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Project risk assessment: A holistic risk identification, analysis and evaluation approach, The case of EPC projects

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ABSTRACT

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This study presents a comprehensive framework for Project Risk Management (PRM), tailored specifically for Engineering, Procurement, and Construction (EPC) projects. Addressing gaps in traditional risk assessment methodologies, the proposed approach integrates advanced techniques for risk identification, analysis, and evaluation based on risk characteristics. A three-stage framework is proposed utilizing the Delphi method for risk identification and contextualization of risks, the risk analysis stage employs the Fuzzy Level-Based Weight Assessment (F-LBWA) method to achieve fuzzy weights for risk characteristics which the risks will be evaluated by. The final evaluation stage uses the Fuzzy Combined Compromise Solution (F-CoCoSo) method to rank risks, categorizing them as threats, opportunities, or hybrids. A case study of an EPC project demonstrates the framework's practical application, highlighting construction-phase risks as the most critical threats (negative risks) while also emphasizing opportunities (positive risks) which can be exploited. By incorporating fuzzy logic and innovative Multi-Criteria Decision-Making (MCDM) methods, the framework provides a flexible and robust tool for modern PRM.

1. Introduction

Projects are essential for industries, organizations, and businesses to accomplish strategic goals and improve their assets or departmental conditions (Yepifanova & Dzhedzhula, 2022; Zwikael & Smyrk, 2019), Traditionally, they are viewed as temporary endeavors aimed at achieving positive changes, such as delivering specific products or services. Project management is the systematic approach that facilitates these transformations (PMI, 2017). On a global scale, projects account for more than 20% of economic activity, with some emerging economies seeing this figure rise above 30% (Turner et al., 2013), thus; projects serve as crucial tools for driving change within organizations, industries, and businesses, as well as for ensuring the implementation of particular standards. The successful completion of projects often results in enhanced organizational efficiency and productivity (Serrador & Turner, 2015). As modern societies become increasingly reliant on projects (Jensen et al., 2016), organizations encounter ongoing challenges in managing them. Given that projects represent a significant portion of organizational budgets and strategic planning, it is imperative for organizations to carefully select projects by evaluating resource constraints and potential outcomes to maintain competitiveness (Rafiee et al., 2014; Schoper et al., 2018).

There have been many definitions of risk over the years, such as; "*Risk is combination of hazard and exposure*" (Chicken & Posner, 1998) or "*Risk is exposure to the consequences of uncertainty*" (Cooper et al., 2005), this study adopts the definition of (PMI, 2000) stating that "*Risk an uncertain occurrence or condition that, if happens, has a positive or a negative result on a project objective*", indeed an important characteristic of risks is their two sided effect which could be both advantageous and disadvantageous, this is further translated as threats and opportunities, having either a positive or negative consequence originated from different events (Islam et al., 2008). Once triggered, risks have the potential to cause change in time, cost, quality, project scope and objectives, able to change the trajectory of the project (Kassem, 2022). Risks are categorized into

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different groups based on varying methods, such as; initial risk source, nature of risk, originator of the risk or the its various levels within projects (Sharma & Gupta, 2019), for example; based on their nature, project risks can be classified into groups of financial, hazardous, operational and strategic risks (Ferreira de Araújo Lima et al., 2020). Traditionally the impacts of risks are assessed using two primary characteristics: the probability of their occurrence and their potential severity. Risk severity is influenced by various factors, including those related to human resources, the workplace, materials, and equipment. These factors are often challenging to quantify accurately using traditional methods (Modarres, 2016). Though probability and severity are the primal characteristics of risks which are used to evaluate the risk score, there are other characteristic of risks which are often dismissed (e.g. risk detection, manageability, persistency, predictability, ubiquity, uniqueness, etc.) (Aven, 2010; Sharma & Gupta, 2019), involving these characteristics in the evaluation of risks could produce more accurate results for the total score of the risks.

Managing risks is a crucial practice done in many sectors and fields of science and practice, risk management in projects is usually seen as one of the most important groups of risk management alongside disaster risks and financial risks (Verbano & Venturini, 2011). Following the project management body of knowledge, project management is usually considered a composition of multiple knowledge domains, project risk management (PRM) is one of those domains (PMI, 2017). In practice, uncertainties and risks are inherent to construction projects. PRM focuses on identifying and mitigating risks before they materialize (Zayed et al., 2008), while also reducing the potential of risks, mitigating the impact of possible losses (Bajo et al., 2012). Numerous risks arise during the execution phase of projects, potentially diminishing performance efficiency or even leading to project failure. Project risk management following a specific cycle based on different standards, usually consist of multiple phases; risk planning, risk identification, risk analysis, risk response and the monitor/ control of the risks as seen in Fig. 1 (PMI, 2017).

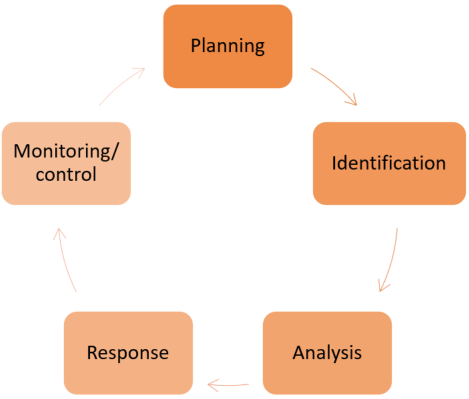

Fig. 1. Risk management cycle (PMI. 2017)

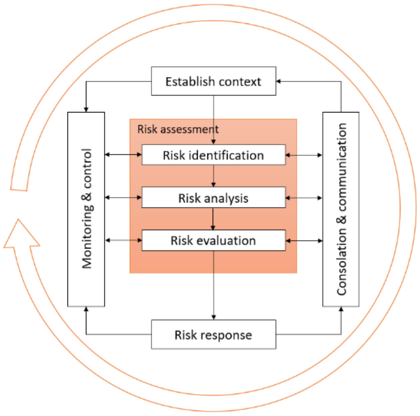

Fig. 2. Risk processes based on ISO 31000: 2018

Amongst these phases, risk identification combined with risk analysis have garnered more attention in scientific research (Afzal et al., 2021; Ahmed et al., 2007; Al Qudah et al., 2024) due to their practicality. Risk identification is traditionally based on expert opinion, usually determined by one of the following methods; brainstorming (Taghi Zadeh et al., 2016), Interviews (Hong Pham & Hadikusumo, 2014), check lists (Chou et al., 2021) and the Delphi method (Habibi et al., 2014). Risk analysis is generally addressed through two main approaches:

- Qualitative risk analysis methods: These methods are particularly beneficial when objective data or information is unavailable, relying instead on collective experiential judgment and subjective opinions (Alomari et al., 2020; Erol et al., 2022).
- Quantitative risk analysis methods: These methods are widely utilized and are particularly effective for systems with high repeatability (Jafari et al., 2020; Zermane et al., 2022).

Another standard to consider would be the ISO 31000 risk management standard of 2018, which although similar to the previous risk management cycle, has minor differences as illustrated in Fig. 2, in here risk assessment is a combination of risk identification, analysis and evaluation.

Though over the recent years, there have been studies on quantifying qualitative data with various methods such as entering into fuzzy space (Y. Hong et al., 2020; Ma & Wong, 2018). These approaches define various methods of risk analysis, each fitting a different scenario and context. One of the more popular methods of risk analysis is the Failure mode and effects analysis (FMEA), developed in the early 1960s (Liu et al., 2019); this method is consists of a structured procedure and determines the risk score by considering risk severity, probability and detectability by means of multiplication. This method has been utilized in various sectors such as engineering (Shafiee & Dinmohammadi, 2014), healthcare (Chanamool & Naenna, 2016) and construction (Askari & Shokrizade, 2014; Cheng & Lu, 2015).

In practice Engineering, Procurement and Construction (EPC) projects are managed the same way as other projects, following the traditional project life cycle process group and globally accepted standards such as the PMBoK (project management body of knowledge) (PMI, 2017), and this applied to all of the phases of EPC projects as well. Managing EPC projects is often complex and requires expertise and knowledge of project management procedures and processes (Sangroungrai et al., 2018). By bundling the engineering, procurement, and construction phases into one contract, EPC projects ensure streamlined project management, improved communication between phases, and better integration of complex systems, ultimately leading to more efficient project delivery. Being part of the construction industry, EPC projects are experience change with the introduction of advanced techniques and technologies, shifting away from the traditional workflows (Moshood et al., 2024; Yahya, 2023). This new complexity combined with heightened quality, safety, and environmental standards, necessitates a comprehensive approach to evaluating and managing associated risks (Paneru & Jeelani, 2021). The inherent risks of these technologies, coupled with the dynamic and often unpredictable nature of construction industry, pose significant challenges to traditional risk assessment methodologies (Zhang et al., 2022). As a result, the adoption of effective risk management practices is essential for achieving optimal performance in EPC projects. Early identification of potential risks allows for the development of strategies and plans to mitigate or avoid their negative impacts (Seyedhoseini et al., 2009; Taylan et al., 2014).

