A novel model for risk management of outsourced construction projects using decision-making methods: a case study

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Abstract

Purpose – Selecting a suitable contract to outsource construction projects is an ongoing concern for project managers and organizational directors. This study aims to propose a comprehensive model to manage the risks of outsourced construction project contracts.

Design/methodology/approach – To employ the proposed model, firstly, the types of contracts and risks in the organization should be identified, then, to prioritize the contracts, the identified risks are considered as criteria. After receiving the experts' opinions, the best–worst method (BWM) integrated with grey relation analysis (GRA) method was used to prioritize the contracts. BWM and GRA are multi-criteria decision-making methods with different approaches and applications. In the current study, BWM has been employed to calculate the weights of criteria because it has better performance than other methods such as the analytic hierarchy process (AHP). After calculating the weights of criteria, the GRA method has been utilized for ranking the alternatives.

Findings – According to the results obtained from the case study, the cost plus award fee contract is the most suitable alternative for outsourcing construction projects. The proposed methodology can be practically applied through different types of the projects such as construction or "engineering, procurement and construction".

Originality/value – To the best of our knowledge, this is the first time a conceptual model has been proposed to select an appropriate contract for construction projects. Also, for the first time, the BWM integrated with GRA method has been used to prioritize project contracts based on the potential risks. The proposed model can contribute to project managers for selecting a suitable contract with the least risk in construction projects.

Keywords GRA, BWM, Risk management, Construction projects, Project management, Decision making

Paper type Research paper

1. Introduction

Nowadays, project management is being widely used across various industrials. As a matter of definition, a project is a temporary effort that has a specific start and endpoint and ultimately leads to a unique service or product (Project Management Institute, 2013, Haiyan *et al.*, 2019). In real-world projects, there are constraints such as cost, time, quality, scope, resources and risk (Feylizadeh *et al.*, 2018; Project Management Institute, 2011). Figure 1 illustrates the major constraints in the projects.

As can be seen from Figure 1, project resource is one of the major constraints in the projects, and it plays a vital role during the implementing phase. On the other hand, resources of organizations are often limited; hence the organization may not be able to perform their projects within the framework of the defined constraints (Momeni and Martinsuo, 2018). To solve this problem, organizations have the option to outsource some of their projects (Buck-Lew, 1992; Elmuti and Kathawala, 2000; Jones, 1996; Olson and Dash Wu, 2010). Identifying the risks of the project, including the risks associated with the scope, cost, time and quality, has a significant impact on contractor selection and how the project should be assigned to the contractor as well (Davison, 2004). One of the main causes of failure of outsourced projects is concluding a contract without considering project risks. The project risk management process consists of a set of distinct procedures, including identifying the potential risks, performing a qualitative and quantitative risk analysis, preparing plan risks response and control risks (Kavčič and Bertoncelj, 2010; Miller, 1992; Project Management Institute., 2009). The process of project risk management is shown in Figure 2 briefly.

Project risk management is done to ensure that the project will be completed within the determined objectives (Mahmoudi and Feylizadeh, 2017). Given the importance of risk management in the current study, we will first identify the potential risks involved in the contracts and then, select the appropriate contract for outsourcing project. There are different types of contracts for projects, including firm fixed-price contracts (FFP), fixed-price incentive fee contracts (FPIF), fixed-price contracts with economic price adjustment (FP–EPA), cost plus fixed-fee contracts (CPFF), cost plus incentive-fee contracts (CPIF), cost plus award-fee contracts (CPAF) and time and material contracts (T&M) (Azariadis and Stiglitz, 1983; Corbett and Tang, 1999; Project Management Institute, 2013). In the rest of the paper, we will examine different types of contracts and identify the risks associated with each of them. After that, we will employ the appropriate multiple criteria decision-making (MCDM) methods for prioritizing the contracts. Finally, a case study will be presented, and based on the results, a general framework for selecting contracts in construction projects will be proposed.

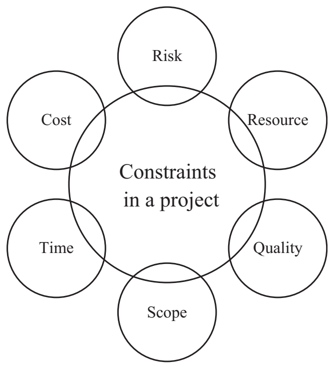

Figure 1.
Project constraints

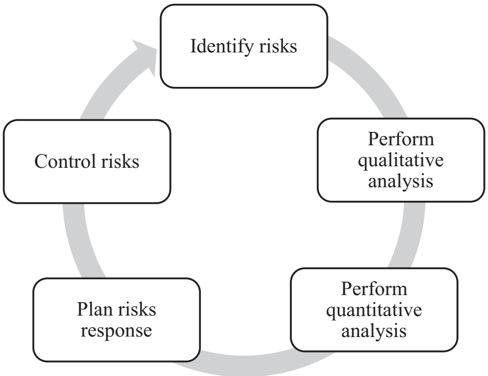

Figure 2.
Project risk management process

2. Literature review

To the authors' best of knowledge, no study has, to date, focused on prioritizing project contracts based on project risks; therefore, this section is a brief review on definitions of project outsourcing. Outsourcing is assignment of some activities in the organization to the third party based on a specified contract. In project outsourcing, in addition to the transfer of activities and production resources such as employees, facilities and technology, decision-making authorities (responsibility and decision-making authority on activities) are also transferred to another organization (Leavy, 2004).

Now, let us first examine the relationship between productivity and outsourcing. Organizations need to outsource some of their activities to increase their productivity. Productivity consists of two main parts, "efficiency" and "effectiveness," where "efficiency" refers to identifying the needs and demands of customers, and "effectiveness" is dependent on the available resources. Measuring both of these parts will determine the organization's productivity. On the other hand, effectiveness is an external viewpoint, whereas productivity is a subjective viewpoint of the organization. Therefore, to measure organizational performance, we have to pay attention to how organizational resources are used and what is the impact of organization on society and its customers. From another perspective, outsourcing of some of the activities of the organization can contribute to managers to focus on more essential issues in the organization. In other words, since managing such activities requires a considerable amount of time, outsourcing may have a positive impact on productivity growth (Klepper, 1995; Shi *et al.*, 2005).

