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Performance evaluation of sustainable projects: a possibilistic integrated novel analytic hierarchy process-data envelopment analysis approach using Z-Number information

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Abstract

Selecting a proper set of projects is an important issue to make crucial decisions for many project-oriented organizations enabling them to achieve their goals despite the existing operational constraints (resources, time, etc.) and competitive environments. Since the results and consequences of the selected projects have short-term and long-range effects on social, economic, and environmental conditions, sustainable development suggests considering both financial and non-financial factors simultaneously. Thus, paying attention to the principles of sustainable development and considering social and environmental criteria along with economic criteria will lead to proper selection of sustainable and balanced project portfolio. In this paper, first, the conventional sustainability criteria are identified and screened; afterward, the importance weights of them will be calculated using the Z-AHP approach. Then by utilizing the Z-DEA, the input and output sustainability criteria are identified and the efficiency of the undertaken projects is finally calculated. In this paper, the project efficiencies have been calculated once using the Z-DEA and once through the Z-AHP-DEA approach. The results show that when the importance weights of sustainability criteria obtained by the Z-AHP are being considered, it will affect the project efficiencies as well as the ranking of the projects and make it possible, to achieve a more effective solution applying the Z-AHP-DEA approach (modified importance weights are considered). The results of AHP, DEA, and AHP-DEA approaches have been compared with the results of certain and fuzzy conditions when the measure of expert opinions is calculated by Z-Number. It has been depicted that by shifting from certainty to uncertainty (certainty, fuzzy, Z-Number (fuzzy considering probability)) the answers get more effective and realistic and it also demonstrates that the proposed Z-AHP-DEA can be used for ranking of projects as a reliable approach.

Keywords Sustainable project selection · Fuzzy set · Z-Number · Z-analytic hierarchy process (Z-AHP) · Z-data envelopment analysis (Z-DEA)

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1 Introduction

All project-oriented companies and organizations are faced with an important issue named project portfolio selection (Carazo et al., 2010). Any organization seeking to invest its resources in projects for profitability or competitive advantages is looking for a proper portfolio of projects (Anagnostopoulos & Mamanis, 2010). The project portfolio might vary from a few projects to one hundred. Currently, all activities related to the project entry in portfolio, their selection, and resources allocation come in the form of project portfolio selection. Project portfolio selection is related to allocating resources among a set of projects, concerning one or more objective functions, and making any mistakes in projects portfolio management will lead to wasting the resources in unsuitable projects. Moreover, the profit which could have been gained by investing in a well-suited project will be lost (Ghasemzadeh & Archer, 2000). Therefore, in order to create an efficient portfolio of projects, it is important to identify appropriate evaluation criteria. Financial factors are the most important criteria considered by almost all project portfolio selection models and maximizing profit is one of the most significant goals that organizations pursue to reach maturity and development (Khalili-Damghani & Tavana, 2014). But in the modern age, in addition to economic issues, environmental and social issues resulting from project implementation must be considered. Hence, the dimensions of sustainable development are moderns age interest and sustainability development has been applied by many companies through their strategy. However, social and environmental dimensions of sustainability are difficult to incorporate in projects (Sánchez, 2015; Labuschagne et al., 2005). Since the project results and consequences have short-term and long-range effects on social, economic, and environmental conditions, sustainable development proposes to consider both financial and non-financial factors. Considering the principles of sustainability as well as taking economic, social, and environmental criteria into account will lead to the selection of a sustainable and balanced portfolio (Frini & Benamor, 2015). Hence, one of the most fundamental issues which project-oriented organizations and companies are facing is the problem of portfolio selection. Every organization seeks to select the most profitable and optimal project among the available projects by appropriate planning because the valuable resources and funds of any organization cannot adequately test and execute all proposed projects. There must be a scientific and manageable procedure for selecting, prioritizing, and categorizing projects that makes it possible to evaluate and predict the past, present, and future direction of projects. Multi-attribute decision-making (MADM) approaches such as AHP is one of the methods that can be used to measure the importance of sustainability criteria along with DEA approach, to evaluate the efficiency of projects for prioritizing them (Beiragh et al., 2020). AHP examines complex problems on the basis of their interactions, converts them into simple ones, and solves them. The importance of using AHP is that it examines both quantitative and qualitative criteria simultaneously, and it is well suited for group decision making and is also understandable to managers and decision-makers (Triantaphyllou & Mann, 1995). Therefore, to weight the sustainability criteria, the AHP approach has been used in this study. Moreover, efficiency is a managerial concept that has a long history in management science. Efficiency illustrates that how an organization has used its resources properly, compared to the best performance at some point in time, to produce. When the decision-making unit has an input and an output, its efficiency is defined as the ratio of the output to the input of the same unit. So, DEA is one of the decision-making approaches by which the efficiency of proposed projects to the organization can be calculated and it means that if a specific project is selected, how efficient it would be for the organization (Ku-Mahamud et al., 2011). Therefore, after weighing the sustainability criteria DEA has been used as a method of measuring efficiency. The main and important advantage of this method is that it enables the comparisons between projects using measurement criteria, but the results, of course, depend on the validity of the used data. One of the factors that needs to be considered for validating data is taking uncertainty conditions into account. Because of the importance of selecting the right project portfolio, the importance of sustainable development dimensions in strategic plans, and high level of uncertainty in the project environment, providing a method for selecting a portfolio by means of sustainable development approach under uncertainty conditions is important. Given the economic conditions and global competition of organizations, this is a tool which helps managers make the right decisions in the direction of development, satisfaction among stakeholders, and achieving strategic goals (Labuschagne et al., 2005). In facing uncertainty conditions due to the uniqueness and novelty of the projects, utilizing fuzzy theories is more applicable to the tools required historical data and it will help future researches (Keshavarz Ghorabaee et al., 2016). So, to get closer to the real world, fuzzy logic is applied to these issues to reflect the views of experts and technicians as much as possible, and to greatly rectify the limitations of their views on such issues. Although fuzzy theories represent the uncertainties of the problem to some extent, the point is that these theories cannot fully incorporate uncertainties into the calculations. For example, estimation of fuzzy parameters is generally done through expert knowledge and the uncertainty in the validity of their opinions cannot be ignored. Z-Numbers are one of the subsets of fuzzy sets which includes considering the probability level in fuzzy numbers because expert judgments and linguistic scale always contain uncertainties (Hendiani & Bagherpour, 2019).

In Sect. 2, a review of the previous literature has been provided. In the first part, fuzzy numbers, in the second part, Z-Numbers, and in the third part, papers related to evaluation, and ranking of sustainable projects with MADM approaches have been addressed accordingly. At the end of Sect. 2, a summary of the papers is summarized as a table and the research gaps have been then investigated. In Sect. 3, the methodology of this paper has been addressed, which consists of four steps. The first step is to identify, classify, and filter sustainability criteria, and the second step is to introduce the Z-AHP approach to obtain the importance weights of sustainability criteria. The third step is to introduce the Z-DEA approach to calculate the efficiency of projects. In the fourth step, the integrated approach of Z-AHP-DEA has been introduced.Presenting a numerical example, the importance weights of sustainability criteria through Z-AHP approach and the efficiency of projects through Z-DEA and Z-AHP-DEA approaches are calculated in Sect. 4. In Sect. 5, the results have been analyzed, which is divided into two parts, that the first part consists of comparing the results in deterministic, fuzzy, and Z-Number conditions and the second part also compares the results obtained through DEA approach and AHP-DEA integrated approach. At last, in Sect. 6, the conclusion and managerial perspectives of this research, and future recommendations have been provided. Given the importance of the mentioned issues, the contributions of this study are mentioned as follows:

- Defining a new probabilistic and linguistic scale for Z-Numbers to examine paired comparisons between sustainability criteria
- Defining a new probabilistic and linguistic scale for Z-Numbers to score sustainability criteria decision-making matrix and proposed projects
- Introducing Z-AHP approach to weighting sustainability criteria
- Introducing Z-DEA approach to measuring the efficiency of projects and ranking

- Introducing the integrated Z-AHP-DEA approach to measure the efficiency of projects and ranking as well as comparing with the Z-DEA approach

2 Literature review

2.1 Fuzzy set

Fuzzy thinking was founded by (L. A. Zadeh, 1965) presenting a paper on fuzzy sets and fuzzy numbers. There is always uncertainty in decision making and the propose of the fuzzy theory was to eliminate and resolve the linguistic ambiguities. The features of the fuzzy concept are as follows:

- Initial rejection in scientific communities
- Envelopment of applications
- Uncertainty versus certainty
- Multiple-value versus double-value statements
- High accuracy versus low accuracy

Fuzzy logic is based on the observations that people make decisions according to inaccurate and non-numeric information. Fuzzy models or sets are mathematical tools for representing ambiguous and inaccurate information. These models are capable of identifying, representing, manipulating, interpreting, and using ambiguous and uncertain data and information.

The fuzzy set theory is feasible to deal with uncertainty associated with vagueness (L. A. Zadeh, 1965). Given that fuzzy can help decision-makers deal with ambiguities related to the ordinal evaluation of the data, it was combined with multi-criterion decision methods to determine the best result and alternative (Hoseini et al., 2020; Taylor et al., 2005). One of the main approaches to simulate the uncertainty related to vagueness is utilizing triangular fuzzy numbers which is closer to the real word than precise value. Expressing the lower point, the upper point, and the most likely point of the preference, the expert suggests a triangular fuzzy number to estimate the judgements (Kahraman et al., 2003) (van Laarhoven & Pedrycz., 1983; Gong et al., 2013). Suppose Q is a fuzzy number on R so that Q^l and Q^u denote the lower bound and upper bound of $\tilde{Q}$, respectively, and Q^m denotes the median value. Therefore $\tilde{Q} = \left(Q^l,\ Q^m,\ Q^u\right)$ will be a triangular fuzzy number if its membership function $Q(x)\ :\ R \rightarrow [0,\ 1]$ is equal to Eq. (1):

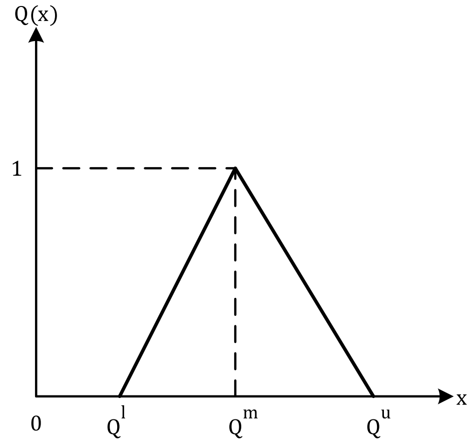
$$Q(x) = \begin{cases} \frac{x-Q^l}{Q^m-Q^l}, & Q^l \le x \le Q^m \\ \frac{Q^u-x}{Q^u-Q^m}, & Q^m \le x \le Q^u \\ 0\ , & otherwise \end{cases} \tag{1}$$

In addition, if $\tilde{Q}_1 = \left(Q_1^l, Q_1^m, Q_1^u\right)$ and $\tilde{Q}_2 = \left(Q_2^l, Q_2^m, Q_2^u\right)$ be triangular fuzzy numbers Fig. 1, the following operation rules are applied (Guttorp et al., 1990):

Triangular fuzzy number addition $\oplus$ Eq. (2):

$$\tilde{Q}_1 \oplus \tilde{Q}_2 = \left(Q_1^l, Q_1^m, Q_1^u\right) \oplus \left(Q_2^l, Q_2^m, Q_2^u\right) = \left(Q_1^l + Q_2^l,\ Q_1^m + Q_2^m,\ Q_1^u + Q_2^u\right) \tag{2}$$

Fig. 1 The triangular fuzzy number



Triangular fuzzy number subtractions ⊖ Eq. (3):

$$\tilde{Q}_1 \ominus \tilde{Q}_2 = \left(Q_1^l, Q_1^m, Q_1^u\right) \ominus \left(Q_2^l, Q_2^m, Q_2^u\right) = \left(Q_1^l - Q_2^u,\ Q_1^m - Q_2^m,\ Q_1^u - Q_2^l\right) \tag{3}$$

Triangular fuzzy number multiplication ⊗ Eq. (4):

$$\tilde{Q}_1 \otimes \tilde{Q}_2 = \left(Q_1^l, Q_1^m, Q_1^u\right) \otimes \left(Q_2^l, Q_2^m, Q_2^u\right) \approx \left(Q_1^l \times Q_2^l,\ Q_1^m \times Q_2^m,\ Q_1^u \times Q_2^u\right) \tag{4}$$

where $Q_i^l > 0,\ Q_i^m > 0,\ Q_i^u > 0$ for $i = 1, 2$.