Considering the importance of PRM, especially in the identification and analysis phases, and the changing state of the construction industry, it is crucial to adapt a multi-dimensional approach when evaluating risks. The FMEA method garnered attention due to the involvement of an extra risk characteristic (i.e. risk detectability), though with the complex state of the industry and the introduction of new phenomenon, this might not necessarily produce the same accurate results as the past. This study aims to address this issue by proposing a comprehensive risk identification, analysis and evaluation framework, focusing on identifying both risks and their critical characteristics, determining the weigh and importance of each individual characteristic, analyzing the risks based on the mentioned characteristics and evaluating them, calculating the overall score of each risk and depicting the most critical ones to prioritize attention to. This study distinguishes itself from previous studies by:

- Introducing a PRM framework addressing the risk assessment phases
- Taking risk characteristics into account and analyzing both positive and negative risks
- Evaluating the importance of characteristic and risks using recent effective decision-making methods
- Risk assessment, evaluation and prioritization is done in fuzzy space to consider uncertainty

The proposed framework will also be utilized on a real-world example of an EPC projects risks to test the framework and view the results.

Going forward; section 2 presents a comprehensive literature review of relevant studies, section 3 proposes the framework and methods used, section 4 evaluates the model by testing it on the risks of an EPC project, sections 5&6 address the discussion and conclusion of the research.

2. Literature review

Historically PRM methodologies aimed at risk analysis date back to the early 2000s (Aven et al., 2007; Miller & Lessard, 2001), different models of project risk management were proposed since 1990 to manage the risks of the projects in order to increase the success of the projects (Boehm, 1991; Cooper et al., 2005). Over the years different methods have been utilized to analyze risks, these methods can be grouped as:

a) Comprehensive and qualitative methods, employing empirical methodology, frequently integrating expert opinion for qualitative risk analysis such as the Work Break-down Structure-Risk Breakdown Structure (WBS-RBS) (Zid & Soomro, 2016) or the Delphi method (Habibi et al., 2014).
b) Statistical and mathematical analysis methods, utilizing mathematical programing to model the risk as an optimization problem and solving it as a linear problem or using Monte Carlo (Koulinas et al., 2021) and numerical simulation (Fanjie et al., 2022).
c) Decision-making approaches, conducting the evaluation process using Multi-Criteria Decision-Making methods or other similar algorithms such as neural networks (Shen et al., 2020)
d) Traditional risk assessment techniques, methods such as, Fault Tree Analysis (Nasirzadeh et al., 2019), Event Tree Analysis (E.-S. Hong et al., 2009), Reliability Analysis (Raja et al., 2024), Bayesian Networks (Chen et al., 2020), etc.

To attain a better grasp on the current trends and avoid redundancies, a thorough literature review was conducted following the steps of a systematic literature review on this topic using the popular search engines (Liberati et al., 2009; Petticrew & Roberts, 2006). Relevant records were identified, screened and analyzed, the relevant records to this study are presented in table 1. Recent studies also applied various methods to analyze risks such as; statistics and mathematical programing, simulation, soft computing and qualitative analysis using expert opinion. The context of the studies varied as well; construction projects, business and organizational development projects and projects in the energy sector to name a few. The trend of the studies is moving away from simplistic and comprehensive methods to more complex and hybrid approaches focusing on uncertainty and risk interaction, or broadening the scope to project portfolio risk management. Recent trends indicate that the use of Fuzzy Logic in risk management has gained significant attention among researchers, due to its effectiveness in addressing the inherent uncertainty and complexity of risks, it would seem that the decision-making methods are slowly moving towards fuzzifying the problems. A thematic breakdown of the literature based on the observed co-occurring keywords is depicted in Fig. 3.

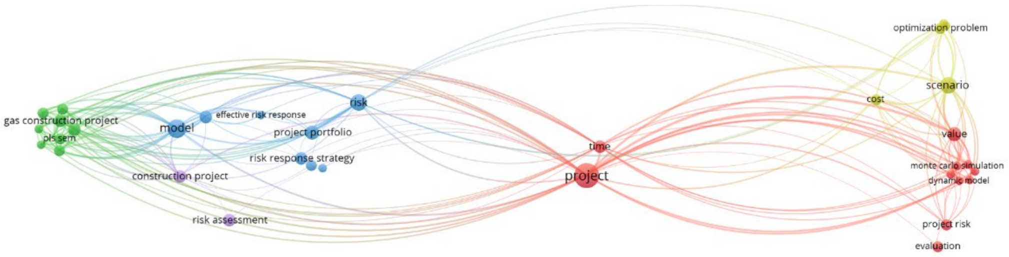

Fig. 3. Network diagram based on re-occurring words (made by VOSviewer)

Table 1
Relevant recent studies

Author/ year	Main theme	Method	Project context
(Santos et al., 2017)	explores the use of robustness as a method for managing risks in the development of complex petroleum fields	Multi-Attribute Utility Theory (MAUT)	Energy sector
(Nielsen et al., 2019)	refines the risk–risk trade-off method to evaluate preferences for reducing mortality and morbidity risks	pre-survey learning experiments and risk-framing techniques	Construction
(Seiti & Hafezalkotob, 2019)	proposes a fuzzy model incorporating risk-based TOPSIS for preventive maintenance planning	Fuzzy reliability model and risk-based TOPSIS methodology	Manufactory
(Al Mhdawi, 2020)	develops an integrated decision support methodology for analyzing risk factors in oil and gas construction projects	artificial neural network (ANN) for risk effect prediction	Energy sector
(Wang et al., 2021)	Development of a two-stage risk management framework for international construction projects	meta-network analysis	Construction
(Moniri et al., 2021)	Development of a hybrid framework for risk assessment and prioritization in turnaround projects	hybrid MADM method integrating fuzzy SWARA and fuzzy EDAS	Energy sector
(Kassem, 2022)	identifies and models risk factors in construction projects, emphasizing internal and external risks' effects on project success	statistical analysis using Relative Importance Index (RII) and Partial Least Squares Structural Equation Modeling	Construction
(Y. Zhang et al., 2023)	A novel model simulates project portfolio risk (PPR) evolution by accounting for risk interactions and contagiousness	Barrat–Barthelemy–Vespignani (BBV) model validated through computational simulations.	Organizational
(Dong et al., 2023)	Exploration of the effectiveness of the fuzzy analytic hierarchy process (FAHP) in project engineering risk management	application of genetic algorithm and neuro-fuzzy systems	Construction
(van Dorp & Shittu, 2023)	Development and characterization of a new asymmetric two-sided distribution for PERT risk management	Mathematical programing algorithms involving PERT	-
(Bai et al., 2023)	Comprehensive and systematic risk analysis of project portfolios, emphasizing the impact of project interdependencies	fuzzy Bayesian network	Organizational
(Nurgaliev et al., 2023)	Comparison of static and dynamic models for biogas projects, with risk evaluation	sensitivity analysis and Monte Carlo simulation	Energy sector
(Zhu et al., 2024)	Risk assessment to address information asymmetry, financing failures, and market risk	integrated approach combining FMEA and fuzzy super-efficiency	Organizational
(He & Zhang, 2024)	proposes a scenario reduction method for optimization problems using higher moment coherent risk measures	Scenario reduction technique	Organizational
(Kherde et al., 2024)	Development of a risk management framework for Indian infrastructure projects, focusing on unique country-specific challenges and risks	Interpretative Structural Modeling	Construction
(Zheng, 2024)	comprehensive project financing risk assessment and identification of optimal financing structures	Bayesian networks and optimization techniques	Organizational
(Lin et al., 2024)	A decision support approach for collapse risk analysis in engineering projects	multi-status Bayesian network and fuzzy set theory	Engineering
(Resende et al., 2024)	A comparison of traditional FMEA with a fuzzy FMEA methodology for improved risk assessment	fuzzy FMEA	Aeronautical sector
(Selva et al., 2024)	introduces the Multiple-Expert management Protocol to integrate expert opinions for multi-hazard risk analyses	structured workflow emphasizing moderated group interactions, blind advice with mathematical aggregation	Multi-sector
(P. Zhang et al., 2024)	The paper develops an improved FMEA-based multi-criteria group decision model for evaluating risks	Correlation Coefficient and Standard Deviation, regret theory, and MULTIMOORA methods	Construction
(Lv et al., 2024)	Investigation of the impact of risk absorption in project portfolio selection	dual-objective project portfolio selection model	Organizational
(Sun et al., 2025)	proposes an innovative method for assessing risks in advanced construction technology projects.	Risk-Based Maintenance and Interval-Oriented Priority Analysis	Construction
(Dranka et al., 2025)	Introduction of a framework for techno-economic and risk-based assessment	A systematic four-stage methodology	Energy sector

