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ORIGINAL ARTICLE

# An efficient claim management assurance system using EPC contract based on improved monarch butterfly optimization models

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**Abstract**

The Engineering Procurement Construction (EPC) contract systems are widely employed in the construction industry. Among the prevalent issues in this sector, cash flow problems frequently lead to decreased productivity and efficiency. To address these challenges, a claim management system is developed based on the Improved Monarch Butterfly Optimization Algorithm (IMBOA) and the principles of EPC. Conventional construction models typically optimize only a single objective, such as time, cost, or delay, which may not effectively enhance overall performance. This study aims to develop a claim management system based on IMBOA and EPC principles to optimize multiple objectives, focusing on minimizing project costs and time delays while ensuring high-quality results. The basic methodology of this research involves integrating EPC and claim management principles with the IMBOA algorithm to create an efficient, high-quality system. This process starts with a comprehensive literature review on EPC, claims, MBOA, and related algorithms. Common disputes and claims in the construction industry are examined, and critical factors influencing these claims are identified. The Monarch Butterfly Optimization Algorithm (MBOA) and its improved version (IMBOA) are explored for their application in optimizing project performance. A case study in China's coal mining industry evaluates the effectiveness of the EPC approach, demonstrating that it minimizes time delays and costs. The IMBOA approach proposed in this study has the potential to mitigate 23% of risks and avoid 32% of risks associated with the action plan of China's coal mining industry. Furthermore, comparative analysis with other optimization models indicates that the developed IMBOA model yields superior results, reducing overall project time by 15% and cost by 18%.

**Keywords** EPC · Claim management system · Improved monarch butterfly optimization · Risk analysis · Cost · Quality

## 1 Introduction

The term project management is described as the process of achieving the project objectives, such as on-time completion concerning the budget cost, the resources used efficiently, and acceptance by the consumers of the required results. In general, about 33% of projects are completed on-time, 36% within three months from the specified time, 13% within six months from the specified time, and 18% take longer than six months. However, oil and gas industry projects have the worst completion time. Only 19% of projects are completed before the deadline, with the remaining taking more than two months after the stipulated period [1].

There are three primary phases in the process of construction: the engineering phase, procurement phase, and construction phase, collectively called Engineering Procurement Construction (EPC) phases [2, 3]. Usually, the success of the complex construction process is robustly linked with its lifecycle performance [4]; hence, top performance indicators are generated and employed to calculate the success of construction. The performance of every EPC phase is recognized based on the cost, quality, and time [5]. Due to the complexity in quality measurement, many researchers exclude quality from the criteria list and focus on the two experimental features of project cost and time [6].

Extended author information available on the last page of the article

The EPC is in contraction mode, and the main building contractor is in charge of the performance, comprising engineering and the provision of fundamental specifications. For this reason, the owners anticipate the contractor to act as the person responsible for all the EPC activities per the specified information and requirements. Moreover, the main contractor faces all the risks of the project's process. The nature of the project is rooted in a cooperative and collaborative management mode. The risks included in international projects are significant compared to domestic projects [7]. Hence, the risks for these projects are more important in risk assessment and future managerial schemes [6, 8].

The word 'claim' is still confusing and has various meanings. Cambridge University has given two definitions as examples—(1) To ask for something that belongs to you because you believe you have the right to ask for it, and (2) To state something true without needing to prove it, whether others believe it or not [9, 10]. The word 'claim' generally benefits project management [11].One of the significant steps in the claim management scheme is documentation, in which all the documents can be accumulated together for further dispute resolution [12]. The link with the documents detects the challenge in the empirical substance and the answers to the queries. Most participants accepted that the provided information was adequate, but they also had to ask for further details. The main issue in claim management based on EPC power projects is that it requires considerable time, specifically during the installation of the power plant [13]. The team responsible for the projects needs to sort out the conflicts soon because of tight scheduling during the plant installation and subsequent delays [14].The potential examination of several factors that cause claims and arguments is significant for the stakeholders to decrease the intensity of arguments at the occurrence level [15]. The causes of claims work independently or collectively to escalate arguments that lead to cost and time overruns. The measure of the significance of the causes of the claim is to generate arguments that will warn the agencies to carry out the contract execution with caution toward these aspects. The strong impact of the argument occurrence concerning the cost of the project, appreciation, and time overruns would be calculated by linking argument occurrences and multiple claim causes [16].

For the EPC project, the supplier assigned by the proprietor is responsible for preparing, procuring the material, and constructing. Owing to the development needs in construction work, the application of EPC works cannot be neglected. The contractor is solely in charge of the construction, and risk procurement comes from the young technicians and common factors throughout the beginning phase of the project [17]. The main objective of risk assessment is to improve project performance by analytically recognizing and measuring the impending risks, developing schemes to minimize or neglect them, and increasing the chances of success. Since risk management has increased its significance in the global construction industry, numerous researchers have extended the risk recognition and estimation methods. Risk management for the construction business mainly focuses on the restricted number of trading functions for the specific project phases that deal with only one kind of plant facility. There is no genuine research covering the entire trading purposes during the life cycle for various types of power plants such as nuclear, gas, and fossil [18].

Nuclear Power Projects (NPP) based on EPC have become increasingly complex, with high prospects of high cost and time delays. The considerable demands to control and observe the NPP EPC construction works in the beginning phase have been sustained, containing high costs on some of the plants in Finland, exceeding the cost by more than 80% of the estimated amount. Simple risk assessments are employed at the mid-phases of the project. This makes it difficult to replicate the impact of risk information on future results since alterations are not made. The major drawback of these EPC projects is cost and delay, resulting in substantial financial losses for the owners and the contractors [19]. Existing EPC models can generate a single optimal solution for either cost/time/delay. Hence, there is a need to develop an improved EPC model that computes the trade-off between project cost and time, helping a project manager select an optimal schedule that simultaneously reduces the time and cost of the project and enhances its quality. This paper aims to present a claim management system based on the Improved Monarch Butterfly Optimization Algorithm (IMBOA) utilizing the EPC concept. The paper seeks to address the time delay and cost associated with construction projects, which are taken as the objectives. To achieve these objectives, design substitutes or construction techniques that meet the minimum requirements of the engineer are selected, and the project manager reviews the document in terms of time delay and cost to make the final decision. This paper utilizes an IMBOA with EPC and claim management to obtain an effective, high-quality system with minimum cost and time delay. Utilizing the IMBOA algorithm provides an optimal resource utilization plan that optimizes construction time and costs, enabling the project manager to visualize the trade-off between project time and cost. These tools help enhance EPC project performance and assist decision-makers in estimating different EPC plans. This paper fulfills the following objectives,