Triangular fuzzy number division ⊘ Eq. (5):

$$\tilde{Q}_1 \oslash \tilde{Q}_2 = \left(Q_1^l, Q_1^m, Q_1^u\right) \oslash \left(Q_2^l, Q_2^m, Q_2^u\right) \approx \left(Q_1^l / Q_2^u,\ Q_1^m / Q_2^m,\ Q_1^u / Q_2^l\right) \tag{5}$$

where $Q_i^l > 0,\ Q_i^m > 0,\ Q_i^u > 0$ whit $i = 1, 2$.

In addition, we further assume that the scale system $0 - 1$ is applied by all the experts, and the following triangular fuzzy additive reciprocal preference relation is given in a GDM problem as in Eq. (6):

$$\tilde{B} = (\tilde{b}_{ij})_{n \times n} = \begin{bmatrix} (0.5,\ 0.5,\ 0.5) & \left(Q_{12}^l,\ Q_{12}^m,\ Q_{12}^u\right) & \cdots & \left(Q_{1n}^l,\ Q_{1n}^m,\ Q_{1n}^u\right) \\ \left(Q_{21}^l,\ Q_{21}^m,\ Q_{21}^u\right) & (0.5,\ 0.5,\ 0.5) & \dots & \left(Q_{2n}^l,\ Q_{2n}^m,\ Q_{2n}^u\right) \\ \vdots & \vdots & \ddots & \vdots \\ \left(Q_{n1}^l,\ Q_{n1}^m,\ Q_{n1}^u\right) & \left(Q_{n2}^l,\ Q_{n2}^m,\ Q_{n2}^u\right) & \cdots & (0.5,\ 0.5,\ 0.5) \end{bmatrix} \tag{6}$$

if $\tilde{b}_{ij}$ be explained as the triangular fuzzy number degree of the alternative x_i over x_j, Q_{ij}^l, Q_{ij}^m, and Q_{ij}^u are nonnegative real numbers so at $0 \le Q_{ij}^l \le Q_{ij}^m \le Q_{ij}^u \le 1$, and have the additive reciprocity of $Q_{ij}^l + Q_{ji}^u = Q_{ij}^m + Q_{ji}^m = Q_{ij}^u + Q_{ji}^l = 1$, for all $i, j = 1, 2, \ldots, n$.

2.2 Z-Number and its applications

The theory of uncertainty has been expanded to the concept of Z-Numbers by (Lotfi A. Zadeh, 2011) for the sake of providing a basis for calculation of unreliable numbers (Azadeh et al., 2013). Mohamad et al. (2014) combined Z-Numbers and AHP to recognize the criteria for evaluation of the best universities under uncertain conditions. Utilizing linguistic models (Peng and Wang, 2017) introduced hesitant uncertain linguistic Z-Numbers and solved an enterprise resource planning (ERP) problem in order to validation of the proposed method. Sahrom & Dom (2015) arranged the priority of 20 bridge structures by developing an AHP-Fuzzy DEA method, using Z-Numbers through integrating reliability and fuzzy numbers. A modification of Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method has been presented by (Yaakob & Gegov, 2016) to solve MCDM problems relying on the concept of Z-Numbers (Z-TOPSIS) and applied in a stock selection problem. The fuzzy events' probability and reliability can be calculated, and it is possible to turn the Z-Numbers to classical fuzzy numbers (Kang et al., 2012a). Lotfi A. Zadeh (2011) declared that a Z-Number is an ordered pair of two fuzzy numbers,$Z = (A, B)$ in which the fuzzy subset of the domain '*X*' of the variable '*Z*' is presented as '*A*' while the fuzzy subset of the unit interval is presented as '*B*'. In the following, the restriction R(X) is described as in Eq. (7).

$$R(X) : X\ is\ A \tag{7}$$

This restriction is denoted as a possibilistic restriction, in which the role of the possible distribution of *'X'* is played by *'A'* It can be described more accurately in Eq. (8) as follows.

$$R(X) : X\ is\ A\ \rightarrow Poss(X = u) = \mu_A(u) \tag{8}$$

In the mentioned equation, the membership function of A, is presented as μ_A and *'u'* is the generic value of *'X'*. μ_A can be viewed as a constraint associated with $R(X)$. This means that $\mu_A(u)$ is the degree to which *'u'* satisfies the constraint. The probability distribution of *'X'* *'X'* plays the role of a probabilistic restriction on if that *'X'* is a random variable. in the following, the probabilistic restriction is expressed in Eq. (9).

$$R(X) : X\ is\ p \tag{9}$$

In the following, the probability density function of *'X''* is described as in Eq. (10).

$$R(X) : X\ is\ p\ \rightarrow Prob(u \leq X \leq u + du) = p(u)du \tag{10}$$

A Z-Number consists of three components in the form of (X, A, B). Data in decision-making problems mainly contain Z-information because of imperfect accuracy and reliability, but due to the difficulty of calculations, they are treated differently. To simplify the calculations, Kang et al. (2012b) converted the Z-Numbers to conventional fuzzy sets and developed the applications of Z-Numbers. As stated in Lotfi A. Zadeh (2011), for Z-Number (A, B), let X be a random variable with a particular distribution, then X is A that indicates a fuzzy event in R with the probability as in Eq. (11):

$$p = \int_R \mu_A(u)p_x(u)d_u \tag{11}$$

The probability distribution of X is presented as p_x. As a restriction, the structure $(X,\ A,\ B)$ will be expressed in X Eq. (12) (Lotfi A. Zadeh, 2011) as follows.

$$Prob(X\ is\ A)\ is\ B \tag{12}$$

By using Eq. (12), $Prob(X\ is\ A)\ is\ B$ would be replaced with $p = \int_R \mu_A(u)p_x(u)d_u$ as Eq. (13):

$$p = \int_R \mu_A(u)p_x(u)d_u\ is\ B \tag{13}$$

Regarding probability rules, the complement of the Z is Z'. In effect, as an example, the complement of Z-Number (A, B) is $\left(A', 1 - B\right)$ or (events in R except A', $1 - B$) (Fig. 2).

Z^{+}-Number is an ordered pair of (A, R) so that A plays the same role that it does in Z-Numbers and R is the probability distribution of a random number. Besides, a Z^{+}-Number could be defined as a pair $\left(\mu_A, p_X\right)$ in which μ_A and p_x are as the membership function of A and the probability distribution of X, respectively. The difference between Z-Number and Z^{+}-Number is that in Z-Numbers, p_x is unknown; however, the probability value of A is specified. The relations between Z^{+}-Number and Z-Number are shown in Eq. (14) as follows (Azadeh et al., 2013) (Lotfi A. Zadeh, 2011):

$$Z(A, B) = Z^{+}\left(A, \mu_A . p_X \text{ is } B\right) \tag{14}$$

According to the DE fuzzy model proposed by (Kang et al., 2012b), for a specific Z-Number $Z = (A, B)$, $\tilde{B} = \left\{(x,\ \mu_{\tilde{B}}(x)|x\ \ [0, 1]\right\}$ denotes the fuzzy reliability value of A and $\mu_{\tilde{B}}(x)$ denotes the membership function. However, the crisp centroid (center of gravity) value of $\tilde{B}$ will be calculated by Eq. (15).

$$\alpha = \frac{\int x\mu_{\tilde{B}}(x)d_x}{\int \mu_{\tilde{B}}(x)d_x} \tag{15}$$

If $\tilde{B} \sim\ TrFS\ [a, b, c]$, the centroid defuzzification of $\widetilde{B}$ is $\frac{a+b+c}{3}$. If $\bar{A} \sim\ TrFS\ \left[d, e, f\right]$, the defuzzified Z-Number is calculated in Eq. (16) as follows.

$$\tilde{A}^{z} = \left[\sqrt{\alpha}d, \sqrt{\alpha}e, \sqrt{\alpha}f\right] = \left[d',\ e', f'\right] \tag{16}$$

By using defuzzification method, the following expression is concluded. Each linguistic possibility is related to the corresponding possibility shown in Table 1.

Utilizing the proposed method by (Kang et al., 2012b), we have provided a numerical value for every corresponding possibility related to each linguistic possibility which is shown in Table 2.

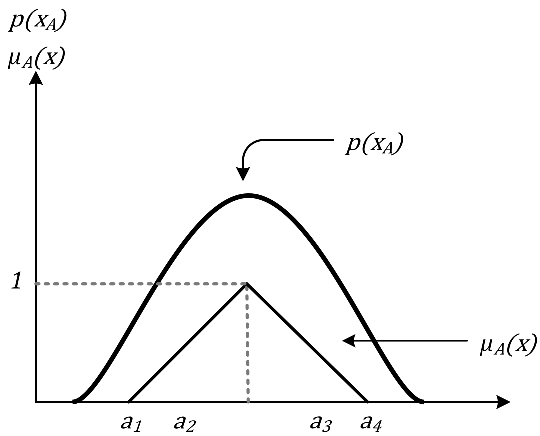


Fig. 2 The probability distribution of X and trapezoidal membership function of event A (Lotfi A. Zadeh, 2011)

Table 1 Linguistic possibilities and their corresponding fuzzy sets (Hendiani & Bagherpour, 2019)

Linguistic possibilities	Acronym	Corresponding possibilities
Unlikely	(U)	(0.1,0.2,0.3)
Fairly Impossible	(FI)	(0.3,0.4,0.5)
Weak	(W)	(0.4,0.5,0.6)
Maybe	(M)	(0.5,0.6,0.7)
Likely	(L)	(0.7,0.8,0.9)
Most Likely	(ML)	(0.8,0.9,1.0)
Certainly	(C)	(1.0,1.0,1.0)

Table 2 The centroid of each possibility measure calculated by Eq. (15) in order to convert Z-Numbers

Linguistic possibilities	Acronym	Corresponding possibilities	α	$\sqrt{\alpha}$
Unlikely	(U)	(0.1,0.2,0.3)	0.2	0.447
Fairly Impossible	(FI)	(0.3,0.4,0.5)	0.4	0.632
Weak	(W)	(0.4,0.5,0.6)	0.5	0.707
Maybe	(M)	(0.5,0.6,0.7)	0.6	0.774
Likely	(L)	(0.7,0.8,0.9)	0.8	0.894
Most Likely	(ML)	(0.8,0.9,1.0)	0.9	0.948
Certainly	(C)	(1.0,1.0,1.0)	1	1

2.3 The importance of project portfolio management, organizational strategic goals, and sustainability dimensions

A portfolio is a collection of projects, programs, or other works that have been put together to facilitate the effective management and the estimation of strategic business objectives. Portfolio is within the organization and includes a set of current components, schedules, and initiatives for the future (Cooper et al., 2001). An organization may have more than one portfolio, each of which is unique to a particular business or a target. However, the special projects or programs inside the portfolio are not necessarily interdependent, and there is no necessity for them to be directly related to each other. By reflecting investments made or programmed by the organization, portfolio management involves processes for identifying organizational priorities, investment decisions, and the resource allocation. Indeed, according to portfolio management, the appropriate projects in a portfolio should be selected and scheduled to achieve greater profitability and organizations' objectives despite facing some limitations (like lack of resources, workforce, equipment, and time). It is worth noting that making a decision of project selection cannot be applied by trial and error since it is possible to select improper projects and allocate enormous budgets and resources to them that causes the detriment for these organizations. Therefore, project selection concept plays a key role in project-based firms (RezaHoseini et al., 2020).

All portfolio components have certain common characteristics: (1) they represent the investment or program chosen by the organization. (2) They are aligned with the strategic goals of the organization. (3) They usually have distinctive features that allow the organization to categorize them for effective management; (4) they are quantitative so they can be measured, ranked, and prioritized (Soari and emama jomeh n.d.). In addition, the project portfolio selection is a complex decision problem which is composed of tangible and intangible criteria. Among the criteria that have taken into consideration nowadays, sustainability and strategic criteria account for the main criteria in this field nowadays. Strategic objectives and changing them have an impact on the view of the managers on the project (Haghighi Rad & Rowzan, 2018). They have prioritized the proposed projects according to the strategic objectives of the companies, and if these strategic goals are changed, the priority of projects for selecting and performing will be altered. Therefore, the organization should determine a conceptual framework consisting of critical metrics that align with the organization's strategic goals since these criteria have a direct impact on the efficiency of decision making of project selection (Smith-Perera et al., 2010).

