27*	Ac 27	1.00000
13	Ac 13	1.40000	28	Ac 28	1.03704
14	Ac 14	1.80952	29	Ac 29	3.00000
15*	Ac 15	1.00000	30	Ac 30	2.04902

In order to identify the DMUs causing inefficiency of other DMUs, benchmarks of each one are presented in Table 7, 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.

Table 7: Benchmark of inefficient projects

DMU No.	DMU Name	Output-Oriented CRS Efficiency	Benchmarks					DMU No.	DMU Name	Output-Oriented CRS Efficiency	Benchmarks				
1	Ac 1	2.80000	Ac 9	Ac 15				16	Ac 16	2.57143	Ac 9				
2	Ac 2	2.90476	Ac 9	Ac 11	Ac 27			19	Ac 19	2.69231	Ac 18	Ac 27			
3	Ac 3	2.50000	Ac 9	Ac 11	Ac 15			21	Ac 21	3.40000	Ac 9	Ac 27			
4	Ac 4	2.25000	Ac 9					22	Ac 22	2.00000	Ac 9				
5	Ac 5	1.12500	Ac 9					24	Ac 24	1.18182	Ac 23	Ac 27			
7	Ac 7	2.57143	Ac 9					25	Ac 25	2.47059	Ac 17	Ac 23	Ac 27		
8	Ac 8	1.08333	Ac 6	Ac 9	Ac 11			26	Ac 26	1.15385	Ac 23	Ac 27			
12	Ac 12	1.20930	Ac 9	Ac 23	Ac 27			28	Ac 28	1.03704	Ac 6	Ac 17			
13	Ac 13	1.40000	Ac 17					29	Ac 29	3.00000	Ac 6	Ac 9	Ac 15	Ac 17	
14	Ac 14	1.80952	Ac 6	Ac 9	Ac 15	Ac 17	Ac 23	30	Ac 30	2.04902	Ac 6	Ac 17	Ac 23	Ac 27	

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 8. In this table, efficient DMUs are marked with (*) and ranked 1 to 10 and inefficient DMUs are ranked from 11 to 30 in table 8.

Table 8: Ranking and sensitivity analysis of efficient (having high risk of delay incidence) and inefficient (having low risk of delay incidence) DMUs

Rank	DMU Name	Activity name	Output-Oriented CCR Super Efficiency	Rank	DMU Name	Activity name	Output-Oriented CCR Super Efficiency
1	*** Ac 27**	**whitening of ceiling**	**0.60458**	16	Ac 12	Stack	1.20930
2	*** Ac 17**	**Providing tank lenses**	**0.73913**	17	Ac 13	Transportation of boiler to the site	1.40000
3	*** Ac 9**	**Sealing Fan**	**0.74561**	18	Ac 14	Purchasing electrical panel	1.80952
4	*** Ac 11**	**Flame Scanner**	**0.74641**	19	Ac 22	Piping for compressed air	2.00000
5	*** Ac 20**	**Concreting of floor and columns**	**0.84252**	20	Ac 30	commissioning	2.04902
6	*** Ac 15**	**Assembly of electrical panel's internal electrical parts**	**0.87179**	21	Ac 4	Designing of mechanical installations system	2.25000
7	*** Ac 10**	**Heater system**	**0.88889**	22	Ac 25	Delicate work	2.47059
8	*** Ac 23**	**Piping for drinkable water and industrial water**	**0.90000**	23	Ac 3	Guard room and restroom designing	2.50000
9	*** Ac 18**	**Pre-assembly and initial welding of the tank**	**0.90000**	24	Ac 16	Roll sheet of the tank	2.57143
10	*** Ac 6**	**Receiving and examination of boiler's technical maps**	**0.92157**	25	Ac 7	Providing and confirmation of boiler's raw materials	2.57143
11	Ac 28	Testing tank leak	1.03704	26	Ac 19	Machine excavation and soil handling	2.69231
12	Ac 8	Steam Drum	1.08333	27	Ac 1	Boiler room designing	2.80000
13	Ac 5	Power supply system designing	1.12500	28	Ac 2	Tank room designing	2.90476
14	Ac 26	Plastering white cement of walls	1.15385	29	Ac 29	Testing boiler's pressure	3.00000
15	Ac 24	Piping for drainage	1.18182	30	Ac 21	Concreting of ceiling	3.40000