Risk management in outsourcing contracts for construction projects means paying attention to the potential risks of outsourcing contracts. If risk management is not considered during the outsourcing of projects, it may lead to business loss. As the market has been faced many changes in recent years, including globalization, outsourcing and strategic alliances, risk management has turned into an important part of the activities in organizations. More and more companies rely on outsourcing to ensure their success in the highly competitive global market. New outsourcing activities emphasize more on mutual trust and commitment with regard to control skills such as formal and informal contracts. The set of communication skills contribute to managing the communication between the contractor and the client as a new strategic asset. Inappropriate communication may impose extra costs on the organization and lead to higher risks of business loss (Aubert *et al.*, 2005; Bahli and Rivard, 2003). Therefore, effective communication is crucial in understanding how to manage communications for building a suitable strategic value. If risk management is carried out regularly to identify potential risks and finding solutions for them, it will serve complementary function for other processes, including planning, budgeting and cost control. Therefore, a project manager who uses risk management can prevent unexpected events throughout the lifecycle of the project.

3. Best–worst method

The best–worst method (BWM) is one of the most recent methods in the MCDM field (Rezaei, 2016a). This method has more consistent comparisons and requires less information for undertaking pairwise comparisons compared with the analytic hierarchy process (AHP) method (Rezaei, 2015). To employ this method, the best and worst criteria are identified and other criteria are compared against these two criteria. After that, this method utilizes a mathematical model to calculate the weight of the criteria (Rezaei, 2016b). In this section, we are going to do a review on conducted researches on BWM. Supplier selection is an important decision that would have a significant effect on the competitive advantage of the company. This decision becomes even more important when a company is looking for new markets for its service(s) or product(s). Rezaei *et al.* (2016) used the BWM to select and evaluate the best supplier. Commercial organizations in developing countries should focus on the great potentials of innovation for maintaining global competitiveness. Gupta and Barua (2016) identified the expert judgment for technology innovators. Then, a multi-criteria decision-making method, known as the BWM, was used for gaining the most important empowerment. PhD projects are a collaboration between the industrial and academic sectors. Salimi and Rezaei (2016) proposed a framework to examine the productivity of PhD projects. They used the BWM to determine the weights of inputs and outputs. Due to the increasing global competition, transportation has become an important concern for organizations. This is due to the fact that the optimization of transportation problems reduce the costs of organizations and has a significant impact on the performance of the organization. These types of problems can be considered as MCDM problem. Rezaei *et al.* (2017) employed BWM to optimize transportation problems. Urban sewage sludge treatment is critical to reducing the risks of environmental pollution and negative impacts on human health. There are several technologies for treating sewage sludge, and it depends on the stakeholders to choose a sustainable technology based on their unique conditions. Ren *et al.* (2017) used a combination of BWM and TOPSIS methods to select the best alternative for urban sewage treatment. Given the global competition among international airlines, they are seeking ways to increase their quality of service. Gupta (2018) reviewed the quality of airline companies using a combination of BWM and VIKOR method. Wrong decisions can be threaten the future of a business seriously. Therefore, it was necessary to reduce the risk of decision-making using group decision-making. Hafezalkotob and Hafezalkotob (2017) presented fuzzy-BWM and evaluated its performance in group decision-making. Their proposed method reported an appropriate inconsistency ratio. BWM has been proposed in recent years yet, it has been employed in many research items. The steps of BWM are as follows (Rezaei, 2015):

Step 1: Determining a set of criteria by the decision-maker. If n is the number of criteria, Eq. (1) will be obtained:

$$\{c_1, c_2, c_3, \ldots, c_n\} \tag{1}$$

Step 2: Determining the best (B) and worst (W) criteria based on the degree of preference.

Step 3: Determining the degree of preference of the best criterion to the other criteria, which is done using a number from 1 to 9. Best-to-others (BO) vector is shown in Eq. (2):

$$A_B = (a_{B1}, a_{B2}, a_{B3} \ldots a_{Bn}) \tag{2}$$

Step 4: Determining the level of preference of each criterion to the worst criterion, which is done using a number from 1 to 9. Others-to-worst (OW) vector is shown in Eq. (3):

$$A_w = (a_{1w}, a_{2w}, a_{3w} \ldots a_{nw})^T \tag{3}$$

Step 5: At this stage, the optimal weights of the criteria should be determined:

$$(W_1^*, W_2^*, W_3^* \ldots W_n^*) \tag{4}$$

To calculate the weight of the criteria, the min-max Model (5) should be employed:

$$\text{Min max}_j \left\{ \left| \frac{W_B}{W_j} - a_{Bj} \right|, \left| \frac{W_j}{W_w} - a_{jw} \right| \right\} \tag{5}$$

$$s.t$$

$$\sum_j W_j = 1$$

$$W_j \geq 0, \ \text{for all}\, j$$

Model (5) is equivalent to Model (6):

$$\min \xi \tag{6}$$

$$s.t$$

$$\left| \frac{W_B}{W_j} - a_{Bj} \right| \leq \xi, \ \text{for all}\, j$$

$$\left| \frac{W_j}{W_w} - a_{jw} \right| \leq \xi, \ \text{for all}\, j$$

$$\sum_j W_j = 1$$

$$W_j \geq 0, \ \text{for all}\, j$$

After solving Model (6), the optimum weights of the criteria are obtained.

In the BWM, the Consistency ratio should be calculated by Eq. (7):

$$\text{Consistency ratio} = \frac{\xi}{\text{Consistency index}} \tag{7}$$

In Eq. (7), the consistency index is determined based on the value of BO vector (Table 1).

