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Research article

Classification, prioritization, efficiency, and change management of EPC projects in Energy and Petroleum industry field using the TOPSIS method as a multi-criteria group decision-making method

Peyman Niayeshnia[1], Morteza Rayati Damavandi[2,*] and Sirous Gholampour[2]

[1] Department of Civil Engineering, Sari Branch, Islamic Azad University, Sari, Iran
[2] Department of Civil Engineering, Qaemshahr Branch, Islamic Azad University, Qaemshahr, Iran

* **Correspondence:** Email: m_rayati@Qaemiau.ac.ir; Tel: +981142155089; Fax: +98112240091.

Abstract: Nowadays, Energy supply is a key factor in defining the strategy of different countries. The Petroleum industry, as a major industry of energy production, has become a specialized field due to its diverse products. In this regard, many countries around the world seriously aim to find the best executive and contractual methods along with careful planning to carry out projects in production, extraction, and development of this field in the Petroleum and Energy industry. One of the low-risk methods for carrying out these projects is the implementation of projects in the field of Energy and Petroleum industry under Engineering, Procurement and Construction (EPC) contracts, which transmits the lowest risk to clients.

Scope, time, cost and quality are the main features of project management that affect its efficiency and any project is analyzed and evaluated by these factors. Accordingly, the purpose of this research is to analyze, prioritize, rank, and manage efficiency of EPC executive projects in Energy and Petroleum industry of Iran, using the TOPSIS method as a multi-criteria group decision-making method. The results show that engineering is the most important factor influencing project. In addition, the construction phase has more influence on productivity than the procurement phase. The results of this research and analyses obtained from TOPSIS show that 'poor planning and sequencing of modeling, design, plan, and layout preparation', 'weakness in project planning and control during execution', and 'defective product performance made with project specifications' have more impact on the failure of EPC projects in the energy and Petroleum industry of Iran.

Keywords: EPC; efficiency; energy; Petroleum industry; TOPSIS

1. Introduction

A project is defined as a temporary attempt to achieve or produce a specified product, and the effect of this effort can be investigated by constraints and parameters defined in the project management context [1]. Projects are often performed by project teams as means of achieving important organizational plans (production or services) [2]. Cost, time, and scope are the triple constraints of the project management triangle, which are associated with performance measurement in project management [3]. Project management forms the basis of any industrial or construction project. Ongoing projects in the Energy and Petroleum industry include multi-faceted and structured operations focusing on achieving a unique product such as constructing a refinery unit or an oil platform [4].

The Petroleum and Energy industry in most countries accounts for a significant portion of GDP[1]. According to the WTO[2], this amount in developing countries is approximately 10% of GDP [5], so a success in Energy industries in any country often leads to its economic growth and stability. In recent years, numerous efforts have been made to improve the productivity and success rates of Iran's Energy and Petroleum projects, often indicating the foundations for successful fulfillment of project management [5]. Optimizing projects based on management planning in Energy industries can lead to a more accurate planning for future projects through data collection and control [6]. Project management, planning and control can lead to success in optimizing projects in this field.

Projects defined in the Petroleum and Energy industry generally involve various complex tasks performed by several specialists in the project life cycle, including the engineering, procurement and construction phases. Energy and Petroleum industry projects include installation, process, construction and infrastructure activities and their success requires careful coordination. Accordingly, the Petroleum industry and the energy sector often face problems in their processes that, in some cases, lead to the complete failure of projects. As such, the Petroleum industry and the energy sector are affected by efficiency and productivity, the importance of which can be analyzed in terms of cost, time, and quality [7].

Successful execution of energy projects in this competitive market of energy plays an important role in the prosperity of the contractors in this industry. This industry, like any other industries, needs unending development. This unending development stems from the Plan-Do-Check-Act cycle, which was first introduced in the implementation and construction issues, and later used in the Petroleum Industry and the Energy sector [8]. PDCA depends on continuous measurement of parameters. This is a four-step repetitive management approach which is used by companies continuously in order to control and improve processes and products [9].

