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Root Cause Analysis of Construction Oil and Gas Project Delays from Engineering and Construction Management Point of View Using Analytic Hierarchy Process (AHP): A Case Study for National Iranian Oil Company Projects

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Abstract

The delays in construction projects affect a very large volume of the countries' resources, therefore making the right decisions at managerial levels prevents the loss of national resources. There are several tools available to project managers for appropriate resource planning, each of which is used at managerial levels to improve the schedule of projects. In fact, delays can be largely prevented if there is an appropriate decision-making model in place to control the projects. This study is aimed at investigating the causes of delays in construction projects through the case study of the National Iranian Oil Company's construction projects by using a hierarchical analysis method and prioritizing the most important delay factors as well as providing a solution. After the background studies, the raw data of the research was collected using 64 questionnaires. This includes valuable experiences of experienced administrators and executives. Then, the preliminary data were analyzed by Expert Choice software, and a model was presented for optimizing the problem in order to prioritize and determine the importance of the causes of project delays. Given the software output, the results showed that the factors affecting the increase of the duration and cost of the projects include the following: 1) Existence of sanctions and restrictions on imports of essential goods and commodities, 2) Governmental policymaking problems in prioritizing the construction projects, 3) Social and environmental effects and conflicts, 4) Financial insolvency of the contractor, 5) Lack of financial resources of the employer, 6) Inconsistencies between consultant and employer, 7) Study and design problems, 8) Lack of specialist and skilled manpower by the contractor, 9) Higher workshop supervision problems, 10) Contractor's technical and equipment problems, 11) The type of contract and contractual issues, and 12) Managerial and technical inability of the employer, the impact of which are 1) 17.3%, 2) 13%, 3) 9.6%, 4) 8.9%, 5) 8.3%, 6) 8.3%, 7) 7.3%, 8) 6.6%, 9) 6.3%, 10) 5.6%, 11) 5.1% and 12) 3.7%, respectively. The results of the study suggests that the sanctions and restrictions on the import of essential goods and commodities, and problems of governmental policymaking in prioritizing the construction projects are superior to other factors in most cases in terms of the studied criteria (time and cost), as well as the case study. Also, other specific project conditions can change these priorities. As a result, project managers should consider the analyses carried out in this research with specific conditions of each project simultaneously and make decisions.

Keywords: Causes of delays • Increased time and cost • Construction projects • Analytic hierarchy process (AHP)

Introduction

One of the problems from which, most projects, whether constructional or non- constructional, suffer is the prolongation of the implementation period and the multiplied cost of completing the projects compared to the initial estimations [1]. Although it rarely happens that a project is completed within its specified time schedule, the timely completion of a project is considered as an indicator of the efficiency and success of the project. On the contrary, we have delays. Delay is an action or event that prolongs the time specified in the contract to perform a certain action. Then, the delay increases the total cost of the project, followed by the need to prolong the presence of human resources in the project. In general, delays are caused by various reasons, which are the result of the project elements functions. Basically, one of the goals of project management knowledge is time management. Since a lot of budget and large resources are often spent on construction projects, avoiding these delays is critical in completing the construction projects. For this purpose, it seems necessary to identify these factors and to classify them according to the importance and frequency of constructions [2].

Delay is one of the most important common phenomena in the construction projects of the country. In most of its constructional projects, Iran is also experiencing the delays occurred, and there have always been efforts to reduce these factors. Over the past decades, this phenomenon has occurred in simple construction projects to the most complex ones, such as petrochemical projects, dam construction, and nuclear power plants, so that the weighted average for the implementation of projects in the country is 11.1 years [3].

Because of the generality of the issue of project delays in all countries and its importance, many researches have studied the factors causing delays in construction projects and the mechanisms involved. For example, according to a report in 2001 in UK, 70% of governmental projects had been delayed [4]. In India, the research by the infrastructures and project monitoring department at the Ministry of Planning and Budget in 2004 showed that 646 projects worth more than $ 50 trillion dollars had been completed by about 40 percent delay compared to their due date of completion. These delays ranged from 1 to 252 months [5]. In the United Arab Emirates, where construction accounts for 14% of the gross domestic product (GDP), a study shows that 50% of construction projects are delayed [6].

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The main indicators in success of the projects are their high quality and on time implementation, because in addition to spending more financial resources, for the reasons such as inflation and rising prices, the prolongation of the construction projects is accompanied by the impossibility of operation of the projects on due time. The delay of construction projects is one of the most important weaknesses in the civil engineering industry in all countries around the world, and studies have shown that, despite today's modern technology, due to delays, the completion date of most projects is still lagging their schedule. The compensation of delays and avoiding their reoccurrence in future projects involves identifying these delays and determining the contribution of each of the factors involved in the projects, which is far more complicated due to the uniqueness of each project. By studying the causes of delay in construction projects of the National Iranian Oil Company through various sources and researchers' viewpoints, while highlighting the causes of delays in projects, we attempt to reveal the common grounds of delay in construction projects, so that delays in projects can be addressed by employers, consultants and contractors as a fundamental problem, and by providing appropriate solutions, the duration of projects is reduced. Finally, by taking into account the delays in construction projects when planning them, they can become as short as possible, and in the best and most ideal situation, even zeroed [7].

So far, various studies have been conducted on delays in construction projects, among which some have investigated the delays in a particular industry or country. Using these studies in this paper, we are going to summarize and compare the causes of delays in developed and developing countries.

Literature Review

Three aspects have been considered in the literature review of this paper. Firstly, investigating the causes of delays in oil and gas projects; secondly, large and costly projects, the delays of which cause problems such as increased costs and doubts in choosing the type of land use, and the last and most important aspect is the investigation of delays in public / governmental projects.