3. Methods

As mentioned in the previous sections the goal is to design a risk assessment approach to produce more accurate risk identification, analysis and evaluation results, for this purpose, a three-stage approach is assumed to identify the risks and their adherent characteristics, analyze the risks based on their respective values and evaluate and prioritize the risks to facilitate further decision making and risk response strategizing. Each of the three stages utilizing 3 different methods for each phase of the standard risk assessment procedure. Fig. 4 illustrates the framework of the study and further explanation is provided in the next subsections.

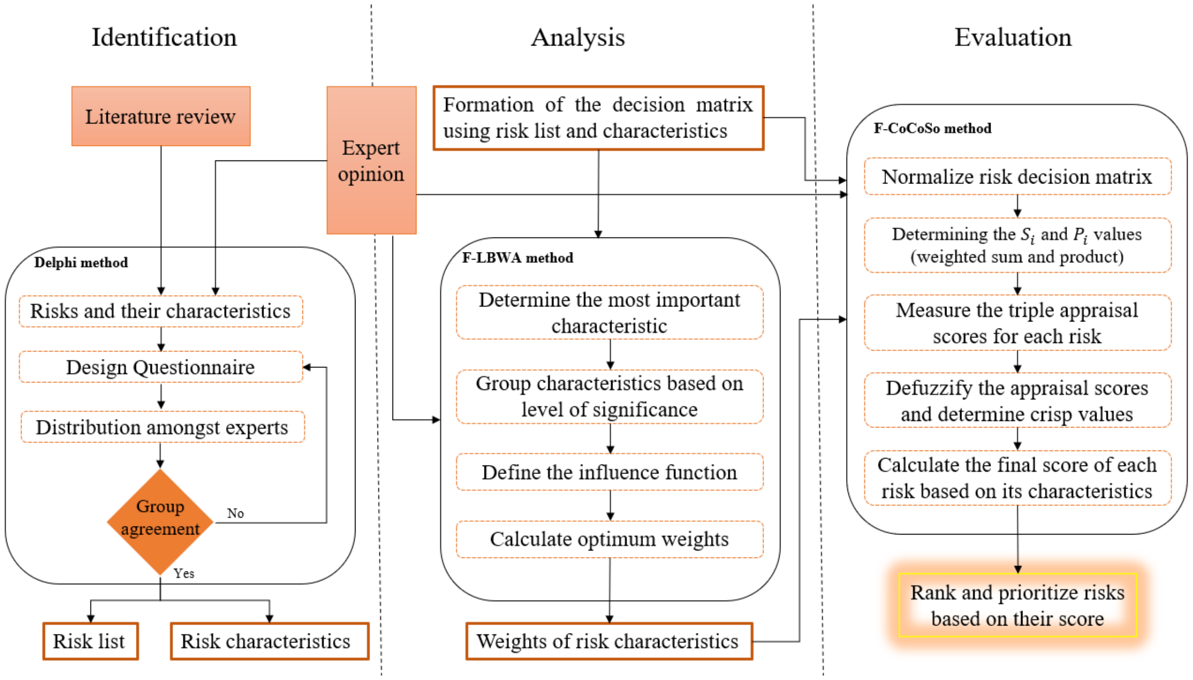

Fig. 4. General framework of the proposed risk assessment approach

3.1 Risk identification

The first stage of the approach revolves around identification; the goal is to not only identify the risks associated with the project as is done traditionally, but also identify the main characteristics of the risks which influence the impact of the risks. For this, there are usually two sources of information, namely; expert opinion and existing literature, by closely studying the existing literature an initial idea is formed about the potential risks and their inherent characteristics, to formalize or contextualize these risks for the specific case expert opinion is used. To efficiently extract the opinions of experts on risk related matters, there are multiple methods, the Delphi method; a structured process for gathering and synthesizing expert opinions through multiple rounds of anonymous surveys (i.e. questionnaires). In each round, experts provide their input, and a facilitator summarizes the responses, sharing the results with the group to refine their opinions in subsequent rounds. This iterative process continues until a consensus or sufficient convergence of views is achieved (Habibi et al., 2014). Thus, after extracting a list of potential risks and risk characteristics, the information is further processed by an iterative Delphi process, enhancing and contextualizing the information further to have more accurate findings.

3.2 Risk analysis

Risk analysis, after identifying potential risks, assesses their likelihood, impact, and consequences, and prioritizes them based on severity. It typically includes qualitative or quantitative methods to analyze risks and inform decision-making on how to manage or mitigate those risks. It involves evaluating the likelihood and impact of each risk, often using qualitative or quantitative methods, to understand their significance, though this study goes beyond just considering probability and impact, it assumes all relevant characteristics which contribute to the significance of the risks. After the initial identification, each risk characteristic (e.g. risk impact, probability, detectability, etc.) is measure and documented for further analysis. Another critical step is to also weigh the characteristics against one another since it is highly likely that the characteristics do not share the same level of significance; to compare these risk characteristics a Multi-Attribute Decision-Making (MADM) weighting method is used, namely; the Level Based Weight Assessment (LBWA) method (Žižovic & Pamucar, 2019). Weighting methods usually are divided into two groups of objective and subjective methods which differ based on their reliance on the Decision Maker (DM) (Ayan et al., 2023), based on the nature of risk assessment, expert opinion serves a vital role which would necessitate a more subjective approach. LBWA is amongst the more recent subjective approaches, utilizing pair-wise comparisons such as the Analytic Hierarchy Process (AHP) method (Saaty, 1988) or the Best-Worst-Method (BWM) (Rezaei, 2015), though unlike the AHP and BWM, the LBWA requires fever numbers of comparisons, coupled with the fact that its algorithm doesn't get complex with the number of criteria, this method is very well suited for problems with higher numbers of criteria (Ayan et al., 2023; Žižovic & Pamucar, 2019). As mentioned in section 2, fuzzy logic (Zadeh, 1965) has gained significant attention in risk analysis studies, the LBWA method has also been utilized in fuzzy space (Ogundoyin & Kamil, 2023; Pamucar et al., 2020; Pamucar & Faruk Görçün, 2022). Hence, a Fuzzy LBWA (F-LBWA) method will be utilized to measure the weight of risk characteristics. To perform F-LBWA the following steps are taken:

Step 1. Assume a number of *n* criteria (risk characteristics) and *m* DMs (experts), select the most important criterion from $S = \{C_1, C_2, C_3, \dots, C_n,\}$, i.e. let C_1 be the most important criterion in the set according to the DM's opinion.

Step 2. Divide the criteria in different groups based on their level of significance, these levels of significance are established based on their relative importance compared to C_1:

> *Level* S_1: The criteria from subset S whose significance is equal to criterion C_1 or up to twice as less;
>
> *Level* S_2*:* The criteria from subset S whose significance is between twice as less as up to three times as less as the significance of the criterion C_1;
>
> . . .
>
> *Level* S_k*:* The criteria from subset S whose significance is between k up to $k + 1$ times less than the significance of the criterion C_1.

