Share determination of stakeholder delays, based on targeted delay analysis of projects, with incursive and defensive (In-De) approach

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Vahid Rooholelm and Abbas Sheikh Aboumasoudi
Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran

Abstract

Purpose – Almost all projects in the world are delayed, and sometimes even lead to the full bankruptcy of their beneficiaries. These delays can be calculated using techniques, but most importantly, there must be a fair and realistic division of delays between project beneficiaries. The most valid delay calculation techniques belong to the SCL Global Protocol, but they also have significant drawbacks, such as these: (1) They do not have the capability to prevent project delays (Delay Risk Management); (2) The protocol identifies and introduces any delays in activities with a ratio of one to one as a delay (Effective Delay); (3) It also does not offer the capability to share delays between stakeholders, which is a huge weakness. Floating in the base schedule activities is one of the cost control tools of projects, but it can hide project delays. In this paper, the researchers believe that the floating ownership belongs to the project and not belong to the stakeholders. This is the main tool for analyzing and sharing delays in this research.

Design/methodology/approach – The research methodology adopted included an extensive literature review, expert interviews, use of questionnaire and designing three innovative linked together models by researchers.

Findings – In this research, an integrated technique is introduced which has the following capabilities; delay risk control, result-based delay analysis and stakeholders delay sharing. This technique with an incursive and defensive approach implements claims management principles and calculates, respectively, non-attributable and attributable delays for each beneficiary.

Originality/value – This creativity led to the introduction of the Incursive and Defensive (In-De) technique; in the SCL protocol techniques, none of these capabilities exist.

Keywords Delay risk management, Claim management, Delay analysis, Effective delay, Floating ownership, Share of delays, Incursive and defensive (In-De)

Paper type Research paper

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 (Chou and Yang, 2017). 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 (Yazeed *et al.*, 2018). 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 re-implementation 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

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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, and thus cannot be generalized. Case studies could be conducted to establish the challenges involved in implementing the proposed framework (Qazi and Irem, 2019).

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 (Hiva *et al.*, 2018).

Today, most developed and developing countries, being aware of limited resources available and existence of highly competitive market, seek to find the root and causes of delay in previous projects in order to make optimal use of resources and gain more profit, so that by proposing strategies, they can reduce delays in future projects or, by finding out the guilty of project delays, they can take action to receive penalty from them. In this regard, employers are seeking to find delay reasons so that they can calculate the losses and delay penalties for contractors, as well as to have proper estimates of the amount of additional imposed costs. Contractors also seek to justify their delays and shirk from payment of penalties; or in cases where failure by the employer for timely fulfillment of obligations has caused losses for the contractors they seek to develop claims for receiving delay penalty from the employers. The result of this analysis is very decisive for both parties (Marziyeh and Hossein, 2016).

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. Therefore, considering the results of researches by other researchers, the researcher's study on the four most commonly used SCL protocol techniques and the ongoing professional activity by the researcher in this regard, which has led to investigation and completion over 300 delay protocols in PC [1], EPC [2] and EPCF [3] projects, 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, which makes this study necessary.

1.1 Describe the research problem

(1) As the ISO 9000 standard says, preventive, corrective action-and as we do in the ISO 45000 standards, first safety after work–and other examples; in delay analysis techniques you must first have a mechanism to prevent delays. The project should be there and then the discussion of delay analysis should be raised. SCL protocol techniques did not take this into account.

(2) Identifies and introduces any delays in activities with a ratio of one to one as a delay (Delay Effect). In other words, minor components in the project that sometimes do not have any role in start of project operation may still not be completed and cause that

passage of any one day more than the contract time will delay the whole project for one day. SCL protocol techniques did not take this into account.

(3) The main topic of calculating the project delay penalty is how it is distributed among the project beneficiaries. Usually none of them are to blame. So in these dangerous situations, it is very important to calculate the share of the delay of each stakeholder in a scientific and computational way and to convince him. SCL protocol techniques did not take this into account.

1.2 Objective

Executives 'experiences and studies in the field of project management have proven that the buoyancy in the timetable often conceals delays and mixes with stakeholders' failure to create project delays. Which stakeholders should use those vessels? Naturally, the beneficiary who has more to do and is more delayed than others will automatically advance the start date of others sooner than others! However, this is not fair.

Researchers have developed an innovative integrated technique that draws on risk delays, performs project delays analysis based on an incursive and defensive approach, and calculates project delays based on achieving the project's primary goal, based on their experience. It also calculates the share of delays based on the results of incursive and defensive [4] delays by identifying the main causes of delays for each stakeholder. The researchers named this integrated technique incursive and defensive (In-De) which presented realistic results, which we will explain below. In this researcher-made technique, firstly, high risk delay factors are identified, efficiency of occurrence of those factors is determined, importance degree of project activities is determined with a result-oriented attitude, a strategy for confronting occurrence of delays is developed based on risk of delays, and ultimately, delays of projects are calculated based on result-orientation of their activities. Delay calculations are performed using an aggressive and defensive approach that is also the basis for calculating project stakeholder delays.

1.3 Application

This technique applies to all projects that have a schedule, such as PC, EPC, EPCF, $EPCF^{+}$, Services, and Supervision Projects.

2. Literature

2.1 Research literature important

In the article on construction delay risk taxonomy, associations and regional contexts, to systematically develop a delay risk terminology and taxonomy been investigated. This research also explores two external and internal dimensions of the taxonomy to determine how much the taxonomy as a whole or combinations of its elements are generalizable. In total, 26 delay risks were identified and grouped into ten categories to form the risk breakdown structure. The universal delay risks and other delay risks that are more or less depending on the project location were determined. Also, it is realized that delays connected to equipment, sub-contractors and design drawings are highly connected to project planning, finance and owner slow decision-making, respectively (Derakhshanfar *et al.*, 2019). In an article entitled "The Project Strategy Matrix Systematizing the Design and Management of an Explicit Project Strategy," to guide the balanced mixture of profound thought and coherent actions that are required in effectively establishing a project's specific course of action; as important input to the process of devising and controlling a project's execution plan; and as a valuable means to consistently communicate a project's key decisions so that to drive project-wise alignment and reduce uncertainty in operational decision-making. Senior leaders can use it as a straightforward tool, e.g., at project kick-off, steering committee, and progress meetings, to proactively identify and act on key project aspects that require senior management attention. In general, the results of applying the project strategy matrix in real projects, based on an empirical, qualitative approach, are very encouraging in what concerns its applicability and its capacity to provide value and drive observable improvements. Finally, our findings guide us to call for an intensification of research on project strategy (Koutsoukos, 2019).

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 goals dictate the activities to be implemented and the activities and barriers combined inform the competencies to be included in a PRM [5] maturity model. Examination of the goals, activities and barriers has permitted the construction of a model which proposes five levels of maturity, nine 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, 2019).

In this study different professionals from different positions and organizations were targeted to guarantee the diversity of the responses which helps giving a general and better view of the data. The collected responses were analyzed using the average, standard deviation, relative importance index, frequency index, and the frequency adjusted importance index. The output of the mathematical analyses has revealed that the top causes of delay in terms of frequency and importance are difficulties in financing project by contractor/manufacturer, late procurement of materials, late delivery of materials, delay in progress payments, and slowness in decision-making. This paper has focused on industrial projects where manufacturing process is involved and that is a point of research that is not heavily revealed in the literature. Most studies focus on the causes of delay in the construction and building projects. That is another key point that makes this research more valuable (Hussein and Adel, 2019). Article titled "Improving Risk Evaluation in FMEA with Cloud Model and Hierarchical TOPSIS Method," a new integrated risk priority model, called cloud hierarchical TOPSIS, is developed to identify and evaluate failure modes in FMEA, where the cloud model is used for modeling the uncertainty of linguistic assessments of FMEA team members and the hierarchical TOPSIS is extended to obtain the risk priority of the individuated failure modes. The proposed risk priority approach provides a structured and systematic framework for the risk evaluation of failure modes and overcomes the weaknesses of the traditional FMEA. Moreover, the proposed model could make an adequate reflection of the importance associated with each FMEA team member considering the knowledge and experience of experts. Finally, two practical cases are presented to demonstrate the proposed FMEA and the results are compared with existing methods. It was showed that the risk priority model developed in this study is more flexible, practical and effective to evaluate and rank the risk of failure modes under uncertain context (Liu *et al.*, 2018).

Given the large number of complicated problems caused by delays incidence in projects, it is necessary to identify their emergence factors, analyze their reasons, calculate the share of each project stakeholder's failure, and share the losses and delay penalties among them (Keane and Caletka, 2015). 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 five 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. As 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 and Gul, 2017).

Findings of the article "Future of Economic Decision Making in Project Management" highlight the importance of economic decision-making and project management throughout all aspects of an organization. Economic decision-making and project management is one element in an organization's business model, but this study shows that the economic decision-making and project management relationship element directly impacts many other elements of an organization. This study has shown that many of the current-state issues seen within an organization's economic decision-making and project management stemmed from the leadership's lack of effectively leading and managing their employees and operational issues. Leadership needs the tools and knowledge to manage their economic decision-making and project management effectively, rather than focusing on the bottom line (i.e. profits and costs). Thus, the performance of an organization will improve and, as a result, the profits and costs will also improve (J. Galli, 2018). 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, and 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 *et al.*, 2019). In the article, hybrid SD-DEMATEL 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 and Shoar, 2017). A claim is a request proposed by one contract party for some essentially correct or correct according to the requestor, reasons, which has often occurred due to actions, orders, and changes applied inconsistent with provisions of the contract and cannot be resolved economically between the parties (PMI, 2018).

The most important part of analysis of delays is to choose the right method for it based on contractual terms. The scheduling plan is the basis of delay analysis but the scheduling plan is representative of realities of the project, not the realities themselves as projects include many unpredictable events. Thus, in order for delay analysis it is necessary to have information about the lowest level of organization in addition to the initial and actual scheduling plan of the project (Keane and Caletka, 2015). Main causes of delay Portuguese country construction industry are slow decision-making, changes to orders, unrealistic timescales and poor contract specifications, financial constraints on the contractor and the type of bidding and contract award process. The main impacts are time and cost overruns and disputes. Factor analysis revealed eight high-level causes that result in 26 of the original causes. Finally, Pearson correlation coefficients were calculated to find the relationship between the extracted factors (latent causes) and impacts, revealing that lack of commitment and substandard contracts are positively correlated with all impacts, and poor consultant performance is negatively correlated with time overrun. These findings are expected to improve the scientific community's knowledge of construction management (Arantes *et al.*, 2015). Claim management is a process that attempts to eliminate or prevent claims, or if they occur, reacts to them (PMBOK, 2017).