Basak and Coffey (2018) investigated the factors affecting the delay in large natural gas projects (case study: Australia). Using the five-point Likert scale, they assessed the frequency and severity of each of the risks caused by delays. The findings showed that 72% of the subjects believed that the delay in gas projects in Australia ranged between 10% and 30% [8]. Gebrehiwet and Luo (2017) investigated the impact of delays in large-scale construction projects based on Relative Important Index (RII) and correlation coefficient in Ethiopia. Public projects are mostly associated with the public-sector with the same management practices, and organizational structure, rules, and regulations. The results showed that the general common conditions will lead to major problems and delays [9]. Niazi and Painting (2017) reviewed the construction projects in Afghanistan, in which increasing construction costs is the most important problem of most of projects [10]. Simanjuntak and Mahendrawan (2015) investigated the factors affecting delay of oil and gas construction projects in Indonesia (Case Study of 2012 – 2013). A large number of oil and gas projects have failed in Indonesia during the schedule of the original contract. The delays in oil and gas construction projects were classified into several major factors based on the construction and engineering plan contracts [11]. Ruqaishi and Bashir investigated the causes of delay in construction projects in the oil and gas industry in the gulf cooperation council countries. The survey results showed that there was a high level of agreement among project stakeholders including employers, contractors and consultants on the causes of project delays, and there is no evidence showing that the project delay is not dependent on the size of the organization and organizational ownership [12]. Also, Fallahnejad (2013) examined the causes of delay in gas pipeline projects of Iran. In this regard, 24 gas pipeline exploration projects were studied. Then, the extracted delay factors were evaluated by ten experts from different fields. As a result, a list of 43 factors was investigated, which was then ranked using a questionnaire [13]. Aswathi and Thomas (2013) studied the causes and impacts of delays in a large railway project between the two cities of Chengannur and Mavelikara in India. For the analysis of the factors causing delays, given their value and importance, a weight and index has been assigned to each of them. Then, using Monte Carlo simulation method and field studies, designing a questionnaire, interviews and surveying civil engineering experts and students, the author managed to identify the main causes [14]. Also, Yang and Wei (2010) focused on the delay factors in planning and design phases. Their findings showed that the most important reasons for delays in planning and designing phases were the changes made in customer demands [15]. Tumi and Omran (2009) identified the causes of delays in the construction industry in Libya. They identified six major reasons for delays [16]. Abd El-Razek et al (2008) investigated the causes of delays in construction projects carried out in the construction industry of Egypt [17]. Sambasivan and Soon (2007) investigated the causes and effects of delays in Malaysian construction industry. The authors identified the ten factors affecting the delays in Malaysian construction industry, which can be integrated into two major effects, i.e. "cost overruns and involvement" [18]. Assaf and Al-Hejji (2006) studied the causes of delays in large projects in Saudi Arabia from the employer's, contractor's and consultant's viewpoints [19]. Lo et al. (2006) reviewed construction delays in Hong Kong civil engineering projects. Firstly, this study was aimed to collect the views of the stakeholders involved in construction on the delay importance. Secondly, it was to check whether the suggestions contained in the report of the Construction Industry Review Committee had any effect or not [20]. Odeh and Battaineh investigated the most important reasons for delays in construction projects with traditional contracts from the viewpoints of construction contractors and consultants [21]. Al-Momani described the root cause of the disputes between the owner and the contractor as "a poor preliminary assessment of the duration of the project." He studied the cause of delays in 130 public projects in Jordan. He compared the planned schedule of the projects versus their real durations and found a linear relationship between them. Finally, he recommended that some adjustments should be made to the initial assessment of project costs and schedule [22].

Based on the information obtained from previous researchers and studying their viewpoints on the causes of delays in projects, after a preliminary summation, 100 factors were identified as the causes of delays in construction projects, summarized briefly as in Table 1. The clear point in the studies was the lack of sufficient information on the causes and effects of delay in the construction projects of the Iranian oil and gas industry, considering that there is an increased competition in the field of the production of oil, gas and petroleum products among Middle Eastern countries.

Materials and Methods

Introduction to the case study (National Iranian Oil Company (NIOC))

National Iranian Oil Company is the Iran's state-owned oil and gas company, and through its subsidiaries, it is also active in the field of exploration and production of crude oil, natural gas and gas condensate, as well as drilling and development of hydrocarbon reservoirs. National Iranian Oil Company was founded in 1948 after nationalization of Iran's oil and replaced the Anglo-Persian Oil Company. With more than 41,000 employees, the company is one of the largest oil companies in the world. The National Iranian Oil Company has a crude oil production capacity of 4 million barrels per day. The company produces 750 million cubic meters of natural gas every day. The amount of gas condensate production is about 900,000 barrels a day. The volume of hydrocarbon reserves managed by the company is estimated to be 157 billion barrels. In terms of oil and gas production, after Aramco company (Saudi Arabia) and Gazprom (Russia), the National Iranian Oil Company is ranked third [23].

Given the data, and the huge volume of investment required, and the fact that Iran's economy is highly dependent on oil revenues, the use of new

Table 1: Causes of delay in previous studies.

Title	Researcher	Causes
Risk Factors Affecting Delays in Upstream Natural Gas Mega-Projects: An Australian Perspective	Basak and Coffey	1) Frequent changes ordered by the employer 2) Unrealistic schedules for contracts 3) Poor organizational structure
Analysis of Delay Impact on Large Construction Projects Based on RII (Relative Important Index) and Correlation Coefficient in Ethiopia	Gebrehiwet and Luo	1) Lack of commitment 2) Inefficient site management 3) Poor site coordination 4) Poor planning 5) The lack of transparency in project scope 6) Lack of communication 7) Non-standard contract
Significant Factors Causing Cost Overruns in the Construction Industry in Afghanistan	Niazia and Painting	1) Corruption 2) Delay in payment by investors 3) Problems in the financial payments of contractors 4) Security 5) Change made in design by the employer during the project 6) Inflation
Factors Affecting Delay of Upstream Oil and Gas Development Projects in Indonesia: Case Study 2012 – 2013	Simanjuntak and Mahendrawan	1) Contractor's performance 2) Procurement, approval and government authorization 3) Issues related to social, environmental and commercial problems
Causes of Delay in Construction Projects in the Oil and Gas Industry in the Gulf Cooperation Council Countries (Case Study: Oman)	Ruqaishi and Bashir	1) Poor management and supervision of the contractor 2) problems with subcontractors, 3) Inappropriate planning and design of the contractor 4) Poor planning management of contractor 5) Delayed delivery of materials 6) Lack of effective communication among project stakeholders 7) Poor engagement with vendors at engineering and logistics stages
Delay causes in Iran gas pipeline projects	Fallahnejad	1) Imported goods 2) Unrealistic estimated project schedule 3) The goods promised to be provided by the employer 4) Disputes on the pipeline route 5) Changes in the general design 6) Contractor selection methods 7) Payments to the contractor 8) Obtaining permissions 9) Employer's financial solvency 10) Contractor's financial solvency
Causes and effects of delay in major railway projects: Introducing Delay Analysis System for Railway Construction Projects between the Cities of Chengannur and Mavelikara in India	Aswathi and Thomas	1) Stockholders performance 2) Project conditions 3) Inefficient planning 4) Financing problems by the contractor 5) Shortage of workforce 6) Relationships between stakeholders 7) Poor management
Causes of delay in the planning and design phases for construction projects	Yang and Wei	1) Changes made in customer demands
Causes of delay in construction industry in Libya	Tumi and Omran	1) Inappropriate planning delays 2) Lack of effective communications 3) Design mistakes 4) Shortages of materials and equipment 5) Late decision-making 6) Financial problems
Causes of delay in building and construction projects in Egypt	Abd El-Razek et al.	1) Investment by contractor during construction 2) Delayed payments to the contractor by the owner 3) Changes in design by the owner or his/ her representative during construction 4) Partial payments during construction 5) Failure to use of professional construction / contract management 6) Delay in delivery of materials 7) Difficulty in coordinating different stakeholders 8) Slow decision making process by experts 9) The relationship between the plans of the subcontractors 10) Preparing drawings and materials samples
Causes and effects of delays in Malaysian construction industry	Sambasivan and Soon	1) Poor design 2) Poor site management 3) Contractor's financial insolvency 4) Employer's capability to pay and financial solvency 5) Subcontractors 6) Shortage of materials 7) Shortage of human resources 8) Shortage of equipment 9) Relationship between project stakeholders 10) Mistakes occurred during the project schedule