Various definitions of sustainable and different sustainable criteria have been presented in which sustainability perspective has consisted of economic value, environmental issues, and social responsibility and finding a balance between them (Jones et al., 2013; Kudratova et al., 2018). Given that these three pillars of sustainability affect the selection and implementation of projects, many studies have adopted them in projects selection and scheduling (Dobrovolskienė & Tamošiūnienė, 2016; Ma et al., 2020; Silvius & Schipper, 2015). Due to the importance of environmental protection, companies and organizations have been compelled to select and employ projects that have less negative effects on the environment by using sustainability issues, and since project investment also can lead to boosting the economy, the economic issue takes a key role in project selection problems. In addition, social aspects are another sector of the sustainable issue that affects projects performance. Traditional project selection has paid attention to just financial criteria and profitability without considering sustainability while, these days, many researchers have also considered sustainability in their studies since a combination of financial and sustainability criteria can trigger to enhance organizations' productivity and competitiveness and can affect project success and project management (Kudratova et al., 2018; RezaHoseini et al., 2020; Silvius & Schipper, 2015).

Due to the importance of sustainable strategic criteria, project evaluation and ranking of projects in portfolio project selection, in the following, studies conducted in this field are reviewed.

2.4 Sustainable project selection

Various criteria play a key role in the decision problems, such as supplier selections and scheduling as a result of which many researchers put forward determining the main criteria in the different fields of decisions. The significant studies in which considered the criteria in project selection mention in the following: According to Jafarzadeh et al. (2018), Huang et al. (2008) applied a fuzzy AHP approach in government R&D projects and to simulate expert judgments in different decision risks, integrated the degree of optimism of decision-makers. Smith-Perera et al. (2010) demonstrated a new analytic network process (ANP)-based approach to prioritization of projects considering the main strategic goals of an electrical company in Caracas (Venezuela). Jung & Seo (2010) presented a new application of ANP under specific conditions of heterogeneous objectives for evaluation of R&D projects belong to programs with different purposes. Results demonstrated that the ANP produced the final priorities of projects based on benefit and cost concerning interdependency among programs and evaluation criteria. To specify the major projects of Six Sigma and the priority of these projects, a new approach has been developed by Büyüközkan & Öztürkcan

(2010) using ANP in combination with the Decision Making Trial and Laboratory (DEMATEL) technique. Integrating these two approaches as a hybrid MCDM approach is a wise option that can be considered as a new integrated tool given the intrinsic dependency and weights of the criteria. Amiri (2010) utilizing AHP and FTOPSIS techniques presented a novel methodology to evaluate alternative projects and assist the decision-maker in selecting the best project for the National Iranian Oil Company. Moreover, it has been shown that the calculation of criteria weights in the FTOPSIS method is important and can influence the ranking. Relying on modified fuzzy ANP and improved VIKOR methods, Ebrahimnejad et al. (2012) have provided a framework under uncertain conditions to select the project in the construction industry. P. T. Chang & Lee (2012) proposed a DEA approach, knapsack formulation, and fuzzy set theory integrated model for project portfolio selection. Additionally, to convert a constrained optimization problem into an unconstrained problem, three constraint handling techniques have been applied, which are factor-free penalty function-based. Ivanović et al. (2013) suggested that the multi-criteria approach may yield different results than the single-criteria approach to the problem. The authors investigated if the ANP as a multi-criteria decision-making approach may help make the right decision regarding the transportation project selection. Aragonés-Beltrán et al. (2014) applied AHP and ANP approaches for special solar-thermal power plant project selection and prioritization of the projects in the company's portfolio. Using analytic tools, Taylan et al. (2014) assessed the construction projects and their overall risks under incomplete and uncertain conditions. Tavana et al. (2015) suggested a three-stage hybrid approach to selecting the optimal combination of projects. Given the different organizational goals, they achieved the maximum fitness between the final selection and the initial project rankings applying DEA, TOPSIS, and linear integer programming (IP) for selecting the most appropriate project portfolio in a fuzzy environment. Walczak & Rutkowska (2017) presented a fuzzy technique for order preference based on TOPSIS for the personalized ranking of projects in a participatory budget (PB) and applied the F-TOPSIS with a modification for PB based on an empirical example from a Pozna ´n PB project in Poland. W. Chen et al. (2018) modeled a mixed-integer linear programming model for coordinating supplier selection and project scheduling model. In their research, suppliers provided non-renewable resources required for projects and projects consisted of several activities. Jafarzadeh et al. (2018) combined quality function development (QFD), fuzzy logic, and DEA to address three important aspects of decision making including prioritization of selection criteria over each other, uncertainty, and interdependencies among projects. To prioritization and thus selecting the best projects for exploiting mineral resources in Iran, a fuzzy combined quantitative method consisting of Fuzzy DEMATEL (F-DEMATEL) and F-ANP techniques known as F-D-ANP method has been presented by Valmohammadi (Valmohammadi & Khaki, 2019). Y. S. Chen et al. (2019) used a balanced scorecard approach and questionnaires completed by experts and DEMATEL and ANP to assess the relationships among project risk, project management, and organizational performance. Their results helped project managers to decline risk and enhance organizational performance. Objective functions were minimizing total cost and the total completion time of the project. A multi-mode resource-constrained project scheduling problem was presented by Abdel-Basset et al. (2019) paper in which projects included activities with various mode and each activity might be implemented based on these modes. Ma et al. (2020) presented a fuzzy logic model based on the TOPSIS approach to select the best sustainable project incorporating uncertainty. Toloo & Mirbolouki (2019) developed an alternative DEA approach for the sake of selecting an efficient composite project with the highest average CCR efficiency score and assigned different weights to the inputs and outputs of all projects as well. Yazdi et al. (2020) combined the best–worst method (BWM) with weighted aggregated sum product assessment (WASPAS), to select the oil projects. Also, to increase the accuracy of the results under conditions of uncertainty, Z-Number approach has been used. In Table 3, the summary of the abovementioned papers is represented.

According to Table 1, most studies have focused on fuzzy concepts rather than Z-Number, so probability and reliability have been ignored in their works. Besides a few studies have been addressing the issue of computing the efficiency and ranking the projects utilizing DEA approach. Due to the importance of DEA approach mentioned in the Introduction section in this study, the DEA and the integrated AHP-DEA techniques to calculate the efficiency of projects in the deterministic, fuzzy, and Z-Number conditions have been utilized. At last, the results also have been analyzed.

3 Methodology

The methodology of this study consists of four main stages:

Step 1 Identifying the sustainability criteria by studying previous papers and interviewing experts, categorizing, and filtering the criteria through a questionnaire in the desired industry

Step 2 Introducing Z-AHP approach to weight sustainability criteria and comparing obtained weights with their deterministic and fuzzy equivalents

Step 3 Introducing the Z-DEA approach to evaluate the efficiency of projects and ranking of them as well as comparing the results with the fuzzy and deterministic equivalents

Step 4 Introducing the Z–AHP-DEA approach to evaluate the efficiency of the projects and ranking of them. Also, comparing the results with the fuzzy determinants equivalents as well as comparing them with the results obtained through the DEA approach

Figure 3 illustrates the research process of this paper.

3.1 Sustainability criteria identification

3.1.1 Sustainability criteria identification by project selection

In the first step to identify the criteria and indices, researches related to the project portfolio selection, criteria, and the project sustainability evaluation indices have been investigated and an initial list of sustainability criteria and indices in project selection extracted. The initial list contains 49 criteria as presented in Table 2.

3.1.2 Classification of sustainable criteria

At this stage, the previously identified criteria are classified. As mentioned before, Fernandez Sanchez and Rodriguez Lopez have proposed a structure for the classification of identified criteria in construction projects, as the Sustainable Breakdown Structure (SBS) based on the three dimensions of sustainability (economic, social, and environmental) (Fernández-Sánchez & Rodríguez-López, 2010). Using the same structure, the identified criteria in Table 4 are categorized in the form of SBS.

Table 3 Summary of articles published

NUM	Reference	Dimension of sustainability			Types of Uncertainty	Approach used
		Economic	Social	Environment		
1	(Huang et al., 2008)	✓	✓		✗	Fuzzy AHP
2	(Smith-Perera et al., 2010)	✓			utility ratio functions	ANP
3	(P. T. Chang & Lee, 2012)	✓			✗	ANP
4	(Büyüközkan & Öztürkcan, 2010)	✓			✗	ANP—DEMATEL
5	(Amiri, 2010)	✓			triangular fuzzy	
number	AHP-FTOPSIS	✓			✗	
6	(Ebrahimnejad et al., 2012)	✓		✓	fuzzy sets theory	ANP-VIKOR
7	(P. T. Chang & Lee, 2012)	✓			fuzzy sets theory	FDEA and knap-sack formulation
8	(Ivanović et al., 2013)	✓	✓	✓	✗	ANP
9	(Aragonés-Beltrán et al., 2014)	✓		✓	✗	AHP-ANP
10	(Taylan et al., 2014)	✓		✓	fuzzy sets theory	F-AHP—FTOPSIS
11	(Tavana et al., 2015)	✓		✓	triangular fuzzy	
number	DEA-TOPSIS-Integer programming	✓		✓	✗	
12	(Walczak & Rutkowska, 2017)	✓		✓	fuzzy sets theory	FTOPSIS
13	(Jafarzadeh et al., 2018)	✓	✓	✓	fuzzy sets theory	FQFD and DEA
14	(Valmohammadi & Khaki, 2019)	✓			triangular fuzzy	
number	F-DEMATEL -F-ANP	✓	✓	✓	✗	
15	(Ma et al., 2020)	✓	✓	✓	fuzzy sets theory	FTOPSIS
16	(Toloo & Mirbolouki, 2019)	✓			✗	DEA
17	(Yazdi et al., 2020)	✓			Z-Number	WASPAS—BWM
18	This paper	✓	✓	✓	Z-Number	AHP-DEA