As it has been proven in research, increasing changes in executive projects are inversely related to the three main objectives of project management, namely time, cost, and quality, so that increasing changes and rework have negative effects on the above three variables [10]. Therefore, according to the knowledge and executive experience of contractors and in order to expedite the implementation and operation of projects, the using new contractual methods and project management strategies such as project implementation under EPC[3] contracts has become more popular [11]. Also, since the

[1] Gross Domestic Product

[2] World Trade Organization

[3] Engineering Procurement Construction

implementing of these types of projects is not for so long time ago, it is possible to make changes in attitudes between its agents. In this paper, the changes of EPC-implemented projects in an important field, i.e., the Petroleum industry, has studied based on EPC projects characteristics [12].

1. These projects can be completed faster than traditional contracts.
2. The employer and the consultants must trust the contractor's skills and experience, and therefore should not interfere in the contractor's work except when the contractor fundamentally deviates from his duties.
3. The activity of the employer and his consultants will be more in the process of tender and excellent supervision during the project.
4. As a general rule, any defect in the defined scope of work will be the responsibility of the contractor and the risk and executive responsibility will be transferred from the client to the contractor.
5. Integrity in the purchase of equipment and goods, especially foreign purchases, will make their management much easier and more economical.

This process not only reduces the time of engineering, purchase, construction, and commissioning stages, but also reduces the time of stopping the operation [13].

Despite the use of different theories, techniques, and tools, Energy and Petroleum Industry projects still globally suffer from inefficiencies in terms of time, cost, and quality, which can lead to delays, disagreements, and losses [14].

2. Literature review

Little research in Iran have investigated the causes of poor productivity of EPC projects in Energy and Petroleum industries, as well as the prioritization of these factors and their interactions with projects' performances. Therefore, this study aims to identify and prioritize the factors affecting the construction project management with respect to the engineering, procurement, and construction (EPC) projects associated in the Petroleum industry and the energy sector in Iran.

Many researches have been done to find the causes of projects'' weaknesses. Oigunde, Jushua has emphasized on the critical criteria of construction projects including financial stability, work progress, standards, HSE[4], QC[5], relationships with stakeholder, facilities, management authority, contractual and claim arguments, and popularity [15]. Among these factors, time and cost are remarkably important due to their capabilities to establish a crucial benchmark for the assessment of projects' efficiency [16].

The success of a project is also measured via productivity measurement, time, cost, and quality parameters [17]. Time, cost, and quality are three essential elements to determine and measure success in projects [13]. Peter Morris did a research on the success of the various stages of the project from conceptual design to delivery, while examining the impact of project management on project success [18]. During the cycle of the project, these three components start with planning and reach their maximum in the handover stage [19]. Maintaining a stable financial flow between these components is important, particularly because it is linked to the execution of required duties and targets set for the main stakeholders of the project (sub-contractors). These stakeholders often

[4] Heathy Safety Environment

[5] Quality Control

impose a considerable financial loading on the project when the predetermined goals aren't met [20]. Some other risks that can affect the project's achievement, apart from increasing its time and cost, are accidents, fluctuation of price, material inadequacy, weather conditions, international situation, and environmental, health and security conditions [21].

Some researchers have identified stakeholder satisfaction as a principal indicator for measuring the efficiency of projects [22]. They have distinguished that this indicator is as important as the previous elements for measuring of construction sufficiency [23].

Some researchers have identified 'time' as a recognized element of 'project success' and 'project management success', with the emphasis on measuring the success of overall project goals, while the latter is mostly measured by traditional methods [24].

Chairawan has done research on professional project management knowledge. He proposed a model in which the effects of different criteria on the project's achievement were studied in relation with various work areas [25], including project time, cost, design, quality, scope, supply, risk and relation [26]. In addition, for non-industrial projects weaknesses in implementation especially in terms of time and delays, costs increase, and decrease in quality have been investigated by several researchers [27].

Recent studies have been carried out to recognize the items influencing cost and time in buildings projects across the world [28]. These items include defects in contract management, mistakes made in duties, wrong selection of project materials, alteration in engineering, and inaccuracy in the choice of sub-contractors and vendors. In addition to the above factors, a combination of variables including productivity, poor labor, lack of materials, in accuracy in estimating required materials, fluctuations in material costs, lack of sufficient experience with the type and geographical situation of the project in success or project failure are effective as well. Other factors that reduce project efficiency include errors and differences in design, management, and poor monitoring of the workshop and project site, and delays in finalizing the minutes [29].