Causes of delay in large construction projects in Saudi Arabia from the employer's, contractor's and consultant's viewpoints	Assaf and Seddiq	1) Delayed payments by the employer 2) Delays in the review and approval of design documentations by the consultant 3) Mistakes and defects in design documentations 4) Late supply of equipment 5) Consultant's inflexibility 6) Late decision-making by the employer
Construction delays in Hong Kong civil engineering projects	Lo et al.	1) Insufficient funding of the contractor 2) Unexpected ground conditions 3) Low base prices 4) Inexperienced contractors 5) Conflicts with existing land use 6) Poor site management and supervision by consultant 7) Announcing an unrealistic contract term by employer 8) Environmental constraints 9) Administrative bureaucracy and lack of appropriate cooperation between authorities 10) Changes made in the plan
Causes of construction delay: traditional contracts	Odeh and Battaineh	1) Owners' interference 2) Inexperienced contractor 3) Inadequate payments at the end of the project 4) Manpower skills 5) Poor site management 6) Slow decision-making 7) Construction methods 8) Inappropriate contracts with subcontractors
Construction delay: a quantitative analysis	Al-Momani	1) Poor design 2) Changes made in orders 3) Weather conditions 4) Site conditions 5) Delayed delivery 6) Increase quantity of economic conditions

ways to improve project management for preventing the loss of investments and opportunities in the field of infrastructural projects in the oil industry seems necessary more than ever. In such projects, the executives of which deal with a variety of issues, including delays in projects, the use of up-to-date management structures and techniques is not only necessary, but also inevitable to get rid of inefficient traditional methods and to take advantage of the latest scientific achievements in this field so that the executive projects are completed within the time and cost limits with optimum quality.

Choosing the causes of delay in this research

The causes of delay are generally identified in most construction projects, and using a questionnaire, the priority and the extent of the effect of these causes on delay are measured. In this study, first, we compile the results of recent research in Iran and other countries on the causes and frequency of delays in construction projects. Then, by comparing the importance and frequency of delay factors in previous research, and also, by taking into account the environmental conditions governing construction in the field of oil and gas in Iran and the views of experts in this field, the factors affecting the causes of delay were classified into four general categories. Then, the factors with more impact were identified, and selected to form a questionnaire. The summarized result for the factors and the causes of their delay are presented in Table 2.

Table 2: The causes of delay selected as a case study.

Row	Factor	Causes of Delay
1	Employer	Type of contract and contractual issues
		Lack of financial resources of the employer
		Managerial and technical inability of the employer
2	Contractor	Lack of sufficient financial solvency of the contractor
		Contractor's technical (operational facilities) and equipment difficulties
		Lack of skilled manpower by the contractor
3	Consultant	Problems in research and design
		Problems in workshop supervision
		Lack of proper coordination between the counselor and the employer (excessive contact with the contractor)
4	Social and critical problems	Governmental policymaking problems in prioritizing the development projects
		The existence of sanctions and the (technical) inability to import essential goods
		Social impacts (public acceptance) and disputes (governmental and military facilities) and environmental degradation impacts

Analytical hierarchy process (AHP)

AHP stands for Analytical Hierarchy Process. The AHP technique was introduced by Thomas L. Saaty in 1983. The analytical hierarchy process technique is aimed to select the best alternative by pairwise comparison based on different criteria. This technique is also used for weighting the criteria, because the increased number of studied elements makes pairwise comparison difficult [24].

Criterion: It is something based on which you select. In this research, the two criteria of time and cost are used to prioritize the causes of project delays.

Alternative: it is something of which one can select. In this research, 12 selected causes are used for AHP.

Applications of the AHP method: The analytical hierarchy process method has been applied as a widely used method in the field of personal and group (organizational) decision making to solve unstructured issues in various fields. Issues such as management, politics, economics, social sciences, medicine, engineering, genetics, geography, and in summary wherever scientific decision-making is required [24].

The AHP method is flexible, and we can say that it does two things for us:

1. Finding the relative importance of criteria (criteria weights) and ranking them from the most important to the least important

2. Ranking the alternatives and choosing their best aimed at decision-making

Validation in AHP: For the purpose of validation or verification in AHP questionnaires, the concept of inconsistency ratio is used.

Acceptable inconsistency ratio: The inconsistency ratio is an index the value of which indicates the potential contradictions and inconsistencies in pairwise comparisons matrix. According to Saaty*, the founder of the AHP method, if the inconsistency ratio is less than 0.1, the consistency of the comparisons matrix is approved and acceptable, but if the inconsistency rate is greater than 0.1, it represents an inconsistency in the assessments and judgments of the experts [24].

How to calculate the inconsistency ratio in the AHP method: Calculation of the inconsistency ratio through manual calculations would be very difficult and complicated. The inconsistency ratio is calculated by Expert Choice software.

1. In the first step, the pairwise comparisons matrix of indices is multiplied by the relative weights vector obtained from it.

2. In the second step, we divide the resulting answer by the vector of relative weights of indices to obtain the consistency vector.

3. In step 3, we calculate the arithmetic mean of the elements of the same vector, which is called λ [24].

4. In step 4, we calculate the inconsistency index as follows:

$$II = \frac{\lambda_{max} - \mathrm{n}}{n-1}$$

5. in the fifth step, based on n (number of criteria), IRI is extracted from the following table of inconsistency index of random matrix, and the inconsistency rate (IR) is calculated from the following equation:

n: number of criteria

λmax: The largest arithmetic mean of vector elements

I.R.: Inconsistency Ratio

I.I.: Inconsistency Index

I.I.R.: Inconsistency Index of Random matrix

$$IR = \frac{\mathrm{I.I}}{IRI}$$

That the Table 3 is as follows:

Building a hierarchy: The first step in the hierarchical process is to create a graphical representation of the problem, in which the objective, criteria and alternatives are displayed. Figure 1 depicts the hierarchical tree structure formed for this research.

Quantization of decision-making states in hierarchical analysis: In hierarchical analysis, the alternatives and criteria are compared in a pairwise manner at each level, and their weight is calculated. Decision-makers will use verbal judgments in these comparisons, so that each alternative is compared with other alternatives in a pairwise manner based on one of the scenarios in Table 4 [24].

Data Analysis

Study of statistical population

In this analysis, the weight of each criterion was determined using a questionnaire (Appendix 1). Of the 79 questionnaires distributed among executive managers, experts and contractors of oil projects with organizational positions, 64 questionnaires were returned. Based on the results presented in Table 5, consultants showed the most cooperation, while employers showed the least cooperation. In addition, the majority of the statistical population had a master's degree and a work experience of over 13 years.

Data analysis by manual calculations

Determining the weight of each of the causes of the delay: First, the raw data obtained from the pairwise comparisons of the questionnaires are averaged by Excel software. Then, they were rounded up to the nearest integer so that they can be used in Expert choice software. In matrix Tables 6 and 7, pairwise comparisons are displayed based on cost and time criteria, respectively. As can be seen, in the pairwise comparisons matrix, the numbers on the lower part of the inverse matrix are the same as the numbers in the upper part of the matrix.