In the article "Appropriate Delay Analysis Techniques to Analyses Delays in Road Construction Projects in Sri Lanka," data analysis techniques (DATs) had been used only in 87.5% of the delayed projects. The "As-Planned v. As-Built" method was the mostly used DAT. The comprehensive literature revealed that the time taken for the analysis, cost and inputs required from experts, complexity, reliability, accuracy and acceptability to tribunals and courts, acceptability to the parties to the contract and workability are criteria used globally in selecting the most appropriate DAT for a given project. In Sri Lanka, time taken for the analysis, cost, inputs required from the experts, complexity, reliability, accuracy and acceptability to the tribunals and courts, acceptability to the parties to the contract and workability are the important criteria used. The most important criterion was the "Acceptability to tribunals and courts" while "cost" and "time" were found to be the least important criteria. "Window Analysis" followed by "Time Impact Analysis" were found to be the two most appropriate DATs. "As-planned v. As-built" method had the least OSS although it was the most used method. The literature survey revealed that "Collapse as Built" and "Window Analysis" are the techniques used most in other countries. The findings of the research revealed that the local contractors prefer to use the "As-planned vs. As built" method in analyzing delays in road construction projects mainly because of its simplicity and inexpensiveness. As a result, the prioritization of the techniques is as follows: (1) As-planned vs. As-built; (2) Impacted as Planned; (3) Time Impact Analysis; (4) Collapsed as Built; and (5) Window Analysis (Ekanayake and Perera, 2016).

Use of non-conforming analysis for delay or computational errors leads to emergence of irrecoverable factors for stakeholders and the project, where, creation of a specialized structure and mechanism, development of new technical methods and instructions are necessary to solve these problems (Yazeed *et al.*, 2018). In the article Causes of delays in construction industry and comparative delay analysis techniques with SCL 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 *et al.*, 2018). Two definitions have been presented about risk management: (1) 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 (PMBOK, 2017); (2) Uncertainty and unawareness about the result of an act (Fereydoun and Vahid, 2016).

Given that over 70% of projects are not delivered in a timely manner because of various reasons, so, there is need for improved and realistic methods for examination of unfair claims by parties and better understanding of how to calculate share in delays (Tabassum *et al.*, 2018). About 80% of public projects and 66.7% of private projects in Malaysia face significant delays that resolving of them always cause dispute between parties to the project. The obtained results show that the existing techniques of delay analysis are different from each other, inadequate and unrealistic, which are not generally accepted by the parties to the dispute (Ramli, 2017). None of the existing delay analysis techniques is adequate as required and does not convince parties to the project in terms of fair calculation of delays, sharing them among project stakeholders and adapting the obtained results to realities (Chou and Yang, 2017). 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 (Ramli, 2017). 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:

(1) Costs for getting expensive of non-renewable resources (equipment and materials to be purchased)

(2) Increased cost of renewable or working resources (human force and machinery)

(3) Costs of continued design and engineering services

(4) Headquarters overhead costs (rental of office, salary and mission, office equipment of the headquarters, etc.)

(5) Efficiency cost, opportunity cost or lost profit

(6) Utilization delay cost or lost profits

(7) Costs for project inspection during the unauthorized delay time

(8) Costs for maintaining current facilities during the unauthorized delay time

(9) Costs for extension of licenses and agreements

(10) Supply cost and cost of interest capital expenditures

(11) Interest cost arising from project financing (loans, borrowing)

(12) Loss due to losing competition market

(13) Becoming the uneconomic project

(14) Lack of employment in the country

(15) Reduced government revenue and social welfare of people

(16) Escalation costs (Rooholelm and Rashidi, 2019).

In an article entitled Understanding project management directions from project management trends, They have achieved some interesting results Projects are becoming more complex and project managers should actively tailor methods that they deem fit to suit their needs at work. Having access to this knowledge is essential, for example which tool is best for what purpose and how to use them is important (Ng, 2019). 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 (Si *et al.*, 2018).

2.2 Summary of previous research results

(1) In the area of risk management, previous researchers have only focused on identifying the risk factors for project delays. They have been identified and listed, and in some cases they have been ranked by pairwise and hierarchical comparison techniques.

(2) Techniques of analysis have introduced valid and invalid delays, tested them in different projects, compared them, and examined their strengths and weaknesses.

(3) The stakeholders have not paid attention to sharing project delays. While this is much more important than calculating overall project delays, it is always the site of major disagreements among stakeholders.

2.3 Solving problems with researchers' innovations

Researchers performed an innovative incursive and defensive approach, managing project changes and delays, analyzing project delays with the goal realization approach, and ultimately determining the share of delinquent and non-attributable delays to each project beneficiary.

3. Research method

The original idea of this research was formed due to the lack of a solution to share project delays among its stakeholders in the SCL protocol. The SCL Protocol is a valid and widely used protocol for projects globally. Researchers have used delay analysis techniques for many years to discover deficiencies. Solving these deficiencies is the subject of this research, as follows:

(1) In delay analysis techniques you must first have a mechanism to prevent delays. The project should be there and then the discussion of delay analysis should be raised. SCL protocol techniques did not take this into account.

(2) Identifies and introduces any delays in activities with a ratio of one to one as a delay (Delay Effect). In other words, minor components in the project that sometimes do not have any role in start of project operation may still not be completed and cause that passage of any one day more than the contract time will delay the whole project for one day. SCL protocol techniques did not take this into account.

(3) The main topic of calculating the project delay penalty is how it is distributed among the project beneficiaries. Usually none of them are to blame. So in these dangerous situations, it is very important to calculate the share of the delay of each stakeholder

in a scientific and computational way and to convince him. SCL protocol techniques did not take this into account.

The researchers then integrated a strategy to manage the risk of project delays, and also deliberately calculated and analyzed project delays. The researchers call this unified innovation the incursive defensive (In-De) technique naming. Following is a flowchart presenting the implementation steps of this innovative technique. The researchers implemented their integrated technique for the first time in a refinery project. Results will be presented step by step in this section (see Figure 1).

3.1 Flowchart performing the (In-De) technique

3.2 To carry out this technique and achieve results, the stages of doing this work are as follows (According to Figure 1).

3.2.1 Step 1: Formation of a team of experts. Selection of a team of academic and industrial experts. These experts will be with the researchers at various stages of implementation of this innovative technique.

3.2.2 Step 2: Identification of delays incidence factors (Initial). The number of these indicators was two hundred and ten. Due to the long list of indicators, we will display the selected indicators (most important ones) in the next step.

3.2.3 Step 3: Achieving to selected delay factors (Secondary). The researcher by using the team of experts, conducting interviews and brainstorming, has presented 50 delay causes as the selected factors (Secondary) in creation of specific delays and has presented them in the form of Table 1.

3.2.4 Step 4: Selection of ultimate effective causes of occurrence of delays. 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 method (Andrzej, 2017). Accordingly, the researcher collected the experts' opinions about intensity of the impact of relationships between delay causes with a 5 point scale (0–4) and by questionnaire method, and entered them into DEMATEL method according to matrix $n \times n$ (50×50) analyzed. The final influential delay factors of the project were extracted as is shown in Figure 2 and Table 2.

3.2.5 Step 5: Weight factor. Weight factor is the value share of each activity in the whole project and shows the impact of realization of that activity on advancement of the whole project. Various types of introduced weight factors include time weight factor, cost weight factor, weight factor of workload, and combined weight factor. Sum of these weights resulted from all individual project activities is equal to 100 or a multiple of 100. The primary goal of providing a weight factor is considering higher weight for more important activities and its secondary goal is determining the amount of actual and planned work done in projects (Mulcahy *et al.*, 2016).

3.2.6 Step 6: 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 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 "Project for designing, supply, and implementation of power plant boiler house" as EPC. He has prepares this project in the form of 136 activities and sub-activities, time duration of