By this classification, if the significance of the criterion C_j is denoted by $s(C_j)$, where $j \in \{1, 2, \dots, n\}$ then we'll have $S = S_1 \cup S_2 \cup \dots \cup S_k$, where for every level $i \in \{1, 2, \dots, k\}$ the following can be assumed:

$$S_i = \{C_{i_1}, C_{i_2}, \dots, C_{i_s}\} = \{C_j \in S: i \le s(C_j) \le i + 1\} \tag{1}$$

Step 3. After the formation of the significance levels, each individual DM is tasked with comparing the criteria of each group; each $C_{i_i} \in S_i$ from the subset $S_i = \{C_{i_1}, C_{i_2}, \dots, C_{i_s}\}$ is assigned an integer value $I_{i_i} \in \{1, 2, \dots, \lambda\}$ such as the lower the integer number, the higher its perceived value is, i.e. the value of $I_1 = 0$ if C_1 is the most important criteria, and between two criteria C_p and C_q the one with a lower I_i is seen more significant. As mentioned, the maximum value of these integer numbers is r which is defined by Eq. (2):

$$r = Max\{|S_1|, |S_2|, |S_3|, \dots, |S_k|\} \tag{2}$$

At this stage the fuzzification commences, due to the difference in DM opinion when comparing and scoring the criteria in different groups. This is done by applying Eq. (3):

$$\widetilde{I_{\iota_\iota}} = \left(I_i{}^{(l)}, I_i{}^{(m)}, I_i{}^{(u)}\right) \Rightarrow I_i{}^{(l)} = \min_m\{I_{i_i}{}^m\};\ I_i{}^{(m)} = \frac{1}{m}\sum_{e=1}^{m} I_{i_i}{}^e;\ I_i{}^{(u)} = \max_m\{I_{i_i}{}^m\} \tag{3}$$

where *m* is the total number of participating decision makers.

Step 4. Next, the influence function is defined, before that, the elasticity coefficient is proposed as r_0 which is based on the maximum scale value r which was defined in equation 2. r_0 also known as the elasticity coefficient, is a real number that is $r_0 > r$, usually considered as $r_0 = r + 1$. Based on r_0 the influence function is portrayed in Eq. (4):

$$\tilde{f}(C_{i_i}) = \frac{r_0}{i \times r_0 + \widetilde{I_{\iota_\iota}}} \tag{4}$$

where *i* presents the number of the defined significant levels by the DMs.

Step 5. Finally, the fuzzy weights of the criteria are determined, this done by initially calculating the weight of the most important criterion using Eq. (5), afterwards calculating the remaining criteria weights using Eq. (6).

$$\omega_1 = \frac{1}{\sum_{i=1}^{n} f(C_i)} \tag{5}$$

$$\omega_j = f(C_j) \times \omega_1 \tag{6}$$

Using the F-LBWA the weights of the risk characteristics is determined, depicting the difference the importance of the characteristics.

3.3 Risk evaluation

The final stage in the risk assessment framework involves risk evaluation; the act of evaluating and measuring the overall importance of each risk to further prioritize and rank them which will facilitate strategizing and responding to them. This is usually done based on the multiplication of typical risk characteristics (e.g. multiplying probability, severity and detectability in the FMEA method). In the risk evaluation stage of the framework the risks are evaluated using a Multi-Criteria Decision-Making (MCDM) method in which the alternatives are the risks and the criteria the risk characteristics, these create a table known as the decision matrix where a series of mathematical algorithms are performed to evaluate and assign each alternative with a score used to rank them based on the criteria. To establish this decision matrix, the data from the previous stage, namely; the identified risks, their characteristics, values and weights of the characteristics are fed into the matrix. The mathematical procedure that scores the risks differs based on the MCDM method utilized, similar to weighing methods, there are also a plethora of methods introduced in the literature (Taherdoost & Madanchian, 2023). The method proposed to use in this study is the Combined Compromise Solution (CoCoSo) method (Yazdani et al., 2019). This relatively recent method is an aggregation of the Weighted Sum Method (WSM) and the Weighted Product Method (WPM) similar to the Weighted Aggregated Sum Product Assessment (WASPAS) method (Chakraborty et al., 2015), though this method shares the simplicity of the WASPAS method, due to its ability to integrate the simplicity of weighted aggregation with the flexibility of compromise programming; it efficiently combines the weighted sum model, the weighted product model, and geometric averaging, enhancing its capacity to handle complex decision-making scenarios. Previous studies also depict this method compatible with the F-LBWA method (Korucuk et al., 2023; Pamucar & Faruk Görçün, 2022; Torkayesh et al., 2021). The CoCoSo method has also been developed in the fuzzy space and utilized in previous studies(Chatterjee & Chakraborty, 2024; Ogundoyin & Kamil, 2023; Yang & Li, 2024). The steps of the Fuzzy CoCoSo (F-CoCoSo) method include:

Step 1. The decision matrix is established using fuzzy values, the fuzzy triangular values are defined based on the opinion of experts following a (1-9) qualitative scale, the fuzzy linguistic terms presented adopt a similar design as (Lin et al., 2024), Table 2 depicts an example of this scale for project probability and severity characteristics.

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{12} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mn} \end{bmatrix}; 1 \leq i \leq m;\ 1 \leq j \leq n \tag{7}$$

Step 2. The matrix is normalized to attain global homogeneity amongst the matrix columns, this is done through equation 8 if we are dealing with a benefit criterion, and Eq. (9) if it is a cost criterion:

$$\tilde{r}_{ij} = \left(r_{ij}{}^{(l)}, r_{ij}{}^{(m)}, r_{ij}{}^{(u)}\right) = \frac{\tilde{x}_{ij} - \min\limits_{i} \tilde{x}_{ij}}{\max\limits_{i} \tilde{x}_{ij} - \min\limits_{i} \tilde{x}_{ij}} \tag{8}$$

$$\tilde{r}_{ij} = \left(r_{ij}{}^{(l)}, r_{ij}{}^{(m)}, r_{ij}{}^{(u)}\right) = \frac{\max\limits_{i} \tilde{x}_{ij} - \tilde{x}_{ij}}{\max\limits_{i} \tilde{x}_{ij} - \min\limits_{i} \tilde{x}_{ij}} \tag{9}$$

Table 2
Fuzzy linguistic terms for decision matrix values (Lin et al., 2024)

Linguistic terms for impact	Linguistic terms for probability	Percentage	Triple fuzzy numbers
Negligible	Rare	(<1%)	(0.1,0.1,0.2)
Very Low	Very Unlikely	(1–5%)	(0.1,0.2,0.3)
Low	Unlikely	(6–15%)	(0.2,0.3,0.4)
Below Moderate	Below Possible	(16–25%)	(0.3,0.4,0.5)
Moderate	Possible	(26–40%)	(0.4,0.5,0.6)
Above Moderate	Above Possible	(41–60%)	(0.5,0.6,0.7)
High	Likely	(61–75%)	(0.6,0.7,0.8)
Very High	Very Likely	(76–90%)	(0.7,0.8,0.9)
Critical	Almost Certain	(>90%)	(0.8,0.9,0.9)

Step 3. The next phase involves calculating the weighted sum value (S) and the weighted product value (P) for the comparability sequence each risk, this is done by performing Eq. (10) and Eq. (11):

$$\tilde{S}_{ij} = \left(S_{ij}{}^{(l)}, S_{ij}{}^{(m)}, S_{ij}{}^{(u)}\right) = \sum_{j=1}^{n} \tilde{\omega}_j\ \tilde{r}_{ij} \tag{10}$$

$$\tilde{P}_{ij} = \left(P_{ij}{}^{(l)}, P_{ij}{}^{(m)}, P_{ij}{}^{(u)}\right) = \sum_{j=1}^{n} \tilde{r}_{ij}{}^{\tilde{\omega}_j} \tag{11}$$

Step 4. The relative weights of the alternatives are determined next using the aggregation strategies, three appraisal score strategies are computed to generate relative weights of each risk, these appraisal scores are calculated using Eqs. (12-14):

$$K_{ia} = \frac{\tilde{S}_i + \tilde{P}_i}{\sum_{i=1}^{m}(S_i + \tilde{P}_i)} \tag{12}$$

$$K_{ib} = \frac{\tilde{P}_i}{\min\limits_i \tilde{P}_i} + \frac{\tilde{S}_i}{\min\limits_i S_i} \tag{13}$$

$$K_{ic} = \frac{\lambda(\tilde{S}_i) + (1-\lambda)(\tilde{P}_i)}{(\lambda \max\limits_i \tilde{S}_i + (1-\lambda) \max\limits_i \tilde{P}_i)}, 0 \leq \lambda \leq 1 \tag{14}$$

where λ represents balance coefficient related to the compromise between the two values of S and P, this λ is determined by the DM, though it is usually valued equal to 0.5, this value also help the F-CoCoSo method to remain flexible based on values ranging from 0 to 1.