Calculating the normal weights of matrices: The weights obtained from the questionnaire are not normal. Saaty introduced the use of geometric mean as the best method for combining paired comparisons [25]. Therefore, the geometric mean was determined for the data in each row. The normal weight means that the total weight of each column should be equal to 1. Therefore, the geometric mean obtained in each row is divided by the sum of the elements of the geometric mean column. The new column, which contains the normalized weight of each alternative, is called the eigenvalue vector or the eigenvector. In Tables 8 and 9, the normalized matrices are presented based on cost and time criteria, respectively. The final weight of each matrix is the same as the eigenvector column. Table 10 summarizes the eigenvectors results.

Table 3: The table of inconsistency index of random matrix.

n	1	2	3	4	5	6	7	8	
IRI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

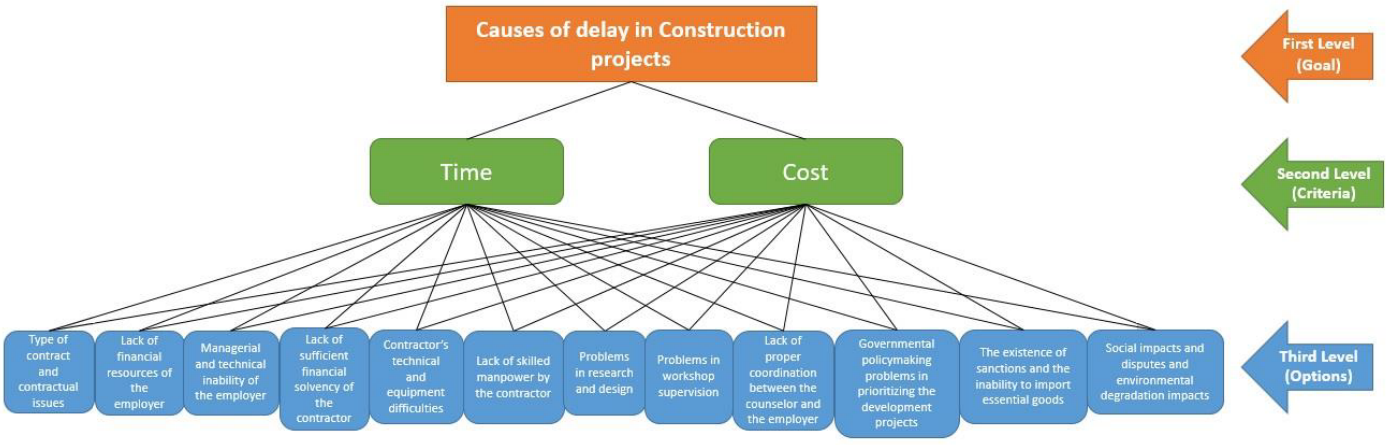


Figure 1: The structure of the tree hierarchy.

Table 4: Quantization of decision-making states [24].

Numerical value	Preferences (verbal judgment)
9	Quite favorable
7	Very very favorable
5	Very favorable
3	Slightly more favorable
1	The same desirability
2, 4, 6 and 8	Preferences between the above intervals

Pairwise comparison of the time and cost criteria: Just the same as alternatives, pairwise comparison is carried out for the criteria to determine the relative weights of each. In order to provide more correct solutions, at this stage, the comparison is examined from different perspectives. In other words, in each option considered, the superiority of a criterion over other criteria is tangible, in order to provide a basis for decision making according to the requirements and factors involved (Tables 11 and 12).

Finally, the eigenvector matrix of the criteria is multiplied by the eigenvector of the alternatives vector, so that the final percentage of

Table 5: Results of the statistical population analysis.

Factors	Frequency in employers (%)	Frequency in Counselors (%)	Frequency in contractors (%)	Total
Sex				
Male	19(%30)	23(%36)	22(%34)	64(%100)
Female	0	0	0	0
Age				
31-40	3(%16)	12 (%52)	6 (%27)	21 (%33)
41-50	11 (%58)	7 (%30)	9 (%41)	27 (%42)
Over 50	5 (%26)	4 (%18)	7 (%32)	16 (%25)
Work experience in years				
1-5	0 (%0)	3 (%13)	2 (%10)	5 (%7)
6-12	4 (%21)	7 (%30)	6 (%27)	17 (%27)
13-20	6 (%31)	8 (%35)	10 (%45)	24 (%38)
Over 20	9 (%48)	5 (%22)	4 (%18)	18 (%28)
Education				
Bachelor	7 (%37)	5 (%22)	14 (%64)	26 (%40)
Master's degree	10(%53)	12 (%52)	8 (%36)	30 (%47)
P.H.D	2 (%10)	6 (%26)	0 (%0)	8 (%13)

Table 6: Pairwise comparisons of alternatives based on the cost criterion.

No.	Options	Type of contract and contractual issues	Lack of financial resources of the employer	Managerial and technical inability of the employer	Lack of sufficient financial solvency of the contractor	Contractor's technical and equipment difficulties	Lack of skilled manpower by the contractor	Problems in research and design	Problems in workshop supervision	Lack of proper coordination between the counselor and the employer	Governmental policymaking problems in prioritizing the development projects	The existence of sanctions and the inability to import essential goods	Social impacts and disputes and environmental degradation impacts
1	Type of contract and contractual issues	1.000	0.500	3.000	0.333	0.333	0.500	0.333	0.500	0.500	2.000	0.333	0.500
2	Lack of financial resources of the employer	2.000	1.000	3.000	1.000	0.500	0.500	0.500	0.333	0.500	1.000	0.333	0.333
3	Managerial and technical inability of the employer	0.333	0.333	1.000	0.500	0.333	0.500	0.333	0.500	0.500	0.333	0.333	0.333
4	Lack of sufficient financial solvency of the contractor	3.000	1.000	2.000	1.000	2.000	2.000	0.500	1.000	0.333	2.000	0.333	0.500
5	Contractor's technical and equipment difficulties	3.000	2.000	3.000	0.500	1.000	0.333	0.500	3.000	0.500	2.000	0.333	0.500
6	Lack of skilled manpower by the contractor	2.000	2.000	2.000	0.500	3.000	1.000	0.500	2.000	0.500	4.000	0.333	0.500
7	Problems in research and design	3.000	2.000	3.000	2.000	2.000	2.000	1.000	3.000	2.000	2.000	0.500	2.000
8	Problems in workshop supervision	2.000	3.000	2.000	1.000	0.333	0.500	0.333	1.000	0.500	2.000	0.500	0.333

9	Lack of proper coordination between the counselor and the employer	2.000	2.000	2.000	3.000	2.000	2.000	0.500	2.000	1.000	3.000	0.333	0.333
10	Governmental policymaking problems in prioritizing the development projects	0.500	1.000	3.000	0.500	0.500	0.250	0.500	0.500	0.333	1.000	0.500	0.333
11	The existence of sanctions and the inability to import essential goods	3.000	3.000	3.000	3.000	3.000	3.000	2.000	2.000	3.000	2.000	1.000	3.000
12	Social impacts and disputes and environmental degradation impacts	2.000	3.000	3.000	2.000	2.000	2.000	0.500	3.000	3.000	3.000	0.333	1.000
13	Sum of Column	23.833	20.833	30.000	15.333	17.000	14.583	7.500	18.833	12.667	24.333	5.167	9.667