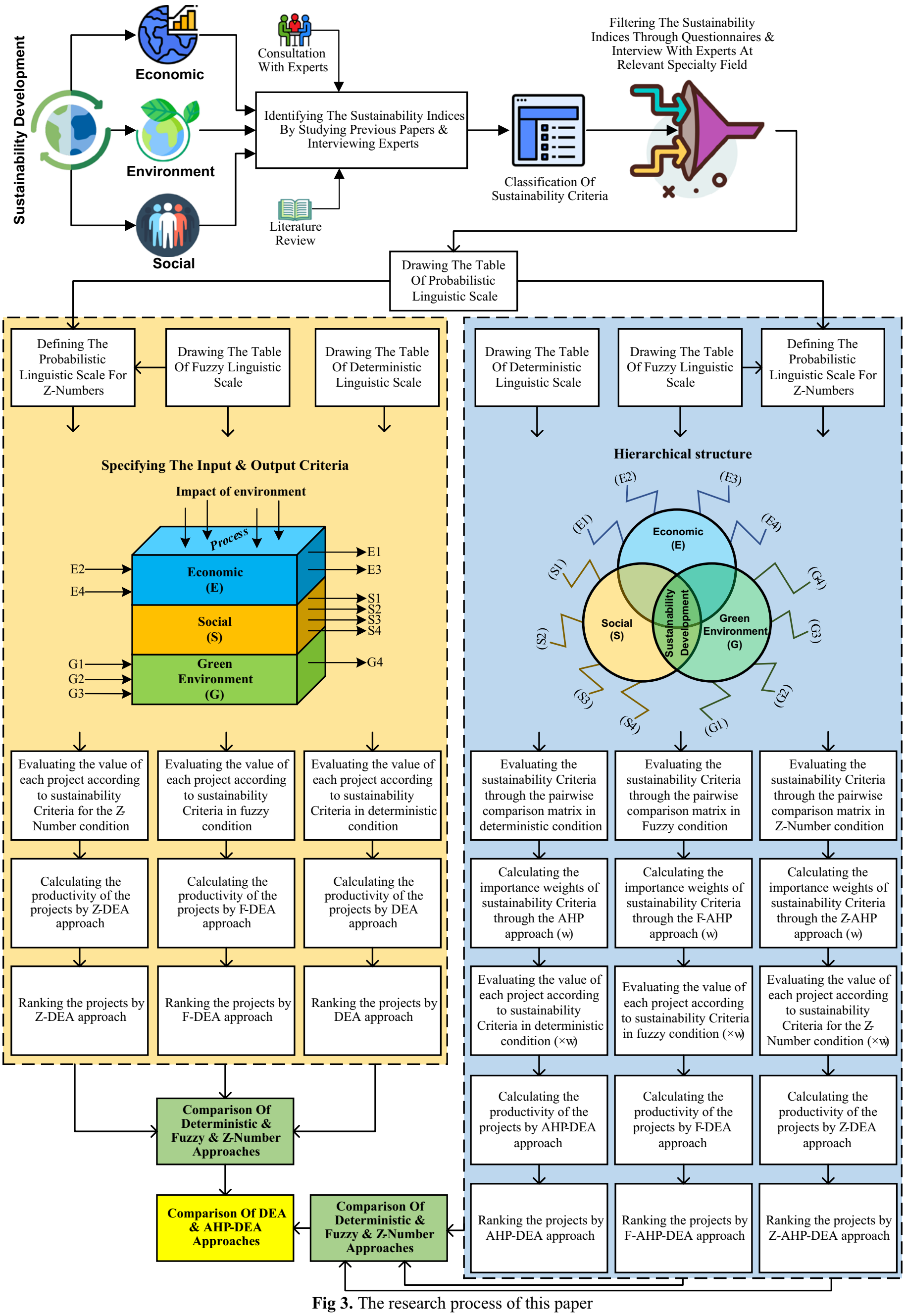


Fig. 3 The research process of this paper

Table 4 Sustainable Breakdown Structure (Fernández-Sánchez & Rodríguez-López, 2010)

Sustainable Dimension	Sustainable Index	Sustainable criteria
Economic	Financial	Net Present Value (NPV)
		Rate of Return (ROR)
		Pay Back Period (PBP)
		Expected benefit
		Investment liquidity
	Technical	Availability of required technology
		Project buildability
		Organizational preparation
		Technology transfer and training rate
		Necessity and urgency
		Existence of basic infrastructure
	Risk analysis	Business risk, technology risk and execution risk
		Effect of sanctions
	Marketing and project competition	Project alignment with environmental laws and regulations
		Competitive advantage
		Impact on the competitive market
		Probability of project success
Social	Human resources	Executive team familiarity with the project
		Synergy among the pillars of the project
		Staff Satisfaction
		Upgrading the capabilities and capabilities of the company staff
		Influence on working conditions in community
		Employees' health and safety
	Customers (client)	Aligning the project with the needs and wants of customer(client)
		Customer satisfaction
		Customer safety and health
	Society	Job creation rate

Table 4 (continued)

Sustainable Dimension	Sustainable Index	Sustainable criteria
		The amount of local workforce used in construction (project Utilization)
		Impact on the international community and public opinion
		Satisfaction with society
		Respect for local culture and differences
		Community acceptance
	Participation	The willingness of unions, organizations and governments to participate in project implementation
		Stakeholder participation
Environmental	Materials and Resources	Material reusability
		Use of recyclable consumables in the project
		Durable material usage
	Energy	Non-renewable energy Consumption
		Use of natural energy
		Greenhouse gas emissions (from natural energy)
	Water	The amount of water consumed
		Water pollution
	Soil	Soil pollution
	Atmosphere	Noise pollution
		Diffusion of dust particles
		Unpleasant odor release
	Waste	The amount of waste recycled
		The amount of waste disposal
	Transportation	The level of local procurement and suppliers as well as domestic production usage

3.1.3 Screening of sustainability criteria

In this step, experts' perspectives and opinions are used to screen the chosen criteria in order to remove the non-important or non-executable items.

It is assumed that the sustainable criteria are independent of each other and do not affect each other.

3.2 Fuzzy AHP (F-AHP), proposed Z-Number AHP (Z-AHP) & definition of new Linguistic scale

The AHP approach has been widely used in selecting an alternative among the other alternatives as well as weighting criteria. But in this method, pairwise comparisons are made for each level to select the best alternative using a linguistic preference scale. Therefore, the application of AHP has drawbacks, such as the AHP method (1) it is mainly used in crisp decision making, (2) deals with a very unbalanced scale of judgment, (3) does not consider uncertainties in individual judgments, (4) ranks almost inaccurately, and (5) the subjective judgment of decision-maker has a great effect on the results of the AHP, besides the fact that people's evaluations of qualitative criteria are always subjective and consequently inaccurate. Thus, the conventional AHP approach seems to be inefficient in meeting the needs of decision-makers accurately. To model this kind of uncertainty in human preferences, the fuzzy set theory must be combined with pairwise comparisons as the development of the AHP technique. This combined decision-making technique provides a more accurate understanding of decision-making process. It is a multi-criteria decision-making tool which can address complex issues in a hierarchical structure, thus simplifying the evaluation of all decision-making criteria (D.-Y. Chang, 1996). Alternatives are compared by considering each criterion using the preference scale, and for each criterion, a priority list of options is obtained. The most commonly used scale is the 1–9 scale. F-AHP approach enables the decision-making analyst to give more realistic scores in cases where there are many uncertainties. D.-Y. Chang's (1996) development analysis model is one of them depending on the probability of each criterion. On the other hand, as stated in the previous sections, fuzzy numbers do not take into account the probability of reliability of expert opinions, so we use the Z-Numbers for pairwise comparisons to advance toward the real world and obtain more reliable answers. Therefore Z-AHP and F-AHP approaches have been described subsequently. Triangular fuzzy numbers (l, m, u) are used to create a pairwise comparison scale, and a paired comparison matrix is created for each level in the hierarchy. Then, the subsets of each row in the matrix are computed to have a new set. The total value of triangular fuzzy number $\left(l_i, m_i, u_i\right)$ for each criterion is calculated by $\frac{l_i}{\sum l_i}, \frac{m_i}{\sum m_i}, \frac{u_i}{\sum u_i}, (i = 1, 2, \ldots, n)$. Membership functions, which are the corresponding weights of the alternatives in the matrix, are calculated using these values for each criterion, and after normalizing the final weight of each criterion is obtained.

$$Fuzzy:\ \tilde{Q} = (l, m, u)$$

$$Z-Number:\ \tilde{Q}^z = \sqrt{\alpha} \times \tilde{Q} = \sqrt{\alpha} \times (l, m, u) = \left(\sqrt{\alpha} \times l, \sqrt{\alpha} \times m, \sqrt{\alpha} \times u\right) = \left(l', m', u'\right)$$

We can calculate for Z-Number in the similar way.

According to Chang's developmental analysis method (1996) (D.-Y. Chang, 1996), each criterion is considered and for each criterion, the sub-criterion g_i is measured. In this study, the F-AHP method is applied to weight and rank the criteria and alternatives. The Chang's method has been used to calculate weights in the AHP method, and to this end, the following steps have been taken.

Step (1) Forming the hierarchical model of problem:

In this step, after identifying the research indices, criteria, and alternatives, a hierarchical model of the problem has to be formed. In the previous section, filtering the criteria was discussed.

Step (2) Forming the paired comparison tables based on the following fuzzy scale (Table 5):

Linguistic scale and the fuzzy numbers corresponding to Z-Numbers in probabilistic condition are expressed in Table 4. Equation (16) has been used to calculate the linguistic scale of Z-Numbers and the linguistic phrase "Fairly Good-Fairly Impossible" is calculated for instance

$$\tilde{Q}^z = \sqrt{\alpha} \times \tilde{Q} = \sqrt{\alpha} \times (l, m, u) = \left(\sqrt{\alpha} \times l, \sqrt{\alpha} \times m, \sqrt{\alpha} \times u\right) = \left(l', m', u'\right)$$

$$= 0.63 \times (5,\ 6,\ 7) = (3.15, 3.78, 4, 41)$$

Table 6 presents the linguistic scale of Z-sNumbers. As can be seen, this scale is similar to the F-AHP scale, except that the probability of fuzzy numbers reliability is taken into account.

Due to the complexity of the Z-Number linguistic scale, experts need to be trained before using these scales to understand how to use them properly.

Step (3) Calculating the inconsistency ratio of the paired comparisons matrices:

In this step, the inconsistency ratio of the pairwise comparisons must be investigated; if the ratio is less than 0.1, the pairwise comparison matrix is considered sufficiently consistent. The inconsistency ratio of fuzzy matrices can be calculated in two ways:

1. Converting the fuzzy matrices into crisp matrices and then calculating the inconsistency ratio.

Table 5 Linguistic preferences scale

linguistic	Acronym	Fuzzy number	Scale of fuzzy number
Perfect	(P)	$\tilde{9}$	(8,9,10)
Absolute	(A)	$\tilde{8}$	(7,8,9)
Very Good	(VG)	$\tilde{7}$	(6,7,8)
Fairly Good	(FG)	$\tilde{6}$	(5,6,7)
Good	(G)	$\tilde{5}$	(4,5,6)
Preferable			
Not Bad			
Weak Advantage			
Equal			

Table 6 Linguistic preferences scale with probabilities

Linguistic phrase	Acronym	Certainty	Fuzzy number	Z-Number
Perfect-Certainly	(PE-C)	$\tilde{9}$	(8,9,10)	(8.000,9.000,10.000)
Absolute-Certainly	(A-C)	$\tilde{8}$	(7,8,9)	(7.000,8.000,9.000)
Very Good-Certainly	(VG-C)	$\tilde{7}$	(6,7,8)	(6.000,7.000,8.000)
Fairly Good-Certainly	(FG-C)	$\tilde{6}$	(5,6,7)	(5.000,6.000,7.000)
Good-Certainly	(G-C)	$\tilde{5}$	(4,5,6)	(4.000,5.000,6.000)
Preferable-Certainly	(P–C)	$\tilde{4}$	(3,4,5)	(3.000,4.000,5.000)
Not Bad-Certainly	(NB-C)	$\tilde{3}$	(2,3,4)	(2.000,3.000,4.000)
Weak Advantage-Certainly	(WA-C)	$\tilde{2}$	(1,2,3)	(1.000,2.000,3.000)
Equal-Certainly	(E-C)	$\tilde{1}$	(1,1,1)	(1.000,1.000,1.000)
Perfect-Most Likely	(PE-ML)	$\tilde{9}$	(8,9,10)	(7.584,8.532,9.480)
Absolute-Most Likely	(A-ML)	$\tilde{8}$	(7,8,9)	(6.636,7.584,8.532)
Very Good-Most Likely	(VG-ML)	$\tilde{7}$	(6,7,8)	(5.688,6.636,7.584)
Fairly Good-Most Likely	(FG-ML)	$\tilde{6}$	(5,6,7)	(4.740,5.688,6.636)
Good-Most Likely	(G-ML)	$\tilde{5}$	(4,5,6)	(3.792,4.740,5.688)
Preferable-Most Likely	(P-ML)	$\tilde{4}$	(3,4,5)	(2.844,3.792,4.740)
Not Bad-Most Likely	(NB-ML)	$\tilde{3}$	(2,3,4)	(1.896,2.844,3.792)
Weak Advantage-Most Likely	(WA-ML)	$\tilde{2}$	(1,2,3)	(0.948,1.896,2.844)
Equal-Most Likely	(E-ML)	$\tilde{1}$	(1,1,1)	(0.948,0.948,0.948)
Perfect-Likely	(PE-L)	$\tilde{9}$	(8,9,10)	(7.152,8.046,8.940)
Absolute-Likely	(A-L)	$\tilde{8}$	(7,8,9)	(6.258,7.152,8.046)
Very Good-Likely	(VG-L)	$\tilde{7}$	(6,7,8)	(5.364,6.258,7.152)
Fairly Good-Likely	(FG-L)	$\tilde{6}$	(5,6,7)	(4.470,5.364,6.258)
Good-Likely	(G-L)	$\tilde{5}$	(4,5,6)	(3.576,4.470,5.364)
Preferable-Likely	(P-L)	$\tilde{4}$	(3,4,5)	(2.682,3.576,4.470)
Not Bad-Likely	(NB-L)	$\tilde{3}$	(2,3,4)	(1.788,2.682,3.576)
Weak Advantage-Likely	(WA-L)	$\tilde{2}$	(1,2,3)	(0.894,1.788,2.682)
Equal-Likely	(E-L)	$\tilde{1}$	(1,1,1)	(0.894,0.894,0.894)
Perfect-Maybe	(PE-M)	$\tilde{9}$	(8,9,10)	(6.192,6.966,7.740)
Absolute-Maybe	(A-M)	$\tilde{8}$	(7,8,9)	(5.418,6.192,6.966)
Very Good-Maybe	(VG-M)	$\tilde{7}$	(6,7,8)	(4.644,5.418,6.192)
Fairly Good-Maybe	(FG-M)	$\tilde{6}$	(5,6,7)	(3.870,4.644,5.418)
Good-Maybe	(G-M)	$\tilde{5}$	(4,5,6)	(3.096,3.870,4.644)
Preferable-Maybe	(P-M)	$\tilde{4}$	(3,4,5)	(2.322,3.096,3.870)
Not Bad-Maybe	(NB-M)	$\tilde{3}$	(2,3,4)	(1.548,2.322,3.096)
Weak Advantage-Maybe	(WA-M)	$\tilde{2}$	(1,2,3)	(0.774,1.548,2.322)