Step 9: Finding the root of causes of delays incidence for efficient DMUs

In order to prevent delays incidence and control their risk, it is necessary to identify and find the root of causes of delays incidence for efficient DMUs. The strategies to control their occurrence risk should be developed by referring to their historical records, holding brainstorming sessions, obtaining experts' opinions and Ishikawa Diagram. In this regard, the root of 10 activities with high risk of delay (efficient DMUs) was found through brainstorming of experts' team which shows the project's way map in order to prevent occurrence of delays. As instance, the results of finding the root and analysis performed for AC 27 are presented in the form of Diagram 2.

Step 10: Production and introduction of importance degree factor (BASA)[18]

One of the innovations of the researcher-made technique is Importance Degree Factor. This factor, which is one of the main pillars of this technique, considers the value of each component of activity, in addition to valuing indices in weight factor (According to step 4), to be influenced by other indicators such as result-orientation of the activity, seasonal period, difficulty of doing the work, accessibility location, past experiences of experts, and complexity of doing the activity. Combination of new indexes considered by the researcher with weight factor, and then the impact of the sensitivity analysis of risk activities having delay risk on it, leads to production of a new factor that has the ability to calculate the risk of conversion of activities prone to delay (efficient) to inefficient ones as well as the risk of conversion of activities non-prone to delay (inefficient) to efficient ones, or to control the risk of remaining of efficient activities in efficiency mode (with a cost management attitude), and it makes it possible to predict risk of occurrence of delays in activities at the beginning of the project as well as while running it. In this regard, the researcher produced the factor (I.D.F) through the following formula and displayed a view of it for 30 selected activities (DMU) with high risk of delays in the form of Table 9.

Importance Degree Factor (BASA) = (Weight Factor) / (Super Efficiency Coefficient)

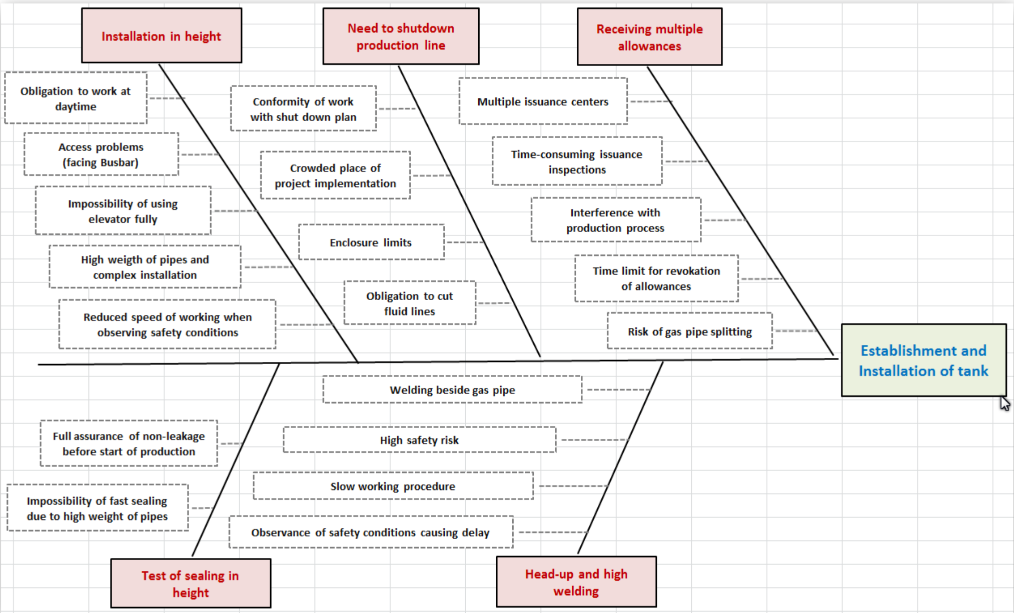


Diagram 2: Finding the root of causes of delay for efficient DMU number AC 27 through brainstorming of experts' team