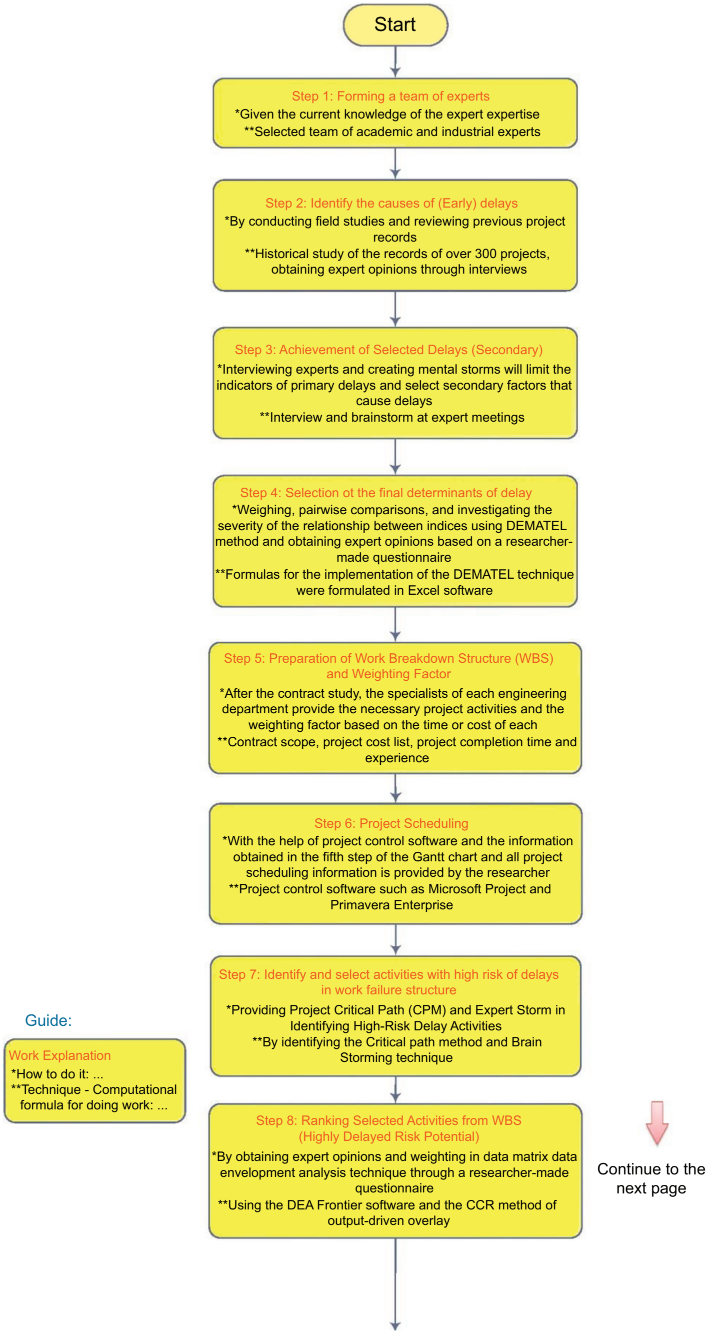


Figure 1.
Flowchart performing the (In-De) technique

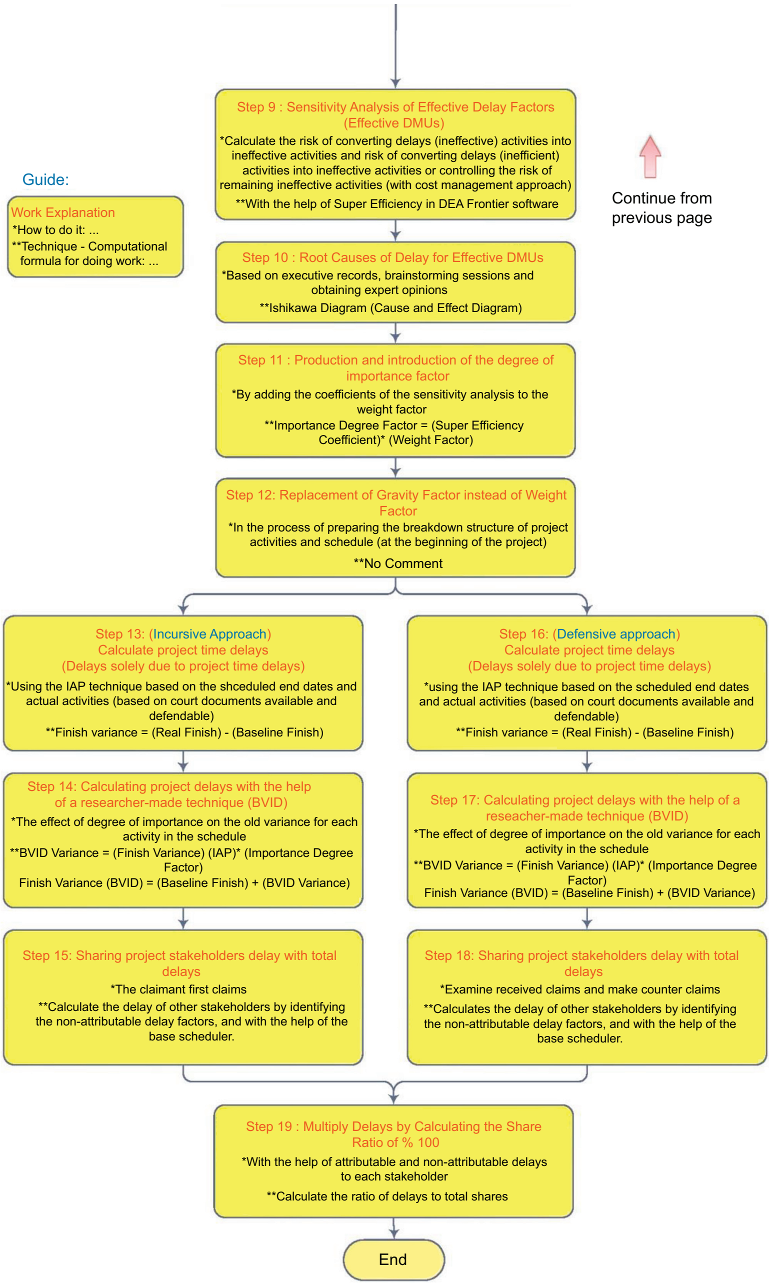

Guide:
Work Explanation
*How to do it: ...
**Technique - Computational formula for doing work: ...
Continue from previous page
Step 9 : Sensitivity Analysis of Effective Delay Factors (Effective DMUs)
*Calculate the risk of converting delays (ineffective) activities into ineffective activities and risk of converting delays (inefficient) activities into ineffective activities or controlling the risk of remaining ineffective activities (with cost management approach)
**With the help of Super Efficiency in DEA Frontier software
Step 10 : Root Causes of Delay for Effective DMUs
*Based on executive records, brainstorming sessions and obtaining expert opinions
**Ishikawa Diagram (Cause and Effect Diagram)
Step 11 : Production and introduction of the degree of importance factor
*By adding the coefficients of the sensitivity analysis to the weight factor
**Importance Degree Factor = (Super Efficiency Coefficient)* (Weight Factor)
Step 12: Replacement of Gravity Factor instead of Weight Factor
*In the process of preparing the breakdown structure of project activities and schedule (at the beginning of the project)
**No Comment
Step 13: (Incursive Approach)
Calculate project time delays
(Delays solely due to project time delays)
*Using the IAP technique based on the shceduled end dates and actual activities (based on court documents available and defendable)
**Finish variance = (Real Finish) - (Baseline Finish)
Step 14: Calculating project delays with the help of a researcher-made technique (BVID)
*The effect of degree of importance on the old variance for each activity in the schedule
**BVID Variance = (Finish Variance) (IAP)* (Importance Degree Factor)
Finish Variance (BVID) = (Baseline Finish) + (BVID Variance)
Step 15: Sharing project stakeholders delay with total delays
*The claimant first claims
**Calculate the delay of other stakeholders by identifying the non-attributable delay factors, and with the help of the base scheduler.
Step 16: (Defensive approach)
Calculate project time delays
(Delays solely due to project time delays)
*using the IAP technique based on the scheduled end dates and actual activities (based on court documents available and defendable)
**Finish variance = (Real Finish) - (Baseline Finish)
Step 17: Calculating project delays with the help of a reseacher-made technique (BVID)
*The effect of degree of importance on the old variance for each activity in the schedule
**BVID Variance = (Finish Variance) (IAP)* (Importance Degree Factor)
Finish Variance (BVID) = (Baseline Finish) + (BVID Variance)
Step 18: Sharing project stakeholders delay with total delays
*Examine received claims and make counter claims
**Calculates the delay of other stakeholders by identifying the non-attributable delay factors, and with the help of the base scheduler.
Step 19 : Multiply Delays by Calculating the Share Ratio of % 100
*With the help of attributable and non-attributable delays to each stakeholder
**Calculate the ratio of delays to total shares
End

Figure 1.

Table 1.
Selected delay factors (Secondary)

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

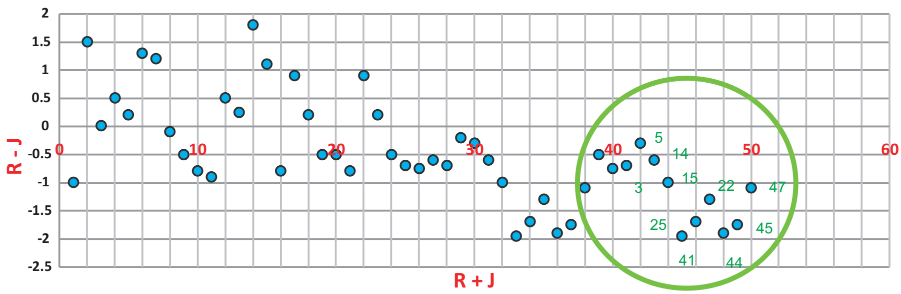


Figure 2.
Final selected influential causes of delay

186 days (from 01.01.2018 to 05.07.2018) and total weight factor of 5% engineering phase, 49.7% supply phase and 45.3% implementation phase, and has put it as the basis of his research. 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.

3.2.7 Step 7: Identification and selection of activities with high risk of delays incidence from work breakdown structure (WBS). Critical path is the set of activities in the scheduling plan that do not have floating and must necessarily begin and end on a given date. Any kind of delay in activities of this path results in an equal delay in achieving general goal of the project. Therefore, this path is a completely strategic path for the project and project manager and needs to be carefully controlled. 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 4.

3.2.8 Step 8: 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:

(1) Converting qualitative factors to quantitative ones in numerical measurement.

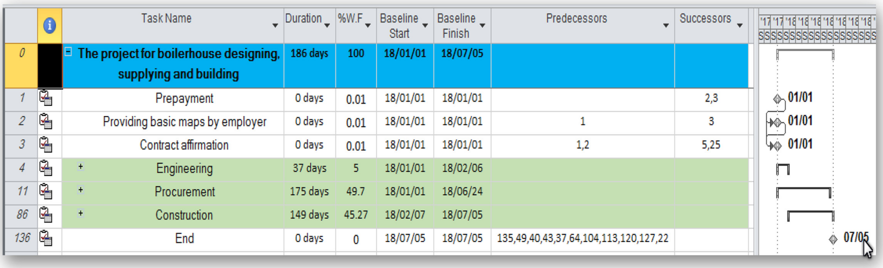
(2) Weighting and ranking decision-making units and selecting the best scenarios.

(3) Comparing inefficient scenarios with efficient ones and identifying causes of inefficiency in order to eliminate them.

(4) Considering decision units as Black Box and evaluating them regardless of their internal performance.

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

Table 2. Final selected influential causes of delay



	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	

Table 3. Level 2 of the base scheduling plan

W.F (%)	Task name	Activity code	W.F (%)	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 Desirer 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

Table 4.
Selected activities of WBS to identify DMUs

(5) Considering decision units as White Box and evaluating them according to their internal performance.