Several studies in the construction industry have also focused on project control [30]. The purpose of project control is to verify that projects are completed on time and in accordance with the approved budget and meet the agreed goals. Practically, project control is done by project managers and includes continuous measurement of project progress and corrective actions if necessary.

A study conducted on the effect of deviation from project management standards in industrial and construction projects has showed that the lack of effective communication between the project parties leads to a poor productivity in the project and failure [31]. Generally, since the construction sectors in different industries require hand activities and are regularly involved with the personnel's salaries and wages, time management can assist in controlling the costs of wages [32].

Generally, project planning and control is a necessity for all industrial and construction projects. Any activity in the Energy and Petroleum industry projects involves several tasks. However, it is the technical planning that determines which tasks need to be performed, when they need to be completed, what resources are needed, and when these resources are needed. Each schedule indicates the whole plan in graphical form, which can be depicted by a linear chart. This chart shows activities on a horizontal time scale (base on days, weeks, months, or even years, depending on the complexity of the project). The master scheduling plan is typically analyzed and finalized before the commencing the construction phase by the project analysis and management team [33].

Moreover, any delays in the schedule can retard the overall duration of the project, especially when a group of workers should execute a specific task, or that activity must be assigned to subcontractors, in which case any delay may lead to their termination of the contract or change of its price. Therefore, contractual disputes may arise or cause loss and further retard the project [34]. Based on the studies conducted, two of the most important controllable and non-controllable causes of project inefficiency are presented in Table 1 [35].

Table 1. The most important factors influencing the failure of projects.

Effective Factors	
1. Controllable:	
	1.1 Insufficient studies and lack of feasibility and basic information
	1.2 Poor planning, poor design, improper implementation, low quality
	1.3 Inefficient personnel control, inadequate resource allocation, poor budget distribution
	1.4 Change in decisions and working conditions
2. Non-controllable:	
	2.1 Failure in outsourcing methods
	2.2 Environmental issues
	2.3 International factors and limitations
	2.4 Unexpected events and force majeure and infectious diseases such as coronavirus

In addition to the above-mentioned factors, other factors such as mistakes made by contractors, consultants, and personnel; unqualified site management, problems with subcontractors, poor planning, payment problems, and inexperienced or unskilled personnel cause delays in the project and impair its performance and success [36]. Additionally, delays are also caused by other factors that are not under the control of project participants, such as economic instability (e.g., oil price changes), natural disasters, riots, and unpredictable weather conditions, and some other factors created by stakeholders and decision makers, such as changes in design or payment delays and changes in project completion priorities [37].

Poor efficiency can result from unexpected events. Such events can influence the construction and supply of the project goods severely. In one study, three important categories of delays due to unexpected events [38] were analyzed. Delays in starting, prolonging time and suspending work during project implementation are the three main causes of project management inefficiency in different countries and depend on the culture of their construction. In addition, late delivery of materials and consumables, unpredictable land conditions, problems and shortages related to the supply of materials, equipment and manpower, delays in paying employers, financial problems of contractors, design shortcomings, excessive bureaucracy in obtaining a work permit Proper weather conditions, economic losses due to inflation or fluctuations in the prices of goods and materials, and slow decision-making are other factors influencing projects [39].

A study on the impact of the culture of implementing industrial projects on delays indicates that there are differences and similarities in the causes and effects of delays between the Iranian culture and the cultures of other countries. It addressed the effects of effective communication between the parties from the consultant and contractor perspective and their effects [40]. Another study predicted and evaluated the project success by business environment indexes and development models. The importance of the key factors contributing to the success of projects was also worked on by another researcher [41]. Other studies have identified and categorized the main factors for the success of mass builders in Iran [42]. In one study, the factors influencing the success of residential building project contractors were evaluated. It also examined the projects of a reputable investment company in Iran and provided a model for achieving goals in construction projects [43].

Another study evaluated the principal criteria of success in the Azadegan projects [44]. Some studies have examined and identified success criteria in project-based organizations. Some studies have also identified success factors in safety and health processes in Iran [45].