Step 5. After determining the appraisal scores, they are defuzzied and transformed from fuzzy to crisp values using Eqs. (15-17):

$$K_{ia} = \frac{K_{ia}{}^{l} + K_{ia}{}^{m} + K_{ia}{}^{u}}{3} \tag{15}$$

$$K_{ib} = \frac{K_{ib}{}^{l} + K_{ib}{}^{m} + K_{ib}{}^{u}}{3} \tag{16}$$

$$K_{ic} = \frac{K_{ic}{}^{l} + K_{ic}{}^{m} + K_{ic}{}^{u}}{3} \tag{17}$$

Step 6. The final score of each risk is calculated using Eq. (18):

$$K_{ic} = (K_{ia}K_{ib}K_{ic})^{1/3} + \frac{1}{3}(K_{ia} + K_{ib} + K_{ic}) \tag{18}$$

Each risk receives its own score based on the aforementioned calculations, these scores are then used to prioritize risks and rank them; the higher the received score the more importance the risk is. The risks can be one of three; negative (threat), positive (opportunity) or a hybrid (i.e. depending on the situation could produce a positive or negative outcome). When using the approach both positive and negative risks entered in the decision matrix but the values added could be reversely interpreted, for example; when considering monetary impact of a risk, in the case of negative risk, higher value would interpret a more dangerous risk, while for positive risks a higher monetary impact value would translate to an advantage, the higher the better. For hybrid risks, both positive and negative outcomes of the risk are considered and entered as separate risks in the decision matrix. Once the calculation ends and each risk receives its score, the different type of risk and put into different tables and prioritized separately.

4. Case

To illustrate the practicality, this framework was tested using the data provided by a private company specializing in contracting and performing EPC projects. A total of 3 experts agreed to act as DMs for this study and to provide insight on the risks of one of their scheduled EPC projects. The data included risks of different types and from different phases of the project. In the following subsections the stages of the framework are executed and the findings are displayed.

4.1 Risk identification stage

Following the framework, to identify the risks and their characteristics within this specific context of projects, initially the relevant literature was review and an initial list of risks and their characteristics were formed using previous studies (IQBAL et al., 2015; Szymański, 2017; Yousri et al., 2023; Zamri Zakaria et al., 2024). Afterwards this initial list was given to the expert in a systematic fashion following the Delphi method, after two iterations of the Delphi method the information was finalized. The list of risks has been shown in table 3 and the assumed risk characteristics for this case are:

- **Cost**: The financial impact associated with the occurrence of a risk.
- **Probability**: The likelihood that a risk will occur.
- **Quality**: The potential effect of a risk on the quality, scope or performance of deliverables.
- **Detectability**: The ease with which a risk can be identified or recognized.
- **Schedule**: The impact a risk could have on project timelines.
- **Manageability**: The extent to which a risk can be controlled or mitigated (risk response).

Table 3
List of risks

Risk		Description
$E1^-$	Design risk	Errors or omissions in the basic design can lead to rework and project delays.
$E2^-$	Inaccurate estimations	Unrealistic estimations lead to inappropriate allocations, cost overruns and delays.
$E3^-$	Inflation and fluctuation of price	Cause change in budget and material cost.
$E4^+$	Introduction of new technologies	Could facilitate processes and save time and costs.
$E5^-$	Organizational risk	Internal structural issues disrupt planning and decision-making.
$E6^-$	Lack of skills and technical experts	Insufficient expertise results in subpar designs and flawed estimations.
$E7^\pm$	Well (or poorly) recognized competition	(Dis)advantages for the marketing.
$P1^+$	Bulk purchase discount	Usually adds a chance to receive discounts based on the material and vendor.
$P2^-$	Rising prices of materials and equipment	Escalating costs hinder procurement.
$P3^-$	Delay in supply	Late delivery of materials disrupts project timelines.
$P4^+$	Local sourcing opportunities	Identification of local suppliers reduces transportation costs and lead times.
$P5^+$	Supplier competition	Intense competition between suppliers leads to better pricing and delivery terms.
$P6^-$	Incompetent vendors	Unreliable vendors supply defective or delayed materials.
$P7^-$	Unavailability of funds and financial failure	Financial issues stall procurement activities.
$P8^-$	Bidding decision risk	Poor bid evaluations lead to unsuitable contractor selection.
$C1^-$	Material quality risk	Substandard materials compromise structural integrity.
$C2^\pm$	Site condition	Unforeseen site condition could benefit or damage the project.
$C3^-$	Poor performance of the project management team	Ineffective leadership reduces efficiency.
$C4^-$	Construction environmental risk	Environmental factors negatively impact progress and could cause damages.
$C5^-$	Delay in technical inspection	Late inspections prevent timely project completion.
$C6^-$	Lack of material	Material shortages halt construction activities.
$C7^-$	Poor coordination and communication	Misalignment between teams causes inefficiencies.
$C8^-$	Incompetent subcontractors	Poor subcontractor performance impacts quality.
$C9^-$	Installation and erection risk	Incorrect installation leads to operational issues and catastrophes.
$C10^+$	Positive stakeholder feedback	Early recognition from clients or stakeholders.
$C11^+$	Labor motivation	Situations where work is expedited due to labor bravado.

Six risk characteristics were selected and 26 risks were identified, the risks were coded passed on their respective phase (i.e. engineering, procurement and construction), amongst the risk the positive, negative and hybrid ones were also depicted. Since two of the risks C2 and E7 were hybrid risks, both their positive and negative effects were considered, effectively changing the number of total risks to be analyzed to 28.

4.2 Risk analysis stage

After the risks and their characteristics were identified and organized, the next step involved the determination of the risk values and their analysis. In this stage the decision matrix was formed using the opinions of the experts and the fuzzy linguistic terms mentioned in Table 2. A simple aggregation of the risk values is illustrated by Fig. 5.

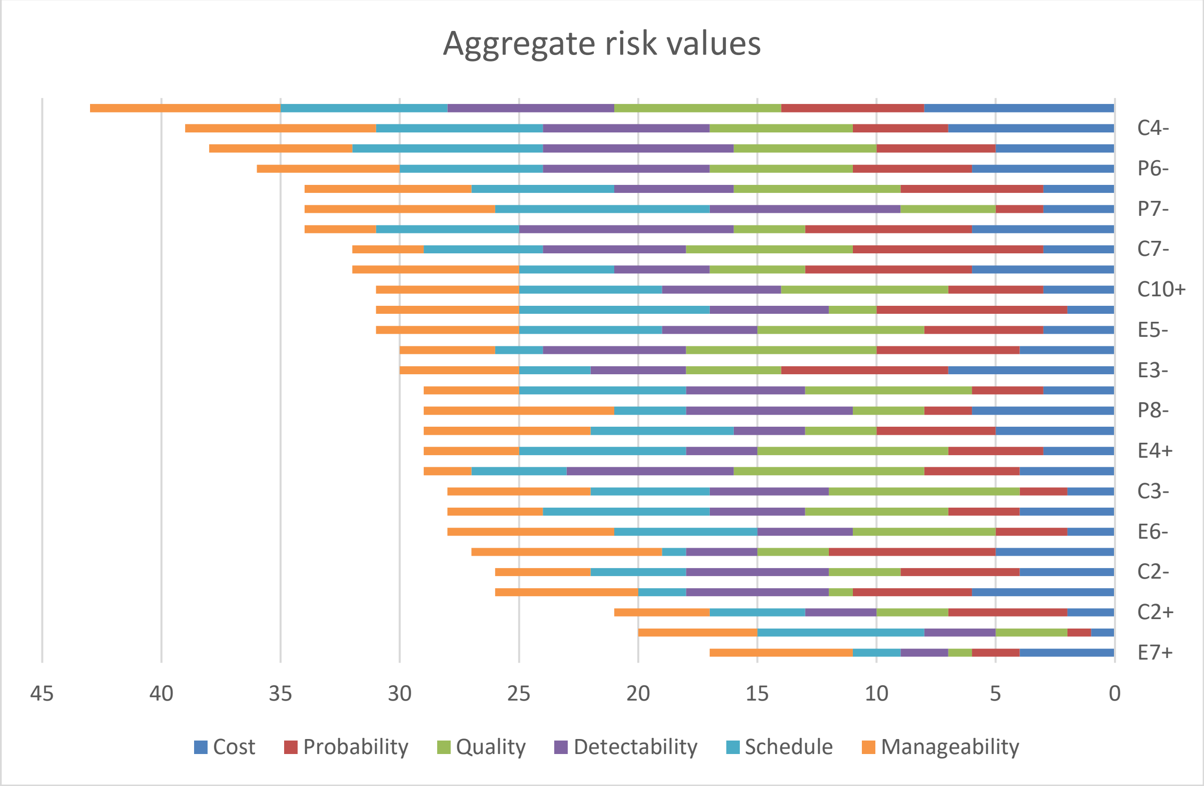

Fig. 5. Simple depiction of aggregated risk values

Fig. 5 brilliantly shows the proportion of each characteristic on every risk. At first glance it would seem that negative procurement and construction risks had the most values allocated, though this was a simple summation of the values without considering the weight of each characteristic. To weigh the characteristic the F-LWBA method is employed. First, the most important criterion was determined to be the cost characteristic. Next, the characteristics were grouped into the following levels based on their significance:

Level S_1 up to twice as less significant than cost: Cost, Probability
Level S_2 twice to three times less significant than cost: Detectability
Level S_4 four to five times less significant than cost: Quality, Schedule, Manageability

Afterwards, each item of the group was given a score by the experts, the scores are shown in Table 4.