(6) Ranking positive ideal decision units according to the related weights (Aboumasoudi, 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 (Alireza and Kavous, 2013). At this stage, it is required to determine the number of DMUs needed for entering ranking stage, which is obtained through the following equations:

(Number of outputs + Number of inputs) 3 $\leq$ Number of candid activities to determine efficiency

According to the number of inputs (4 inputs) and the number of outputs (6 outputs) and using the above defined equation (first equation), we have: $(4 + 6)\,3 = 30$

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 5.

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.

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.

3.2.9 Step 9: 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.

3.2.10 Step 10: 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 expert's 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 AC27 are presented in the form of Figure 3.

3.2.11 Step 11: Production and introduction of importance degree factor (IDF). 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 (discussed in fifth step), 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 IDF 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.

Table 5.
Data entry in DEA Frontier software

	Delay factors main effective									
	1	2	3	4	5	6	7	8	9	10
	Input (v)						Output (u)			
Activity code	Economic stability v1(1~4)	Accuracy in initial identification of project activities v2(1~4)	Access to mechanism v3(1~4)	Technological level of project v7(1~4)	Changes in plan u1 (1~10)	Economic restrictions u1(1~10)	Delay in confirmation of maps u2(1~10)	Prolongation of acquiring legal allowances u3(1~10)	Outdated working methods u4(1 ~10)	Novelty of project typ[e] 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

(continued)

Table 5.

	Delay factors main effective									
	1	2	3	4	5	6	7	8	9	10
	Input (v)						Output (u)			
Activity code	Economic stability v1(1~4)	Accuracy in initial identification of project activities v2(1~4)	Access to mechanism v3(1~4)	Technological level of project v7(1~4)	Changes in plan u1 (1~10)	Economic restrictions u1(1~10)	Delay in confirmation of maps u2(1~10)	Prolongation of acquiring legal allowances u3(1~10)	Outdated working methods u4(1 ~10)	Novelty of project typ[e] u5(1~10)
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

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

$$\text{Importance degree factor} = (\text{Weight factor})/(\text{Super efficiency coefficient})$$

Result: By comparing the results obtained in weight factor and importance degree factor columns (based on 100) for efficient DMUs, there is only a significant upward trend (such as, AC15, in which weight factor of 1.2 has been converted into importance degree factor of 3.1), but in the case of inefficient DMUs, according to the results obtained from Super Efficiency Coefficient, we mostly seen a decreasing trend and, in some cases, a slight increase (such as AC2 in which weight factor of 1 has decreased to importance degree factor of 0.78).

3.2.12 Step 12: Replacement of IDF [6] instead of WF in the scheduling plan. In the researcher-made technique, it is required to replace WF by IDF in the base scheduling plan. From now on, the scheduling plan is equipped with IDF; values of physical progress of the project (planned and actual) based on IDF of activities, as well as their risk taking and risk aversion are calculated and the required ground for controlling risk of project delays by the manager and decision maker of the project is provided that the results are presented in Table 10.

3.2.13 Step 13: (With Incursive approach) calculation of project time delays by impacted as-planned (IAP) technique. In connection with the science of delay analysis, there are six valid techniques in the SCL global protocol that these techniques, There are four commonly used methods is; IAP [7], CAB [8], APAB [9] and TIA [10].

The researcher has used Impacted As-Planned (IAP) technique in order to conduct delay analysis in his case study. The most important reasons for use of this technique include:

(1) It analyzes the delays based on CPM.

(2) It acts based on scheduling plan and influenced by risky events of project stakeholders.

(3) It has the lowest number of variables and is the simplest form of examination of delay analysis.

(4) It uses Impacted as Planned (IAP) technique in order to identify production delays.

(5) It can specify Concurrency Approximate in order to evaluate simultaneous delays and the right to extend time.

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	

Table 7. Benchmark of inefficient projects

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**	**Attemprator Desirer Heater**	**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

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

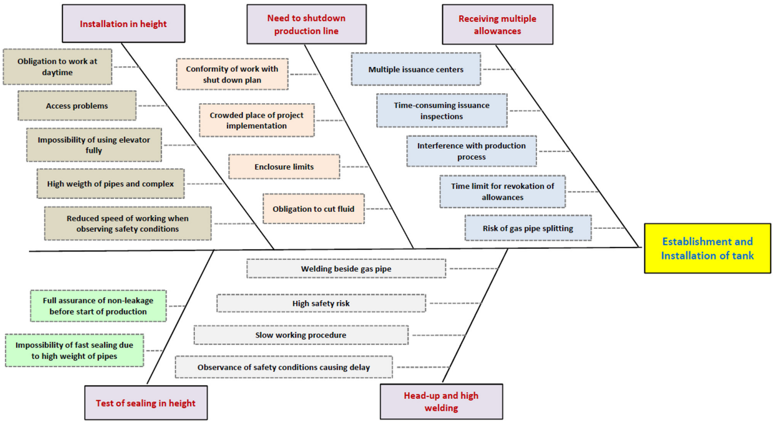


Figure 3.
Finding the root of causes of delay efficient DMU number AC27 through brainstorming of experts' team

(6) It can be conducted based on actual records and documents that rely on scheduling plans.

(7) It has the ability to display delays of future events (Society of Constriction LAW Delay and Disruption Protocol, 2017).

In this regard, for efficient DMUs (activities with high risk of delays and result-oriented) as well as inefficient DMUs (activities with low risk of delays or without risk of delays and also having low result-orientation feature or not result-oriented), delay analysis has been done using IAP method and its delays are presented in "Finish Variance" column in Tables 11 and 12, respectively. It should be remembered that this technique, without the feature of identification and control of risk of delays, calculates delays only on the basis of prolongation of time duration of finishing the activity and with the same ratio.

The researcher-made technique can be used in analysis of delays through the six techniques of SCL Global Protocol that is introduced in the operational phase as a model, by forming a combination. In this regard, given the comparability of the results of IAP technique with based on variance and Importance Degree (BVID) technique, the results of case study are presented as simultaneous comparison in the following.

3.2.14 Step 14: Difference with other global techniques: calculation of project delays through researcher-made BVID [11]technique. After calculating project delays using IAP technique, values of time delays that are presented in "Finish Variance" column, using the following formula, are influenced by the combinative factor of risk and importance degree, and the result is transferred to "Actual Finish" column. At this stage, the software adjusts values of project delays contained in "Finish Variance" column and the result-oriented delays are obtained.

$$\text{BVID variance} = (\text{Finish variance})\ (\text{IAP}) * (\text{Importance degree factor})$$

$$\text{Finish variance (BVID)} = (\text{Baseline finish}) + (\text{BVID variance})$$

At this stage, for efficient DMUs (having high risk of delay and result-oriented activities) as well as inefficient DMUs (activities with low risk of delays or without risk of delays and also having low result-orientation feature or not result-oriented), delay analysis is done using the researcher-made BVID technique and in the form of MSP software, and its results are

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%
		Refinery Project - EPC Project			**100.0**	**435.1**	**47.11**	**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	Attemprator Desirer Heat	*	**	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
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

Table 9.
Production and introduction of Importance degree factor

presented in "Finish variance" column in Tables 13 and 14, respectively, which can be compared to the results in Tables 11 and 12.

Important note: We have fully described the incursive method. This method uses the beneficiary who initiates the claim. In his claim, he mainly says that I am not responsible for project delays.This is done by including non-delayed items in the base program. The defensive approach is used in response to the offensive. Insert delayed items attributed to the claim initiator in the base program and calculate the attributed delays. The defensive approach is similar to the offensive one, except that we replace the attributed delay items with the non-attributable delay items and repeat the calculations that were not mentioned in the article

4. Analysis of findings

At this stage, researcher-made technique BVID, with Incursive and Defensive Approach and different combinations of low-risk and not result-oriented (inefficient) DMUs, is compared to

	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	

Table 10.
Replacement of IDF instead of W.F in the base scheduling plan

	Task Name	Duration	%W.F	Baseline Start	Start	Baseline Finish	Finish	Predecessors	Successors	Constraint Date	Finish Variance
0	**The project for boilerhouse designing, supplying and building**	**260 days**	**100**	**18/01/01**	**18/01/01**	**18/07/05**	**18/09/17**			**NA**	**74 days**
1	Prepayment	0 days	0.01	18/01/01	18/01/01	18/01/01	18/01/01		2,3	NA	0 days
2	Providing basic maps by employer	0 days	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1	3	NA	0 days
3	Contract affirmation	0 days	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1,2	5,25	NA	0 days
4	Engineering	37 days	5	18/01/01	18/01/01	18/02/06	18/02/06			NA	0 days
11	Procurement	175 days	49.7	18/01/01	18/01/01	18/06/24	18/06/24			NA	0 days
12	Purchasing construction materials	56 days	8	18/01/09	18/01/09	18/03/05	18/03/05			NA	0 days
23	Purchasing boiler	175 days	19.5	18/01/01	18/01/01	18/06/24	18/06/24			NA	0 days
50	Purchasing electrical panel	63 days	12.3	18/01/20	18/01/20	18/03/23	18/03/23			NA	0 days
65	Purchasing compressed air tank	52 days	9.9	18/03/24	18/03/24	18/05/14	18/05/14			NA	0 days
86	Construction	223 days	45.27	18/02/07	18/02/07	18/07/05	18/09/17			NA	74 days
87	Soil operations	16 days	2.7	18/02/07	18/02/07	18/02/22	18/02/22			NA	0 days
91	Leveling	4 days	1	18/02/23	18/02/23	18/02/26	18/02/26			NA	0 days
93	Foundation implementation	8 days	4	18/02/27	18/02/27	18/03/06	18/03/06			NA	0 days
96	Concreting	7 days	4.6	18/03/07	18/03/07	18/03/13	18/03/13			NA	0 days
99	enclosuring and stone façade	18 days	3.5	18/03/14	18/03/14	18/03/31	18/03/31			NA	0 days
102	Installation of frames and windows	9 days	1.7	18/04/01	18/04/01	18/04/09	18/04/09			NA	0 days
105	Piping the installations	40 days	4.6	18/03/07	18/03/07	18/04/15	18/04/15			NA	0 days
109	Delicate work	33 days	3.4	18/04/16	18/04/16	18/05/18	18/05/18			NA	0 days
114	Installation of boiler	30 days	5.2	18/05/17	18/05/17	18/06/15	18/06/15			NA	0 days
118	Installation of electrical panel	15 days	3.1	18/05/17	18/05/17	18/05/31	18/05/31			NA	0 days
121	Installation of Compressed air tank	14 days	2.5	18/05/17	18/05/17	18/05/30	18/05/30			NA	0 days
124	Installation of doors	67 days	2.4	18/06/16	18/06/16	18/06/21	18/08/21			NA	61 days
128	Installation of supplementary tools	80 days	1.4	18/06/16	18/06/16	18/06/21	18/09/03			NA	74 days
132	Testing and commissioning	14 days	5.17	18/06/22	18/09/04	18/07/05	18/09/17			NA	74 days
136	End	0 days	0	18/07/05	18/09/17	18/07/05	18/09/17	ɜ,37,64,104,113,		NA	74 days
137	**Delay Items**	**13 days**	**0**	**NA**	**18/08/21**	**NA**	**18/09/03**			**NA**	**0 days**
138	Out-of-time responding to correspondences (prescribed or standard)	0 days	0	NA	18/08/21	NA	18/08/21		127	18/08/21	0 days
139	Out-of-time decision making	0 days	0	NA	18/09/03	NA	18/09/03		131	18/09/03	0 days