The executive stages of EPC projects are different from those of conventional projects because of the interactions that involve a series of activities to achieve project goals at a particular time. Performing EPC projects requires one of the most sophisticated techniques that can affect a project's success. Some researchers have identified three aspects of success in EPC projects, including execution process, the project value, and client satisfaction. Another researcher emphasized the importance of time, cost, quality, and customer satisfaction in the EPC process phases [46]. In general, the success of industrial projects is strongly related to the efficiency of the project life cycle, and the efficiency of each EPC phase can be attributed to the triangle of time, cost, and quality [47]. Numerous studies have examined the impact of stakeholder decisions on project efficiency. They examined the relationship between the employer, contractors, consultants, suppliers, and sub-contractors [48]. The use of time, cost, and quality as important factors in the success of development projects to evaluate the productivity of development projects has been widely studied by many researchers [49]. However, understanding these factors with respect to the different stages of EPC projects and prioritizing the factors that can affect the success of the project in different parts of the EPC is a prerequisite for success and prevention of project conflicts. Although much more research has been done on the conditions and factors influencing the management of construction and road construction projects, little research has been done on identifying, classifying and prioritizing the factors that affect the poor productivity of industrial projects, especially in the Energy and Petroleum industry. Some researchers have studied factors affecting the poor performance of industrial projects in Iran's Petroleum industry, but little research has identified, classified and prioritized these factors with respect to the EPC stages of these projects. The EPC consists of three stages in each project: (1) engineering, (2) procurement, (3) construction, any of which comprises factors affecting the efficiency of projects in this area in relation to the project target. Also, it is not possible to create a model for all industrial projects due to differences in size, nature, type of contract, contract amount, method of financing, and complexity of projects. Therefore, identifying and prioritizing the reasons for the failure of Petroleum industry projects in Iran have not been specifically studied and such research is needed more than ever.

Although the above research has helped to better understanding of problems associated with poor efficiency in industrial projects, there are some limitations to this:

1. Although several studies have shown the reasons and effects of poor efficiency in the construction industry, only little research has been done on industrial projects, especially the Petroleum industry and the energy sector.

2. Researches have scarcely focused on the identification, prioritization and interaction of efficiency-related factors in the engineering, procurement, and construction (EPC) of Petroleum projects.

This paper has identified and prioritized the major factors that cause project management inefficiency in the executive projects of Iran's Energy and Petroleum industry in terms of time, cost and quality.

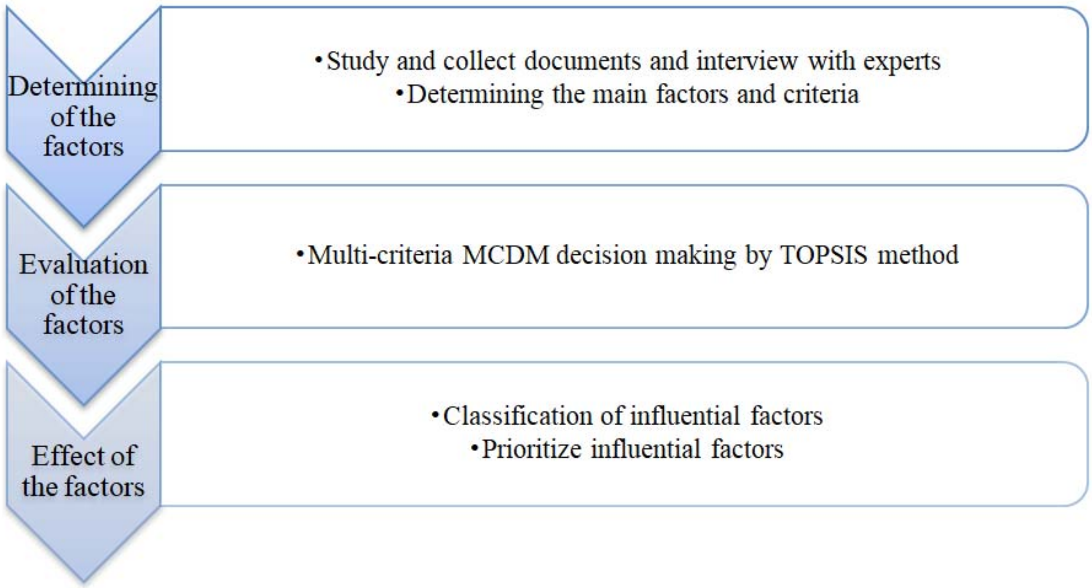

Figure 1. Conceptual framework of the research.