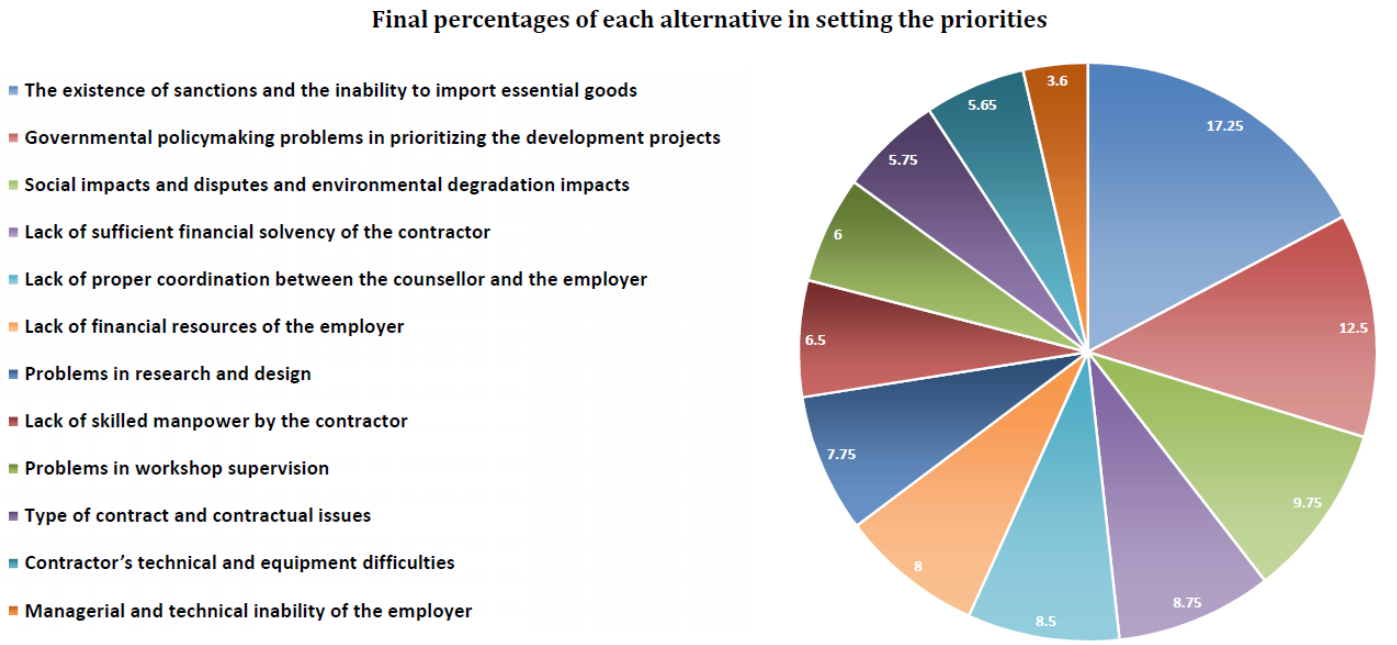


Figure 2: Pie chart of the results of the analysis of prioritizing the causes of delays. The alternative of sanctions and the impossibility of importing the essential (technical) goods are of the highest percentage (17%) among the experts surveyed for the National Iranian Oil Company projects.

the priority of each alternative is determined according to the presented criteria (time and cost). Table 13 shows the weight and final percentage of each cause of delay. In the following, the final results of the analysis are presented as a pie graph in Figure 2.

Software analysis of the research

Introducing the expert choice software: Expert Choice software is a unique method to use pairwise comparisons and extract the priorities, which can reflect your ideas with more accuracy than other methods and yield more accurate results. The software combines and integrates the priorities obtained in each part of your decision-making process, so that the final priorities of your alternatives are determined [24].

Expert choice software results: At first, the analytical hierarchy structure was introduced to the software, which included the analysis objective, the comparison criteria, as well as the alternatives that are the main causes of project delays, respectively. Then, the initial raw data obtained from the questionnaires, including Tables 6, 7 and 11, were given to the software, and the results of the software analysis are as follows.

Figure 3, or dynamic sensitivity for each alternative, shows the final weights for the alternatives and criteria in percentages in separate bar graphs. Among the criteria, time with 75% is the most important. Also among the alternatives, imposed sanctions and the impossibility of importing essential (technical) goods with 17.3% has gained the highest weight. In Figure 4, the performance sensitivity and variations for each alternative are depicted on a linear graph, and the results can be verified and compared.

Figure 5 shows the pairwise comparison graph of the two top

Table 7: Pairwise comparisons of alternatives based on the time criterion.

No.	Options	Type of contract and contractual issues	Lack of financial resources of the employer	Managerial and technical inability of the employer	Lack of sufficient financial solvency of the contractor	Contractor's technical and equipment difficulties	Lack of skilled manpower by the contractor	Problems in research and design	Problems in workshop supervision	Lack of proper coordination between the counselor and the employer	Governmental policymaking problems in prioritizing the development projects	The existence of sanctions and the inability to import essential goods	Social impacts and disputes and environmental degradation impacts
1	Type of contract and contractual issues	1	0.5	2	0.333	2	0.5	0.5	0.5	0.5	1	0.5	0.5
2	Lack of financial resources of the employer	2	1	2	0.5	2	2	3	0.5	3	0.333	0.333	2
3	Managerial and technical inability of the employer	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	1	0.5	0.333	0.5
4	Lack of sufficient financial solvency of the contractor	3	2	2	1	2	2	3	2	1	0.333	0.333	0.5
5	Contractor's technical and equipment difficulties	0.5	0.5	2	0.5	1	0.5	2	2	0.5	0.333	0.333	0.333
6	Lack of skilled manpower by the contractor	2	0.5	2	0.5	2	1	1	2	0.5	0.333	0.333	0.5
7	Problems in research and design	2	0.333	2	0.333	0.5	1	1	0.5	0.5	0.333	0.333	2
8	Problems in workshop supervision	2	2	2	0.5	0.5	0.5	2	1	0.333	0.5	0.333	0.5
9	Lack of proper coordination between the counselor and the employer	2	0.333	1	1	2	2	2	3	1	0.333	0.5	0.5
10	Governmental policymaking problems in prioritizing the development projects	1	3	2	3	3	3	3	2	3	1	1	3
11	The existence of sanctions and the inability to import essential goods	2	3	3	3	3	3	3	3	2	1	1	4
12	Social impacts and disputes and environmental degradation impacts	2	0.5	2	2	3	2	0.5	2	2	0.333	0.25	1
13	Sum of Column	20	14.167	23	13.167	21.5	18	21.5	19	15.333	6.333	5.583	15.333

Table 8: Normalization of weights derived from pairwise comparisons of alternatives based on the cost criterion.