4. Grey relation analysis method

The grey system theory was introduced by Chinese researcher Julong Deng in 1982 (Julong, 1989). This theory is beneficial for examining systems with incomplete or/and unknown information (Liu and Forrest, 2010; Zare *et al.*, 2018; Mahmoudi *et al.*, 2019a). It has wide applications in the project management field, which is employed in some researches recently (Mahmoudi and Feylizadeh, 2018; Mahmoudi *et al.*, 2019b). One of the methods that has been used to deal with uncertainty is the grey relation analysis (GRA), which is one of the essential components of the grey system theory (Liu *et al.*, 2017). The main idea behind GRA is the correlation between two factors based on their degree of similarity. Likewise TOPSIS and VIKOR methods, the GRA method begins with a decision matrix. However, in addition to distinguishing between cost and benefit-type criteria, it also considers the most desirable values (Liu and Du, 2008). It should be noted that a GRA model ought to be utilized carefully because some common errors in terms of using the GRA model have been reported by Javed *et al.* (2018). The GRA method has many advantages yet, it is not able to calculate the weights of criteria. Therefore, we need to employ another method to calculate the weight of criteria in MCDM problems. In this section, we are going to do a review on the GRA method.

Supplier selection is an important topic that hugely depends on company's strategies. Peng and Wang (2011) investigated the supplier selection problem using TOPSIS and GRA methods. Zhang *et al.* (2011) used fuzzy linguistic variables in the GRA method. They mentioned that the use of crisp numbers does not have the required performance in MCDM problems. Kuo and Liang (2011) assessed the quality of Northeast-Asian international airport services by conducting customer surveys. They believed that service quality assessment is a complex MCDM problem. Kuo and Liang (2011) combined the concepts of VIKOR and GRA methods to launch a new fuzzy MCDM approach for assessing the existing problems at international airports. Sun (2014) combined entropy and GRA approaches. The method presented by Sun (2014) was used in four computer design companies. According to the obtained results, the proposed method had reasonable performance. Wang *et al.* (2015) examined the performance of the largest airline in China. They used a combination of entropy and GRA methods and concluded that the entropy method has a suitable performance in calculating the weights of criteria. Gangurde (2016) proposed a framework to evaluate a factory data collection (FDC) system. In his research, the weights of the criteria were calculated based on AHP method, while GRA was used to rank the alternatives. Li and Zhao (2016) proposed a new fuzzy MCDM method by combining VIKOR and GRA approaches to evaluate the performance of eco-industrial thermal power plants. Tseng *et al.* (2018) proposed a new method using interval-valued triangular fuzzy numbers (IVTFN) and GRA method for evaluating green supply chain management. Javed and Liu (2018) and Javed *et al.* (2019) employed the GRA method to examine the relationship between patient satisfaction and five dimensions of healthcare service quality. They conducted a case study in Pakistan so as to evaluate the performance of the model while reasonable results were reported.

In fact, many research studies have used the GRA method because it has excellent performance and consists of simple steps, as follows (Kuo *et al.*, 2008; Peide, 2008; Slavek and Jović, 2012):

Step 1: If the number of alternatives is m and the number of the criteria are n, then the decision matrix ($m \times n$) can be formed like Eq. (8). Each expert uses a number between 1 and 9 for proposing the decision matrix.

Table 1.
Consistency index
Rezaei (2016a, b)

A_{Bw}	1	2	3	4	5	6	7	8	9
Consistency index	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Note(s): Consistency ratio is always a value between 0 and 1. Ratios closer to 0 indicate more consistency

$$X = \begin{bmatrix} x_1(1), x_1(2), \ldots x_1(n) \\ x_2(1), x_2(2), \ldots x_2(n) \\ \ldots. \\ \ldots. \\ x_m(1), x_m(2), \ldots x_m(n) \end{bmatrix} \tag{8}$$

where $x_m(n)$ is the value of the m^{th} alternative and n^{th} criterion.

Step 2: In the GRA method, there are three kind criteria as follows:

- benefit-type criteria (the bigger, the better);
- cost-type criteria (the smaller, the better); and
- medium-type (the closer to a specific value, the better).

Based on the type of criterion, the standardized transformation must be chosen. Equation (9) is suitable for the benefit-type criteria:

$$x_i(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i(k) - \min x_i(k)} \tag{9}$$

Equation (10) is suitable for cost-type criteria:

$$x_i(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)} \tag{10}$$

Equation (11) is suitable for medium-type criteria:

$$x_i(k) = \frac{|x_i(k) - x_0(k)|}{\max x_i(k) - x_0(k)} \tag{11}$$

Step 3: The absolute difference between the referential and the compared series can be calculated using Eq. (12):

$$\Delta x_i(k) = |x_0(k) - x_i(k)| \tag{12}$$

Step 4: In the GRA method, grey relation coefficient ξ is calculated using Eq. (13):

$$\xi_i(k) = \frac{\Delta\min + p\Delta\max}{\Delta x_i(k) + p\Delta\max} \tag{13}$$

The distinguishing coefficient p is a number between 0 and 1. The value of this parameter is usually considered to be 0.5.

Step 5: Finally, the relation degree is calculated using Eq. (14):

$$R_i = \sum[w(k)\xi(k)] \tag{14}$$

w (k) is the weight of the k^{th} criterion. The sum of all *w(k)* is 1.