- To enhance the quality and timely completion of the project by evaluating and mitigating project risks and

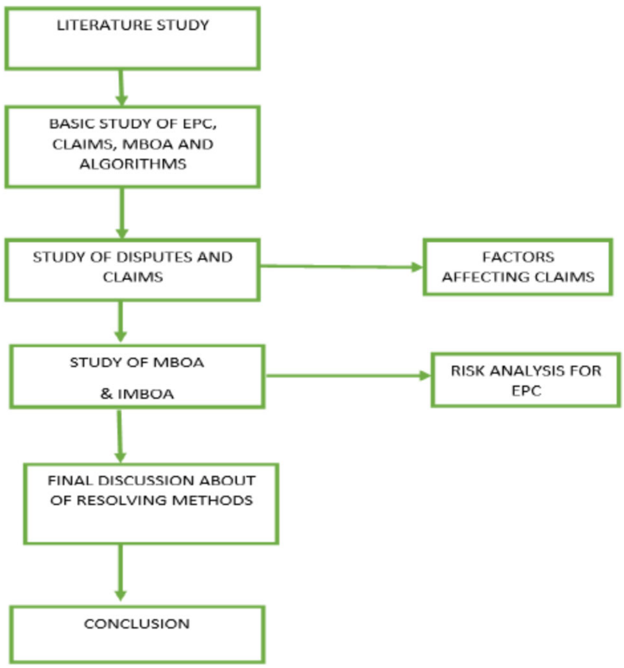



**Fig. 1** Methodology

utilizing EPC principles for equipment and material procurement, design, and construction.
To identify and resolve particular problems, which include determining the dispute and the claim and estimating the associated time and cost required to settle the claim.
To optimize project performance by minimizing time delay and cost using the IMBOA algorithm.

The rest of the paper is organized into the following sections. Section 2 describes the literary works regarding the EPC and claim management system. Section 3 provides the problem statement and its main objectives. Section 4 provides a comprehensive overview of the EPC concept utilized in the claim management system, covering the design, construction, and procurement of equipment and materials. Another approach is to use IMBOA to achieve a high-quality system that minimizes cost and time delay. Then, the experimental results and the comparative analysis of various optimization algorithms are described in Sect. 5. Section 6 concludes the study.

## 2 Literature study

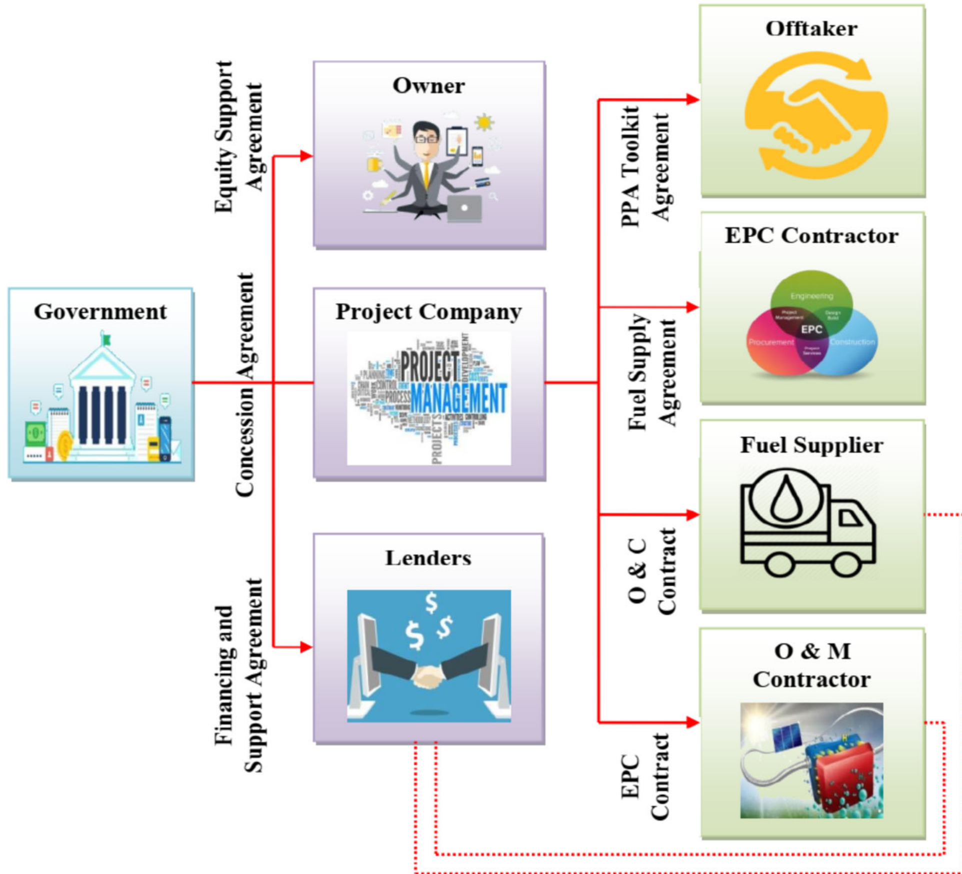
In global EPC projects, considerable risks are encountered throughout various stages, including estimation, design, financing, construction, procurement, and interconnection. Assessing these risks primarily involves identifying factors that could threaten project construction. Risk allocation entails assigning responsibility for identifying risks to new team members introduced to the freshly generated system. This system relies on a micro risk breakdown structure (MRBS) and a recently launched recognition method known as preventive root cause and efficient remedial (PRCER).

The proposed approach introduces the risk responsibility matrix (RRM), which links every risk between projects. Evaluation is carried out using fuzzy set theories, with most risks identified in EPCM projects. The database is compiled from lessons learned and managerial process resources. Case studies for qualitative risk assessment and quantitative assessment [20] include the Sydney Opera House (SOH) [21] and the Urban Highway Construction Project. Kabirifar et al. have analyzed and graded crucial activities of EPC across large-scale housing construction projects in Iran using the TOPSIS method, a multi-feature group decision-making process [22]. Key attributes contributing to project performance include project planning, engineering design, and controls. The database is collected through questionnaires from local EPC companies certified by Iran Construction Engineering organizations. Measures such as safety, satisfaction, and sustainability determine project success [23]. Waziri et al. have revealed the successful applications of artificial neural networks (ANNs) in predicting cost, scheduling and optimization, claims, arguments, and risk assessment resolution results and decision-making [24, 25. Their study examined how ANNs have been employed to resolve complex issues with conventional numerical and statistical analysis. The combination of ANN with other methods [26, 27], such as Ant Colony Optimization [28], Particle Swarm Optimization [29, 30], Fuzzy Logic, Genetic Algorithm, and Artificial Bee Colony, has shown improved outcomes compared to traditional ANNs [31, 32].