Table 4
Initial F-LBWA input values

Characteristics	Level	DM_1	DM_2	DM_3	r_0
Cost	1	0	0	0	$r_0 = 3$
Probability	1	1	2.5	1	
Quality	4	3	2.5	3	
Detectability	2	2	1	2	
Schedule	4	1	1.5	1	
Manageability	4	2	2	3	

These initial data are further modified by executing equation (3-6); they are fuzzified, the influence function is established with a standard elasticity value of $r_0 = 4$, the weight of the most important characteristic (i.e. cost) is calculated and finally the remaining fuzzy weight of the rest of the characteristics are also measured. Table 5 and figure 6 present a view of the fuzzy weights.

Table 5
Fuzzy weight of risk characteristics

Risk characteristics	Fuzzy Weights
Cost	(0.342, 0.357, 0.376)
Probability	(0.228, 0.259, 0.301)
Quality	(0.062, 0.076, 0.084)
Detectability	(0.137, 0.148, 0.167)
Schedule	(0.072, 0.083, 0.088)
Manageability	(0.068, 0.078, 0.084)

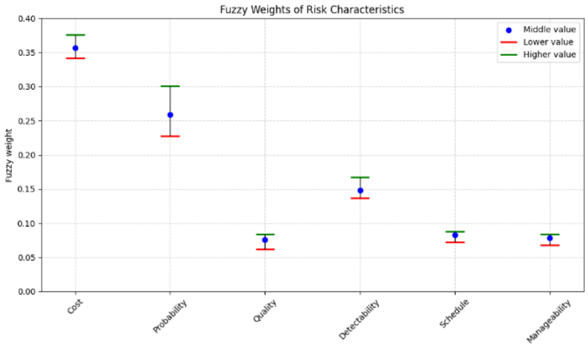

Fig. 6. Fuzzy weight of risk characteristics

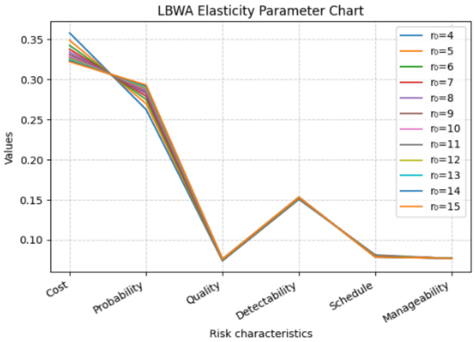

Fig. 7. Change in weights based on different elasticity coefficients

It would seem that after the most valued characteristic which is cost, probability and detectability weigh highest which are the same variable considered when utilizing the FMEA method. The rest of the characteristics weigh in a similar lower range, lower than the previous ones but not neglectable. The F-LBWA method was conducted with the elasticity coefficient $r_0 = 4$, though this number is the standard amount, changing the coefficient is arbitrarily and the DM is free to change this number and increase it to test alternative values, taking advantage of the method's flexibility. Different values of r_0 were places and the result of the different characteristic weight outcome is illustrated by Fig. 7.

4.3 Risk evaluation stage

By collecting both the fuzzy values of each risk (based on characteristic) and the fuzzy weights of the characteristic, the decision matrix is prepared and ready to measure each risks value.

Table 6
Fuzzy triple appraisal values

		K_a			K_b			K_c	
E1^{-}	0.038	0.038	0.038	4.555	4.647	4.561	0.945	0.941	0.937
E2^{-}	0.033	0.034	0.034	4.608	4.711	4.597	0.801	0.803	0.800
E3^{-}	0.040	0.040	0.040	5.321	5.344	5.223	0.971	0.968	0.966
E4^{+}	0.036	0.035	0.035	3.640	3.742	3.660	0.896	0.891	0.881
E5^{-}	0.030	0.030	0.030	3.322	3.424	3.460	0.753	0.747	0.747
E6^{-}	0.025	0.026	0.025	2.545	2.693	2.606	0.640	0.643	0.641
E7^{+}	0.021	0.021	0.021	2.028	2.125	2.068	0.541	0.540	0.533
E7^{-}	0.033	0.033	0.033	4.637	4.668	4.567	0.780	0.785	0.784
P1^{+}	0.033	0.033	0.033	4.484	4.605	4.499	0.790	0.791	0.788
P2^{-}	0.038	0.038	0.038	4.255	4.379	4.341	0.938	0.936	0.932
P3^{-}	0.037	0.037	0.038	4.112	4.319	4.357	0.919	0.925	0.923
P4^{+}	0.039	0.039	0.039	4.739	4.820	4.736	0.951	0.948	0.945
P5^{+}	0.038	0.038	0.038	4.291	4.393	4.337	0.940	0.937	0.933
P6^{-}	0.037	0.037	0.037	4.153	4.250	4.183	0.933	0.929	0.923
P7^{-}	0.038	0.038	0.038	4.632	4.720	4.528	0.941	0.938	0.929
P8^{-}	0.037	0.037	0.037	4.507	4.521	4.360	0.920	0.913	0.905
C1^{-}	0.038	0.038	0.038	4.374	4.493	4.450	0.937	0.937	0.934
C2^{+}	0.033	0.033	0.032	2.815	2.963	2.923	0.847	0.843	0.831
C2^{-}	0.034	0.034	0.034	3.219	3.371	3.360	0.875	0.875	0.866
C3^{-}	0.033	0.033	0.032	2.843	2.990	2.947	0.847	0.843	0.831
C4^{-}	0.041	0.042	0.042	5.562	5.648	5.487	0.996	0.996	0.994
C5^{-}	0.038	0.038	0.038	4.357	4.482	4.407	0.945	0.944	0.939
C6^{-}	0.030	0.029	0.028	2.426	2.395	2.395	0.769	0.751	0.740
C7^{-}	0.039	0.040	0.040	4.870	5.010	4.978	0.964	0.964	0.964
C8^{-}	0.042	0.042	0.042	5.679	5.746	5.624	1.000	1.000	1.000
C9^{-}	0.042	0.042	0.042	5.665	5.703	5.544	0.997	0.995	0.994
C10^{+}	0.039	0.039	0.039	4.590	4.705	4.618	0.956	0.955	0.951
C11^{+}	0.037	0.037	0.037	4.236	4.354	4.249	0.927	0.924	0.916

F-CoCoSo is initiated, the normalized values are calculated, the S and P values are measured and the fuzzy triple appraisal values are also determined. Due to the large size of the fuzzy decision matric, it was added to the appendix section, however; the fuzzy triple appraisal values are presented by Table 6. Using the measured triple appraisal values, and assuming the balance coefficient of λ = 0.5, the triple appraisal values are defuzzied and transformed into crisp values and finally, the total risk score based on the F-CoCoSo method is calculated. The final outcome can be seen in table 7 and figure 8.