Table 11.
(With incursive approach) Delays analysis using IAP technique for inefficient DMUs of project (Without risk of delays and not result-oriented activities of the project)

the results of IAP technique, and the results are summarized in Tables 15 and 16. Also, at this stage, researcher-made technique BVID, With Incursive and Defensive Approach and different combinations of low-risk and not result-oriented (efficient) DMUs, is compared to the results of IAP technique, and the results are summarized in Tables 18 and 19. Then, stakeholder delay share calculations for inefficient and efficient delay factors have been calculated, the results of which are presented in Tables 17 and 20 respectively.

4.1 For DMUs and activities with low risk of delays and not result-oriented nature (Inefficient)

4.1.1 With incursive approach. **Sensitivity analysis:* In Table 15, two inefficient activities in the assumed project with numbers ID127 and ID131 were delayed. The results of delay

Table 12. (With incursive approach) Delay analysis using IAP technique for efficient DMUs of project (Having high risk of delays and result-oriented activities)

	Task Name	Duration	%W.F	Baseline Start	Start	Baseline Finish	Finish	Predecessors	Successors	Finish Variance	Gantt
0	**The project for boilerhouse designing, supplying and building**	**218 days**	**100**	**18/01/01**	**18/01/01**	**18/07/05**	**18/08/06**			**32 days**	
1	Prepayment	0 days	0.01	18/01/01	18/01/01	18/01/01	18/01/01		2,3	0 days	01/01
2	Providing basic maps by employer	0 days	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1	3	0 days	01/01
3	Contract affirmation	0 days	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1,2	5,25	0 days	01/01
4	+ Engineering	37 days	5	18/01/01	18/01/01	18/02/06	18/02/06			0 days	
11	− Procurement	203 days	49.7	18/01/01	18/01/01	18/06/24	18/07/22			28 days	
12	+ Purchasing construction materials	56 days	8	18/01/09	18/01/09	18/03/05	18/03/05			0 days	
23	+ Purchasing boiler	203 days	19.5	18/01/01	18/01/01	18/06/24	18/07/22			28 days	
50	+ Purchasing electrical panel	63 days	12.3	18/01/20	18/01/20	18/03/23	18/03/23			0 days	
65	+ Purchasing compressed air tank	75 days	9.9	18/03/24	18/03/24	18/05/14	18/06/06			23 days	
86	− Construction	149 days	45.27	18/02/07	18/03/11	18/07/05	18/08/06			32 days	
87	+ Soil operations	16 days	2.7	18/02/07	18/03/11	18/02/22	18/03/26			32 days	
91	+ Leveling	4 days	1	18/02/23	18/03/27	18/02/26	18/03/30			32 days	
93	+ Foundation implementation	8 days	4	18/02/27	18/03/31	18/03/06	18/04/07			32 days	
96	+ Concreting	7 days	4.6	18/03/07	18/04/08	18/03/13	18/04/14			32 days	
99	+ enclosuring and stone façade	18 days	3.5	18/03/14	18/04/15	18/03/31	18/05/02			32 days	
102	+ Installation of frames and windows	9 days	1.7	18/04/01	18/05/03	18/04/09	18/05/11			32 days	
105	+ Piping the installations	40 days	4.6	18/03/07	18/04/08	18/04/15	18/05/17			32 days	
109	+ Delicate work	33 days	3.4	18/04/16	18/05/18	18/05/18	18/06/19			32 days	
114	+ Installation of boiler	30 days	5.2	18/05/17	18/06/18	18/06/15	18/07/17			32 days	
118	+ Installation of electrical panel	15 days	3.1	18/05/17	18/06/18	18/05/31	18/07/02			32 days	
121	+ Installation of Compressed air tank	14 days	2.5	18/05/17	18/06/18	18/05/30	18/07/01			32 days	
124	+ Installation of doors	6 days	2.4	18/06/16	18/07/18	18/06/21	18/07/23			32 days	
128	+ Installation of supplementary tools	6 days	1.4	18/06/16	18/07/18	18/06/21	18/07/23			32 days	
132	+ Testing and commissioning	14 days	5.17	18/06/22	18/07/24	18/07/05	18/08/06			32 days	
136	End	0 days	0	18/07/05	18/08/06	18/07/05	18/08/06	‑3,37,64,104,113,		32 days	08/06
137	− **Delay Items**	**71 days**	**0**	**NA**	**18/03/11**	**NA**	**18/05/21**			**0 days**	
138	Lack of economic stability, inflation, and international limitations	0 days	0	NA	18/05/02	NA	18/05/02		42	0 days	05/02
139	Changes in engineering plan, implementation data, and technical characteristics of equipment	0 days	0	NA	18/05/21	NA	18/05/21		79	0 days	05/21
140	Contrasts between land conditions and reports by soil mechanic and mapping	0 days	0	NA	18/03/11	NA	18/03/11		88	0 days	03/11

Table 13. (With incursive approach) Delay analysis using the researcher-made technique (BVID) for inefficient DMUs of project (without risk of delays and not result-oriented activities of the project)

	Task Name	Duration	%IDF	Baseline Start	Start	Baseline Finish	Finish	Predecessors	Actual Finish	Finish Variance	BVID variance	BVID finish	Gantt
0	**The project for boilerhouse designing, supplying and building**	**257 days**	**100**	**18/01/01**	**18/01/01**	**18/07/05**	**18/09/14**		**NA**	**71 days**	**335.2**	**19/06/05**	
1	Prepayment	1 day	0.01	18/01/01	18/01/01	18/01/01	18/01/01		18/01/01	1 day	0.01	18/01/01	
2	Providing basic maps by employer	1 day	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1	18/01/01	1 day	0.01	18/01/01	
3	Contract affirmation	1 day	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1,2	18/01/01	1 day	0.01	18/01/01	
4	+ Engineering	37 days	3.98	18/01/01	18/01/02	18/02/06	18/02/07		18/02/07	1 day	0.97	18/02/07	
11	− Procurement	175 days	49.82	18/01/01	18/01/02	18/06/24	18/06/25		18/06/25	1 day	9.3	18/07/04	
12	+ Purchasing construction materials	56 days	6.52	18/01/09	18/01/10	18/03/05	18/03/06		18/03/06	1 day	4	18/03/09	
23	+ Purchasing boiler	175 days	22.96	18/01/01	18/01/02	18/06/24	18/06/25		18/06/25	1 day	8.37	18/07/03	
50	+ Purchasing electrical panel	62 days	11.07	18/01/20	18/01/23	18/03/23	18/03/25		18/03/25	2 days	9.3	18/04/02	
65	+ Purchasing compressed air tank	51 days	9.27	18/03/24	18/03/25	18/05/14	18/05/14		18/05/14	0 days	0.45	18/05/15	
86	− Construction	219 days	46.17	18/02/07	18/02/08	18/07/05	18/09/14		18/09/14	71 days	335.2	19/06/05	
87	+ Soil operations	16 days	3.23	18/02/07	18/02/08	18/02/22	18/02/23		18/02/23	1 day	3.5	18/02/26	
91	+ Leveling	4 days	0.64	18/02/23	18/02/24	18/02/26	18/02/27		18/02/27	1 day	0.64	18/02/27	
93	+ Foundation implementation	9 days	2.58	18/02/27	18/02/28	18/03/06	18/03/08		18/03/08	2 days	3.22	18/03/09	
96	+ Concreting	10 days	5.46	18/03/07	18/03/09	18/03/13	18/03/18		18/03/18	5 days	22.47	18/04/05	
99	+ enclosuring and stone façade	19 days	2.25	18/03/14	18/03/19	18/03/31	18/04/06		18/04/06	6 days	6.96	18/04/07	
102	+ Installation of frames and windows	7 days	1.09	18/04/01	18/04/06	18/04/09	18/04/13		18/04/13	4 days	2.32	18/04/12	
105	+ Piping the installations	39 days	4.31	18/03/07	18/03/09	18/04/15	18/04/16		18/04/16	1 day	22.05	18/05/07	
109	+ Delicate work	33 days	2.18	18/04/16	18/04/17	18/05/18	18/05/19		18/05/19	1 day	0.84	18/05/19	
114	+ Installation of boiler	32 days	7.82	18/05/17	18/05/18	18/06/15	18/06/18		18/06/18	3 days	8.58	18/06/24	
118	+ Installation of electrical panel	16 days	3.3	18/05/17	18/05/18	18/05/31	18/06/02		18/06/02	2 days	3.9	18/06/04	
121	+ Installation of Compressed air tank	14 days	3.77	18/05/17	18/05/18	18/05/30	18/05/31		18/05/31	1 day	7.83	18/06/07	
124	+ Installation of doors	27 days	1.55	18/06/16	18/06/19	18/06/21	18/07/15		18/07/15	24 days	9.36	18/07/01	
128	+ Installation of supplementary tools	22 days	0.9	18/06/16	18/06/19	18/06/21	18/07/10		18/07/10	19 days	4.94	18/06/26	
132	+ Testing and commissioning	66 days	7.09	18/06/22	18/07/11	18/07/05	18/09/14		18/09/14	71 days	335.2	19/06/05	
136	End	0 days	0	18/07/05	18/07/05	18/07/05	18/07/05	43,37,64,104,113,1	18/07/05	0 days	0	18/07/05	07/05
137	− **Delay Items**	**13 days**	**0**	**NA**	**18/08/21**	**NA**	**18/09/03**		**NA**	**0 days**	**0**	**#ERROR**	
138	Out-of-time responding to correspondences (prescribed or standard)	0 days	0	NA	18/08/21	NA	18/08/21		NA	0 days	0	#ERROR	08/21
139	Out-of-time decision making	0 days	0	NA	18/09/03	NA	18/09/03		NA	0 days	0	#ERROR	09/03

analysis of these two activities and their impact on other activities and the whole project were compared in two IAP and BVID techniques, and were summarized as follows:

(1) Delay of ID127 activity using IAP technique was calculated as 61 days, while according to the researcher-made technique BVID, given the inefficiency and not result-orientation of this activity, the effective delay of this activity on the project was obtained as 24 days.