Nasirzadeh et al. present the new hybrid fuzzy system dynamics (SD) approach for constructing claims. This approach has presented the most important claims that affect the projects. The numerical relationships between the variables are verified, and the quantitative analysis constructs the claims model [33, 34]. This approach was executed on a real-time project, and the impacts on the cost of the project were enumerated. The proposed approach is utilized flexibly in several projects to measure the construction claims cost. The drawback of this approach is that historical data may restrict the proposed approach applications with restricted data or qualified experts [35].

Jalal et al. have introduced the claim management model, which depends on building information modeling (BIM), which can be displayed in BIM models. Here, ten claims that can be displayed in BIM schemes are detected. One BIM-based claim management scheme is created and employed in the case study. The claim management

Fig. 2 Fundamental EPC structure




process has four steps—extraction of project information, mechanically linking the dataset to construct the information scheme, claim simulation in constructing the information scheme and final computations and report [36, 37]. The benefits are information stability, huge space for data storage, enhanced collaboration, etc. Jalal et al. [38] have analyzed the causal attributes that shape the EPC projects that convince the objective of the projects from the end-user's perception [39, 40]. The database is collected from the online survey of questionnaires and managed by the end-users working in main oil and gas projects. The efficiency of the EPC structural scheme is generated and tested, utilizing the PLS-structural model of the numerical system [8].

Guocheng Li et al. have proposed the multidimensional contract administration performance model (CAPM) to construct and calculate the construction contract administration (CAA) and detect the merits and demerits of the CCA schemes for completing the projects [41]. The research plan follows the chronological data collection and examination. The fuzzy set is selected due to the fuzziness and ambiguity linked with the significance of various key markers that affect the performance of the system [42, 43]. In the future, alternative methods will be used for analysis purposes to reduce the cost and delay [44]. The consistent risk management approach for the construction of a nuclear power plant (NPP) by the capacity of evaluating the typical risk features between gas, fossils, and NPP has been proposed by Kim et al. The method consists of normal risk categorizations and structured risk assessment methods with respect to likelihood, weightings, and impact for various power plants [45]. The database used here is a large number of historical databases based on the projects [46]. The disadvantages of this method include the smaller number of participants who need skilled estimation. In the future, the proposed method is to be integrated with a self-evolving process for better evaluation [18].

## 3 Problem statement and objective

Generally, the owners/engineers consider cost, environment, time, and quality-related factors for a construction project. These factors balance the construction project based on the materials used, equipment, workers, etc., for the construction site. When a new technology is applied to solve this problem (enhance the external environment and reduce the time and delay), it often results in an increased project cost, which includes too many complexities in the process. If the initial fixed budget is exceeded, it will be

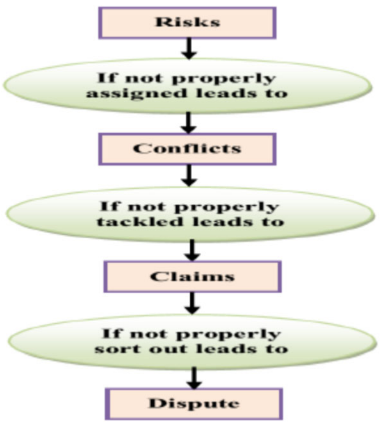



**Fig. 3** Factors that lead to claim and dispute

impossible to overcome the time complexity associated with the task. An optimal solution is obtained using IMBOA to obtain a trade-off between the time delay and cost.

The paper's objectives are the time delay and cost associated with the construction projects. To achieve these objectives, the paper selects alternative designs or construction techniques that meet the minimum requirements of the engineer. Subsequently, the project manager evaluates the document regarding time delay and cost and makes the final decision. Hence, this paper takes the time delay and cost as the two objectives that need to be solved, and they are estimated using Eqs. (1) and (2).

$$Time - Delay = \sum_{x=1}^{t} TD_x^n \tag{1}$$

here $TD_x^n$ is the time taken for the construction project($x$) to finish utilizing the$n$number of resources, and$t$is the total number of tasks in hand.

$$\text{Cost} = \sum_{x=1}^{t} \left[ C_x^n + \left( TD_x^n \times D_x^n \right) \right] \tag{2}$$

here the direct cost associated with a project is denoted $C_x^n$, and the daily cost associated with the project per dollar per day is estimated $D_x^n$.

## 4 Proposed IMBOA-based claim management system using EPC

This section provides an in-depth overview of the EPC concept utilized in the claim management system, focusing on the design, construction, and procurement of equipment and materials. The objective and methodology of this paper are to develop a claim management system based on the IMBOA algorithm and EPC principles that can efficiently minimize project costs and time delays while ensuring high-quality results. As shown in Fig. 1, the process begins with a comprehensive literature study on EPC, claims, MBOA, and related algorithms, followed by understanding these areas' fundamental concepts and principles. It then examines common disputes and claims in the construction industry, identifying key factors influencing these claims.