Table 7
Final ranking of positive and negative risks

Threats		Opportunities	
Risk	Rank	Risk	Rank
C8-	1	P4+	1
C9-	2	C10+	2
C4-	3	P5+	3
E3-	4	P1+	4
C7-	5	C11+	5
P7-	8	E4+	6
E1-	9	C2+	7
C1-	10	E7+	8
E2-	11		
P8-	12		
C5-	13		
E7-	14		
P2-	16		
P3-	19		
P6-	20		
C2-	22		
E5-	23		
C3-	24		
E6-	26		
C6-	27		

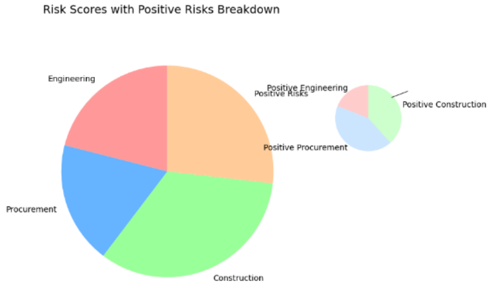

Fig. 8. Risk breakdown based on type

Table 7 presented the risks in order of their magnitude, while figure 8 presented the breakdown of the risk and their aggregate score, it would seem that in both risk types, construction risks have the highest significance; the risks of incompetent subcontractors, installation and erection and construction environment were evaluated to be the biggest threats while local sourcing, positive stakeholder feedback and supplier competition were calculated to be the best opportunities. These scores and ranks were calculated on the basis that the balance coefficient λ = 0.5, similar to the F-LBWA's elasticity coefficient, the balance coefficient is also an arbitrarily values determined by the DM, other values for the balance coefficient are tested and presented in Fig. 9.

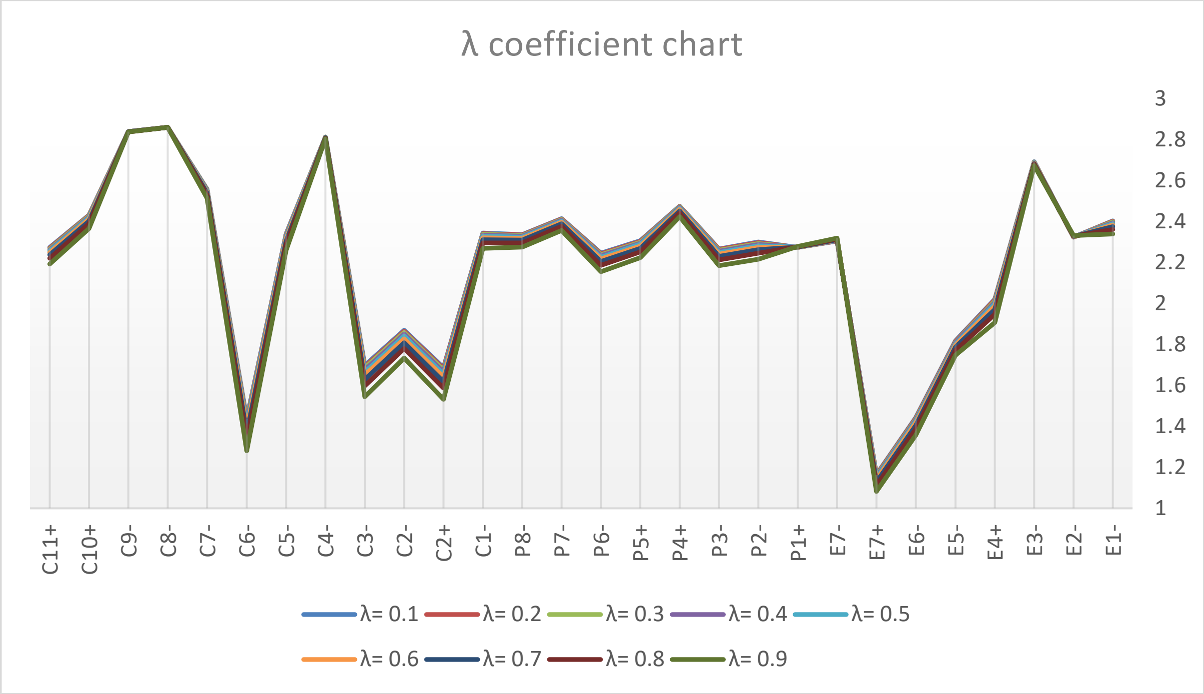

Fig. 9. F-CoCoSo with different balance coefficients

5. Discussion

This paper aimed to propose a new approach towards project risk assessment by introducing an integrated three-stage framework to handle risk identification, analysis and evaluation of project risks. This approach would be based on risk characteristics, which by reviewing the literature was proven to be gap in literature. A systematic framework of identification of risk and their characteristics using literature and the Delphi method composed the first stage of the framework; this would ensure that a comprehensive list of risks and their crucial characteristics would be recognized. Risk analysis using F-LBWA to quantify qualitative information and to obtain Fuzzy weights of risk characteristics was proposed for the second stage; in this stage using the F-LBWA the fuzzy weight of characteristics was determined and by utilizing a nine-scale linguistic term definition, the qualitative risk values were also transformed into triple fuzzy numbers. Although the risks were differentiated mainly by their characteristics, the nature of their impact (i.e. threat or opportunity) was also taken into account within this stage. Finally, to evaluate each individual risk a fuzzy decision matrix was established and F-CoCoSo method was conducted to score each risk, which concluded the third stage of the framework; each risk score represented the magnitude of the risk and using that value, the risks can be prioritized and ranked to give better insight for the next stage in the risk management cycle which would respond and strategize to handle these risks.

The methods used in this approach were relatively new methods which their strengths were previously mentioned, the combination of F-LBWA and F-CoCoSo was also accounted for when conducting this study, interestingly, the elasticity coefficient of F-LBWA and the balance coefficient of F-CoCoSo were very similar in use and function, giving more flexible options to the DM. though to test the consistency of the method, several other fuzzy MCDM methods were also used on the same data, namely; Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (F-TOPSIS), Fuzzy ÉLimination Et Choix Traduisant la REalité (F-ELECTRE) and F-WASPAS, these methods were coupled with the fuzzy decision matrix and used to score and rank the risks and their outcomes were compared with F-CoCoSo, the result is shown in Fig. 10. The method was further tested on an EPC project's risks; a total of 26 risks were identified with 6 crucial risk characteristics, the weights were measured and the values fuzzified and finally the risks were evaluated to produce a ranked list of the risks. As predicted, the most important risks to consider were related to the construction phase of the project (both as threats and opportunities), composing roughly 38.6% of the total calculated risk score. Positive risks were also considered, these opportunities when measured consisted about 26.8% of the total evaluated risk score which is a considerable amount to capitalize on.

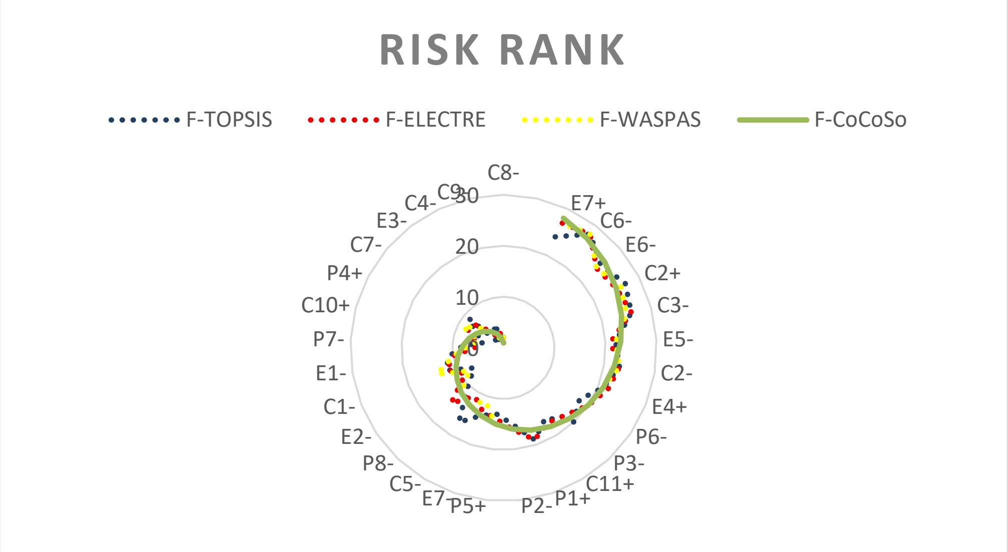

Fig. 10. Comparison of different MCDM methods

This study contributes to the existing body of literature by proposing a comprehensive approach for projects risk assessment on the basis of considering critical risk characteristics and utilizing new and effective MCDM methods to analyze and evaluate the risks. The framework proposed by this study can be both used by practitioners in the field of project risk management to effectively assess risks, and by academics, saturating a gap of the existing body of literature. Assuming a difference between positive and negative risks when assessing risks (which is a crucial consideration, often overlooked) was another strength on this study, resulting in giving insight on not just the existing threats to counter, but also the possible opportunities to exploit. Though this study prioritized the importance of risks characteristics, there are other aspects which determine the outcome of risks, for example; risk factors, risk triggers, risk interdependencies, etc., it studying the simultaneous effect of both risk characteristics and risk factors (or risk interdependencies) on risk analysis and evaluation can be suggested as future research area. In this study both positive and negative aspects of risks were considered and hybrid risks were introduced that depending on the situation could have both positive or negative outcomes, it would be interesting to see risks which produce simultaneous positive and negative results with conflicting characteristics to be considered and weighed. Another limitation of this study was that it was tested via an EPC projects data, provided by a small private company, extending this framework to other project types with varying scales would shine more insight on its practicality. Lastly, risks assessment which was the main topic of this research, is one of the parts of the risk management cycle, other parts sch as risk planning, monitoring & control and most importantly; risk response strategies are yet to be considered.