Table 9: Production and introduction of Importance Degree Factor

Row	DEA Activity No.	Task name	High Risk Activities	Efficient Activity	Weight Factor (W.F.)	Output-Oriented CCR Super Efficiency	Importance Degree factor (I.D.F.)	(I.D.F.) based on 100%
		Boiler house Power Plant EPC Project			**100.0**	**420.37**	**44.40**	**100.0**
6	AC 1	Boiler room designing	*		1.20	2.8	0.43	0.97
7	AC 2	Tank room designing	*		1.00	2.90476	0.34	0.78
9	AC 3	Guard room and restroom designing	*		0.70	2.5	0.28	0.63
10	AC 4	Designing of mechanical installations system	*		0.70	2.25	0.31	0.70
18	AC 5	Power supply system designing	*		1.00	1.125	0.89	2.00
33	AC 6	Receiving and examination of boiler's technical maps	*	**	1.10	0.92157	1.19	2.69
34	AC 7	Providing and confirmation of boiler's raw materials	*		1.00	2.57143	0.39	0.88
35	AC 8	Steam Drum	*		0.90	1.08333	0.83	1.87
39	AC 9	Sealing Fan	*	**	0.60	0.74561	0.80	1.81
42	AC 10	Super Heat System	*	**	0.80	0.88889	0.90	2.03
45	AC 11	Flame Scanner	*	**	0.70	0.74641	0.94	2.11
48	AC 12	Stack	*		1.50	1.2093	1.24	2.79
49	AC 13	Transportation of boiler to the site	*		0.50	1.4	0.36	0.80
62	AC 14	Purchasing electrical panel	*		1.40	1.80952	0.77	1.74
63	AC 15	Assembly of electrical panel's internal electrical parts	*	**	1.20	0.87179	1.38	3.10
76	AC 16	Roll sheet of the tank	*		1.10	2.57143	0.43	0.96
79	AC 17	Providing tank lenses	*	**	1.10	0.73913	1.49	3.35

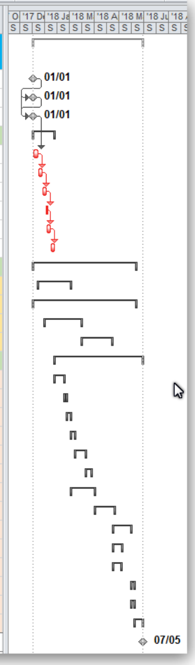
Row	DEA Activity No.	Task name	High Risk Activities	Efficient Activity	Weight Factor (W.F.)	Output-Oriented CCR Super Efficiency	Importance Degree factor (I.D.F.)	(I.D.F.) based on 100%
		Boiler house Power Plant EPC Project			**100.0**	**420.37**	**44.40**	**100.0**
88	AC 18	Pre-assembly and initial welding of the tank	*	**	0.70	0.9	0.78	1.75
90	AC 19	Machine excavation and soil handling	*		1.00	2.69231	0.37	0.84
97	AC 20	Concreting of floor and columns	*	**	1.20	0.84252	1.42	3.21
98	AC 21	Concreting of ceiling	*		3.40	3.4	1.00	2.25
106	AC 22	Piping for compressed air	*		2.80	2	1.40	3.15
115	AC 23	Piping for drinkable water and industrial water	*	**	1.00	0.9	1.11	2.50
116	AC 24	Piping for drainage	*		1.50	1.18182	1.27	2.86
117	AC 25	Delicate work	*		2.70	2.47059	1.09	2.46
120	AC 26	Plastering white cement of walls	*		1.00	1.15385	0.87	1.95
122	AC 27	whitening of ceiling	*	**	0.70	0.60458	1.16	2.61
133	AC 28	Testing tank leak	*		1.93	1.03704	1.86	4.19
134	AC 29	Testing boiler's pressure	*		1.90	3	0.63	1.43
135	AC 30	commissioning	*		1.34	2.04902	0.65	1.47

Step 11: Replacement of importance degree factor instead of weight factor in the schedule

In the researcher-made technique, it is required to replace WF by BASA in the base scheduling plan. From now on, the scheduling plan is equipped with BASA ; values of physical progress of the project (planned and actual) based on BASA of activities, as well as their risk taking and risk aversion are calculated and the required ground for controlling risk of projects changes and projects delays by the manager and decision maker of the project is provided that the results are presented in Table 10.