**Fig. 4** Flow diagram of the proposed approach

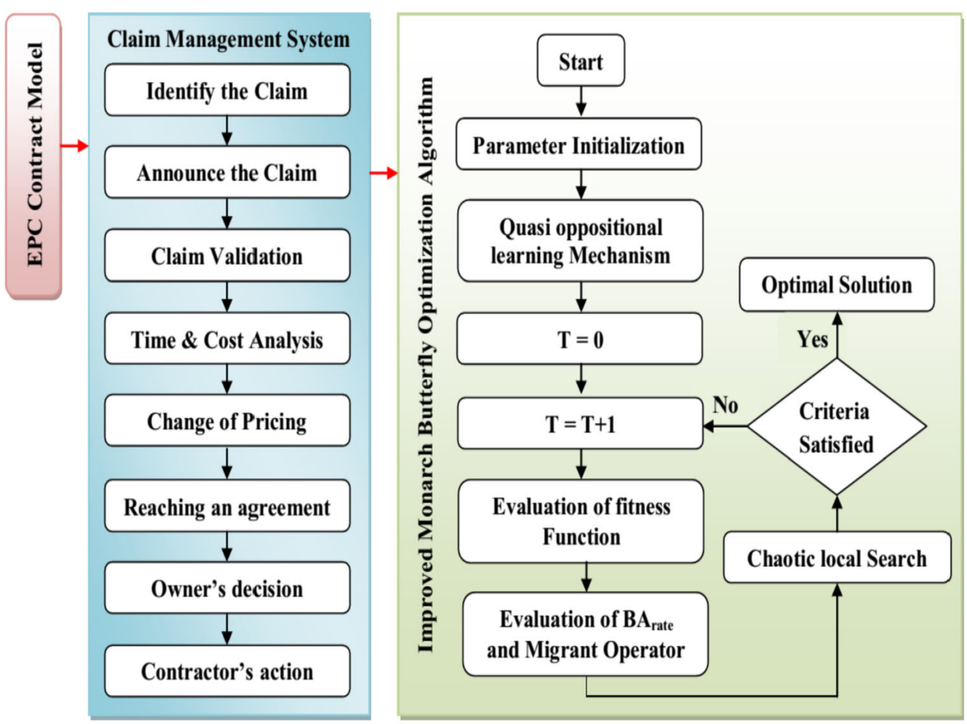


**Table 1** Source of risk parameters

| Sources of risk | Mean | SD | *p*-value |
|---|---|---|---|
| Deadline | 3.72 | 1.138 | 0.0000 |
| Poor selection of technical solution | 3.71 | 0.986 | 0.000 |
| Bad management | 3.62 | 1.090 | 0.001 |
| Errors and omission | 3.54 | 1.410 | 0.008 |
| Improbable cost | 3.49 | 1.488 | 0.031 |
| Unskilled staff | 3.41 | 1.267 | 0.045 |
| Education and culture | 3.34 | 1.183 | 0.029 |
| Alteration in law and standards | 3.34 | 1.074 | 0.065 |
| Weather and soil culture | 3.34 | 1.074 | 0.035 |
| Economical conditions | 3.25 | 1.412 | 0.065 |
| Delay in delivery of materials | 3.14 | 1.178 | 0.043 |
| Late in document preparation | 3.10 | 1.412 | 0.065 |
| Sick leaves | 3.10 | 0.871 | 0.186 |
| Incomplete document | 3.10 | 1.480 | 0.412 |
| Not familiar with local situations | 3.01 | 1.324 | 0.631 |
| Insufficient contractor experience | 2.99 | 1.275 | 1.000 |
| Risk management planning process | 2.97 | 1.187 | 1.000 |
| Lower production | 2.92 | 0.864 | 0.642 |
| Material shortage | 2.86 | 0.975 | 0.642 |
| Inaccurate specification | 2.74 | 1.167 | 0.297 |
| Not a permanent work | 2.68 | 1.263 | 0.154 |
| Worst motivations | 2.42 | 0.982 | 0.035 |
| Insufficient workers | 2.37 | 1.231 | 0.0035 |
| war | 2.28 | 1.573 | 0.005 |
| Natural disaster | 1.96 | 1.486 | 0.000 |

The next step involves analyzing various factors that affect claims within EPC projects. The study then explores the Monarch Butterfly Optimization Algorithm (MBOA) and its improved version (IMBOA), understanding their application in optimizing project performance. A risk analysis specific to EPC projects is performed to identify potential risks and their impact on project outcomes. This is followed by a detailed discussion on effective methods for resolving disputes and claims, leveraging the insights gained from the previous steps. Finally, the conclusion summarizes the findings and proposes recommendations for implementing the IMBOA-based claim management system in EPC projects. By following this structured approach, the paper aims to develop a robust claim management system that addresses the challenges of project cost and time delay challenges, ultimately enhancing EPC projects' overall efficiency and quality.

The procedures of the IMBOA algorithm begin with the initialization phase, where the population of monarch butterflies, representing potential solutions, is established. Each butterfly's position is evaluated based on project cost

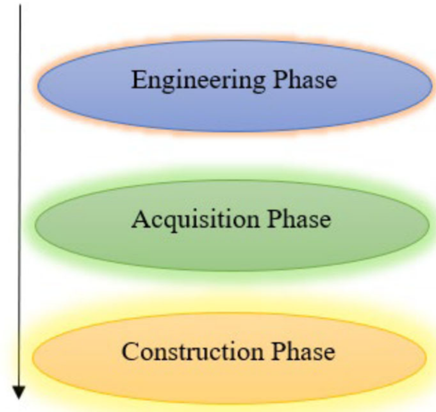



**Fig. 5** Project lifecycle of engineering, acquisition, and construction phase

and time delay. The migration operator is then applied to simulate the natural migration behavior of monarch butterflies, enhancing solution diversity by moving butterflies to new positions. Following this, the adjustment operator is used to fine-tune butterfly positions, ensuring convergence toward optimal values by adjusting positions based on fitness and the best-known solutions. Fitness evaluation is a critical step, where each butterfly's fitness is calculated to minimize project cost and time delay while maintaining high-quality outcomes. Top-performing butterflies, or elites, are selected to guide the search process in subsequent iterations, updating other butterflies' positions using migration and adjustment operators. This step ensures that the search process is directed toward promising regions of the solution space. A risk analysis is performed to identify and adjust for potential risks, ensuring the robustness and resilience of the solutions. These steps are repeated for a predefined number of iterations or until convergence criteria are met, continuously updating and refining the solutions. The final optimal solution is then selected based on the fitness evaluation, representing the EPC project's most efficient and effective claim management strategy, thus minimizing costs and time delays while ensuring high quality.

## 4.1 Engineering procurement construction (EPC)

Many research studies have characterized EPC as a project management system concept that involves the design, construction, and procurement of equipment and materials [47]. The associated indicators that affect the performances of EPC are imperfect estimation, poor project control, site supervision, inadequate machinery or equipment, ineffective subcontractors, accidents, improper building materials, interruption in delivering the building materials, the recreation of an inadequate task, disproportionate inclusion

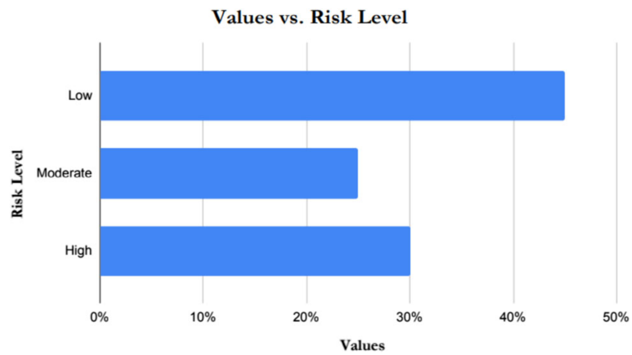



**Fig. 6** Categorization of risk levels in the EPC construction process from the owner's perspective

of bureaucratese, labor with poor technical skills, changes during the execution of a project, reputation losses, distributing the old materials for construction, incomplete construction design, creating disputes among the stakeholders, etc. [23]. In addition, it is also essential to identify and recognize the risk that happens during the investigation of productivity during the EPC contract. Figure 2 describes the fundamental EPC structure. This EPC contract structure is applied in numerous industrial projects, particularly manufacturing [48].