Table 6 (continued)

Linguistic phrase	Acronym	Certainty	Fuzzy number	Z-Number
Equal-Maybe	(E-M)	$\tilde{1}$	(1,1,1)	(0.774,0.774,0.774)
Perfect-Weak	(PE-W)	$\tilde{9}$	(8,9,10)	(5.656,6.363,7.070)
Absolute-Weak	(A-W)	$\tilde{8}$	(7,8,9)	(4.949,5.656,6.363)
Very Good-Weak	(VG-W)	$\tilde{7}$	(6,7,8)	(4.242,4.949,5.656)
Fairly Good-Weak	(FG-W)	$\tilde{6}$	(5,6,7)	(3.535,4.242,4.949)
Good-Weak	(G-W)	$\tilde{5}$	(4,5,6)	(2.828,3.535,4.242)
Preferable-Weak	(P-W)	$\tilde{4}$	(3,4,5)	(2.121,2.828,3.535)
Not Bad-Weak	(NB-W)	$\tilde{3}$	(2,3,4)	(1.414,2.121,2.828)
Weak Advantage-Weak	(WA-W)	$\tilde{2}$	(1,2,3)	(0.707,1.414,2.121)
Equal-Weak	(E-W)	$\tilde{1}$	(1,1,1)	(0.707,0.707,0.707)
Perfect-Fairly Impossible	(PE-FI)	$\tilde{9}$	(8,9,10)	(5.056,5.688,6.320)
Absolute-Fairly Impossible	(A-FI)	$\tilde{8}$	(7,8,9)	(4.424,5.056,5.688)
Very Good-Fairly Impossible	(VG-FI)	$\tilde{7}$	(6,7,8)	(3.792,4.424,5.056)
Fairly Good-Fairly Impossible	(FG-FI)	$\tilde{6}$	(5,6,7)	(3.160,3.792,4.424)
Good-Fairly Impossible	(G-FI)	$\tilde{5}$	(4,5,6)	(2.528,3.160,3.792)
Preferable-Fairly Impossible	(P-FI)	$\tilde{4}$	(3,4,5)	(1.896,2.528,3.160)
Not Bad-Fairly Impossible	(NB-FI)	$\tilde{3}$	(2,3,4)	(1.264,1.896,2.528)
Weak Advantage-Fairly Impossible	(WA-FI)	$\tilde{2}$	(1,2,3)	(0.632,1.264,1.896)
Equal-Fairly Impossible	(E- FI)	$\tilde{1}$	(1,1,1)	(0.632,0.632,0.632)
Perfect-Unlikely	(PE-U)	$\tilde{9}$	(8,9,10)	(3.576,4.023,4.470)
Absolute-Unlikely	(A-U)	$\tilde{8}$	(7,8,9)	(3.129,3.576,4.023)
Very Good-Unlikely	(VG-U)	$\tilde{7}$	(6,7,8)	(2.682,3.129,3.576)
Fairly Good-Unlikely	(FG-U)	$\tilde{6}$	(5,6,7)	(2.235,2.682,3.129)
Good-Unlikely	(G-U)	$\tilde{5}$	(4,5,6)	(1.788,2.235,2.682)
Preferable-Unlikely	(P-U)	$\tilde{4}$	(3,4,5)	(1.341,1.788,2.235)
Not Bad-Unlikely	(NB-U)	$\tilde{3}$	(2,3,4)	(0.894,1.341,1.788)
Weak Advantage-Unlikely	(WA-U)	$\tilde{2}$	(1,2,3)	(0.447,0.894,1.341)
Equal-Unlikely	(E-U)	$\tilde{1}$	(1,1,1)	(0.447,0.447,0.447)

2. Calculating the incompatibility ratio method using Gauss and Butcher method.

Step 4 Integrating the pairwise comparisons (for group decision making) using geometric mean method.

Step 5 Calculating weights using Chang's development analysis method:

Firstly, the value of S_i is calculated for each row of fuzzy pairwise comparison matrix given the following equations (Eq. (17)):

$$S_i^z = \sum_{j=1}^{m} M_{gi}^{zj} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{zj} \right]^{-1} \tag{17}$$

where g_i is the target set and $M_{g_i}^{j}$ are triangular fuzzy numbers and M_{gi}^{zj} are triangular Z-numbers. Then, according to the following equations, the preference degree of each S_i to each S_k is obtained (if S_i is preferred to S_k,we write $S_i > S_k$) (Eq. (18)):

$$V\left(S_i^z > S_k^z\right) = \begin{cases} 1 & m_i \geq m_k \\ 0 & l_k \geq u_i \\ \frac{l'_k l_k - u'_i u_i}{\left(m'_i m_i - u'_i u_i\right) - \left(m'_k m_k - l'_k l_k\right)} & otherwise \end{cases} \tag{18}$$

Finally, using the following equations the raw weights are obtained and then the normal weight will be calculated by dividing each raw weight by the sum of the raw weights (Eq. 19):

$$\begin{aligned} V\left(S^z \geq S_1^z, S_2^z, \ldots, S_k^z\right) &= V\left(\left(S^z \geq S_1^z\right) and \left(S^z \geq S_2^z\right) and \ldots and \left(S^z \geq S_k^z\right)\right) \\ &= min\ V\left(S^z \geq S_i^z\right) \quad i = 1, 2, \ldots, k \end{aligned} \tag{19}$$

Step (6) Calculating the final weight vector

The non-normalized weight vector will be as follows (Eq. (20)):

$$W^z = \left(minV\left(S^z \geq S_i^z\right)\right)^T \tag{20}$$

To obtain the final weight vector, the weight vector calculated in the previous step should be normalized. Hence (Eq. (21)):

$$W_n^z = \left(minV\left(S^z \geq S_i^z\right)\right)_n^T \tag{21}$$

3.3 Z-number data envelopment analysis (Z-DEA)

3.3.1 DEA Andersen and Petersen (AP-DEA)

Conventional DEA models do not allow for efficient units to be compared with one another due to the lack of complete ranking between efficient units. Therefore, super-efficiency models were proposed to deal with this problem assuming that the decision-making unit under evaluation is excluded from the reference set. Though in conventional DEA models the maximum efficiency score is equal to one, in super-efficiency models the decision-making units can achieve the efficiency scores greater than one. In this paper, the Anderson and Peterson super-efficiency DEA models proposed in 1993 (Andersen & Petersen, 1993) have implemented.

Sets	
Set of inputs ($i = 1, \ldots, m$)	i
Set of Outputs ($r = 1, \ldots, s$)	r
Set of SPs ($j = 1, \ldots, n$)	j
SP under evaluation	$SP_\circ$

Sets	
Parameters	
related to SP_j Value of input i^{th}	x_{ij}
Value of output r^{th} related to SP_j	y_{rj}
variables	
Weight of variables (Project j Weight)	λ_j
Objective value	θ_0

Here, the AP-DEA model for SPs with fuzzy parameters is extended. It is assumed that the inputs and outputs of DEA model are triangular fuzzy numbers. Thus $\tilde{x}_{ij}$ is related to the input ith of the SP_j and represented by $\tilde{x}_{ij} \sim TFN\left(x_{ij}^{l}, x_{ij}^{m}, x_{ij}^{u}\right)$ and $\tilde{y}_{rj}$ is related to the output rth of the SP_j and represented by $\tilde{y}_{rj} \sim TFN\left(y_{rj}^{l}, y_{rj}^{m}, y_{rj}^{u}\right)$. The following model is used to convert the AP model to the fuzzy- linear-AP formulation. As previously mentioned, the defuzzified value of instance fuzzy Z-Number $\underset{\sim}{x}_{ij}^{z}$ is calculated in this way:

$$\tilde{x}_{ij} = \left(x_{ij}^{l}, x_{ij}^{m}, x_{ij}^{u}\right)$$

$\tilde{x}_{ij}^{z} = \sqrt{\alpha}\tilde{x}_{ij} = \left(\sqrt{\alpha}x_{ij}^{l}, \sqrt{\alpha}x_{ij}^{m}, \sqrt{\alpha}x_{ij}^{u}\right) = (x_{ij}^{\prime l}, x_{ij}^{\prime m}, x_{ij}^{\prime u}).\left(x_{ij}^{\prime l}, x_{ij}^{\prime m}, x_{ij}^{\prime u}\right)$. Replacing the Z-Number values, the fuzzy programming of AP model will be as follows (Eq. (22)-(25)):

$$min\theta_0 \tag{22}$$

s.t:

$$\sum_{\substack{j=1 \\ j\neq 0}}^{n} \lambda_j\left(x_{ij}^{\prime m} + x_{ij}^{\prime u}\right)u \leq \theta_0\left(x_{i0}^{\prime m} + x_{i0}^{\prime l}\right) \quad i = 1, \ldots, m \in \mathbb{N} \tag{23}$$

$$\sum_{\substack{j=1 \\ j\neq 0}}^{n} \lambda_j\left(y_{rj}^{\prime m} + y_{rj}^{\prime l}\right) \geq y_{r0}^{\prime m} + y_{r0}^{\prime u} \quad r = 1, \ldots, s \in \mathbb{N} \tag{24}$$

$$\lambda_j \geq 0 \quad j = 1, \ldots, n \tag{25}$$

Qualitative criteria may also be negative (input) or positive (output) depending on their impact on alternatives. The values can be entered into the decision matrix using a five-point fuzzy scale ranging from $\underset{\sim}{1}$ (Very Low) to $\underset{\sim}{9}$ (Very High) represented in Table 7.

For Z-Numbers, the linguistic scale is defined as given in Table 4 and corresponding fuzzy Z-Numbers in probabilistic condition are expressed in Table 8. As can be seen, the scale is similar to the F-DEA scale, except that the probability of fuzzy number reliability is taken into account. The linguistic phrase “Low-Likely” is calculated for instance:

Table 7 Linguistic scoring scale

Linguistic phrase	Acronym	Fuzzy number	Scale of fuzzy number
Very High	(VH)	$\tilde{9}$	(7,9,9)
High	(H)	$\tilde{7}$	(5,7,9)
Medium	(M)	$\tilde{5}$	(3,5,7)
Low	(L)	$\tilde{3}$	(1,3,5)
Very Low	(VL)	$\tilde{1}$	(1,1,3)

Low-Likely:

$$\tilde{x}^z = \sqrt{\alpha} \times \tilde{x} = \sqrt{\alpha} \times \left(x^l, x^m, x^u\right) = \left(\sqrt{\alpha} \times x^l, \sqrt{\alpha} \times x^m, \sqrt{\alpha} \times x^u\right) = \left(x'^l, x'^m, x'^u\right)$$

$$= 0.89 \times (1, 3,\ 5) = (0.89, 2.67, 4.45)$$

Due to the complexity of the Z-Number linguistic scale, experts need to be trained before using these scales to understand how to use them properly.