3. Methodology

The Iranian entities involved in the study included the National Iranian Oil Company (NIOC), the National Iranian South Oil Company (NISOC), the National Iranian Oil Refining and Distribution Company (NIODC), contractors and consultant Companies working in Energy and Petroleum field.

This questionnaire includes components that affect the unsuccessfulness of projects activity from the time of the tender until the handover of projects in Petroleum and Energy industry projects in accordance with EPC projects. This questionnaire was distributed among the experts.

Step 1: Efficiency-related Factors

In this study, many factors have identified based on Energy and Petroleum industry beneficiaries' opinion, including employers, consultants, and Petroleum industry contractors, for success in EPC projects and achieving better efficiency for industrial projects. This study examined the main factors of previous research that have been identified as potential factors important for the efficiency of EPC projects [22–37]. The items are presented in Table 2.

Table 2. Preliminary attributes and indexes measurement.

Project phase	Index	EPC project efficiency attributes
Engineering	X_{11}	Poor design in implementation period
	X_{12}	Failure to comply with design criteria to reduce implementation costs
	X_{13}	Weakness in technical calculations and design during the tender period
	X_{14}	Weakness in estimating the cost of execution in tenders and budgeting
	X_{15}	Poor planning and sequencing of modeling, design, plan and layout preparation
	X_{16}	Applying taste in design by the execution department
	X_{17}	Neglecting part of the project in engineering and design calculations
	X_{18}	Weakness in receiving sufficient and accurate information during the tender period
Procurement	X_{21}	Delay in goods and materials delivery
	X_{22}	Change customs rules and shipping of goods and supply chain
	X_{23}	Defective product Performance made with project specifications
	X_{24}	Failure to provide spare parts and consumables during the commissioning period
	X_{25}	Insufficient stakeholder engagement for ordering
	X_{26}	Poor monitoring in the process of manufacturing and supply of goods
	X_{27}	Contractual and financial disputes with the manufacturer and supplier
	X_{28}	Dispute and difference of taste in choice of goods
Construction	X_{31}	Weak in project planning and control during execution
	X_{32}	Lack of review of project contract specifications during implementation-reworking
	X_{33}	Low quality of materials and consumables for construction
	X_{34}	Inflation and price fluctuations
	X_{35}	Poor supervision of the workshop and site
	X_{36}	Unexpected environmental, weather and political events
	X_{37}	Defective operation or commissioning due to the performance of the subcontractor
	X_{38}	Contradiction of project conditions with tender conditions

Step 2: Data collection and evaluation

Data were collected from various companies, particularly EPC contracting companies ranked by the management and planning organization for use in the model developed in step 1. The structure of the questionnaire is based on two parts. The first part is about acquiring audience experience in the Energy and Petroleum industry including the competence and rank of companies, their experience, business activity and nature. The second part is based on the productivity of the contractors in the Energy and Petroleum industry projects. The collected data were quantitatively analyzed. All stakeholders in Iran's Energy and Petroleum industry including consultants, contractors, subcontractors and suppliers, engineers and project managers, and project practitioners were sent 45 questionnaires by email or through communication applications. Survey participants also included engineers, managers, and people with more than fifteen years of work experience and a minimum of a bachelor's degree up to the PhD degree. However, only 39 questionnaires were returned, accounting for about 86% of the responses. The questionnaires were distributed via e-mail and application among selected experts and managers, which show that among the respondents, 33% are employer companies, 36% are contracting companies and 31% are consulting companies. The situation and the experience of the respondents show that their opinions and ideas have competence and represent the society (Table 3).

Table 3. Investigating the characteristics of the respondents.