(2) Delay of ID131 activity using IAP technique was calculated as 74 days, but given the inefficiency and not result-orientation of this activity, the impact of this delay on the project based on BVID technique was obtained to be 19 days.

	Task Name	Duration	%IDF	Baseline Start	Start	Baseline Finish	Finish	Predecessors	Actual Finish	Finish Variance	BVID variance	BVID finish
0	**The project for boilerhouse designing, supplying and building**	**265 days**	**100**	**18/01/01**	**18/01/01**	**18/07/05**	**18/09/22**		**NA**	**79 days**	368.72	**19/07/09**
1	Prepayment	1 day	0.01	18/01/01	18/01/01	18/01/01	18/01/01		18/01/01	1 day	0.01	18/01/01
2	Providing basic maps by employer	1 day	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1	18/01/01	1 day	0.01	18/01/01
3	Contract affirmation	1 day	0.01	18/01/01	18/01/01	18/01/01	18/01/01	1,2	18/01/01	1 day	0.01	18/01/01
4	+ Engineering	37 days	3.98	18/01/01	18/01/02	18/02/06	18/02/07		18/02/07	1 day	0.97	18/02/07
11	− Procurement	250 days	49.82	18/01/01	18/01/02	18/06/24	18/09/08		18/09/08	76 days	257.95	19/03/09
12	+ Purchasing construction materials	56 days	6.52	18/01/09	18/01/10	18/03/05	18/03/06		18/03/06	1 day	4	18/03/09
23	+ Purchasing boiler	250 days	22.96	18/01/01	18/01/02	18/06/24	18/09/08		18/09/08	76 days	217.62	19/01/28
50	+ Purchasing electrical panel	62 days	11.07	18/01/20	18/01/23	18/03/23	18/03/25		18/03/25	2 days	9.3	18/04/02
65	+ Purchasing compressed air tank	114 days	9.27	18/03/24	18/03/25	18/05/14	18/07/16		18/07/16	63 days	257.95	19/01/27
86	− Construction	199 days	46.17	18/02/07	18/03/07	18/07/05	18/09/22		18/09/22	79 days	368.72	19/07/09
87	+ Soil operations	30 days	3.23	18/02/07	18/03/07	18/02/22	18/04/06		18/04/06	43 days	98	18/05/31
91	+ Leveling	0 days	0.64	18/02/23	18/03/15	18/02/26	18/03/15		18/03/15	17 days	10.88	18/03/09
93	+ Foundation implementation	19 days	2.58	18/02/27	18/03/16	18/03/06	18/04/03		18/04/03	28 days	45.08	18/04/20
96	+ Concreting	67 days	5.46	18/03/07	18/04/04	18/03/13	18/06/09		18/06/09	88 days	288.9	18/12/27
99	+ enclosuring and stone façade	24 days	2.25	18/03/14	18/05/16	18/03/31	18/06/08		18/06/08	69 days	84.68	18/06/24
102	+ Installation of frames and windows	11 days	1.09	18/04/01	18/05/08	18/04/09	18/05/19		18/05/19	40 days	23.2	18/05/02
105	+ Piping the installations	80 days	4.31	18/03/07	18/04/04	18/04/15	18/06/22		18/06/22	68 days	277.2	19/01/17
109	+ Delicate work	29 days	2.18	18/04/16	18/04/29	18/05/18	18/05/27		18/05/27	9 days	9.24	18/05/27
114	+ Installation of boiler	46 days	7.82	18/05/17	18/05/28	18/06/15	18/07/12		18/07/12	27 days	91.52	18/09/15
118	+ Installation of electrical panel	26 days	3.3	18/05/17	18/05/28	18/05/31	18/06/22		18/06/22	22 days	42.9	18/07/13
121	+ Installation of Compressed air tank	28 days	3.77	18/05/17	18/05/28	18/05/30	18/06/24		18/06/24	25 days	75.69	18/08/14
124	+ Installation of doors	4 days	1.55	18/06/16	18/07/02	18/06/21	18/07/06		18/07/06	15 days	9.28	18/06/30
128	+ Installation of supplementary tools	2 days	0.9	18/06/16	18/06/27	18/06/21	18/06/29		18/06/29	8 days	2.88	18/06/24
132	+ Testing and commissioning	72 days	7.09	18/06/22	18/07/13	18/07/05	18/09/22		18/09/22	79 days	368.72	19/07/09
136	End	0 days	0	18/07/05	18/07/05	18/07/05	18/07/05	3,37,64,104,113,	18/07/05	0 days	0	18/07/05
137	− **Delay Items**	**71 days**	**0**	**NA**	**18/03/11**	**NA**	**18/05/21**		**NA**	**0 days**	**0**	**#ERROR**
138	Lack of economic stability, inflation, and international limitations	0 days	0	NA	18/05/02	NA	18/05/02		NA	0 days	0	#ERROR
139	Changes in engineering plan, implamentation data, and technical characteristics of equipment	0 days	0	NA	18/05/21	NA	18/05/21		NA	0 days	0	#ERROR
140	Contrasts between land conditions and reports by soil mechanic and mapping	0 days	0	NA	18/03/11	NA	18/03/11		NA	0 days	0	#ERROR

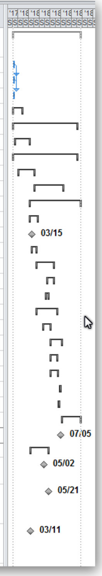


Table 14. (With incursive approach) Delay analysis using researcher-made technique (BVID) for efficient DMUs of project (having high risk of delays and result-oriente activities)

(3) Finally, total project delay using IAP technique was calculates as 74 days, while BVID technique has calculated total effect of these two inefficient activities on total project to be equal to 71 days.

The decreased results obtained from BVID technique in this analysis indicate not result-orientation and existence of low risk of delays for delayed activities. Also, the project could be launched in spite of the mentioned delays, so the cause of creation of these delays should not be penalized based on the results of only prolongation of completion time of project activities (IAP technique), but it should be penalized based on the decreased results obtained from the researcher-made technique BVID.

*4.1.2 With defensive approach. *Sensitivity analysis:* The analysis of table is similar to the table above but with the results of this table.

4.1.3 Calculates stakeholder delay share. Based on the results of Tables 15 and 16, based on the ownership of the float for the project and also the following relationships, the share of attributable and non-attributable delays to each stakeholder is calculated:

Row	Cause of delay	Activity delayed name	Activity delayed No.	Baseline start	Actual start	Delay amount (Day) IAP	BVID
Total						74	71
1	Timely reply to the letters	Install door locks	ID 127	2018/06/21	2018/08/21	61	24
2	Getting timely decisions	Install mirror toilet	ID 131	2018/06/21	2018/09/03	74	19

Table 15. (With incursive approach) Occurrence of delay in inefficient DMUs and activities

$$\text{In-De}_{(\text{Incursive})} = \text{Non–Attributable} = (\text{Incursive variance})/(\text{Incursive variance} + \text{Defensive variance})$$

$$\text{In-De}_{(\text{Defensive})} = \text{Attributable} = (\text{Defensive variance})/(\text{Incursive variance} + \text{Defensive variance})$$

**Sensitivity analysis*: Based on Table 17 results, here the share of delays was calculated by two techniques (SCL protocol and (In-De) technique) and for two beneficiaries. With the IAP technique, the share of delay attributable to the contractor (*Non-Attributable* = 64.91%) and the share of delay attributable to the employer (*Attributable* = 35.09%) were obtained. And also with the technique of (In-De) the share of delay attributable to the contractor (*Non-Attributable* = 71.71%) and the share of delay attributable to the employer (*Attributable* = 28.28%) were obtained.

4.2 For DMUs and activities with high risk of delays and result-oriented nature (Efficient)

*4.2.1 With incursive approach. *Sensitivity analysis:* In Table 18, three efficient DMUs in the assumed project were delayed.

(1) Analysis of DMU delays with activity number of ID39 was done using IAP technique and showed 31 days of delay, while given the result-orientation and efficiency of this DMU, BVID technique calculated the impact of this delay on the project as being increased and equal to 56 days.

(2) Analysis of DMU delays with activity number of ID45 using IAP technique, calculated delay as 31 days, while given the result-orientation and efficiency of this activity, BVID technique calculated the impact of this delay on the project to be 66 days.

Table 16.
(With defensive approach) Occurrence of delay in inefficient DMUs and activities

Row	Cause of delay	Activity delayed name	Activity delayed No.	Baseline start	Actual start	Delay amount (Day) IAP	BVID
Total						40	28
1	Delayed order registration	Super Heater	ID 41	2018/03/20	2018/04/22	32	27
2	Delay in supply	Pilot	ID 44	2018/04/26	2018/05/27	31	25

Table 17.
Table calculating the share of delays (Inefficient)

Analysis technique		IAP		(In-De)	
Share of delays		Share of non-attributed delays	Share of attributable delays	Share of non-attributed delays	Share of attributable delays
Calculate the share of delays	Day	74	40	71	28
	%	74/(74+40)=64.91%	40/(74+40)=35.09%	71/(71+28)=71.71%	29/(71+29)=28.28%

(3) Analysis of DMU delays with activity number of ID88 using IAP technique, calculated delay as 28 days , while given the result-orientation and efficiency of this activity, BVID technique calculated the impact of this delay on the whole project to be 49 days.