In contrast, more than one building contractor or tenderer works under this EPC contract. These building contractors perhaps agree to deliver the projects, which are referred to as joint ventures [49]. In general, the EPC contract structure consists of numerous interconnected processes and activities that necessitate a great deal regarding the financial commitment and support of the tenderer. Also, this EPC contract approach provides a possibility to achieve the project's goal, which further leads to a value-based synergic process [47]. The EPC contract handles various issues with enhanced sophistication compared to several other contracts. For the successful execution of the EPC contract, it is necessary to provide a few terms and conditions, namely understanding and managing the risk allocation and identifying the level of risks. The most common risk of the EPC contract system is the contractor's claim that results in the organizational behavior of the owners, namely changing of tender, ineffective processing, premature payments, as well as external risks that include natural hazards, socio-political risks, and In addition, the EPC projects comprise numerous potential risks that include delay in transferring data, issues regarding the quality of the construction site, scheduling interruptions, and hostile relations [50]. Therefore, the EPC type of projects ensures a minimum risk for the building contractor, achieving an optimal output with enhanced quality and minimum cost.

## 4.2 Claim management

Execution of a project is not considered an easy task. After all, most challenges are more manageable tasks because most challenges occur, and the project participants cannot solve them in a more accessible manner. In this phase, the contractors mainly anticipate time extension, a refund or compensation for the extra cost incurred, and sometimes the contractors' claim [51]. The requirements listed by the contactor are known as a claim [52, 53]. If the owner agrees with the demands made by the contractor, then to overcome the issue, they may sometimes offer compensation, and in some instances, they will extend the time. If the problem is not solved by providing them, they offer both. In some cases, the owner does not agree with the claim caused by the contractor and does not offer any benefits. This is when an issue known as a dispute arises. Modern projects always include claims that further result in unpreventable and un-escapable trouble. A person raises claims typically because they have high demands for the novel technologies and terms used in the project. Figure 3 explains the process of claim management.

The claims can also be brought up by the owner and not by the contractor alone. Every party must know something

**Table 2** Study of risk analysis during the engineering phase

| Code | Identified risk | Risk level | Risk category | IF | Probability of risk | Ranking of risk |
|---|---|---|---|---|---|---|
| *R*1 | Less accurate results are obtained in the initial phase of study about the engineering concept and external environment | 12 | High | 3 | 2 | 2 |
| *R*2 | The contractor quality does not match the needs | 4 | Low | 2 | 1 | 10 |
| *R*3 | The design phase is delayed | 3 | Medium | 3 | 3 | 8 |
| *R*4 | The labors and pieces of equipment obtained from the trade contractors do not accompany the contract offer | 2 | Low | 2 | 2 | 11 |
| *R*5 | The project land used and the issues related to the external environment are unsatisfactory | 9 | High | 5 | 1 | 3 |

**Table 3** Risk analysis in the acquisition phase

| Code | Identified risk | risk level | Risk category | IF | Probability of risk | Ranking of risk |
|---|---|---|---|---|---|---|
| *A*1 | The acquisition timing is not satisfactory | 9 | High | 4 | 2 | 4 |
| *A*2 | The suppliers are the least acceptable | 8 | Medium | 2 | 3 | 5 |

**Table 4** Risk analysis in the construction phase

| Code | Identified risk | Risk level | Risk category | IF | Probability of risk | Ranking of risk |
|---|---|---|---|---|---|---|
| *C*1 | Low Accuracy in quantity estimation | 5 | Medium | 2 | 2 | 6 |
| *C*2 | The contractor's performance is not as planned | 3 | Low | 1 | 1 | 9 |
| *C*3 | The starting time of the project is delayed | 5 | Medium | 2 | 2 | 7 |
| *C*4 | A rapid increase in project cos | 1 | Low | 1 | 1 | 12 |
| *C*5 | Contractors' order to change the contract | 11 | High | 3 | 3 | 1 |


**Fig. 7** Categorization of risk responses in the EPC construction process from the owner's perspective"

about the procedures and systems set in place, and some resources should always be allocated to prevent any disputes that arise in the future. Every construction project has a construction claim associated with it. These construction claims can be used when the issue needs to be cleared or if any party involved in the process requires a change to be made. The construction claim significantly impacts the construction project cost and the time spent to finish the project. Every construction claim has some delay associated with it, and in many cases, the delay is increased up to 100 times as per the time specified in the original contract. The project cost also varies, similar to time, because overall, every construction project exceeds the cost by up to 30 percent after the contract is signed. Countries such as

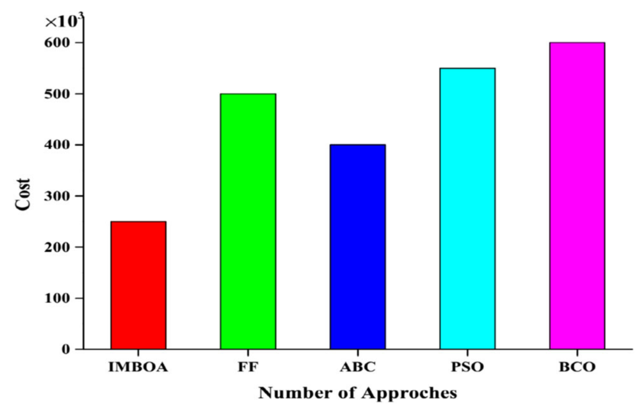



**Fig. 8** Cost versus number of approaches

the United States, Thailand, and Canada have shown that project costs always increase by more than 7 percent when the project is signed.