5. Best–worst method integrated with grey relation analysis

The GRA method cannot be used alone because it cannot calculate the weight of the criteria. BWM is one of the best methods for calculating the weights of the criteria, and it can calculate weights of the criteria. Therefore, the current study proposes a combination of BWM and GRA method to deal with this issue. The BWM integrated with the GRA method consists of the following steps:

Step 1: Determining the set of decision-makers (Eq. (15)), criteria (Eq. (16)) and alternatives (Eq. (17)):

$$\{E_1, E_2, E_3, \ldots, E_k\} \tag{15}$$

$$\{c_1, c_2, c_3, \ldots, c_n\} \tag{16}$$

$$\{a_1, a_2, a_3, \ldots, a_m\} \tag{17}$$

Step 2: Providing the decision matrices by each expert:

$$\{X^{E_1}, X^{E_2}, X^{E_3}, \ldots, X^{E_k}\} \tag{18}$$

Step 3: Using the geometric mean method to integrate the decision matrices:

$$X_i = \left. \prod_{i=1}^{k} X^{E_i} \right)^{1/k} \tag{19}$$

Step 4: Using one of the following states (i to iii) to normalize the decision matrix:

- Benefit-type criteria:

$$x_i(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i(k) - \min x_i(k)} \tag{20}$$

- Cost-type criteria:

$$x_i(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)} \tag{21}$$

- Medium – type criteria:

$$x_i(k) = \frac{|x_i(k) - x_0(k)|}{\max x_i(k) - x_0(k)} \tag{22}$$

Step 5: After that, the absolute difference between the referential and the compared series is calculated based on Eq. (23):

$$\Delta x_i(k) = |x_0(k) - x_i(k)| \tag{23}$$

Step 6: Grey relation coefficient ξ is calculated based on Eq. (24):

$$\xi_i(k) = \frac{\Delta\min + p\Delta\max}{\Delta x_i(k) + p\Delta\max} \tag{24}$$

Step 7: At this step, the best and worst criteria are determined by each expert:

$$\{B^{E_1}, B^{E_2}, B^{E_3} \ldots, B^{E_k}\} \tag{25}$$

$$\{w^{E_1}, w^{E_2}, w^{E_3} \ldots, w^{E_k}\} \tag{26}$$

Step 8: At this step, each expert determines the degree of preference of the best criterion to the other criteria:

$$\begin{aligned} &A_B^{E_1} = (a_{B1}^{E_1}, a_{B2}^{E_1}, a_{B3}^{E_1} \ldots a_{Bn}^{E_1}) \\ &. \\ &. \\ &. \\ &A_B^{E_k} = (a_{B1}^{E_k}, a_{B2}^{E_k}, a_{B3}^{E_k} \ldots a_{Bn}^{E_k}) \end{aligned} \tag{27}$$

Step 9: At this step, each expert determines the degree of importance of criteria 1 to n to the worst criterion:

$$\begin{aligned} &A_w^{E_1} = (a_{1w}^{E_1}, a_{2w}^{E_1}, a_{3w}^{E_1} \ldots a_{nw}^{E_1})^T \\ &. \\ &. \\ &. \\ &A_w^{E_k} = (a_{1w}^{E_k}, a_{2w}^{E_k}, a_{3w}^{E_k} \ldots a_{nw}^{E_k})^T \end{aligned} \tag{28}$$

Step 10: The optimal weight for the criteria can be determined by the following model:

$$\begin{aligned} &\min \xi \\ &s.t \\ &\left|\frac{W_B}{W_j} - a_{Bj}\right| \le \xi, \text{ for all } j \\ &\left|\frac{W_j}{W_w} - a_{jw}\right| \le \xi, \text{ for all } j \\ &\sum_j W_j = 1 \\ &W_j \ge 0, \text{ for all } j \end{aligned} \tag{29}$$

Step 11: After solving Model (29) for each expert, we use Eq. (30) for aggregating the weights:

$$W_j = \left(\prod_{i=1}^{k} W^{E_i} \right)^{1/k} \tag{30}$$

Step 12: The grey relation grade is calculated based on Eq. (31). Then, the alternatives are prioritized according to the obtained scores.

$$R_i = \sum [W_j \xi(k)] \tag{31}$$

6. A conceptual model for outsourcing projects

In this section, we would like to present a model for prioritizing project contracts based on the associated level of risk. The proposed model is shown in Figure 3.

6.1 Providing a group of subject matter experts

There are different methods for identifying experts in different topics, one of which is snowball sampling (Biernacki and Waldorf, 1981). For this purpose, the first expert is identified through an interview and the next experts will be introduced by the last interviewee. This process continues until no new expert is introduced by the last experts.

6.2 Identifying the type of contracts in the organization

One of the most comprehensive and specialized sources with regard to the type of contracts is the Project Management Body of Knowledge (PMBOK) standard. After reviewing types of outsourcing contracts, seven types of contracts were identified for projects. The identified contracts are as follows (Project Management Institute, 2013):

(1) FFP contracts

In this type of contract, a fixed price is determined for a specific product. Any changes in the scope will increase the contract price.

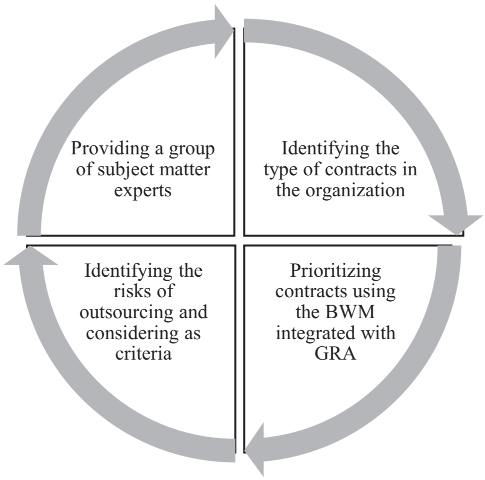

Figure 3.
A conceptual model for outsourcing projects

(2) FPIF contracts

In this type of contract, a fixed price is considered with an incentive fee. The incentive fee is determined based on the performance of the contractor at the end of the work.

(3) FP–EPA contract

This contract has a fixed price with an adjustment factor. In cases where the duration of the project is long and the large-scale economic conditions influence the project, this type of contract is suggested.

(4) CPFF contracts

In this type of contract, the employer pays the costs of performing the work by paying a fixed fee to the contractor.

(5) CPIF contracts

In this type of contract, the employer pays the costs of performing the contract work and also takes into account the incentive fee for a specific performance. If the contractor demonstrates a specified performance, they will receive an incentive fee. It should be noted that the incentive fee is limited.

(6) CPAF contracts

In this type of contract, the employer pays the cost of performing work to the contractor. Based on the objectives set for the contractor, a reward amount is also paid to the contractor.