(4) In general, total project delay using IAP technique was calculated to be 28 days, while BVID technique calculated total project delays with a result-orientation approach to be 74 days.

Existence of this difference in the results of the two techniques shows result-orientation of the delayed activities, prediction of high risk of delays for those activities from the beginning of the project and overall, efficiency of these activities in the project. Therefore, these delayed activities will cause the project not to be able to be launched and so, the cause of those delays, in addition to the delay penalty determined in the contract, must also compensate for some of the other losses of delay in launching the project (according to the titles of costs mentioned in the research literature).

*4.2.2 With defensive approach. *Sensitivity analysis:* The analysis of this table is similar to the table above but with results of table.

4.2.3 Calculates stakeholder delay share. Based on the results of Tables 18 and 19 calculating;

**Sensitivity analysis:* Based on Table 20 results, here the share of delays was calculated by two techniques (SCL protocol and (In-De) technique) and for two beneficiaries. With the IAP technique, the share of delay attributable to the contractor (*Non-Attributable* = 41.7%) and the share of delay attributable to the employer (*Attributable* = 58.82%) were obtained.

Row	Cause of delay	Activity delayed name	Activity delayed No.	Baseline start	Actual start	Delay amount (Day) IAP	BVID
Total						28	74
1	Sanctions	Sealing Fan supply	ID 39	2018/03/02	2018/04/02	31	56
2	Bug in engineering drawings	Flame Scanner supply	ID 45	2018/05/16	2018/06/16	31	66
3	Land status (location of project implementation)	Identification of underground barriers	ID 88	2018/02/07	2018/03/07	28	49

Table 18. (With incursive approach) Occurrence of delay in efficient DMUs and activities

Row	Cause of delay	Activity delayed name	Activity delayed No.	Baseline start	Actual start	Delay amount (Day) IAP	BVID
Toatl						40	50
1	Error in initial estimation	Connecting pipes, installations and sealing	ID 116	2018/06/01	2018/08/15	46	53
3	Bug on connections	Leakage of tanks	ID 133	2018/06/22	2018/07/30	38	49

Table 19. (With defensive approach) Occurrence of delay in efficient DMUs and activities

And also with the technique of (In-De) the share of delay attributable to the contractor (*Non-Attributable* = 59.67%) and the share of delay attributable to the employer (*Attributable* = 40.33%) were obtained.

5. Conclusion

5.1 Ability to control risk of delays incidence in (In-De) technique

The (In-De) technique was applied to 12 different projects, within 40 months. The experiences of each project were applied to the next project, with each project delaying a decrease compared to the previous project (achieving optimization). 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 Figure 4. The actual project under consideration in the last experiment (CS12) compared to the results of other experiments, ended with about 60% less delay. Achieving this result proves effectiveness of using the researcher-made method of managing delay risks as (In-De) technique.

Important 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.

5.2 Ability to analyze delays based on (In-De) technique

(1) Activities with lower importance degree (inefficient), lower result-orientation feature and lower prediction for delays risk incidence, if analyzed using (In-De) technique in terms of their delays, apply lower effective delay impacts on other project activities

Table 20.
Table calculating the share of delays (Inefficient)

Analysis technique		IAP		In-De	
Share of delays		Share of non-attributed delays	Share of attributable delays	Share of non-attributed delays	Share of attributable delays
Calculate the share of delays	Day	28	40	74	50
	%	28/(28+40)=41.17%	40/(40+28)=58.82%	74/(74+50)=59.67%	50/(74+50)=40.33%

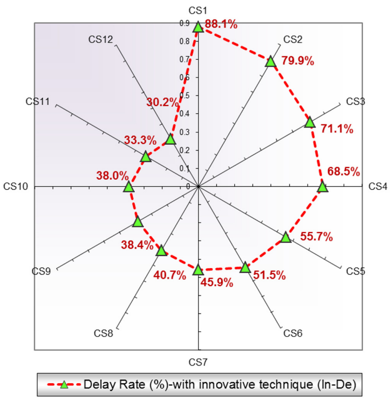


Figure 4.
Results of reducing project delays by applying (In-De) technique

because without realization of those activities, the project has been put into operation. But in IAP technique, these delays are only calculated according to prolongation of project time and therefore, more delays are calculated and displayed. The results are presented in Tables 15 and16.

(2) Activities with higher importance degree (efficient), higher result-orientation feature, and higher prediction for delays risk incidence, whose confrontation strategy has also been developed from the beginning of the project, if analyzed using (In-De) technique in terms of their delays, apply more effective delay impacts on other project activities compared to IAP technique, 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, in IAP technique, these delays are only calculated according to prolongation of project time and therefore, less delays are calculated and displayed. The difference between results is presented in Tables 18 and 19 it has been shown.

As the number of effective activities is usually, lower than the ineffective in the project, the advantage of using the (In-De) technique for delay analysis is greatly enhanced. Confirmation of this theory in the results presented in Figure 5, it has been shown. The difference between the results of the SCL protocol and the (In-De) technique is the difference between the delay in efficient and ineffective activities and the impact on the project.

Important Note: The effects of the differences in the results of these two techniques on the calculation of penalties for delays will be very large. This issue is being investigated by the authors in a separate article due to its extent.

(3) The SCL protocol has no approach to sharing stakeholder delays. While in projects, delay sharing is more important than calculating total delays. Researchers have developed an innovative technique that offers delay sharing with an Incursive (Not attributable) and defensive (attributable) approach. The calculation method is shown in Tables 17 and 20. The results of its use in the twelve sample projects are shown in Figure 6.

5.3 Comparative results

Following is a comparison of the strengths and weaknesses of the four most commonly used SCL protocol techniques with the researcher-made technique (In-De) in Table 21. The results in this table are derived from the researchers' experience of executing over three hundred

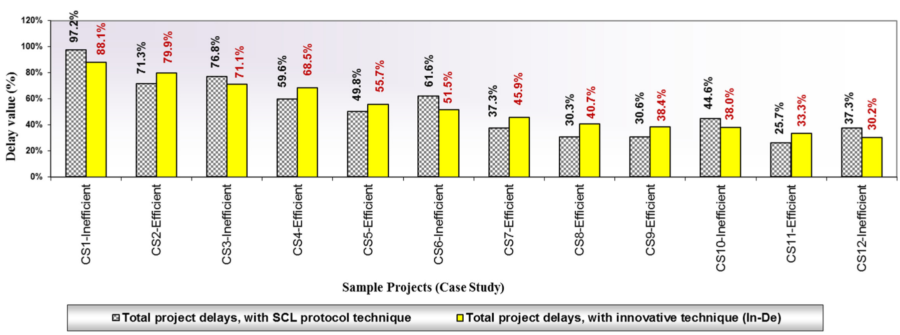


Figure 5.
Comparative chart of project delay penalties

projects. Along the way, the materials and results contained in the publications (Avalon and Rider, 2018), (Richard *et al.*, 2018a), (Richard, 2018) and (Richard *et al.*, 2018b) have been used.

5.4 Final conclusions and article innovation

Given the unique capabilities that the innovative (In-De) technique has over other SCL protocols, it can be incorporated as the eighth technique in the protocol and will benefit the project's members from further justice in the analysis.

6. How decision or policymakers could benefit from this study?

With this innovative technique (In-De), they can prevent delays as much as possible. They can also perform targeted analysis and divide project delays precisely, scientifically and practically among project stakeholders.

7. The main limitations of this approach

7.1 – Projects must have a base schedule.

7.2 – Periodic progress reports shall be regularly produced and approved in the standard format provided in the PMBOK standard.

7.2 – Historical data with acceptable accuracy to predict project delays.

7.3 – The availability and availability of expert specialists.

7.4 – To control the risk of delays, this technique should be used from the beginning of the project.

8. Suggestions for future work by other researchers

8.1 – Failure to complete the base schedule is an important principle in the implementation of the (In-De) technique. It is recommended that other researchers investigate how to modify old scheduling programs developed without adhering to the basics.

8.2 – Given the complexity of projects unknown, it is critical to predict, analyze and make accurate and accurate decisions with the help of multi-objective and intelligent techniques such as the BVID technique. Researchers in the fields of project management, industrial engineering and Information Technology should continue their research in this regard.

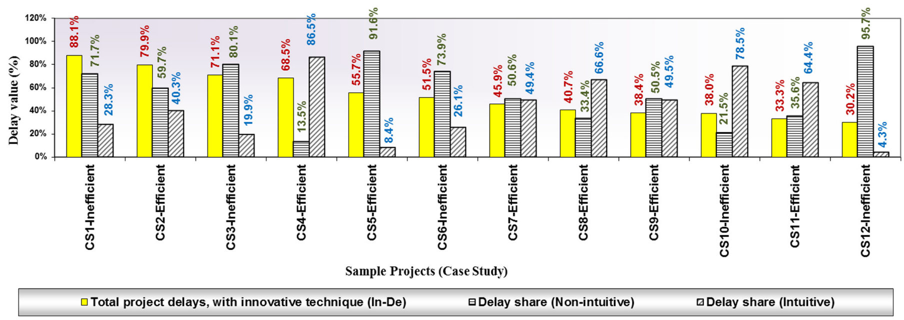


Figure 6.
Sharing stakeholder delays (attributable and non-attributable share to each beneficiary)