A successful business organization should always reduce the conflicts and disputes between the owner and the contractor and manage the trust between the two parties

**Table 5** Relationship between project parties

| | Agreement | | |
|---|---|---|---|
| | Owner/Engineer | Contractor | Expert |
| Owner/Engineer | 1 | | |
| Contractor | 0.931 | 1 | |
| Expert | 0.779 | 0.714 | 1 |

**Table 6** Critical delays caused concerned in the construction projects

| Reason for delay | Various rank | | | |
|---|---|---|---|---|
| | Owner | Contractor | Expert | Overall |
| Sector specific factors | 1 | 6 | 3 | 1 |
| Poor Interaction between the project parties | 7 | 5 | 4 | 3 |
| Payment delay | 6 | 1 | 2 | 2 |
| External factors such as flood, and rain | 5 | 3 | 1 | 5 |
| Design related issues | 22 | 14 | 6 | 6 |
| Lack of contractors experience | 8 | 2 | 5 | 9 |
| Construction material shortage | 4 | 8 | 8 | 7 |
| Shortage of skilled workers | 12 | 9 | 9 | 4 |

involved. In this way, the inter-communication, teamwork, and problem-solving capacity between the two parties can be improved. Alliancing and partnership measures can be done to efficiently manage the conflicts and disputes that arise between two parties [54]. To overcome the unexpected changes in construction projects, one should face promising claims [55]. In construction projects, the managerial tasks are known as claims, which help to proceed with the construction plan made as planned and manage specifications related to the contract "leave-off." The leave-off contract specifies specific changes from the initial contracts, such as altered conditions, changes in the design structure, description of flaws incurred, varying quantities, disruption, speed, and delay. The majority of the claims that arise between two people can be solved without any disputes or problems between each other. Still, specific claims cause conflict between the owner and the contractor, leading to an unavoidable dispute. The dispute should never be subjected to unjust treatment, and every solution strategy should be tried. Parties can proceed with the resolution mechanism when the lawyers demand justice for their owners from a single-sided amendment. Here, the main aim of the lawyers is to protect their clients by proving that the condition presented in the contract conflicts with the vows first given. The total construction costs are mainly increased by an improper risk allocation that denies the truth present in the contract. Construction projects typically include disclaimer clauses [56]: project

**Table 7** Case study sketch

| Activity type | Nos | Precedent activity | Coal mining techniques | Duration (in days) | Cost (in dollars) | Optimized duration | Optimized cost |
|---|---|---|---|---|---|---|---|
| Preparation of site | 1 | – | Crew 1 + Technique 1 | 15 | 1200 | 13 | 800 |
| | | | Crew 2 + Technique 2 | 14 | 8000 | 12 | 7500 |
| | | | Crew 3 + Technique 3 | 18 | 400 | 15 | 200 |
| Surface mining | 2 | – | Technique 1 | 17 | 1200 | 14 | 1000 |
| | | | Technique 2 | 18 | 1800 | 16 | 1700 |
| | | | Technique 3 | 19 | 400 | 18 | 300 |
| | | | Technique 4 | 21 | 5000 | 19 | 3500 |
| Strip mining | 3 | 1 | Technique 1 | 19 | 6000 | 15 | 5000 |
| | | | Technique 2 | 24 | 14000 | 20 | 13500 |
| Contour mining | 4 | 1 | Technique 1 | 20 | 12000 | 17 | 10000 |
| | | | Technique 2 | 25 | 25000 | 20 | 23000 |
| Underground mining | 5 | 1 | Long wall mining | 25 | 26000 | 20 | 22000 |
| | | | Continuous mining | 27 | 15000 | 21 | 14000 |
| | | | Blast mining | 12 | 14000 | 8 | 13000 |
| | | | Room and pillar mining | 14 | 11000 | 7 | 10000 |

delays, discovery, unclear work conditions, lack of satisfaction in the contract, and liquidated and ascertained damages.

Efficient claim management should professionally deal with the parties involved in the construction contract and employ significant construction claim management tasks in their infrastructure. The party responsible for the claim should announce it immediately after discovering it, and they should also validate the facts. Based on the decision of the opposite party for whom the claim is made, it can be settled in two ways: One is done pleasantly, and another raises a dispute. The claim management process follows a specific set of steps, which are listed below:

This paper aims to create a claim management system based on IMBOA using EPC to achieve a cost-effective and time-efficient system. The following section provides an overview of both the standard monarch butterfly optimization algorithm and the enhanced monarch optimization algorithm.

### 4.3 Monarch butterfly optimization algorithm (MBOA)

The Monarch Butterfly Optimization Algorithm (MBOA) is one of the practical metaheuristic algorithms that imitate the behavior of monarch butterflies demonstrated. The initial process of the MBOA algorithm is the Monarch Butterflies (MB) population, which is uniform, and a random population, which is comprised of solution candidates. The MB population is generally classified under two major categories, Land one and Land two, formulated in the following equation.

$$L_I = n_p(1) \times C(r \times n_p) \tag{3}$$

$$L_I = n_p - n_p(1) \times n_p(2) \tag{4}$$

From Eqs. (3) and (4), the total number of populations for $L_I$ and $L_{II}$ are represented as $n_p(1)$ and $n_p(2)$. $C(x)$ signifies the value of neighboring integer, which is equal to or greater than $(x)$. $r$ represents the ratio of $L_I$ and $L_{II}$ of monarch butterflies.

The conception based on the generation of a new child population by the parent monarch butterflies $L_I$ is expressed in Eq. (5). Thus,

$$Z_{I,J}^{T+1} = Z_{R1,J}^{T} \tag{5}$$

The above equation represents the element containing the position at a generation of the monarch butterfly over iterations $Z_{I,J}^{T+1}$. Then, the $Jth$ element is updated, and it is denoted by $Z_{R1,J}^{T}$. Here, the individual $R_{1,}$ represents the random number for the land $L_I$. Then, the current iterations are represented by $T$. If the value of $r$ is equal to or less than $R$, then the new monarch butterfly containing the $Jth$ element is described in Eq. (6)

$$r = \gamma \times \delta \tag{6}$$

From Eq. (4), the uniform and random number and the period of migration are represented by $\gamma \, and \, \delta$, respectively. The conception based on the generation of a new child population by the parent monarch butterflies is expressed in Eq. (7).

$$Z_{I,J}^{T+1} = Z_{R2,J}^{T} \tag{7}$$

From Eq. (7), the individual $R_{1,}$ represents the random number for the land $L_2$. Thus, the child generated contains a minimal value that is equal to or less than the updated expression, and then the updated expression is formulated in Eq. (8).

$$Z_{I,J}^{T+1} = Z_{\mathrm{BEST,J}}^{T} \tag{8}$$

From the above Eq. (8), the $J$th element $Z_{\mathrm{BEST}}$ employed in developing the best optimal solution is represented as $Z_{\mathrm{BEST,J}}^{T}$.