(7) T&M contracts (T&M)

This type of contract is usually calculated based on man-hours. The cost per man-hour is specified in the contract beforehand, and the price of the contract is determined based on the man-hours spent.

However, some organizations may not be able to choose some of these contracts; therefore, it is vital to check the types of contracts that are feasible in the organization.

6.3 Identifying the risks of outsourcing and considering as criteria

At this step of the model, the risks of project outsourcing should be identified. There are several methods for identifying potential risks. The following techniques have been recommended (Project Management Institute, 2013).

(1) documentation reviews;

(2) expert judgment;

(3) information gathering techniques;

(4) checklist analysis;

(5) assumptions analysis;

(6) diagramming techniques;

(7) SWOT analysis; and

(8) lesson learned.

In general, construction projects involve the following risks:

(1) *Quality risks*

Deliverable quality is always one of the main criteria against which the success of a project is evaluated. Quality risks include rework and scrap in project deliverables.

(2) *Intellectual property risks*

The intellectual property risks involve using the name of the project by the contractor to advance the company's aims. For example, contractor may use the authority that retrieved from the client to advance personal goals.

(3) *Business loss risks*

Failure to fulfill the defined objectives of the project can lead to the loss of credibility and degradation of the brand. The employer should take preventive actions and choose the best type of contract to avoid such risks. Placing full trust in the contractor increases the risk of business loss.

(4) *Data security risks*

The security of personal and organizational information in today's competitive market has a massive impact on the success of the organization. Information security risks imply the leakage of some vital information by the contractor to the outside world.

(5) *Lack of client authority*

In some contracts, the employer does not have sufficient control over the contractor's executive activities. In this case, there are much time and risk aversion. This risk refers to the lack of control of the company and the organization over the implementation of some of the activities carried out by the contractor.

(6) *Supplier risks*

Supplier risks include delays in deliveries and/or improper quality. If the material of the project is not provided at the agreed-upon time with proper quality, it will cause considerable risks for the employer.

(7) *Cultural risks*

The type of contract and how to work with the contractor can have a significant impact on organizational culture. Therefore, cultural risks should be considered when choosing a specific type of contract.

(8) *Time risks*

If the project is not completed within the defined time framework, it may lead to uneconomical development of the project. Time risks are the result of poor time management. The employer should work with a contractor who can manage the project on time and prevent contractor delays.

(9) *Psychological risks*

Choosing the type of contract can have many psychological impacts on the staff of client. For instance, the working hours or salaries of contractor's personnel may have a negative impact on the client's personnel. Therefore, psychological risks should be taken into consideration during contract selection process.

(10) *Financial risks*

If the initial estimates by the employer are not properly executed, it may result errors in fixed-price contracts, which could potentially lead to a significant loss of financial resources. Financial risks are those that lead to the loss of corporate finance.

6.4 Prioritizing contracts using the best–worst method integrated with grey relation analysis

After identifying the risks, we would consider them as criteria and the identified contracts as alternatives. Then, we collect the opinions of the experts and, ultimately, use the BWM integrated with GRA method for prioritizing the contracts. After prioritization, the best contract with the lowest risk should be chosen.

7. Real-world application

Pars Special Economic Energy Zone is located on the borders of the Persian Gulf in an area of 46,000 ha in Bushehr Province, Iran. This zone consists of three regions, namely, Pars I (South Pars) with an area of 14,000 ha (including Asaluyeh city), Pars II (Kangan) with an area of 16,000 ha (which includes Kangan city) and Pars III (The Northern Pars) with an area of 16,000 ha (comprising the cities of Daeir, Dashti, Tangestan and Bushehr). Pars Special Economic Energy Organization (EFA), on behalf of the Iranian Ministry of Petroleum and the National Iranian Oil Company, is responsible for the management and operation of the South Pars, Pars Kangan and North Pars regions. The main activities of the EFA include the definition, approval (design, implementation, construction and maintenance) of the establishment and construction of public infrastructure, including roads, railways, ports, airports, electricity, water and management of the region.

7.1 Providing a group of subject matter experts

To identify the risks as well as the outsourcing contracts, the authors joined the South Pars Energy Special Economic Zone Organization to interview with the team of experts. Snowball sampling was used to identify these experts. For this purpose, the authors began the interview by identifying the first expert in the organization and the next experts within the organization were introduced from the viewpoint of the last expert. After fully completing these steps, seven experts were identified in the South Pars of the Special Economic Energy Organization. The team of experts was identified and introduced in coordination with this organization. The information regarding the members of the team of experts is shown in Table 2.

7.2 Identifying the type of contracts in your organization

After interviewing the experts, it was found that all types of mentioned contracts can be potentially used in the organization. The list of contracts types is shown in Table 3.

Identifier	Gender	Educational degree	Field of study	Work experience (year)
E1	Male	Bachelor	Mechanical engineering	15
E2	Male	Bachelor	Law	10
E3	Male	Bachelor	Civil engineering	13
E4	Male	Bachelor	Electrical engineering	20
E5	Male	Masters	Industrial engineering	15
E6	Male	Masters	Industrial management	18
E7	Male	Masters	Governmental management	15

Table 2. Information of experts

7.3 Identifying the risks of outsourcing and considering as criteria

After using the risk management techniques (expert judgment, documentation reviews, etc.), Table 4 has been presented for identified risks in the organization.

7.4 Prioritizing the contracts using the BWM integrated with GRA method

Step 1: The sets of decision-makers, criteria and alternatives are defined as follows:

$$\text{Expert} = \{E_1, E_2, E_3, E_4, E_5, E_6, E_7\} \tag{32}$$

$$\text{Criteria} = \{C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9, C_{10}\} \tag{33}$$

$$\text{Alternative} = \{A_1, A_2, A_3, A_4, A_5, A_6, A_7\} \tag{34}$$

Step 2: All the information was collected using a questionnaire, and Cronbach's α was calculated ($\alpha = 83\%$) based on Eq. (35). Finally, the decision matrices for each expert are shown in Table 5.

$$D = |\text{Max}\, F(x) - S_N(x)| \tag{35}$$

Step 3: After using the geometric mean operator to integrate the decision matrices in Step 2, the results are shown in Table 6.