Comparative Table of Capabilities of Delay Analysis Techniques					
	The methods introduced in the Global SCL Protocol				The method of the researchers
SCL protocol techniques and (In-De) technique / Capabilities	Collapsea As-Built	Impacted As-Planned (IAP)	As-Planned versus As-Built (APAB)	Time Impact Analysis (TIA)	Based on Incursive and Defensive (In-De)
Schedule type					
Baseline		✓	✓	✓	✓
Actual Scheduling	✓		✓		
Updated schedule					
Regulatory Schedules	✓	✓			✓
Type of information					
No CPM (bar chart)			✓		
No CPM (with work progress report)	✓			✓	
With CPM approved / no update		✓	✓		✓
With CPM approved / with update		✓	✓		✓
Forecast		✓			✓
Real time		✓		✓	✓
Understand / During the course	✓	✓	✓		✓
Understand / after project completion	✓	✓	✓	✓	✓
Capabilities					
Floating Consumption / Critical Path	✓	✓	✓		✓
Project Extension	✓	✓	✓	✓	✓
Correction	Dependent on	Dependent on	Dependent on		Dependent on
Simultaneous delays			✓	✓	✓
Rearrange	✓		Dependent on		✓
The dynamic nature of CPM				✓	✓
Accelerate			✓	✓	✓
Result-Based Delays (Result-Based)					✓
Spend time and money					
Method of analysis	Decrease	Additive	Observational	Observational	Additive
Effort level	medium	Low	Low	Much	Low
Others					
Control the risk of delays					✓
Calculate the risk of delays					✓
Information on physical coefficients					✓
CBS Cost Breakdown Structure					✓
Contract (Item / Article of Contract)					✓
Ability to calculate stakeholder delays					✓

Table 21. Comparison of the four most commonly used SCL protocol techniques with researcher-made (In-De) techniques

Notes

1. Procurement and Construction (PC)
2. Engineering, Procurement and Construction (EPC)
3. Engineering, Procurement, Construction, Finance (EPCF)
4. Incursive-Defensive (In-De)
5. Project risk management (PRM)
6. Importance Degree Factor (IDF)
7. Impacted As-Planned
8. Collapse as Built
9. As-Planned Versus As-Built
10. Time Impact Analysis
11. based on variance and Importance Degree (BVID)

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Corresponding author
Abbas Sheikh Aboumasoudi can be contacted at: a_sh_edu@yahoo.com

Appendix

Table A1. Complete list of sources studied

Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
1	Delay in contract procurement (EPC)	Ghanbari Marziyeh, Ghorbaniyan H ossein	2016	Library Research	Employers Notice: 1- Do not pay the minimum price for the contractors in the tenders but rather select their hardware and software features. Make payments to contractors based on their percentage of physical progress. 3. Minimize changes in the nature of the work. Contractors Note: 1- Perform resource management with careful planning from the beginning of the project. 2. Use sufficient specialist force. 3. Updating the project's financial management mechanism. 4. Adjust project cash flow based on employer Davments
2	Empirical study of critical risk factors causing delays in construction projects	Rao Aamir Khan, Warda Gul	2017	SPSS and Rll (Relative Importance Index)	A 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
3	Causes of delays in the construction industry and delays analysis techniques with the SCL protocol	Shahsavand and *et al.*	2018	Questionnaires and Rll and SPSS software were used	1. Delays in outsourcing or outsourcing of the contractor were component, 2. Poor site management and oversight, 3. Problems in financing the project

(*continued*)

Table A1.

Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
4	A framework for analyzing the failure modes and its effects in fuzzy conditions for complicating the causes of delays in Kurdistan provincial modern schools development projects	Hiva *et al.*	2018	FMEA	Factors such as insufficient financial resources, rising inflation, weak technical skills in bidding, little background and high costs of energy carriers have identified important delays
5	Claim management and delay analysis in construction contracts based on SCL protocol and executive experience	Rooholelm and Rashidi	2019	TIA, IAP , CAB , APAB . Windows	The book has been compiled and translated by a researcher. In this regard, the researcher, with 17 years of experience in project management, has reviewed over 300 delayed bills and incorporated his findings into his experience with the localization of science and claims management expertise in the country. It is in print that parts of the book have been used and addressed in this research. In this compilation, the researcher identified problems with delay analysis techniques that led to the proposed new BVID technique in this study
6	Study of factors influencing construction delays at rural area in Malaysia	Ramli M.Z.	2017	Questionnaire method using RII relative importance index and Ukert scale	1- Improper handling by contractor 2- Improper weather conditions (Heavy rain) 3- Delayed delivery 4- Destruction of site equipment 5- Poor technical support of contractors during project implementation

(*continued*)

Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
7	Dematel as a weighting method in multi-criteria decision analysis, multiple criteria decision making	Kobryri Andrzej	2017	DEMATEL	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 method
8	Factors influencing the selection of delay analysis methods in construction projects in UAE	Abdelhadi Yazeed *et al.*	2018	Results for a project were calculated and compared with the two analytical methods TIA and IAP	1- Analyst neutrality 2- Availability and completeness of primary documentation 3- Quality of initial planning *A*- Availability of updated programs 5- Availability of periodic progress reports, time and budget constraints 6- Defined Floating ownership in the early schedule and revisions
9	A systematic review of the state-of-the-art literature on methodologies and applications	Sheng-Li Si *et al.*	2018	DEMATEL	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
10	The future of economic decision making in project management	Brian J. Galli	2018	Return on Investment, Present Worth	economic decision-making and project management relationship element directly impacts many other elements of an organization

(*continued*)

Table A1.

Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
11	Improving risk evaluation in FMEA with cloud model and hierarchical TOPSIS method	Hu-Chen Liu, Member, IEEE, Li-En Wang, ZhiWu Li. Fellow, IEEE and Yu-Ping Hu1	2018	TOPSIS, FMEA	The proposed risk priority approach provides a structured and systematic framework for the risk evaluation of failure modes and overcomes the weaknesses of the traditional FMEA. Moreover, the proposed model could make an adequate reflection of the importance associated with each FMEA team member considering the knowledge and experience of experts
12	Causes of delay in Iranian oil and gas projects: a root cause analysis	Sweis *et al.*	2019	Comparative	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

(*continued*)

Table A1.

Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
13	Major factors causing delay in the delivery of manufacturing and building projects in Saudi Arabia, buildings	Abdellatif Hussein and Alshibani Adel	2019	Comparative	The output of the mathematical analyses has revealed that the top causes of delay in terms of frequency and importance are difficulties in financing project by contractor/manufacturer, late procurement of materials, late delivery of materials, delay in progress payments, and slowness in decision-making
14	The project strategy matrix: Systematizing the design and management of an explicit project strategy	Georgios Koutsoukos	2019	guide the balanced mixture of profound thought and coherent actions that are required in effectively establishing a project's specific course of action	the results of applying the project strategy matrix in real projects, based on an empirical, qualitative approach, are very encouraging in what concerns its applicability and its capacity to provide value and drive observable improvements
15	Exploring the value of risk management for projects: Improving capability through the deployment of a maturity model	James Champman Robert	2019	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 capturina risk competencies	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

(*continued*)

Table A1.

Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
16	From risk matrices to risk networks in construction projects	Qazi Abroon and Dikmen Irem	2019	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	A comprehensive project risk management process could be developed and a suitable decision support system be designed to prioritize risks and risk mitigation strategies
17	Construction delay risk taxonomy, associations and regional contexts	Derakhshanfa r Hossein *et al.*	2019	Comparative	In total, 26 delay risks were identified and grouped into ten categories to form the risk breakdown structure. The universal delay risks and other delay risks that are more or less depending on the project location were determined. Also, it is realized that delays connected to equipment, sub-contractors and design drawings are highly connected to project planning, finance and owner slow decision-making, respectively
18	DELAY ANALYSIS IN CONSTRUCTION CONTRACTS, THE ATRIUM, SOUTHERN GATE	P. J. Keane and A. F. Caletka	2015	SCL protocol and IAP, APAB, TIA, CAB techniques	Introducing Delay Analysis Techniques Introduced in SCL Protocol and Window Supplementary Technique
19	Delays in construction projects – causes and impacts	Amilcar Arantes *et al.*	2015	Positively correlated with all impacts	That lack of commitment and substandard contracts are positively correlated with all impacts, and poor consultant performance is negatively correlated with time overrun

(*continued*)

Table A1.

Table A1.

Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
20	Appropriate delay analysis techniques to analyses delays in road construction projects in Sri Lanka	Ekanayake E.M.K. and Perera B.A.K.S.	2016	RLL and Comparative	As a result the prioritization of the techniques is as follows: (1) As-planned vs. As-built; (2) Impacted as Planned; (3) Time Impact Analysis; (4) Collapsed as Built; and (5) Window Analysis
21	A hybrid SD-DEMATEL approach to develop a delay model for construction projects	Majid Parchami Jalal and Shahab Shoar	2017	Comparative	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
22	In the article Causes of delays in construction industry and comparative delay analysis techniques with SCL protocol	Shahsavand Parvaneh *et al.*	2018	CAB, IAP, TIA, As-planned	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
23	Comparison of construction delay analysis methods	Tabassum Abid *et al.*	2018	They performed the daily analysis method in easy plan software	The new approach does not consider accelerating performance

(*continued*)

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Row	Subject	Researcher / Researchers	Publication year	Techniques and variables used	Research results
24	Understanding project management directions from project management trends	Jun Jie Ng	2019	RESEARCH	Projects are becoming more complex and project managers should actively tailor methods that they deem fit to suit their needs at work. Having access to this knowledge is essential, for example which tool is best for what purpose and how to use them is important

About the authors

Vahid Rooholelm is a professor and senior international consultant for projects and industry in the specialized sciences in industrial engineering (18 years of experience) and IMS Survey of SGS Multinational Company. He has completed PhD (1st degree) in industrial engineering (project management) in 2017, MS (1st degree) in industrial engineering (financial engineering) in 2011 and BS (1st degree) in industrial engineering (industrial production) in 2001. He is the author of several university books on project management, claim management, financial engineering, strategic management and application of specialized industrial engineering software. He is also the author of several internationally acclaimed and innovative articles in the fields of industrial and financial engineering.

Abbas Sheikh Aboumasoudi currently works at the Department of Industrial Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran. He has completed PhD in industrial engineering and economic management. He has a work experience of about 42 years and the first 8 years of it was in executive management, such as the managing director of some industries and about other 34 years so far as a university professor. He is also a consultant for some industries and organizations. He has expertise in industrial engineering, strategic management, economic analysis and financial analysis. He has written 10 books, including the final book published by the Lambert Institute in English (Design of the value chain models in multi-stage production systems for achieve to effective profit management strategy). He is the author of many articles in the above four fields in domestic and foreign journals and was the supervisor of more than 80 master's thesis and PhD dissertations. He has designed various industrial engineering systems for different companies during the 32 years of his working life. Abbas Sheikh Aboumasoudi can be contacted at: a_sh_edu@yahoo.com