Table 10: Replacement of BASA instead of WF in the base scheduling plan

	Task Name	Duration	%W.F	%IDF	Baseline Start	Baseline Finish	Predecessors	Successors
0	**The project for boilerhouse designing, supplying and building**	**186 days**	**100**	**100**	**18/01/01**	**18/07/05**		
1	Prepayment	0 days	0.01	0.01	18/01/01	18/01/01		2,3
2	Providing basic maps by employer	0 days	0.01	0.01	18/01/01	18/01/01	1	3
3	Contract affirmation	0 days	0.01	0.01	18/01/01	18/01/01	1,2	5,25
4	Engineering	37 days	5	3.98	18/01/01	18/02/06		
5	Development of general plan	8 days	1	0.64	18/01/01	18/01/08	3	6,13
6	Boiler room designing	8 days	1.2	0.97	18/01/09	18/01/16	5	7,14
7	Tank room designing	6 days	1	0.78	18/01/17	18/01/22	6	8
8	Guard room and restroom designing	1 day	0.4	0.26	18/01/23	18/01/23	7	9
9	Designing of mechanichal installations system	7 days	0.7	0.63	18/01/24	18/01/30	8	10
10	Power supply system designing	7 days	0.7	0.7	18/01/31	18/02/06	9	88,18
11	Procurement	175 days	49.7	49.82	18/01/01	18/06/24		
12	Purchasing construction materials	56 days	8	6.52	18/01/09	18/03/05		
23	Purchasing boiler	175 days	19.5	22.96	18/01/01	18/06/24		
50	Purchasing electrical panel	63 days	12.3	11.07	18/01/20	18/03/23		
65	Purchasing compressed air tank	52 days	9.9	9.27	18/03/24	18/05/14		
86	Construction	149 days	45.27	46.17	18/02/07	18/07/05		
87	Soil operations	16 days	2.7	3.23	18/02/07	18/02/22		
91	Leveling	4 days	1	0.64	18/02/23	18/02/26		
93	Foundation implementation	8 days	4	2.58	18/02/27	18/03/06		
96	Concreting	7 days	4.6	5.46	18/03/07	18/03/13		
99	enclosuring and stone façade	18 days	3.5	2.25	18/03/14	18/03/31		
102	Installation of frames and windows	9 days	1.7	1.09	18/04/01	18/04/09		
105	Piping the installations	40 days	4.6	4.31	18/03/07	18/04/15		
109	Delicate work	33 days	3.4	2.18	18/04/16	18/05/18		
114	Installation of boiler	30 days	5.2	7.82	18/05/17	18/06/15		
118	Installation of electrical panel	15 days	3.1	3.3	18/05/17	18/05/31		
121	Installation of Compressed air tank	14 days	2.5	3.77	18/05/17	18/05/30		
124	Installation of doors	6 days	2.4	1.55	18/06/16	18/06/21		
128	Installation of supplementary tools	6 days	1.4	0.9	18/06/16	18/06/21		
132	Testing and commissioning	14 days	5.17	7.09	18/06/22	18/07/05		
136	End	0 days	0	0	18/07/05	18/07/05	135,49,40,43,37,64,104,113,120,127,22	



4. Results

4.1. Ability to control risk of delays incidence in BASA technique:

The BASA technique was applied to ten different projects Within Three years. The experiences of each project were applied to the next project, with each project delaying a decrease compared to the previous project. This shows that the researchers' innovative approach to managing changes and managing project delay risk is very effective and efficient. See Reduction of Project Delay in Diagram 3.