Step 4: Proper normalization method for this case is Eq. (21) because all the criteria are cost type. After employing Eq. (21), Table 7 has been obtained.

Step 5: The absolute difference between the referential series and the compared series has been shown in Table 8.

Table 3. The list of contracts types

Identifier	Type of contract (alternative)
A1	CPAF
A2	T&M
A3	CPIF
A4	CPFF
A5	FP–EPA
A6	FFP
A7	FPIF

Table 4. Identified risks for contracts

Identifier	Criterion
C1	Quality risks
C2	Intellectual property risks
C3	Business loss risks
C4	Data security risks
C5	Lack of client authority
C6	Supplier risks
C7	Cultural risks
C8	Time risks
C9	Psychological risks
C10	Financial risks

Alternatives	Expert	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	E1	2	3	3	4	2	1	1	3	3	3
	E2	4	1	1	1	1	1	4	4	2	2
	E3	2	3	3	5	4	2	1	3	4	4
	E4	1	3	2	2	3	3	4	5	5	1
	E5	4	1	3	3	2	1	2	1	3	3
	E6	4	5	6	2	1	1	3	3	2	1
	E7	4	6	5	1	2	3	3	3	5	4
A2	E1	4	3	2	1	3	5	4	4	3	4
	E2	3	5	4	4	4	2	2	4	4	3
	E3	4	5	5	4	6	5	4	4	2	1
	E4	2	3	3	3	4	4	2	2	3	2
	E5	3	5	4	4	2	1	1	8	4	3
	E6	1	2	2	3	3	3	1	1	2	2
	E7	1	3	3	2	1	1	5	5	1	2
A3	E1	4	5	1	1	2	3	3	3	4	2
	E2	2	3	3	4	5	5	4	4	3	1
	E3	4	5	6	5	1	1	3	2	4	2
	E4	2	1	3	3	5	4	4	5	2	3
	E5	1	2	1	3	3	2	4	5	4	4
	E6	5	4	2	1	3	1	1	2	1	1
	E7	1	3	2	5	4	4	2	3	3	1
A4	E1	5	4	5	4	8	7	5	4	4	3
	E2	1	3	5	4	5	5	8	7	3	5
	E3	4	5	6	6	4	5	5	4	4	5
	E4	5	4	4	8	7	4	4	6	5	4
	E5	1	3	3	3	5	8	7	7	4	6
	E6	2	4	5	5	6	6	6	8	7	7
	E7	1	4	5	5	4	4	5	5	4	4
A5	E1	5	6	7	5	6	2	6	4	8	7
	E2	4	6	5	4	4	4	5	5	5	4
	E3	4	6	5	4	4	6	6	8	7	4
	E4	8	7	5	4	6	6	4	4	5	5
	E5	4	6	2	1	3	8	8	9	8	7
	E6	4	6	5	4	4	2	2	3	3	4
	E7	4	6	6	4	4	4	4	4	6	8
A6	E1	8	7	7	6	5	8	7	6	8	7
	E2	8	8	7	5	4	4	8	7	7	6
	E3	7	8	7	5	4	6	4	8	7	7
	E4	7	8	5	4	6	8	7	7	8	9
	E5	4	5	6	6	8	7	9	7	8	8
	E6	7	5	4	4	6	6	8	7	7	8
	E7	7	7	8	8	8	6	5	4	8	7
A7	E1	5	6	6	4	4	4	5	5	4	6
	E2	4	5	4	8	7	5	4	6	4	6
	E3	4	6	6	5	4	5	5	4	5	8
	E4	1	3	2	1	5	7	9	8	9	8
	E5	4	5	6	8	7	7	5	5	6	4
	E6	4	4	6	6	8	7	7	4	6	4
	E7	4	6	5	5	8	8	7	7	7	7

Table 5.
Decision matrices for each expert

Table 6.
Integrated decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	2.691800	2.603142	2.874102	2.187914	1.919471	1.511209	2.245649	2.874102	3.221389	2.245649
A2	2.245649	3.524061	3.120319	2.737476	2.900723	2.493898	2.279705	3.387628	2.479397	2.245649
A3	2.279705	2.917689	2.155229	2.642620	2.917689	2.415653	2.737476	3.221389	2.737476	1.738511
A4	2.131663	3.803711	4.621092	4.786966	5.402919	5.402919	5.577926	5.668967	4.293146	4.696516
A5	4.559409	6.133595	4.723985	3.387628	4.310458	4.067874	4.636775	4.913285	5.725117	5.349929
A6	6.713476	6.732880	6.140781	5.285239	5.652293	6.284286	6.632299	6.443162	7.555032	7.373869
A7	3.387628	4.868194	4.715455	4.517566	5.906800	5.982904	5.798880	5.402919	5.639591	5.930620

Table 7. The normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	0.877748	1.000000	0.819630	1.000000	1.000000	1.000000	1.000000	1.000000	0.853813	0.910008
A2	0.975122	0.777003	0.757853	0.822569	0.753908	0.794118	0.992236	0.856117	1.000000	0.910008
A3	0.967689	0.923834	1.000000	0.853194	0.749653	0.810512	0.887881	0.902695	0.949153	1.000000
A4	1.000000	0.709287	0.381299	0.160872	0.126371	0.184654	0.240359	0.216919	0.642656	0.475099
A5	0.470134	0.145115	0.355483	0.612661	0.400354	0.464357	0.454908	0.428650	0.360529	0.359150
A6	0.000000	0.000000	0.000000	0.000000	0.063829	0.000000	0.000000	0.000000	0.000000	0.000000
A7	0.725880	0.451526	0.357623	0.247850	0.000000	0.063142	0.189990	0.291461	0.377380	0.256106

Table 8.
The absolute difference between the referential series and the compared series