No.	Options	Type of contract and contractual issues	Lack of financial resources of the employer	Managerial and technical inability of the employer	Lack of sufficient financial solvency of the contractor	Contractor's technical and equipment difficulties	Lack of skilled manpower by the contractor	Problems in research and design	Problems in workshop supervision	Lack of proper coordination between the counselor and the employer	Governmental policymaking problems in prioritizing the development projects	The existence of sanctions and the inability to import essential goods	Social impacts and disputes and environmental degradation impacts	Eigenvector
1	Type of contract and contractual issues	0.042	0.024	0.100	0.022	0.020	0.034	0.044	0.027	0.039	0.082	0.065	0.052	0.046
2	Lack of financial resources of the employer	0.084	0.048	0.100	0.065	0.029	0.034	0.067	0.018	0.039	0.041	0.065	0.034	0.052
3	Managerial and technical inability of the employer	0.014	0.016	0.033	0.033	0.020	0.034	0.044	0.027	0.039	0.014	0.065	0.034	0.031
4	Lack of sufficient financial solvency of the contractor	0.126	0.048	0.067	0.065	0.118	0.137	0.067	0.053	0.026	0.082	0.065	0.052	0.075
5	Contractor's technical and equipment difficulties	0.126	0.096	0.100	0.033	0.059	0.023	0.067	0.159	0.039	0.082	0.065	0.052	0.075
6	Lack of skilled manpower by the contractor	0.084	0.096	0.067	0.033	0.176	0.069	0.067	0.106	0.039	0.164	0.065	0.052	0.085
7	Problems in research and design	0.126	0.096	0.100	0.130	0.118	0.137	0.133	0.159	0.158	0.082	0.097	0.207	0.129
8	Problems in workshop supervision	0.084	0.144	0.067	0.065	0.020	0.034	0.044	0.053	0.039	0.082	0.097	0.034	0.064
9	Lack of proper coordination between the counselor and the employer	0.084	0.096	0.067	0.196	0.118	0.137	0.067	0.106	0.079	0.123	0.065	0.034	0.098
10	Governmental policymaking problems in prioritizing the development projects	0.021	0.048	0.100	0.033	0.029	0.017	0.067	0.027	0.026	0.041	0.097	0.034	0.045
11	The existence of sanctions and the inability to import essential goods	0.126	0.144	0.100	0.196	0.176	0.206	0.267	0.106	0.237	0.082	0.194	0.310	0.179
12	Social impacts and disputes and environmental degradation impacts	0.084	0.144	0.100	0.130	0.118	0.137	0.067	0.159	0.237	0.123	0.065	0.103	0.122
13	Sum of Column	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 9: Normalization of weights derived from pairwise comparisons of alternatives based on the time criterion.

No.	Options	Type of contract and contractual issues	Lack of financial resources of the employer	Managerial and technical inability of the employer	Lack of sufficient financial solvency of the contractor	Contractor's technical and equipment difficulties	Lack of skilled manpower by the contractor	Problems in research and design	Problems in workshop supervision	Lack of proper coordination between the counselor and the employer	Governmental policymaking problems in prioritizing the development projects	The existence of sanctions and the inability to import essential goods	Social impacts and disputes and environmental degradation impacts	Eigenvector
1	Type of contract and contractual issues	0.050	0.035	0.087	0.025	0.093	0.028	0.023	0.026	0.033	0.158	0.090	0.033	0.057
2	Lack of financial resources of the employer	0.100	0.071	0.087	0.038	0.093	0.111	0.140	0.026	0.196	0.053	0.060	0.130	0.092
3	Managerial and technical inability of the employer	0.025	0.035	0.043	0.038	0.023	0.028	0.023	0.026	0.065	0.079	0.060	0.033	0.040
4	Lack of sufficient financial solvency of the contractor	0.150	0.141	0.087	0.076	0.093	0.111	0.140	0.105	0.065	0.053	0.060	0.033	0.093
5	Contractor's technical and equipment difficulties	0.025	0.035	0.087	0.038	0.047	0.028	0.093	0.105	0.033	0.053	0.060	0.022	0.052
6	Lack of skilled manpower by the contractor	0.100	0.035	0.087	0.038	0.093	0.056	0.047	0.105	0.033	0.053	0.060	0.033	0.062
7	Problems in research and design	0.100	0.024	0.087	0.025	0.023	0.056	0.047	0.026	0.033	0.053	0.060	0.130	0.055
8	Problems in workshop supervision	0.100	0.141	0.087	0.038	0.023	0.028	0.093	0.053	0.022	0.079	0.060	0.033	0.063
9	Lack of proper coordination between the counselor and the employer	0.100	0.024	0.043	0.076	0.093	0.111	0.093	0.158	0.065	0.053	0.090	0.033	0.078
10	Governmental policymaking problems in prioritizing the development projects	0.050	0.212	0.087	0.228	0.140	0.167	0.140	0.105	0.196	0.158	0.179	0.196	0.155
11	The existence of sanctions and the inability to import essential goods	0.100	0.212	0.130	0.228	0.140	0.167	0.140	0.158	0.130	0.158	0.179	0.261	0.167
12	Social impacts and disputes and environmental degradation impacts	0.100	0.035	0.087	0.152	0.140	0.111	0.023	0.105	0.130	0.053	0.045	0.065	0.087
13	Sum of Column	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 10: Summary of pairwise comparisons results for alternatives (summary of eigenvectors).

No.	Causes of Delay	Time	Cost
1	Type of contract and contractual issues	0.057	0.046
2	Lack of financial resources of the employer	0.092	0.052
3	Managerial and technical inability of the employer	0.040	0.031
4	Lack of sufficient financial solvency of the contractor	0.093	0.075
5	Contractor's technical and equipment difficulties	0.052	0.075
6	Lack of skilled manpower by the contractor	0.062	0.085
7	Problems in research and design	0.055	0.129
8	Problems in workshop supervision	0.063	0.064
9	Lack of proper coordination between the counsellor and the employer	0.078	0.098
10	Governmental policymaking problems in prioritizing the development projects	0.155	0.045
11	The existence of sanctions and the inability to import essential goods	0.167	0.179
12	Social impacts and disputes and environmental degradation impacts	0.087	0.122
	Sum of Columns	1.000	1.000

Table 11: Pairwise comparison of criteria - determining the priority of the criteria.

No.	Alternative	Time	Cost
1	Time	1.00	3.00
2	Cost	0.33	1.00
Sum of Columns		1.33	4.00

Table 12: Normalization of weights of priority of the criteria.

No.	Alternative	Time	Cost	Eigenvector
1	Time	0.75	0.75	0.75
2	Cost	0.25	0.25	0.25
	Sum of Columns	1.33	1.00	1.00

Table 13: Weights and final percentages of each alternative in setting the priorities.