Category	Item	Frequency	Percent
Type	Experts of employers' companies	13	33
	Experts of contracting companies	14	36
	Experts of consulting companies	12	41
Skill	General Manager/Agent	11	28
	Project Manager/Manager	14	36
	Director	10	26
	Supervisor	4	10
Experience	More than 26 years of work experience	10	26
	25–21 years of work experience	18	46
	16–20 years of work experience	11	28

It should be noted that in order to investigate the reliability of the research data, after obtaining the data from the questionnaire, the internal consistency method was used. The results of this study showed that Cronbach's alpha coefficient based on the following formula is greater than 0.80 in all parts of change management. Therefore, the used questionnaire has the necessary research reliability.

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K}\sigma_i^2}{\sigma^2}\right) \tag{1}$$

The stakeholders involved in EPC projects were asked to answer questions on a seven-point Likert scale and their evaluation is summarized in Table 4.

Step 3: Creating a group Decision-making model and data analysis

A multi-attribute group decision making is an optimization technique that can solve the problem of complex and conflicting situations. Group-based mathematical optimization model is developed to combine the factors identified in Step 1 and collected in Step 2 in a composite decision matrix in order to describe the productivity of EPC contractors well [50]. The purpose of multi-attribute decision making is to select the most desirable project management approaches that have the highest degree of productivity. In this decision making approach, decision makers should select and rank options related to either consistent or inconsistent features. The multi-attribute decision-making technique is needed to list different factors [51].

In this study, the TOPSIS[6] method was used to rank project management approaches in terms of their impact on project performance. The TOPSIS method, which is a group decision making method, offers several solutions for functional activities and path selection through conflicting goal identification and goal path optimization [52]. In addition, by producing a decision matrix and criterion sensitivity analysis, TOPSIS can be used to select the right strategy for a specific program, including the rational ranking of EPC contractors [53].

The TOPSIS technique is one of the well-known classical multi-criteria decision-making techniques, which was first introduced by Hwang and Yoon. The principle logic of TOPSIS is to define the best alternative and the worst alternative solution. The best alternative solution is a way to maximize positive criteria and minimize negative ones. In short, the best alternative solution contains all available values and criteria, while the worst alternative solution is a combination of the worst values and available criteria.

The major assets of the presented TOPSIS method over the others is the basic TOPSIS method aggregate the decision matrices by the aggregation operator and then decide relative coefficients based on the aggregated matrices. But in our approach, we find the relative coefficient of each decision matrix individually and then give the final results for each alternative. Finally, we aggregate the results of each decision-maker and get new relative coefficients for final ranked results. As such, this approach gives both the individual and aggregated ranked results of decision-makers [54].

In addition to considering the distance of an A_i option from the best alternative point, this method considers the distance from the worst alternative point. That is to say, the chosen option should have the shortest distance from the best alternative solution and simultaneously have the shortest distance from the worst alternative solution. The technique is also based on the following concepts:

A. The desirability of each indicator must be consistently incremental or decreasing. The greater the r_{ij} (the score obtained by option i in criterion j), the more desirable it is. The best value of an index represents its best alternative, and its worst value indicates the worst alternative of it.

B. The distance of an option from the best alternative or the worst alternative may be calculated as Euclidean distance or as the sum of the absolute value from linear distances, which depends on the rate of exchange and substitution between the indexes.

The TOPSIS method will be performed in six steps as follows:

Step I. Converting the existing decision matrix into an unscaled matrix using the following formula [55]:

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^{2}}} \tag{2}$$

Step II. Creating a weighted non-scale matrix assuming the W Vector as input to the Algorithm [55]:

$$w = \{w_1, w_2, \ldots w_n\} \tag{3}$$

[6] Technique of Order Preference Similarity to the Ideal Solution

Weighted non-scale matrix: $=V=N_D.W_{n\times n}=\begin{vmatrix} V_{11},\dots V_{1j},..V_{1n} \\ V_{m1},\dots V_{mj},..V_{mn} \end{vmatrix}$

N_D is a matrix in which the scores of indexes are unscaled and comparable and $W_{n\times n}$ is a matrix whose elements of main diameter will only be non-zero.