$$\text{If } r < \delta \text{ then, } Z_{I,J}^{T+1} = Z_{R3,J}^{T}; \quad \text{where } R_3 \in \left\{1, 2, \ldots n_p(2)\right\} \tag{9}$$

From Eq. (9), the $Jth$ element selected randomly $L_2 Z_{R3}$ is represented as $Z_{R3,J}^{T}$.

$$\text{If } \mathrm{BA_{RATE}} < \delta \text{ then, } Z_{I,J}^{T+1} = Z_{I,J}^{T} + \beta\left[dZ_J - \frac{1}{2}\right] \tag{10}$$

where Eq. (10) $dZ_J$ of the $Jth$ component signifies the walk step of the individual that is formulated in the following expression in Eq. (11)

$$dZ = \mathrm{levy}(Z_J^T) \tag{11}$$

$$\beta = \frac{M_{\mathrm{WS}}}{T^2} \tag{12}$$

From Eq. (12), the weighting coefficient and the maximum walk step are represented by $\beta$ and $M_{\mathrm{WS}}$, respectively. If the value $\beta$ is small, then the impact of $dZ$ on $Z_{I,J}^{T+1}$ will come under the exploitation mechanism. If the value $\beta$ is significant, then the effect of $dZ$ on $Z_{I,J}^{T+1}$ will be increased, and it comes under the exploration mechanism. The extended form of MBOA is the improved MBOA which is delineated in the following section.

### 4.4 Improved monarch butterfly optimization algorithm (IMBOA)

As mentioned in the previous section, when the value $\beta$ is significant (i.e., during excessive exploration mechanism), the time consumed is very high, and to overcome such shortcomings, an improved version of MBOA is demonstrated by employing two different mechanisms [15].

- *Mechanism 1* Quasi-oppositional learning mechanism

Initially, the oppositional-based learning approach [57] is necessary to understand the concept of a quasi-oppositional learning mechanism. Generally, the oppositional-based learning approach is employed to improve the solution's convergence speed and precision. Let us assume *ds* be the dimensional space containing the actual number as $R_N$ with the interval $(M, N)$ and $\overrightarrow{R_N}$ be the opposite candidate $R_N$ in Eq. (13)

$$\overrightarrow{R_{N(I)}} = M_I + N_I - R_{N(I)}; \quad \text{where } I = \{1, 2, \ldots ds\} \tag{13}$$

Then, the based on the quasi-opposite number, itis formulated in the following Eq. (14)

$$\overset{\wedge}{R_{N(I)}} = \text{Ran}\left[\frac{M_I + N_I}{2}\right], \overrightarrow{R_{N(I)}} \tag{14}$$

- *Mechanism 2* Chaotic local search mechanism

This mechanism is employed to resolve premature convergence. The mathematical formulation of the chaotic mechanism is represented as follows

$$(\text{Ch.M})_{L+1}^{\text{DM}} = F(\text{Ch.M})_1^{\text{DM}} \tag{15}$$

From Eq. (15), the dimensional mapping is represented by DM the value of L, which ranges from $L = \{1, 2, \ldots \text{DM}\}$. (Ch.M) Signifies the chaotic model. Then, the logistic mapping of the population [58] is expressed in Eq. (16)

$$\Psi_{\text{DM}+1} = \rho \times \Psi_{\text{DM}} \times (1 - \Psi_{\text{DM}})\,; \text{where } \rho = 4 \tag{16}$$

where the chaotic value ranges from $0, 1$ is represented by $\Psi_{\text{DM}}$. Then, the expression for the chaotic sequence is formulated in the following Eq. (17)

$$\lambda_{O,N,Q} = 4 \times \Psi_{O,N,Q}(1 - \Psi_{O,N,Q}) \tag{17}$$

From Eq. (17), *O, N and Q* signify the quantity of the system generator, population number, and iteration number, respectively. From Eq. (18), the monarch butterfly based on the chaotic mechanism is expressed as follows.

$$Z_{I,J}^{T+1} = Z_{I,J}^{T} + \Psi_{O,N,Q} \times \left[dZ_K - \frac{1}{2}\right] \tag{18}$$

Figure 4 describes the flow chart for the proposed IMBOA-based claim management system using EPC.

## 5 Experimental analysis and design

In this study, the primary data are obtained by administering a questionnaire and conducting interviews, as shown in Table 1. From this data, risks are identified along with their probabilities and impacts. Secondary data are then collected through various sources, including journals, books, magazines, and construction project data. Specifically, EPC project files [55, 59], as well as other project documents, are utilized. A case study related to the coal mining industry in China [60] is reviewed to analyze the EPC approach. Feedback is obtained from decision-makers involved in relevant projects. The risk analysis process consists in using a risk breakdown structure to assign a rank to each risk.

### 5.1 Risk analysis of the EPC approach

A risk analysis of the EPC process is performed using the lifecycle procedure outlined in Fig. 5. The project is divided into three phases: Engineering, Acquisition, and construction. Within these phases, a total of 12 risks are identified and analyzed.

**Risk analysis**

The Risk Breakdown Structure method is utilized for the risk analysis process. Based on the importance of the data, a probability value and the risk impact factor are analyzed. The risk level is computed after the probability value and impact are gathered and multiplied. The EPCR risk analysis procedure is presented in Tables 2, 3 and 4.

The risk level is classified into three categories: Low, medium, and high, as illustrated in Fig. 6. The analysis shows that most risks fall under the low category; while, 30% are categorized as high. Additionally, 25% of the risks are considered moderate.

Feedback

The risk response and action plan are obtained based on the participants' replies. While employing this process, it minimizes the probability and impact of the risk. The risks are categorized as risks received, avoided, and mitigated. The experimental results are presented in the form of a graph, as shown in Fig. 7.

### 5.2 Mutual agreement between the project parties

A Spearman's rank-order correlation coefficient (SPROC) is used to find the degree of agreement between two parties. The value of SPROC ranges from + 1 to − 1, and the values near the positive value indicate a strong argument, and the values near the negative value indicate a weak agreement. The values are equal to zero, which implies no consent/agreement. The formula is generated, as shown below in Eq. (19)

$$R_s = \frac{1 - 6\sum \text{rank}^2}{p^3 - p} \tag{19}$$

The SPROC rank correlation coefficient is $R_s$; for an average delay, the rank value indicates the difference between the two parameters, and $p$ is the total number of rank pairs used. Based on the delay factors, the relationship between the owners and the contractors tends to be very strong as per the agreement (0.931). In the next place, the agreement between the owners and the experts occurs (0.779). The last substantial agreement value between the contractor and the expert is (0.714). The agreement between the two project parties is set at a correlation level of 0.01. Table 5 explains the agreement between the project parties.