No.	Causes of Delay	Weighted rate	Percentage (%)
1	The existence of sanctions and the inability to import essential goods	0.1725	17.25
2	Governmental policymaking problems in prioritizing the development projects	0.125	12.50
3	Social impacts and disputes and environmental degradation impacts	0.0975	9.75
4	Lack of sufficient financial solvency of the contractor	0.0875	8.75
5	Lack of proper coordination between the counsellor and the employer	0.085	8.50
6	Lack of financial resources of the employer	0.08	8.00
7	Problems in research and design	0.0775	7.75
8	Lack of skilled manpower by the contractor	0.065	6.50
9	Problems in workshop supervision	0.06	6.00
10	Type of contract and contractual issues	0.0575	5.75
11	Contractor's technical and equipment difficulties	0.0565	5.65
12	Managerial and technical inability of the employer	0.036	3.6
	Sum of Columns	1	100

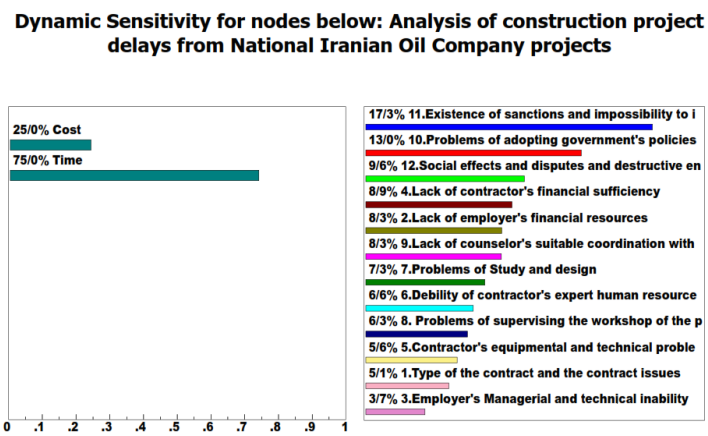


Figure 3: Dynamic sensitivity for each alternative. The final weights for the alternatives and criteria in percentages in separate bar graphs. Among the criteria, time with 75% is the most important.

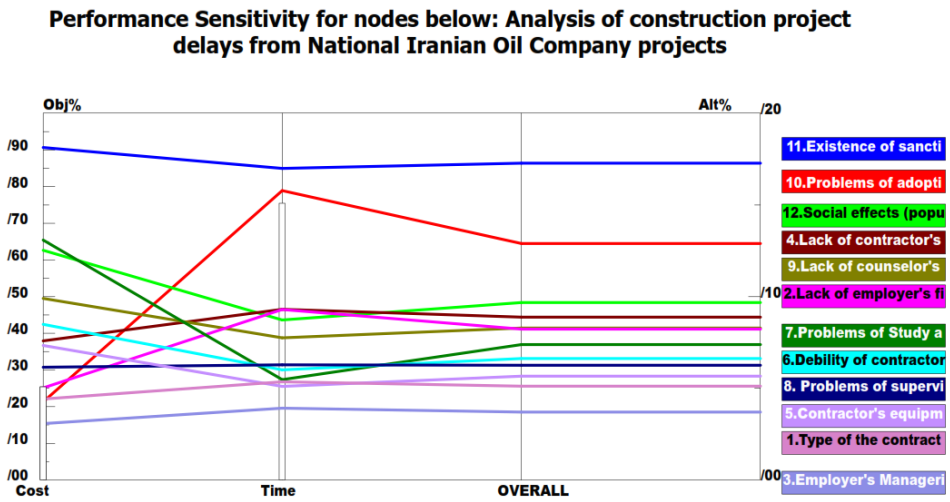


Figure 4: Performance sensitivity for each alternative.

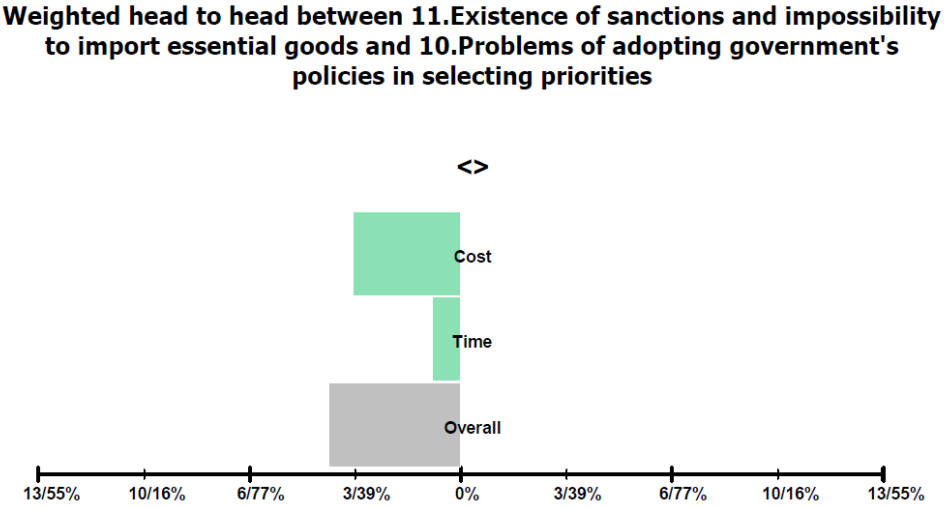


Figure 5: Pairwise comparisons between the alternatives “Existence of sanctions and the impossibility of importing essential (technical) goods” and "Governmental policy-making problems in prioritizing the construction projects.

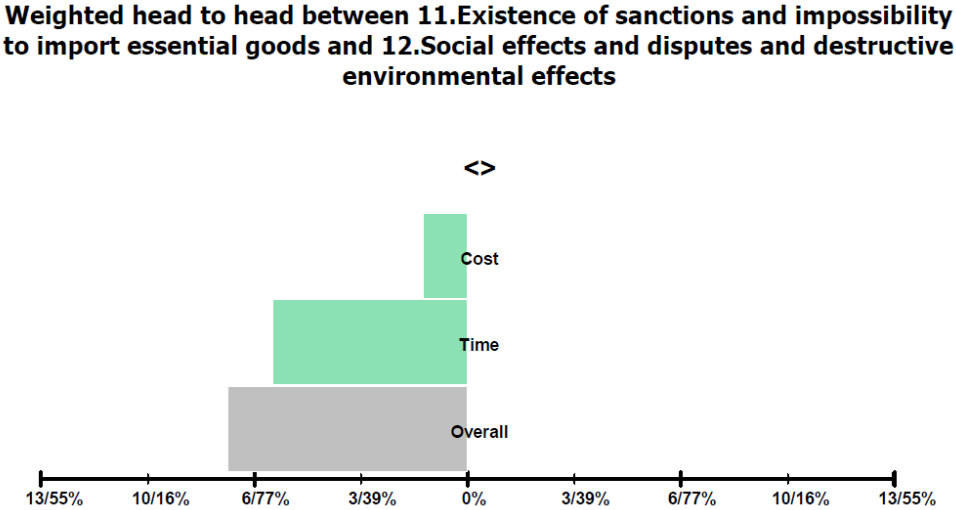


Figure 6: Pairwise comparisons between the alternatives “Existence of sanctions and the impossibility of importing the essential (technical) goods” and “social impacts (public acceptance) and disputes (state-owned and military facilities) and environment.