The advantages of using the DEA approach are as follows (Cooper et al., 2006):

- It is not sensitive to units of measurement and inputs and outputs can have different units.
- Data envelopment analysis Method is a management method that measures the performance of units (here projects) in relative terms.
- This method is more extendable and expandable than other methods, and applying it in one unit (in a project) for one topic can provide the background for future work.
- This method only determines efficiency and does not have the disadvantages of other measurement systems that pursue a kind of absolutism, and efficiency in this model is an achievable quantity.
- While units (projects) have multiple inputs and multiple outputs, the linear programming method can easily determine the optimal combination of inputs and outputs for an efficient unit (efficient project).
- Data envelopment analysis provides a very high capability in the complete ranking of decision-making units (proposed projects) under study and models such as Anderson–Peterson can also rank efficient units and select the most efficient unit (most efficient project) among efficient units.
- The number and type of resources which are saved by increasing the efficiency of each DMU are measured by the Data Envelopment Analysis (DEA) technique. In this way, inefficient units (inefficient projects) are encouraged to be efficient or their productivity is improved through some policies.
- Since the inefficiency of low-productivity units has been measured, management can measure the amount of financial savings by optimizing them. Even with the help of DEA, managers can make efficient DMUs (projects) more active and improve their productivity without adding input (new resources).

Table 8 Linguistic scoring scale with probabilities

Linguistic phrase	Acronym	Deterministic	Fuzzy number	Z-Number
Very High-Certainly	(VH-C)	$\tilde{9}$	(7,9,9)	(7.000,9.000,9.000)
High-Certainly	(H-C)	$\tilde{7}$	(5,7,9)	(5.000,7.000,9.000)
Medium-Certainly	(M-C)	$\tilde{5}$	(3,5,7)	(3.000,5.000,7.000)
Low-Certainly	(L-C)	$\tilde{3}$	(1,3,5)	(1.000,3.000,5.000)
Very Low- Certainly	(VL-C)	$\tilde{1}$	(1,1,3)	(1.000,1.000,3.000)
Very High-Most Likely	(VH-ML)	$\tilde{9}$	(7,9,9)	(6.636,8.532,8.532)
High-Most Likely	(H-ML)	$\tilde{7}$	(5,7,9)	(4.740,6.636,8.532)
Medium-Most Likely	(M-ML)	$\tilde{5}$	(3,5,7)	(2.844,4.740,6.636)
Low-Most Likely	(L-ML)	$\tilde{3}$	(1,3,5)	(0.948,2.844,4.740)
Very Low-Most Likely	(VL-ML)	$\tilde{1}$	(1,1,3)	(0.948,0.948,2.844)
Very High-Likely	(VH-L)	$\tilde{9}$	(7,9,9)	(6.258,8.046,8.046)
High-Likely	(H–L)	$\tilde{7}$	(5,7,9)	(4.470,6.258,8.046)
Medium-Likely	(M-L)	$\tilde{5}$	(3,5,7)	(2.682,4.470,6.258)
Low-Likely	(L-L)	$\tilde{3}$	(1,3,5)	(0.894,2.682,4.470)
Very Low-Likely	(VL-L)	$\tilde{1}$	(1,1,3)	(0.894,0.894,2.682)
Very High-Maybe	(VH-M)	$\tilde{9}$	(7,9,9)	(5.418,6.966,6.966)
High-Maybe	(H-M)	$\tilde{7}$	(5,7,9)	(3.870,5.418,6.966)
Medium-Maybe	(M-M)	$\tilde{5}$	(3,5,7)	(2.322,3.870,5.418)
Low-Maybe	(L-M)	$\tilde{3}$	(1,3,5)	(0.774,2.322,3.870)
Very Low-Maybe	(VL-M)	$\tilde{1}$	(1,1,3)	(0.774,0.774,2.322)
Very High-Weak	(VH-W)	$\tilde{9}$	(7,9,9)	(4.949,6.363,6.363)
High-Weak	(H-W)	$\tilde{7}$	(5,7,9)	(3.535,4.949,6.363)
Medium-Weak	(M-W)	$\tilde{5}$	(3,5,7)	(2.121,3.535,4.949)
Low-Weak	(L-W)	$\tilde{3}$	(1,3,5)	(0.707,2.121,3.535)
Very Low-Weak	(VL-W)	$\tilde{1}$	(1,1,3)	(0.707,0.707,2.121)
Very High-Fairly Impossible	(VH-FI)	$\tilde{9}$	(7,9,9)	(4.424,5.688,5.688)
High-Fairly Impossible	(H-FI)	$\tilde{7}$	(5,7,9)	(3.160,4.424,5.688)
Medium-Fairly Impossible	(M-FI)	$\tilde{5}$	(3,5,7)	(1.896,3.160,4.424)
Low-Fairly Impossible	(L-FI)	$\tilde{3}$	(1,3,5)	(0.632,1.896,3.160)
Very Low-Fairly Impossible	(VL-FI)	$\tilde{1}$	(1,1,3)	(0.632,0.632,1.896)
Very High-Unlikely	(VH-U)	$\tilde{9}$	(7,9,9)	(3.129,4.023,4.023)
High-Unlikely	(H-U)	$\tilde{7}$	(5,7,9)	(2.235,3.129,4.023)
Medium-Unlikely	(M-U)	$\tilde{5}$	(3,5,7)	(1.341,2.235,3.129)
Low-Unlikely	(L-U)	$\tilde{3}$	(1,3,5)	(0.447,1.341,2.235)
Very Low-Unlikely	(VL-U)	$\tilde{1}$	(1,1,3)	(0.447,0.447,1.341)

- By receiving information about the efficiency of production and service sectors (projects), management can increase its capabilities, especially in decision making, and lead the organization to excellence.
- In the DEA technique, there is no need to express the mathematical form of the relationship between inputs and outputs, and the relationship is determined by the input and output values themselves. This classifies it as a non-parametric method.
- The use of DEA may model new communications that have not been discovered and hidden in other ways.
- It is possible to use multiple inputs and outputs simultaneously in data envelopment analysis.
- Different types of inputs and outputs can be used in data envelopment analysis (DEA).
- Influencing resources in inefficiency of organizations are analyzed through the use of DEA.
- DEA efficiency scores for each DMU can be seen as integral measure of their performance.
- No need of predetermined offsetting of the functional form of transformation of resources (input variables) into results (output variables).
- Weights for input and output variables are formulated within the model without their a priori setting
- DEA method allows to include several output variables into model.
- Input and output variables can be expressed in different units.
- In DEA models, user can take into account external factors (in form of environmental variables)
- DEA method evaluates changes in input and output variables needed for reaching the efficiency frontier.
- DEA method can be used for forecasting the efficiency scores of DMUs.

3.4 New Z-AHP & Z-DEA methodology

The steps of the proposed methodology are as follows:

Step 1: Implementing the triangular Z-AHP method.

Establishment of hierarchy structure consists of three layers. The goal layer at the top, criteria, and indices at the intermediate layer and alternatives at the lowest layer.

Construction of pairwise comparison matrices for dimension and criteria and then collecting expert judgments using the linguistic scoring scale given in Table 6.

The pairwise comparison matrix, to achieve the weights of dimension and criteria, is shown as in Eq. (26), in which t denotes the number of inputs.

$$\tilde{A}^z = \begin{bmatrix} (1,1,1) & \tilde{a}^z_{12} & \cdots & \tilde{a}^z_{1t} \\ 1/\tilde{a}^z_{12} & (1,1,1) & \ldots & \tilde{a}^z_{2t} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}^z_{1t} & 1/\tilde{a}^z_{2t} & \cdots & (1,1,1) \end{bmatrix} \tag{26}$$

In Eq. (27) & (28), $\tilde{a}^z_{12}$ is as follows for example:

$$\tilde{a}^z_{12} = \left(a'^L_{12}, a'^M_{12}, a'^U_{12}\right) \tag{27}$$

And

$$1/\tilde{a}_{12}^{z}=\left(\frac{1}{a_{12}^{\prime U}},\frac{1}{a_{12}^{\prime M}},\frac{1}{a_{12}^{\prime L}}\right) \tag{28}$$

Consistency check of fuzzy pairwise comparison matrices

Calculating the geometric mean of each row in $\tilde{A}^z$ matrices using Eq. (29) and (30).

$$\tilde{g}_r=\left[\tilde{a}_{r1}^{z}\otimes\ldots\otimes\tilde{a}_{rn}^{z}\right]^{\frac{1}{n}} \tag{29}$$

where

$$\tilde{g}_r^z=\left(\left(\prod_{j=1}^{n}a_{rj}^{\prime L}\right)^{\frac{1}{n}},\left(\prod_{j=1}^{n}a_{rj}^{\prime M}\right)^{\frac{1}{n}},\left(\prod_{j=1}^{n}a_{rj}^{\prime U}\right)^{\frac{1}{n}}\right) \tag{30}$$

Calculating the Z-Number weights of the r^{th} Criteria ($\tilde{w}_r^z$) using Eq. (31), respectively.

$$\tilde{w}_r^z=\tilde{g}_r^z\otimes\left[\tilde{g}_1^z\otimes\ldots\otimes\tilde{g}_2^z\otimes\ldots\otimes\tilde{g}_t^z\right]^{-1} \tag{31}$$

Defuzzification of fuzzy weights, to specify the importance weights of inputs and outputs using Eq. (32)

$$\frac{a_{rj}^{\prime L}+2\times a_{rj}^{\prime M}+a_{rj}^{\prime U}}{4} \tag{32}$$

Step (2): Implementing the triangular Z-DEA method.

Use the scale given in Table 8 to assign the Z-Number preferences into inputs and outputs matrices

Obtain the Z-Number decision matrix for each decision-maker "k" as shown in Eq. (33). This matrix includes the whole inputs and outputs of the DEA model where m and n denote the number of alternatives and the total number of inputs and outputs, respectively.

$$\begin{bmatrix}\tilde{d}_{11,k}^{z} & \tilde{d}_{12,k}^{z} & \cdots & \tilde{d}_{1(n-1),k}^{z} & \tilde{d}_{1n,k}^{z}\\ \tilde{d}_{21,k}^{z} & \tilde{d}_{22,k}^{z} & \ldots & \tilde{d}_{2(n-1),k}^{z} & \tilde{d}_{2n,k}^{z}\\ \vdots & \vdots & \ddots & \vdots & \vdots\\ \tilde{d}_{m1,k}^{z} & \tilde{d}_{m2,k}^{z} & \cdots & \tilde{d}_{m(n-1),k}^{z} & \tilde{d}_{mn,k}^{z}\end{bmatrix} \tag{33}$$

Normalize the experts' evaluations in DEA input and output matrices (Eq. (34)).

$$Norm\ d_{ij}^{z}=\left[\frac{d_{ij}^{\prime L},d_{ij}^{\prime M},d_{ij}^{\prime U}}{\underset{i}{max}d_{ij}^{\prime U}}\right]\forall i,j \tag{34}$$

Aggregate the normalized input and output matrices, considering the weights of experts (Eq. (35)).

$$\tilde{D}^{z}_{ag} = \begin{bmatrix} \tilde{d}^{z}_{11} & \tilde{d}^{z}_{12} & \cdots & \tilde{d}^{z}_{1(n-1)} & \tilde{d}^{z}_{1n} \\ \tilde{d}^{z}_{21} & \tilde{d}^{z}_{22} & \ldots & \tilde{d}^{z}_{2(n-1)} & \tilde{d}^{z}_{2n} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \tilde{d}^{z}_{m1} & \tilde{d}^{z}_{m2} & \cdots & \tilde{d}^{z}_{m(n-1)} & \tilde{d}^{z}_{mn} \end{bmatrix} \tag{35}$$

Obtain the weighted aggregated input and output matrix by multiplying the matrix (31) by the weights of inputs and outputs derived from Z-AHP (Eq. (36) and (37)).

$$\tilde{D}^{z}_{ag,w} = \begin{bmatrix} w_1 \times \tilde{d}^{z}_{11} & w_2 \times \tilde{d}^{z}_{12} & \cdots & w_{(n-1)} \times \tilde{d}^{z}_{1(n-1)} & w_n \times \tilde{d}^{z}_{1n} \\ w_1 \times \tilde{d}^{z}_{21} & w_2 \times \tilde{d}^{z}_{22} & \ldots & w_{(n-1)} \times \tilde{d}^{z}_{2(n-1)} & w_n \times \tilde{d}^{z}_{2n} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ w_1 \times \tilde{d}^{z}_{m1} & w_2 \times \tilde{d}^{z}_{m2} & \cdots & w_{(n-1)} \times \tilde{d}^{z}_{m(n-1)} & w_n \times \tilde{d}^{z}_{mn} \end{bmatrix} \tag{36}$$

$$\tilde{D}^{z}_{ag,w} = \begin{bmatrix} \tilde{d}^{i}_{11} & \ldots & \tilde{d}^{i}_{1t} & \tilde{d}^{o}_{11} & \ldots & \tilde{d}^{o}_{1u} \\ \tilde{d}^{i}_{21} & \cdots & \tilde{d}^{i}_{2t} & \tilde{d}^{o}_{21} & \ldots & \tilde{d}^{o}_{2u} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \tilde{d}^{i}_{m1} & \ldots & \tilde{d}^{i}_{mt} & \tilde{d}^{o}_{m1} & \ldots & \tilde{d}^{o}_{mu} \end{bmatrix} \tag{37}$$

where $t + u = n$.