Step III. Defining the best alternative (A+) and the worst alternative (A−) [56]:

The best alternative option: $= A^{+} = \{(\max V_{ij} \mid j \in J), (\min V_{ij} \mid j \in J') \mid i = 1,2,\dots m\}$

The worst alternative option: $= A^{-} = \{(\min_i V_{ij} \mid j \in J), (\min_i V_{ij} \mid j \in J') \mid i = 1,2,\dots m\}$

J is related to the profit: $J = \{j = 1,2,\dots, n|$

Step IV. Calculating the distance of the 'I' option from the ideal using the Euclidean method [57]:

Distance of 'I' from the best alternative: $d_{i+} = \left\{ \sum_{j=1}^{n} (V_{ij} - V_j^{+})^2 \right\}^{0/5} \quad i = 1,2,\dots, m$

Distance of 'I' from the worst alternative: $d_{i-} = \left\{ \sum_{j=1}^{n} (V_{ij} - V_j^{-})^2 \right\}^{0/5} \quad i = 1,2,\dots, m$

Step V. Calculating the relative proximity of A_i to the worst alternative solution. This relative proximity is defined as follows [58]:

$$i = 1,2,\dots,m \qquad 0 \le cl_{i+} < 1 \qquad cl_{i+} = \frac{d_{i-}}{(d_{i+} + d_{i-})},$$

It is observed that if $+A_i = A$, then $d_{i+} = 0$ and $cl_{i+} = 1$; and if $-A_i = A$, then $d_{i-} = 0$ and $cl_{i+} = 0$.

Thus, the closer the A_i option is to the ideal solution (A+), the closer the cl_{i+} will be to the unit.

Step VI. Ranking the options. Based on the descending order cl_{i+}, the options available from the given problem can be ranked.

4. Analysis

TOPSIS is an effective method for analyzing and ranking alternatives and uses the Net Concordance (NC) value which is an optimistic method and Net Discordance (ND) value which is a pessimistic method. TOPSIS concurrently considers both NC and ND distances to calculate a Net Concordance Dominance (NCD) value [57]. The NCD notion is derived from prospect theory, which is used to identify the ideal point. In this paper, TOPSIS and the notion of NCD are used to develop score values for each project management approaches in each engineering, procurement, and construction phase.

Table 4. Ranking of important factors on the efficiency of EPC project in Petroleum industry and Energy field.

Index	ID	EPC Efficiency Related Indicators	NC	ND	NCD	RANK
X_{11}	A1	Poor design in implementation period	0.82	0.79	0.805	5
X_{12}	A2	Failure to comply with design criteria to reduce implementation costs	0.61	0.81	0.71	9
X_{13}	A3	Weakness in technical calculations and design during the tender period	0.59	0.71	0.65	12
X_{14}	A4	Weakness in estimating the cost of execution in tenders and budgeting	0.7	0.78	0.74	8
X_{15}	A5	Poor planning and sequencing of modeling, design, plan and layout preparation	0.96	0.92	0.94	1
X_{16}	A6	Applying taste in design by the execution department	0.42	0.3	0.36	22
X_{17}	A7	Neglecting part of the project in engineering and design calculations	0.93	0.82	0.875	4
X_{18}	A8	Weakness in receiving sufficient and accurate information during the tender period	0.61	0.44	0.525	16
X_{21}	A9	Delay in goods and materials delivery	0.75	0.58	0.665	11
X_{22}	A10	Change customs rules and shipping of goods and supply chain	0.33	0.29	0.31	23
X_{23}	A11	Defective product performance made with project specifications	0.9	0.88	0.89	3
X_{24}	A12	Failure to provide spare parts and consumables during the commissioning period	0.51	0.5	0.505	17
X_{25}	A13	Insufficient stakeholder engagement for ordering	0.25	0.34	0.295	24
X_{26}	A14	Poor monitoring in the process of manufacturing and supply of goods	0.81	0.69	0.75	7
X_{27}	A15	Contractual and financial disputes with the manufacturer and supplier	0.42	0.55	0.485	18
X_{28}	A16	Dispute and difference of taste in choice of goods	0.72	0.4	0.56	15
X_{31}	A17	Weak in project planning and control during execution	0.9	0.95	0.925	2
X_{32}	A18	Lack of review of project contract specifications during implementation- reworking	0.37	0.45	0.41	19
X_{33}	A19	Low quality of materials and consumables for construction	0.6	0.66	0.63	13
X_{34}	A20	Inflation and price fluctuations	0.64	0.74	0.69	10
X_{35}	A21	Poor supervision of the workshop and site	0.79	0.39	0.59	14
X_{36}	A22	Unexpected environmental, weather and political events	0.48	0.32	0.4	20
X_{37}	A23	Defective operation or commissioning due to the performance of the subcontractor	0.82	0.7	0.76	6
X_{38}	A24	Contradiction of project conditions with tender conditions	0.48	0.26	0.37	21