### 5.3 Delay analysis

Project delays primarily occur when the duration of two projects extends beyond the stipulated time. This situation can arise due to the contractor/engineer, owner, or expert causing an increase in the project's completion time. Table 6 outlines the eight significant delays that were encountered during the coal mining project.

### 5.4 Optimization of project delay and cost using IMBO algorithm

Table 7 presents the time delay and cost optimization results for the coal mining case study, which were obtained using the IMBO algorithm. The primary objective of this paper is to utilize the IMBO algorithm to minimize both time delay and cost. Based on the fitness function calculated, these values are underestimated. Hence, the proposed IMBO algorithm improves the quality of the construction plan, its time delay, and cost. Hence, by optimizing the construction plan [61], too much delay and time can be saved if a robust approach is delivered.

### 5.5 Comparative analysis of different optimization algorithms

All experiments were conducted on a Windows 10 PC with a 3.0 GHz lightweight processor, and simulations were performed using MATLAB 9.4 R2018a. This section presents a comparative analysis of the Improved Monarch Butterfly Optimization Algorithm (IMBOA) proposed by Dongfang Yang et al. [62] and Feng et al. [63], alongside several other algorithms, namely the FireFly (FF) Optimization Algorithm [64], Ant Bee Colony (ABC) Optimization Algorithm [65], Particle Swarm Optimization (PSO) Algorithm [66, 67], and Bee Colony (BC) Optimization Algorithm [68]. The population size is 15, and the total number of iterations is 100. The validation is based on the estimated plan cost profile obtained from the experimental data. The results shown in Fig. 7 are obtained from a maximum of thirty independent runs. The graphical analysis is plotted between the cost and the number of approaches. The graphical analysis in Fig. 7 shows that the proposed IMBOA approach offers better quality with minimum cost compared to all other methods. The results indicate that the proposed algorithm achieves the lowest price compared to other optimization algorithms, demonstrating its superior robustness over the other algorithms.

This section presents a comparative analysis between the proposed Improved Monarch Butterfly Optimization Algorithm (IMBOA) and several other optimization algorithms, including the Firefly (FF) Optimization Algorithm [64], Ant Bee Colony (ABC) Optimization Algorithm [65], Particle Swarm Optimization (PSO) Algorithm [66] and Bee Colony (BC) Optimization Algorithm [68]. A graphical analysis is conducted, plotting the cost against the number of approaches. The results of the graphical analysis are depicted in Fig. 8, demonstrate that the IMBOA approach provides minimum cost with better quality compared to all other approaches.

## 6 Conclusion

The success of a construction project hinges on precise coordination, as it involves complex tasks requiring input from professionals and non-professionals alike. However, challenges in the construction industry often lead to poor performance. Construction companies must correctly utilize their resources, such as materials, workers, cost, and time to improve performance. Although existing construction models can optimize a single objective, such as time, cost, or delay, they are inefficient in enhancing overall performance. The IMBOA model is more effective than other methods because it offers multi-objective optimization, enhancing project quality and performance by considering time, cost, and other factors simultaneously. It reduces computational complexity through the EPC concept, allowing for efficient and comprehensive analysis of large datasets, which aids in better decision-making and project management. Comparative studies show that IMBOA consistently provides lower costs and higher-quality outcomes than other algorithms. Its versatility allows it to be applied to various construction projects, and future integration with emerging technologies like AI and machine learning could further enhance its effectiveness and decision-making capabilities. This study proposes using the IMBOA algorithm to optimize multi-objective construction projects, including time and cost, to improve project quality and performance. The proposed IMBOA-based claim management system uses the EPC concept to reduce the computational complexity associated with EPC projects. The model helps construction planners analyze a large search space and find the optimal solution that satisfies different project objectives. This paper uses time delay and cost as objectives in construction projects. We select design substitutes or construction techniques that meet the minimum requirements of the engineer to achieve these objectives. The project manager then reviews the documentation regarding time delay and cost and makes the final decision. Using the IMBOA algorithm, EPC, and claim management, we aim to develop an effective, high-quality system with minimal cost and time delay. We review the experimental analysis of the EPC approach using a case study related to the coal mining industry in China. The time delay and cost optimization are conducted and depicted based on the fitness function, with calculated values minimized. Comparative analysis of the proposed IMBOA with several other algorithms reveals that it provides the lowest cost and better quality than all other approaches.

Additionally, the proposed IMBOA approach can mitigate 23% of risks and avoid 32% of risks associated with China's coal mining industry's action plan. While the IMBOA shows promise in optimizing multi-objective construction projects, it may introduce complexity due to its computational requirements. Implementing IMBOA effectively may necessitate significant computational resources and expertise, which could be a limitation for smaller construction companies or projects with limited resources. The advantages of using IMBOA include efficient multi-objective optimization, enhanced project quality and performance, reduced computational complexity in EPC projects, and the mitigation of significant risks and avoidance of potential issues. However, disadvantages include high computational requirements and the necessity for substantial expertise, potentially limiting accessibility for smaller companies. Future directions should focus on developing more user-friendly interfaces and scalable versions of IMBOA to ensure broader applicability. Additionally, integrating IMBOA with other emerging technologies, such as artificial intelligence and machine learning, could enhance its efficiency and decision-making capabilities, making it a more robust tool for the construction industry. Further research should also explore the application of IMBOA in different types of construction projects beyond the coal mining industry to validate its versatility and effectiveness.

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## Declarations

**Conflict of interests** To the best of my knowledge and belief any actual, perceived or potential conflicts between my duties as an employee and my private and/or business interests have been fully disclosed in this form in accordance with the requirements of the journal.

**Ethical approval** This material is the authors' own original work, which has not been previously published elsewhere. The paper is not currently being considered for publication elsewhere. The paper reflects the authors' own research and analysis in a truthful and complete manner.

**Consent to participate** I have been informed of the risks and benefits involved, and all my questions have been answered to my satisfaction. Furthermore, I have been assured that any future questions I may have will also be answered by a member of the research team. I voluntarily agree to take part in this study.

**Consent to publish** Individuals may consent to participate in a study, but object to having their data published in a journal article.

**Human and animals rights** The authors hereby assure that this research does not involves any human participants or animals.



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