Apply the DEA model proposed in Sect. (3.4.2) (Eq. (38–41)).

$$min\theta_0 \tag{38}$$

s.t:

$$\sum_{\substack{j=1 \\ j \neq 0}}^{n} \lambda_j \left(x'^{m}_{ij} + x'^{u}_{ij} \right) \leq \theta_0 \left(x'^{m}_{i0} + x'^{l}_{i0} \right) \quad i = 1, \ldots, m \in \mathbb{N} \tag{39}$$

$$\sum_{\substack{j=1 \\ j \neq 0}}^{n} \lambda_j \left(y'^{m}_{rj} + y'^{l}_{rj} \right) \geq y'^{m}_{r0} + y'^{l}_{r0} \quad r = 1, \ldots, s \in \mathbb{N} \tag{40}$$

$$\lambda_j \geq 0 \quad j = 1, \ldots, n \tag{41}$$

Prioritizing the projects with consider to their efficiencies

4 Case study

In this section, in order to apply the proposed methodology into practice, a numerical example has been given. Assuming that a project-oriented organization wants to evaluate and rank its construction projects (including 10 sustainable projects (SP)) based on sustainability criteria filtered by experts. In the first part, the screened criteria in organization have been introduced and explained, and then in the second part, the pairwise comparisons between sustainability dimensions and criteria using the linguistic preference scale, taking the proposed probabilities of Table 6 into account, have been obtained. Afterward, the ranking of the projects through Z-DEA and Z-AHP-DEA approaches (the ranking is also compared with the DEA, F-DEA, AHP-DEA and F-AHP-DEA approaches) have been addressed.

In order to implement the proposed approach in this research, one of the project-oriented companies of mass production and infrastructure in Iran has been used. In order to filter the sustainable criteria, 2 experts and 1 senior expert of the project portfolio management office of that company have been used and 1 senior expert of the project portfolio management office has been used with full familiarity with the goals and prospects of the company. Therefore, in order to filter the identified and categorized sustainable criteria, we used questionnaires prepared by 2 experts and 1 senior expert of the project portfolio management office. In this way, each of these people gives numbers from 0 to 10 (ineffective to very effective) in the direction of the company's goals and prospects to these criteria and then the arithmetic mean is taken and any criteria that is greater than 5 is selected.

4.1 Sustainable criteria identification after screening

In this section, based on the sustainable failure structure of the criteria presented in Table 2, the sustainability criteria are scored by experts and then twelve sustainability criteria were filtered to select the appropriate sustainable projects of the organization which are listed in Table 9.

The sustainability dimensions and filtered criteria, along with the codes assigned to them, are shown in Fig. 4.

4.2 Calculating Sustainable Criteria importance Weights by Z-AHP

In this section, at first, pairwise comparisons between the sustainability dimensions (Table 10), economic dimension (Table 11), social dimension (Table 12), and environmental dimension (Table 13) have been made based on the linguistic scale of preferences considering the probabilities (Table 6).

In the following, we convert the linguistic scale to the fuzzy equivalent numbers based on the linguistic preferences scale considering probabilities. Therefore in Table 14 fuzzy equivalent of pairwise comparisons between the sustainability dimensions, in Table 15 equivalent fuzzy pairwise comparisons of economic dimension, in Table 16 fuzzy equivalent pairwise comparisons of social dimension and finally in Table 17 fuzzy equivalent of pairwise comparisons of environment dimension have been shown as well as the importance weights and incompatibility rates.

The importance weights of sustainability dimensions and criteria in Z-Number condition are shown in Table 18.

Finally, the importance weights of the sustainability dimensions and criteria in the certainty, fuzzy, and Z-Number conditions are given in Table 19.

Table 9 Screened sustainability criteria

Sustainable Dimension	Sustainable Criteria	Description
Economic	Expected benefit	Difference between the expected revenue and the cost of the project
	Pay Back Period (PBP)	The amount of time required to recover the funds expended in an investment
	Effect of sanctions	Impact of sanctions on the success and failure of the project. Such as material and technology sanctions
	Probability of project success	How likely or not the project is to succeed
	Job creation rate	Is a measure of net hiring of full- and part-time adult workers
Social	Synergy among the Factors of the project	The creation of a whole that is greater than the simple sum of its parts
	Community acceptance	The reaction of communities when projects are proposed in their local areas
	Staff Satisfaction	Degree to which *staff* are content/happy in their work roles
Environment	Greenhouse gas emissions (from natural energy)	Expected emissions of greenhouse gases such as CO2 and SO2 resulting from project implementation
	Non-renewable energy Consumption	Expected amount of renewable energy use, such as fossil fuels, which we are looking to reduce
	The amount of water consumed	Expected use of water resources that we try to reduce
	Use of recyclable consumables	Expected use of renewable and environmentally friendly resources that can be used after the end of the project operation period

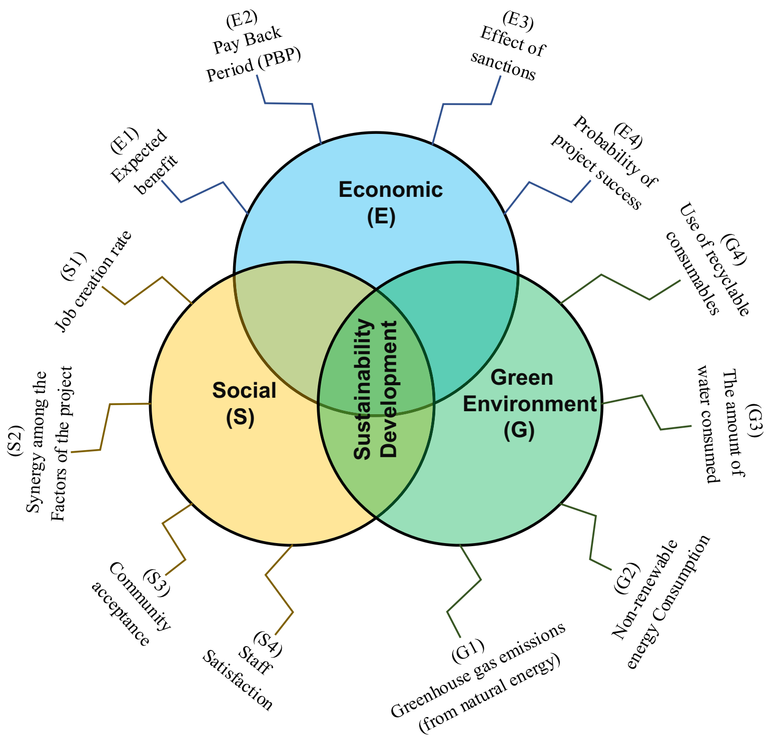


Fig. 4 Sustainable Criteria Identification after Filtering

Table 10 Pairwise comparison matrix of the sustainability dimensions with respect to the Goal

Goal	Economic	Social	Environment
Economic		WA-M	WA-FI
Social			E-M
Environment			

Table 11 Pairwise comparison matrix for the criteria with respect to the economic dimension

Economic	E1	E2	E3	E4
E1		WA-L	NB-U	NB-L
E2			WA-ML	WA-M
E3				E-W
E4				E4

Table 12 Pairwise comparison matrix for the criteria with respect to the social dimension

Social	S3	S2	S1	S4
S1	WA-W	WA-ML	E-L	
S2	E-M	WA-M		
S3	E-U			
S4				

Table 13 Pairwise comparison matrix for the criteria with respect to the environment dimension

Environment	G1	G2	G3	G4
G1		WA-FI	WA-U	P-M
G2			E-W	WA-ML
G3				WA-L
G4				

Table 14 Z-Number pairwise comparison matrix of the sustainability dimensions with respect to the Goal

Goal	Economic	Social	Environment	Weight
Economic	(1,1,1)	(0.774,1.548,2.322)	(0.632,1.264,1.896)	0.418
Social	(0.431,0.646,1.292)	(1,1,1)	(0.744,0.774,0.774)	0.336
Environment	(0.527,0.791,1.582)	(1.292,1.292,1.344)	(1,1,1)	0.246

$CR_m = 0.011 CR_m = 0.011$
$CR_g = 0.031 CR_g = 0.031$
compatible

Table 15 Z-Number pairwise comparison matrix for the criteria with respect to the economic dimension

Economic	E1	E2	E3	E4	Weight
E1	(1,1,1)	(0.894,1.788,2.682)	(0.894,1.341,1.788)	(1.788,2.682,3.576)	0.166
E2	(0.373,0.559,1.119)	(1,1,1)	(0.948,1.896,2.844)	(0.774,1.548,2.322)	0.130
E3	(0.560,0.746,1.119)	(0.352,0.527,1.055)	(1,1,1)	(0.707,0.707,0.707)	0.054
E4	(0.280,0.373,0.559)	(0.431,0.646,1.292)	(1.414,1.4141,1.414)	(1,1,1)	0.069

$CR_m = 0.053 CR_m = 0.053$
$CR_g = 0.013 CR_g = 0.013$
compatible

Table 16 Z-Number Pairwise comparison matrix for the criteria with respect to the social dimension

social	S1	S2	S3	S4	Weight
S1	(1,1,1)	(0.894,0.894,0.894)	(0.948,1.896,2.844)	(0.707,1.414,2.121)	0.114
S2	(1.119,1.119,1.119)	(1,1,1)	(0.774,1.548,2.322)	(0.744,0.774,0.774)	0.086
S3	(0.352,0.527,1.055)	(0.431,0.646,1.292)	(1,1,1)	(0.447,0.447,0.447)	0.021
S4	(0.471,0.707,1.414)	(1.344,1.344,1.344)	(2.237,2.237,2.237)	(1,1,1)	0.115

$CR_m = 0.023CR_m = 0.023$
$CR_g = 0.06CR_g = 0.06$
compatible

Table 17 Z-Number pairwise comparison matrix for the criteria with respect to the environment dimension

Environment	G1	G2	G3	G4	Weight
G1	(1,1,1)	(0.632,1.264,1.896)	(0.447,0.894,1.341)	(2.322,3.096,3.870)	0.085
G2	(0.527,0.791,1.582)	(1,1,1)	(0.707,0.707,0.707)	(0.948,1.896,2.844)	0.062
G3	(0.746,1.119,2.237)	(1.414,1.414,1.414)	(1,1,1)	(0.894,1.788,2.682)	0.074
G4	(0.258,0.323,0.431)	(0.352,0.527,1.055)	(0.373,0.560,1.119)	(1,1,1)	0.025

$CR_m = 0.011CR_m = 0.011$
$CR_g = 0.011CR_g = 0.011$
compatible

Table 18 Importance weights of sustainability dimensions and criteria in Z-Number condition

Sustainable dimension	Weight toward the goal	Sustainable criteria	Weight toward the dimension	Weight toward the goal
Economic	0.418	Expected benefit	0.396	0.166
		Pay back period (PBP)	0.310	0.130
		Effect of sanctions	0.130	0.054
		Probability of project success	0.164	0.069
Social	0.336	Job creation rate	0.340	0.114
		Synergy among the factors of the project	0.255	0.086
		Community acceptance	0.063	0.021
		Staff Satisfaction	0.343	0.115
Environment	0.246	Greenhouse gas emissions (from natural energy)	0.344	0.085
		Non-renewable energy Consumption	0.251	0.062
		The amount of water consumed	0.302	0.074
		Use of recyclable consumables	0.103	0.025