Table 4 presents the respective Net Concordance Dominance (NCD) value obtained from the TOPSIS method by using the software. The table shows that 'poor planning and sequencing of modeling, design, plan and layout preparation' (NCD = 0.94), 'weak in project planning and control during execution' (NDC = 0.93), and 'defective product performance made with project specifications' (NDC = 0.89) have greater effects than other critical factors in EPC project management in Energy and Petroleum industry. Moreover, the TOPSIS analysis shows that the engineering phase plays a significant role in project efficiency.

5. Results

Although several researchers have studied some causes of poor productivity as well as efficiency of industrial and construction projects in Iran, there is a vital gap in identification, categorization, and prioritization of these factors in industrial projects which was the focus of this study. The executive projects of the Petroleum industry play a significant economic role regarding stakeholders and resources involved in it. Poor efficiency of projects resulting from poor project planning and control is among the most important issues affecting project success. This paper reports recent studies and aims to prioritize the main activities of EPC contractors to achieve better goals in project management system performance.

The results of this study show that most experts of this industry believe that careful execution of design and engineering activities is the key to project success. In fact, the engineering phase have been ranked the first in this study, drawing our attention to the importance of design and planning at the outset of the project, so that the failure of many industrial and executive projects in the Petroleum industry and energy sector can be attributed to poor design and planning [59]. Financial interests generally play the most important role in initiating a project in various industries, which is shared among all project stakeholders. This accelerates project start-up without estimating the appropriate and accurate volumes and values. Therefore, in this case, the success of the project may turn into a failure of the project.

Table 5 shows that the engineering phase of EPC projects has a leading role in project efficiency, and accurate performance of engineering activities in different stages can ensure the success of the project. Also, the construction phase is more important than the procurement and supply of goods phase in Energy and Petroleum industry EPC projects.

Table 5. Ranking of EPC steps and their impact on project efficiency.

EPC Phases	NC	ND	NCD	Rank
Engineering	0.7050	0.6963	0.7006	1
Procurement	0.5863	0.5288	0.5575	3
Construction	0.6350	0.5588	0.5969	2

6. Conclusions

With regard to the set criteria, most EPC project contractors involved in this study, as well as consulting engineers, executives, and employers believe that careful planning in design and engineering and careful planning in preparing engineering documents should be undertaken during the engineering phase in order to prevent project deficiencies and deviation from project goals. In addition, the careful planning and control of the project in implementation during the construction phase and the care in ordering, manufacturing, purchasing and delivery of goods in accordance with the specifications required by the project during the procurement phase will improve the efficiency of EPC projects.

The results of this study can be applied to all project stakeholders, including Petroleum and energy employers, planners, contractors, consulting engineers and companies related to Energy and Petroleum industry, especially the National Iranian Oil Company, the National Iranian South Oil Company and the National Iranian Oil Refining and Distribution and all companies involved in the implementation of EPC projects in the Energy and Petroleum industry in all countries, because they create more quantitative and computational indexes and standards for project productivity, while measuring, comparing, and modifying progress over time by setting goals. Employers can also assign the projects to the qualified contractors based on their previous productivity by utilizing the TOPSIS indexes presented in this article and comparing the contractors at the bidding stage. The TOPSIS technique according to the ranking of options and the ideal solution guides to the best choice and provides a more realistic form of modeling for multi-attribute group decision-making, since it creates a logical relationship among design and engineering activities, product procurement, construction, and execution. This study focuses on the critical triangle of the project (cost, time, and scope) because these factors are more tangible to project stakeholders for the evaluation of project success. However, factors such as safety, sustainability and satisfaction can also be discussed as measures of project success.

For the development of future research, factors such as safety, sustainability and satisfaction can also be discussed as proposed measures to evaluate and rank risks and project changes.

Conflict of interest

The authors declare there are no conflicts of interest in this paper.

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