Compared to similar projects implemented before, the actual project under consideration in the last experiment (Project 10) ended with about 70% less delay. Achieving this result proves effectiveness of using the researcher-made method of managing delay risks as BASA technique.

Note: Always pay attention to project knowledge management, record and review past events, record keeping, information evaluation, data ratings, quantify their importance, utilize expert knowledge in rooting and data analysis, as the best starting road map subsequent projects. Analyzing this information and planning it reduces the likelihood of repetition of past bugs and manages project changes, which directly impacts project risk management and reduces delays.

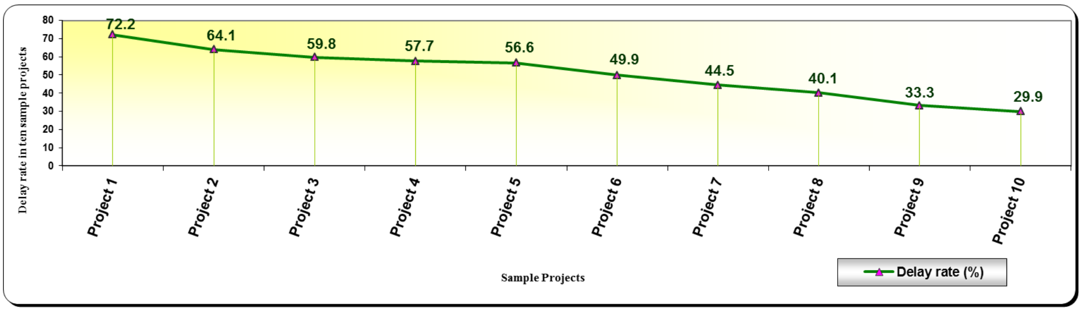


Diagram 3: Results of reducing project delays by applying BASA technique

4.2. Ability to analyze delays based on variance and weight factor in BASA technique:

A. Activities with lower importance degree, lower result-orientation feature and lower prediction of delays risk incidence, if analyzed using BASA technique in terms of their delays, apply lower effective delay impacts on other project activities because without realization of those activities, the project has been put into operation. But using the weight factor, these delays are only calculated according to prolongation of project time and therefore, more delays are calculated and displayed.

B. Activities with higher importance degree, higher result-orientation feature, and higher prediction of delays risk incidence, whose confrontation strategy has also been developed from the beginning of the project, if analyzed using BASA technique in terms of their delays, apply more effective delay impacts on other project activities compared Using the weight factor, because without realization of those activities, the project will not be put into operation and in addition to creation of contractual delay costs, will cause delay in launching the project. Therefore, it is necessary that as much as possible, some part of its costs will be compensated according to the titles of costs mentioned in the research literature. However, using the weight factor, these delays are only calculated according to prolongation of project time and therefore, less delays are calculated and displayed.

As the number of ineffective activities is usually lower than the number of ineffective projects in the project, the advantage of using the BASA technique for delay analysis is greatly enhanced. The proof is clear in the results presented in the Diagram 4 The difference between the results using the weight factorand the BASA technique is the difference between the delay in efficient and ineffective activities and the impact on the project.

To further substantiate their views, the researchers compared the two approaches in ten projects and showed the results of their calculation of penalties for contractual delays in Diagram 5 The difference in the results proves that:

A. Projects At the time of their contract, they usually terminate or terminate most of the main activities associated with the end result.

B. Always the number of ineffective activities is much higher than the efficient ones in projects.

C. The existence of a maximum and maximum delays law for unauthorized delays in contracts allows the BASA technique to create equity between the pillars of the project. For example, the BASA technique in projects 6 and 10, subject to the permissible delays in the contract, exempts the contractor from penalties. Or also in Project 7, this technique provides a penalty ceiling for the contractor (such as projects 6, 7 and 10 in Diagram 5).

D. Extension of some ineffective activities (activities not related to the final outcome of the project) should not cause any loss or bankruptcy to the contractor (such as projects 1, 3, 5, 6, 8, 9 and 10 in Diagram 4).