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	0.122252	0.000000	0.180370	0.000000	0.000000	0.000000	0.000000	0.000000	0.146187	0.089992
A2	0.024878	0.222997	0.242147	0.177431	0.246092	0.205882	0.007764	0.143883	0.000000	0.089992
A3	0.032311	0.076166	0.000000	0.146806	0.250347	0.189488	0.112119	0.097305	0.050847	0.000000
A4	0.000000	0.290713	0.618701	0.839128	0.873629	0.815346	0.759641	0.783081	0.357344	0.524901
A5	0.529866	0.854885	0.644517	0.387339	0.599646	0.535643	0.545092	0.571350	0.639471	0.640850
A6	1.000000	1.000000	1.000000	1.000000	0.936171	1.000000	1.000000	1.000000	1.000000	1.000000
A7	0.274120	0.548474	0.642377	0.752150	1.000000	0.936858	0.810010	0.708539	0.622620	0.743894

Step 6: In this step, the grey relation coefficient ξ should be calculated. In this case, the grey relation coefficient is shown in Table 9.

Step 7: The best and worst criteria are as follows:

$$B = \{c_{10}, c_1, c_5, c_5, c_8, c_8, c_1\} \tag{36}$$

$$W = \{c_9, c_9, c_2, c_2, c_7, c_7, c_9\} \tag{37}$$

Step 8: At this step, each expert should determine the degree of preference of the best criterion to the other criteria. The results are shown in Table 10.

Step 9: At this step, each expert should determine the degree of preference of the other criteria to the worst criterion. The results are shown in Table 11.

Step 10: The optimal weight for each criterion was calculated by each expert based on Model (28). The optimal weights are shown in Table 12.

Step 11: If the weights of criteria that have been calculated based on all experts' opinion aggregate using geometric mean, Table 13 will be resulted.

Step 12: Employing Eq. (31), the grey relation grade for each alternative is calculated in Table 14.

During the process of selecting a suitable contract, different risk factors are involved. The current study focuses on prioritizing project contracts based on the identified risks. The importance of all the risks is taken into account in decision-making process based on their weights. Based on the overall results, the CPAF contract has the least risk, and the FPIF contract has the most risk for the organization. Indeed, the CPAF contract has an appropriate risk level for outsourcing construction projects. In the current research, different types of contracts and project risks were considered. Therefore, the results obtained for this case study may also be used for other projects with the same characteristic. Figure 4 shows the contracts with the highest and lowest associated risks in each criterion.

7.4.1 Sensitivity analysis. One of the critical issues in the GRA method is checking priority sustainability. Given that the value of the distinguishing coefficient in the present study is 0.5, and one might ask whether or not this value was appropriate. For this purpose, by changing the value of the distinguishing coefficient, the degree of change in the grey relation grade is examined. Figure 5 shows different results based on different values for distinguishing coefficient in GRA method.

As can be seen from Figure 5, the value of the grey relation grade increases for each alternative by increasing the distinguishing coefficient. Therefore, it is resulted that the priority of the alternatives remains constant with any change in the distinguishing coefficient. Figure 6 also shows the priority of the alternatives for different values of the distinguishing coefficient. As can be seen from Figure 6, the ranks of alternatives has not

Table 9.
Grey relation coefficient for each alternative

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	0.885985	1.000000	0.840433	1.000000	1.000000	1.000000	1.000000	1.000000	0.866640	0.913468
A2	0.974481	0.809891	0.796882	0.842623	0.794253	0.821883	0.991894	0.868466	1.000000	0.913468
A3	0.967107	0.925776	1.000000	0.866151	0.791438	0.833707	0.894438	0.907090	0.949196	1.000000
A4	1.000000	0.765689	0.605597	0.530985	0.520939	0.538138	0.555672	0.548157	0.726664	0.644111
A5	0.641950	0.526349	0.595792	0.710366	0.613043	0.639454	0.635412	0.624445	0.597683	0.597165
A6	0.487179	0.487179	0.487179	0.487179	0.503666	0.487179	0.487179	0.487179	0.487179	0.487179
A7	0.776068	0.633979	0.596593	0.558118	0.487179	0.503483	0.539770	0.572793	0.604087	0.560838

experienced any change for different values of distinguishing coefficient in the GRA method. Determine the optimum value for distinguishing coefficient was a challenge in many conducted researches. It can be seen the results presented in this study enjoy a high level of stability and can be used in different projects confidently. The proposed model can contribute project managers to reduce the risk of outsourcing construction projects.

8. Conclusion and recommendations

Selecting the best contract is always one of the most critical factors for the success of any project. If project manager does not select an inappropriate contract for the project, it can lead to financial loss or failure of the project as well. Project managers should choose the best contract according to organization condition and the identified risks. In the present study, a conceptual model was presented to select the appropriate contract for construction projects. The proposed model was examined through a case study, and its performance was evaluated. According to the results obtained from the case study, the CPAF contract is the most suitable

Expert	Best criterion	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
E1	C10	9	3	9	7	5	3	3	7	9	1
E2	C1	1	4	5	5	6	3	5	9	9	1
E3	C5	1	9	4	6	1	8	8	9	2	9
E4	C5	1	9	5	6	1	8	8	2	9	2
E5	C8	9	5	7	6	5	2	2	1	2	8
E6	C8	9	6	6	6	5	6	3	1	3	8
E7	C1	1	3	5	5	3	3	3	9	3	5

Table 10. The degree of preference of the best criterion to other criteria

Expert	Worst criterion	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
E1	C9	9	3	7	5	5	3	9	3	1	9
E2	C9	9	3	8	7	7	5	3	9	1	5
E3	C2	9	1	3	5	9	6	2	8	2	9
E4	C2	9	1	5	3	9	6	2	8	2	9
E5	C7	9	5	6	5	5	8	1	9	3	3
E6	C7	9	6	6	6	5	6	1	9	3	8
E7	C9	9	3	9	7	3	5	1	9	1	5

Table 11. The degree of preference of the other criteria to the worst criterion for each expert