6. Conclusion

PRM is a crucial practice for the success of projects, especially in the construction industry. An important part of the risk management cycle involves risk assessment; the process of risk identification, analysis and evaluation. The comprehensive framework developed in this study represents a significant contribution to the field PRM, especially in the context of EPC projects. By integrating a structured, multi-dimensional approach to risk identification, analysis, and evaluation, the research addresses critical gaps in existing literature and provides actionable insights for both academics and practitioners. A framework was developed, utilizing methods such as the Delphi, F-LBWA and F-CoCoSo for each stage of risk assessment, adapting a risk characteristic passed approach. The application of the framework to a real-world EPC project demonstrates its practicality and relevance. The study's results show that construction-phase risks, particularly those related to incompetent subcontractors, installation errors, and environmental factors, dominate the risk profile as significant threats. Conversely, opportunities such as local sourcing, stakeholder feedback, and supplier competition highlight areas where strategic advantages can be realized. The findings underscore the importance of a balanced approach to PRM that considers both risk mitigation and opportunity exploitation. In addition to its methodological contributions, this study offers practical implications for project managers and decision-makers. The framework equips practitioners with a structured approach to identifying critical risks, prioritizing them based on multi-dimensional criteria, and informing strategic risk responses. The focus on hybrid risks (those with both positive and negative outcomes depending on context) adds a layer of sophistication, enabling managers to adopt nuanced strategies tailored to specific scenarios.

In conclusion, the proposed framework represents a versatile approach to PRM, particularly for EPC projects. By integrating innovative methods such as F-LBWA and F-CoCoSo, the framework not only addresses the limitations of traditional risk assessment approaches but also provides a flexible, scalable, and effective tool for identifying, analyzing, and evaluating risks. The emphasis on both threats and opportunities ensures a balanced perspective that aligns with the evolving demands of contemporary project environments. As the construction industry continues to adopt advanced technologies and techniques, frameworks like the one proposed in this study will play a critical role in ensuring successful project outcomes and fostering a proactive approach to risk management.

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Appendix

Fuzzy decision matrix

Weight/	**Cost**			**probability**			**Quality**			**Detectability**			**Schedule**			**Manageability**		
Risks	0.34	0.36	0.38	0.23	0.26	0.30	0.06	0.08	0.08	0.14	0.15	0.17	0.07	0.08	0.09	0.07	0.08	0.08
E1-	0.43	0.53	0.63	0.40	0.50	0.60	0.70	0.80	0.87	0.50	0.60	0.70	0.43	0.53	0.63	0.23	0.33	0.43
E2-	0.40	0.50	0.60	0.50	0.60	0.70	0.33	0.43	0.53	0.70	0.80	0.87	0.67	0.77	0.83	0.17	0.27	0.37
E3-	0.67	0.77	0.87	0.50	0.60	0.70	0.47	0.57	0.67	0.40	0.50	0.60	0.33	0.43	0.53	0.30	0.40	0.50
E4+	0.33	0.43	0.53	0.20	0.30	0.40	0.57	0.67	0.77	0.37	0.47	0.57	0.60	0.70	0.80	0.40	0.50	0.60
E5-	0.13	0.20	0.30	0.53	0.63	0.73	0.43	0.53	0.63	0.20	0.30	0.40	0.63	0.73	0.83	0.63	0.73	0.83
E6-	0.23	0.33	0.43	0.13	0.23	0.33	0.40	0.50	0.60	0.20	0.30	0.40	0.63	0.73	0.83	0.67	0.77	0.83
E7+	0.27	0.37	0.47	0.23	0.33	0.43	0.10	0.17	0.27	0.20	0.30	0.40	0.23	0.33	0.43	0.40	0.50	0.60
E7-	0.60	0.70	0.80	0.50	0.60	0.70	0.10	0.17	0.27	0.43	0.53	0.63	0.20	0.30	0.40	0.53	0.63	0.73
P1+	0.40	0.50	0.60	0.70	0.80	0.87	0.37	0.47	0.57	0.33	0.43	0.53	0.17	0.23	0.33	0.63	0.73	0.83
P2-	0.37	0.47	0.57	0.47	0.57	0.67	0.43	0.53	0.63	0.40	0.50	0.60	0.33	0.43	0.53	0.47	0.57	0.67
P3-	0.17	0.27	0.37	0.57	0.67	0.77	0.27	0.37	0.47	0.53	0.63	0.73	0.60	0.70	0.80	0.53	0.63	0.73
P4+	0.50	0.60	0.70	0.50	0.60	0.70	0.30	0.40	0.50	0.30	0.40	0.50	0.47	0.57	0.67	0.53	0.63	0.73
P5+	0.40	0.50	0.60	0.43	0.53	0.63	0.33	0.43	0.53	0.40	0.50	0.60	0.43	0.53	0.63	0.43	0.53	0.63
P6-	0.37	0.47	0.57	0.30	0.40	0.50	0.37	0.47	0.57	0.50	0.60	0.70	0.63	0.73	0.83	0.40	0.50	0.60
P7-	0.40	0.50	0.60	0.20	0.30	0.40	0.40	0.50	0.60	0.73	0.83	0.90	0.63	0.73	0.80	0.70	0.80	0.87
P8-	0.60	0.70	0.80	0.17	0.27	0.37	0.43	0.53	0.63	0.43	0.53	0.63	0.37	0.47	0.57	0.60	0.70	0.80
C1-	0.40	0.50	0.60	0.47	0.57	0.67	0.53	0.63	0.73	0.43	0.53	0.63	0.23	0.33	0.43	0.43	0.53	0.63
C2+	0.20	0.30	0.40	0.23	0.33	0.43	0.43	0.53	0.63	0.27	0.37	0.47	0.40	0.50	0.60	0.43	0.53	0.63
C2-	0.20	0.30	0.40	0.27	0.37	0.47	0.33	0.43	0.53	0.57	0.67	0.77	0.27	0.37	0.47	0.43	0.53	0.63
C3-	0.20	0.30	0.40	0.20	0.30	0.40	0.57	0.67	0.77	0.30	0.40	0.50	0.43	0.53	0.63	0.37	0.47	0.57
C4-	0.50	0.60	0.70	0.40	0.50	0.60	0.57	0.67	0.77	0.70	0.80	0.87	0.70	0.80	0.87	0.60	0.70	0.80
C5-	0.33	0.43	0.53	0.33	0.43	0.53	0.53	0.63	0.73	0.53	0.63	0.73	0.63	0.73	0.80	0.50	0.60	0.70
C6-	0.10	0.17	0.27	0.27	0.33	0.43	0.30	0.40	0.50	0.27	0.37	0.47	0.50	0.60	0.70	0.47	0.57	0.67
C7-	0.37	0.47	0.57	0.57	0.67	0.77	0.63	0.73	0.80	0.60	0.70	0.80	0.37	0.47	0.57	0.33	0.43	0.53
C8-	0.57	0.67	0.77	0.47	0.57	0.67	0.40	0.50	0.60	0.60	0.70	0.80	0.63	0.73	0.83	0.63	0.73	0.80
C9-	0.63	0.73	0.83	0.40	0.50	0.60	0.50	0.60	0.70	0.50	0.60	0.70	0.70	0.80	0.87	0.57	0.67	0.77
C10+	0.40	0.50	0.60	0.37	0.47	0.57	0.63	0.73	0.80	0.47	0.57	0.67	0.50	0.60	0.70	0.57	0.67	0.77
C11+	0.37	0.47	0.57	0.43	0.53	0.63	0.67	0.77	0.83	0.30	0.40	0.50	0.63	0.73	0.80	0.27	0.37	0.47