E. The contractor shall offset the non-profitability of the project due to the prolongation of efficient activities (activities related to the final outcome of the project) (in projects 2, 4 and 7 in Diagram 4).

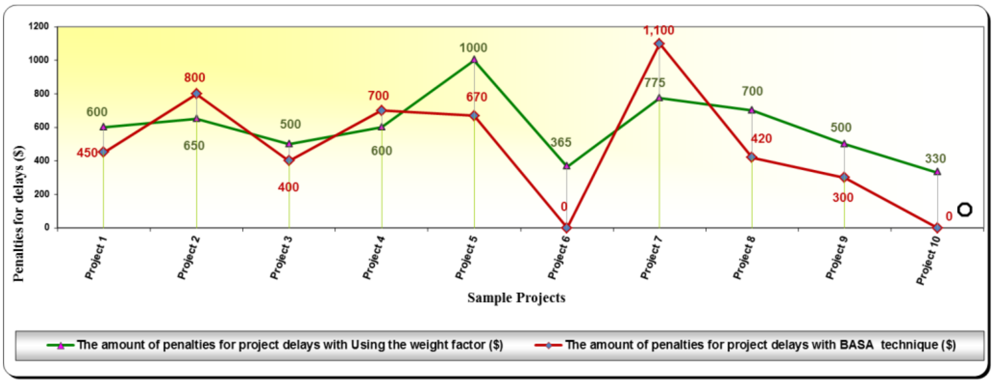


Diagram 4: Comparative chart of project delay penalties

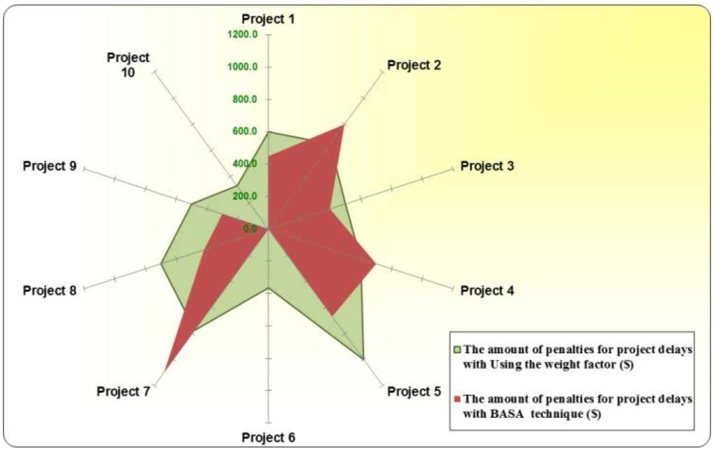


Diagram 5: Radar chart of the effects of the BASA technique on risk management of project delays

5. Discussion and Conclusions

Control is a key tool for management. The higher the level of control, the higher the quality and accuracy can be managed. Also, we know that control, costs significantly. If costs are not controlled, projects will go bankrupt. So to control costs, you have to determine the level of control and manage it. so that we can manage the costs of controlling the projects. So in this study, researchers are trying to make control points as limited as possible so that they can control costs more effectively. To limit, it is necessary to identify high-risk indicators (based on the background and experience of experts), to be technically limited and ranked.

For this purpose, 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. In other words, control costs are applied purposefully and with priority to risk control in projects. 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 standard will be implemented correctly.

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Notes

[1] Data Envelopment Analysis
[2] Constant Return to Scale
[3] Variable Return to Scale
[4] Decision Making Trial And Evaluation
[5] Analytical Hierarchy process
[6] system dynamics Decision Making Trial And Evaluation
[7] Analytical network process
[8] Project risk management (PRM)
[9] Program Evaluation Review Technique
[10] Critical Chain / Project Management
[11] Multiple Risk Level
[12] Society of Construction Law
[13] Microsoft Project
[14] Engineering, procurement, and Construction
[15] Work Breakdown Structure
[16] Decision Making Unit
[17] Charnes, Cooper, and Rhodes
[18] Based on Activity Sensitivity Analysis