	E 1	E 2	E 3	E 4	E 5	E 6	E 7
C1	0.047302	0.152015	0.116159	0.178941	0.044744	0.125897	0.160594
C2	0.103182	0.087910	0.030795	0.014493	0.121326	0.042295	0.092871
C3	0.047302	0.141331	0.047481	0.108232	0.095245	0.042295	0.160594
C4	0.100691	0.130647	0.039023	0.067441	0.121326	0.042295	0.138020
C5	0.128263	0.130647	0.438153	0.178941	0.121326	0.046430	0.092871
C6	0.103182	0.109278	0.033123	0.038455	0.156912	0.042295	0.115445
C7	0.178424	0.087910	0.033123	0.038455	0.011862	0.033377	0.070297
C8	0.100691	0.040301	0.085364	0.164448	0.168774	0.474883	0.042575
C9	0.012540	0.010684	0.060619	0.031652	0.097601	0.057715	0.011287
C10	0.178424	0.109278	0.116159	0.178941	0.060885	0.092520	0.115445

Table 12. The optimal weight of criteria for each expert

Table 13.
The final weight for each criterion

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
0.125841	0.068575	0.097230	0.098604	0.158746	0.087939	0.057409	0.132539	0.034687	0.138431

alternative for outsourcing construction projects. The results presented in this case study can be used in other similar projects. However, there are some limitations in terms of identifying the risks in projects. Also, it takes much time from the project team to provide a comprehensive list of risks in the project. There are some techniques to identifying risks, including documentation reviews, assumptions analysis and checklist analysis, that can contribute to project team to facilitated risk management process. In future studies, other

Alternative	Score	Rank
A1	0.953533173	1
A2	0.870282656	3
A3	0.909704241	2
A4	0.638530695	4
A5	0.621042066	5
A6	0.489796637	7
A7	0.581285013	6

Table 14.
Grey relation grade for each alternative

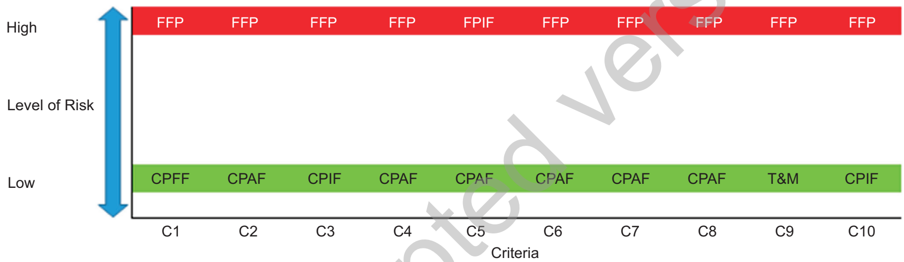

Figure 4.
Best and worst contracts in each criterion

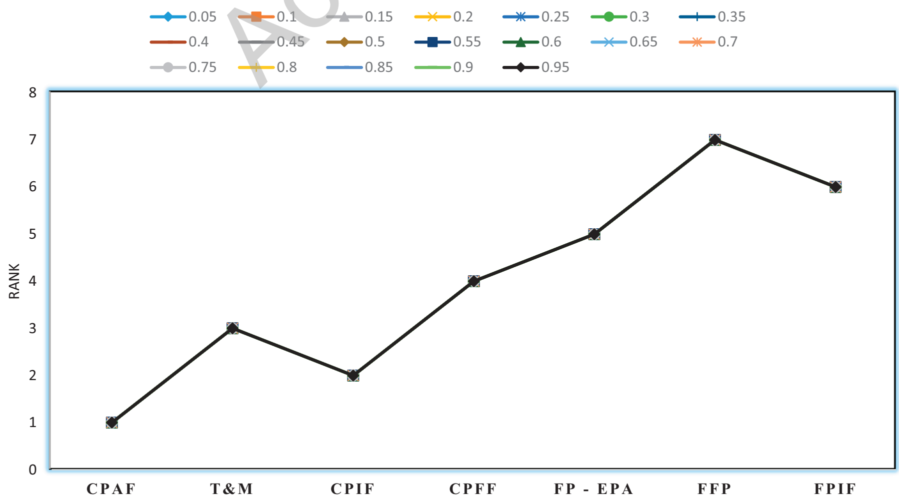

Figure 5.
Sensitivity analysis of the grey relation grade

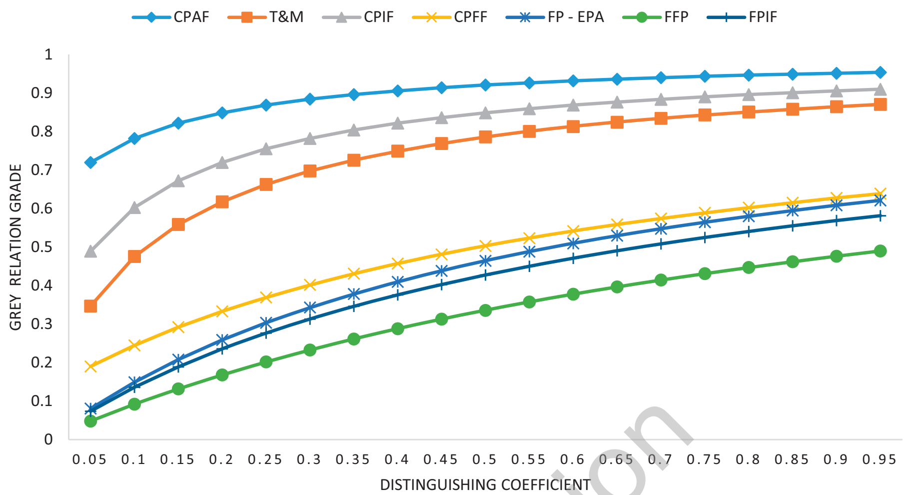

Figure 6.
Sensitivity analysis on the rank of alternatives

MCDM methods can be used to rank the possible contracts. Also, scholars can find some more important factors that involve outsourcing construction projects.

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