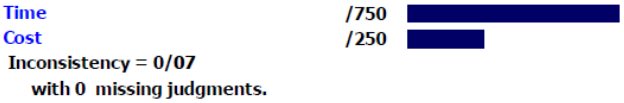
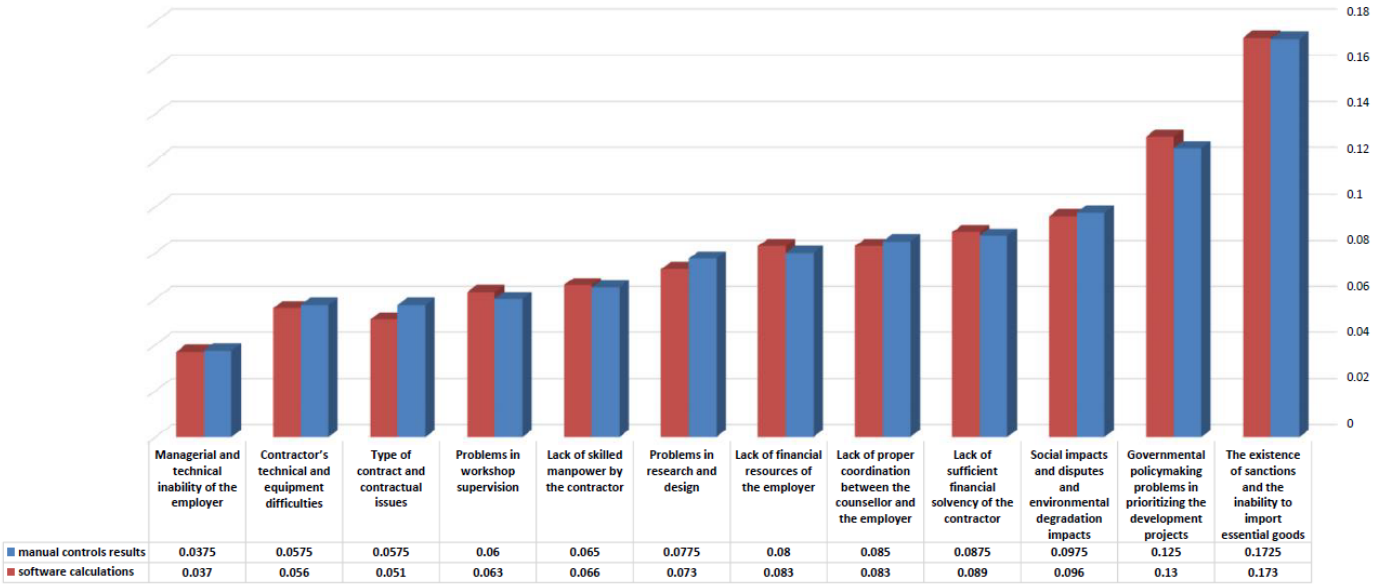


Figure 7: Weighting the criteria.

Figure 8: Final results and weighting options to determine priorities.



	Managerial and technical inability of the employer	Contractor's technical and equipment difficulties	Type of contract and contractual issues	Problems in workshop supervision	Lack of skilled manpower by the contractor	Problems in research and design	Lack of financial resources of the employer	Lack of proper coordination between the counsellor and the employer	Lack of sufficient financial solvency of the contractor	Social impacts and disputes and environmental degradation impacts	Governmental policymaking problems in prioritizing the development projects	The existence of sanctions and the inability to import essential goods
manual controls results	0.0375	0.0575	0.0575	0.06	0.065	0.0775	0.08	0.085	0.0875	0.0975	0.125	0.1725
software calculations	0.037	0.056	0.051	0.063	0.066	0.073	0.083	0.083	0.089	0.096	0.13	0.173

Figure 9: Comparison of software calculations and manual controls results.

alternatives, i.e. “Existence of sanctions and the impossibility of importing the essential (technical) goods” and "Governmental policy-making problems in prioritizing the construction projects” based on the criteria.

Figure 6 shows the pairwise comparison graph of the superior alternative and the third priority, “Existence of sanctions and the impossibility of importing the essential (technical) goods” and “social impacts (public acceptance) and disputes (state-owned and military facilities) and environmentally degrading impacts” based on criteria.

Figure 7 compares the weighted value of the depicted criteria (software output) and the inconsistency ratio of 0.07, which is less than 0.1 and therefore, it is acceptable.

Figure 8 shows the final results and the weight of the alternatives to determine the priorities on a bar graph. The inconsistency ratio is also 0.09, which indicates that the responses of the questionnaires were reasonable, and the analysis results are acceptable, as well.

Conclusion

In national projects, the limited resources and the various issues occurred at the implementation often result in longer schedules and significant cost increases in operationalization of the projects. According to a report by the National Planning and Budget Organization, the average time spent for launching national and capital projects is 8 years, and at both the national and provincial levels, these projects are faced with more than 50% delay during their progress on average [26]. Today, time has a significant impact on productivity, and management based on schedule is the key to progress. Thus, time-based competition, and taking the advantages of the opportunities are the key to success. Therefore, in this research, the causes of delays in National Iranian Oil Company projects were examined, and the obtained data were analyzed by the Expert Choice software. The obtained results were compared with manual controls in Figure 9 that the closeness of the results indicates the accuracy of software calculations.

According to the conducted analysis, the most important factor in increasing the time and costs with the most frequency is the alternative of "Existence of sanctions and the impossibility of importing essential (technical) goods" with a weighting rate of 17.30%. The weighting rates of criteria for this option in comparison with other alternatives are:

Expenses at a weighted rate of 17.86%,

Time at a weighted rate of 16.68%,

And the second alternative is "Governmental policy-making problems in prioritizing the construction projects." The weighting rate of this parameter is 13.00%. The sub-parameters that affect this alternative are:

The costs at a weighted rate of 4.50%,

Time at a weighted rate of 15.46%,

Other alternatives in order of importance include the following:

The third alternative: "Social impacts (public acceptance) and disputes (governmental and military facilities) and environmentally degrading impacts", at a weighted rate of 9.60%,

The fourth alternative: "Financial insolvency of the contractor" at a weighted rate of 8.90%,

The fifth alternative: "Lack of proper coordination between the counselor and the employer (excessive contact with the contractor)" at a weighted rate of 8.30%,

The sixth alternative: "Lack of financial resources of the employer" at a weighted rate of 8.30%,

The seventh alternative: "Problems in research and design" at a weighted rate of 7.30%,

The eighth alternative: "Lack of skilled manpower by the contractor" at a weighted rate of 6.60%,

The ninth alternative: "Problems in workshop supervision" at a weighted rate of 6.30%,

The tenth alternative: "Contractor's technical (operational facilities) and equipment difficulties" at a weighted rate of 5.60%,

The 11th alternative: "Type of contract and contractual issues" at a weighted rate of 5.10%,

The 12th alternative: "Managerial and technical inability of the employer" at a weighted rate of 3.70%,

In this case, it is important to note that it is impossible to prescribe a definitive version for all projects (with different specifications), but the specific conditions of each project must be examined, and the specific causes of the same project must be determined.

Suggestions

Since we have been dealing with a variety of topics on the causes of increased project delays, and each of these issues requires a separate research setting, the suggested topics for further study and research are presented as follows:

1. Analysis of the same topic by other multi-criteria decision-making techniques such as the network analysis process method or structured method of the preferred ranking for enrichment of evaluation as well as comparison of the results obtained by these methods.

2. Further studies to develop various regulations and guidelines, taking into account the specific characteristics of industrial construction projects.

3. Further study on the methods of selecting the contractor company for the project and its consequences.

4. Study on the causes of increased time and costs and providing a model for various types of project contracts according to its capacities and limitations.

5. Study of the individual factors increasing the delay and costs through modeling software and analysis of capacities, and its advantages and disadvantages.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available from the corresponding author by request.

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