Table 19 Comparison between importance weights of sustainability dimensions and criteria in certainty, fuzzy and Z-Number

Sustainable Dimension	Certainty	Fuzzy	Z-Number	Sustainable Criteria	Certainty	Fuzzy	Z-Number
Economic	0.500	0.561	0.418	Expected benefit	0.213	0.316	0.166
				Pay Back Period (PBP)	0.135	0.207	0.130
				Effect of sanctions	0.081	0.019	0.054
				Probability of project success	0.072	0.019	0.069
Social	0.250	0.219	0.336	Job creation rate	0.085	0.084	0.114
				Synergy among the Factors of the project	0.072	0.068	0.086
				Community acceptance	0.042	0.032	0.021
				Staff Satisfaction	0.051	0.035	0.115
Environment	0.250	0.219	0.246	Greenhouse gas emissions	0.111	0.093	0.085
				Non-renewable energy Consumption	0.056	0.054	0.062
				The amount of water consumed	0.056	0.054	0.074
				Use of recyclable consumables	0.028	0.018	0.025

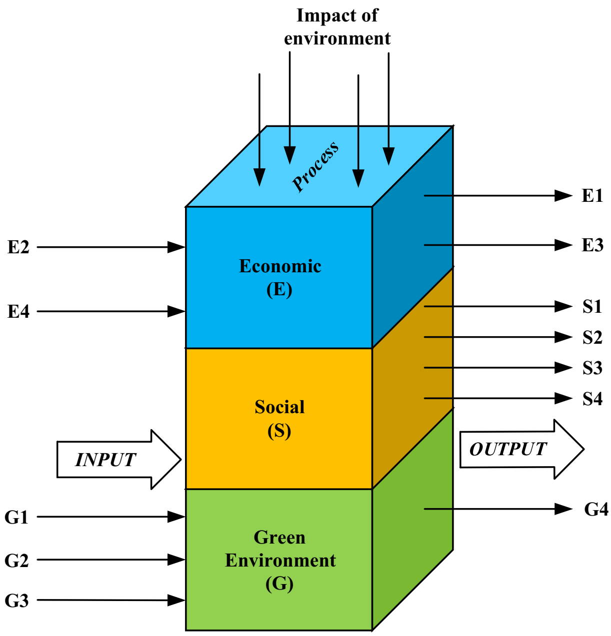


Fig. 5 Sustainability input and output criteria

4.3 Calculating sustainable project performance by Z-DEA

In this section, using the decision matrix and the linguistic scoring scale with probabilities Table 9. Qualitative criteria for sustainable projects are scored by an expert, and quantitative criteria gathered based on past data (worst case, likely, best case) with a probability of 1 for sustainable projects, and then sustainable projects are ranked using Z-DEA and Z-AHP-DEA approaches (for comparison, sustainable projects are ranked through DEA, F-DEA, AHP-DEA, F-AHP-DEA approaches in the next section). In this study, the decision-making unit (which is the unit that generates the output vector by receiving the input vector) is the sustainable projects receiving a series of inputs, such as the payback period, will have a series of outputs, such as expected profit. Figure 5 shows the sustainability of input and output criteria.

The decision-making Table 20 has been filled using the linguistic scoring scale with probabilities Table 9 for qualitative criteria and past data for quantitative criteria.

In the following, based on the linguistic scoring scale with probabilities, we convert the linguistic scale to the fuzzy equivalent numbers. So, the previous decision-making table changes to Table 21.

Table 22 shows the normalized decision-making matrix. An example of a normalization calculation for the first column is as follows.

Table 20 Z-Number decision matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	(0.84,0.98,1.13)	(13,15,17)	M-L	H-ML	VH-M	H-M	VH-U	M-W	VH-FI	M-L	VH-M	H-ML
SP 2	(0.93,1.19,1.32)	(17,19,21)	VL-W	VH-U	M-W	L-L	VL-W	M-W	VL-FI	VL-W	H-ML	H-FI
SP 3	(1.00,1.43,1.65)	(20,23,26)	H–L	V H-ML	L-M	M-U	H-ML	VH-M	VL-U	H-W	L-M	VH-ML
SP 4	(0.41,0.68,0.78)	(09,11,13)	VH-U	VL-FI	M-M	VL-U	VH-FI	VH-U	H-U	H-M	VH-ML	M-U
SP 5	(1.18,1.38,1.67)	(19,22,25)	VH-ML	VL-U	L-W	VL-L	M-ML	M-M	VH-W	VH-U	L-FI	M-L
SP 6	(0.78,0.89,1.07)	(10,12,14)	H-W	L-ML	H-ML	M-U	L-FI	M-U	M-U	VH-L	L-W	VH-W
SP 7	(0.95,1.15,1.22)	(16,18,20)	M-FI	VL-M	L-ML	VL-U	L-FI	VL-ML	H-U	VL-FI	M-U	VL-FI
SP 8	(0.87,1.12,1.40)	(15,17,19)	M-W	VL-FI	M-FI	M-W	M-FI	H-ML	M-ML	M-W	H-W	M-U
SP 9	(0.50,0.70,0.88)	(08,11,14)	L-ML	VL-FI	L-ML	VL-FI	M-FI	VH-ML	H–L	M-U	L-U	VL-M
SP 10	(1.10,1.40,1.80)	(23,26,29)	L-FI	M-W	L-M	L-U	VH-L	L-W	M-ML	H-FI	H-U	L-W

Table 21 Z-Number quantitative decision-making matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
		(13,15,	(2.682,4.47,6.258)	(4.74,6.636,8.532)	(5.418,6.966,6.966)	(3.87,5.418,6.966)	(3.129,4.023,4.023)	(2.121,3.535,4.949)	(4.424,5.688,5.688)	(2.682,4.47,6.258)	(5.418,6.966,6.966)	(4.74,6.636,8.532)
										SP 1	(0.84,0.98,1.13)	17)
		(17,19,	(0.707,0.707,2.121)	(3.129,4.023,4.023)	(2.121,3.535,4.949)	(0.894,2.682,4.47)	(0.707,0.707,2.121)	(2.121,3.535,4.949)	(0.632,0.632,1.896)	(0.707,0.707,2.121)	(4.74,6.636,8.532)	(3.16,4.424,5.688)
										SP 2	(0.93,1.19,1.32)	21)
		(20,23,	(4.47,6.258,8.046)	(6.636,8.532,8.532)	(0.774,2.322,3.87)	(1.341,2.235,3.129)	(4.74,6.636,8.532)	(5.418,6.966,6.966)	(0.447,0.447,1.341)	(3.535,4.949,6.363)	(0.774,2.322,3.87)	(6.636,8.532,8.532)
										SP 3	(1,1.43,1.65)	26)
SP 4	(0.41,0.68,0.78)	(9,11,13)	(3.129,4.023,4.023)	(0.632,0.632,1.896)	(2.322,3.87,5.418)	(0.447,0.447,1.341)	(4.424,5.688,5.688)	(3.129,4.023,4.023)	(2.235,3.129,4.023)	(3.87,5.418,6.966)	(6.636,8.532,8.532)	(1.341,2.235,3.129)
		(19,22,	(6.636,8.532,8.532)	(0.447,0.447,1.341)	(0.707,2.121,3.535)	(0.894,0.894,2.682)	(2.844,4.74,6.636)	(2.322,3.87,5.418)	(4.949,6.363,6.363)	(3.129,4.023,4.023)	(0.632,1.896,3.16)	(2.682,4.47,6.258)
										SP 5	(1.18,1.38,1.67)	25)
		(10,12,	(3.535,4.949,6.363)	(0.948,2.844,4.74)	(4.74,6.636,8.532)	(1.341,2.235,3.129)	(0.632,1.896,3.16)	(1.341,2.235,3.129)	(1.341,2.235,3.129)	(6.258,8.046,8.046)	(0.707,2.121,3.535)	(4.949,6.363,6.363)
										SP 6	(0.78,0.89,1.07)	14)
		(16,18,	(1.896,3.16,4.424)	(0.774,0.774,2.322)	(0.948,2.844,4.74)	(0.447,0.447,1.341)	(0.632,1.896,3.16)	(0.948,0.948,2.844)	(2.235,3.129,4.023)	(0.632,0.632,1.896)	(1.341,2.235,3.129)	(0.632,0.632,1.896)
										SP 7	(0.95,1.15,1.22)	20)
		(15,17,	(2.121,3.535,4.949)	(0.632,0.632,1.896)	(1.896,3.16,4.424)	(2.121,3.535,4.949)	1.896,3.16,4.424)	(4.74,6.636,8.532)	(2.844,4.74,6.636)	(2.121,3.535,4.949)	(3.535,4.949,6.363)	(1.341,2.235,3.129)
										SP 8	(0.87,1.12,1.4)	19)
SP 9	(0.5,0.7,0.88)	(8,11,14)	(0.948,2.844,4.74)	(0.632,0.632,1.896)	(0.948,2.844,4.74)	(0.632,0.632,1.896)	(1.896,3.16,4.424)	(6.636,8.532,8.532)	(4.47,6.258,8.046)	(1.341,2.235,3.129)	(0.447,1.341,2.235)	(0.774,0.774,2.322)
		(23,26,	(0.632,1.896,3.16)	(2.121,3.535,4.949)	(0.774,2.322,3.87)	(0.447,1.341,2.235)	(6.258,8.046,8.046)	(0.707,2.121,3.535)	(2.844,4.74,6.636)	(3.16,4.424,5.688)	(2.235,3.129,4.023)	(0.707,2.121,3.535)
										SP 10	(1.1,1.4,1.8)	29)

Table 22 Normalized Z-Number decision-making matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	G1	G2	G3	G4	S4
SP 1	(0.467,0.544,0.628)	(0.448,0.517,0.586)	(0.314,0.524,0.733)	(0.556,0.778,1.000)	(0.635,0.816,0.816)	(0.455,0.635,0.816)	(0.367,0.472,0.472)	(0.519,0.667,0.667)	(0.314,0.524,0.733)	(0.635,0.816,0.816)	(0.556,0.778,1.000)	(0.249,0.414,0.580)
SP 2	(0.517,0.661,0.733)	(0.586,0.655,0.724)	(0.083,0.083,0.249)	(0.367,0.472,0.472)	(0.249,0.414,0.580)	(0.105,0.314,0.524)	(0.083,0.083,0.249)	(0.074,0.074,0.222)	(0.083,0.083,0.249)	(0.556,0.778,1.000)	(0.370,0.519,0.667)	(0.249,0.414,0.580)
SP 3	(0.556,0.794,0.917)	(0.690,0.793,0.897)	(0.524,0.733,0.943)	(0.778,1.000,1.000)	(0.091,0.272,0.454)	(0.157,0.262,0.367)	(0.556,0.778,1.000)	(0.052,0.052,0.157)	(0.4140.580,0.746)	(0.091,0.272,0.454)	(0.778,1.000,1.000)	(0.635,0.816,0.816)
SP 4	(0.228,0.378,0.433)	(0.310,0.379,0.448)	(0.368,0.472,0.471)	(0.074,0.074,0.222)	(0.272,0.454,0.635)	(0.052,0.052,0.157)	(0.519,0.667,0.667)	(0.262,0.367,0.472)	(0.455,0.635,0.816)	(0.778,1.000,1.000)	(0.157,0.262,0.367)	(0.367,0.472,0.472)
SP 5	(0.656,0.767,0.928)	(0.655,0.759,0.862)	(0.778,1.000,1.000)	(0.052,0.052,0.157)	(0.083,0.249,0.414)	(0.103,0.103,0.314)	(0.333,0.556,0.778)	(0.580,0.746,0.746)	(0.367,0.472,0.472)	(0.074,0.222,0.370)	(0.314,0.524,0.733)	(0.272,0.454,0.635)
SP 6	(0.43,0.494,0.594)	(0.345,0.414,0.483)	(0.414,0.580,0.746)	(0.111,0.333,0.556)	(0.556,0.778,1.000)	(0.157,0.262,0.367)	(0.074,0.222,0.370)	(0.157,0.262,0.367)	(0.733,0.943,0.943)	(0.083,0.249,0.414)	(0.580,0.746,0.746)	(0.157,0.262,0.367)
SP 7	(0.528,0.639,0.678)	(0.552,0.621,0.690)	(0.222,0.370,0.519)	(0.098,0.098,0.272)	(0.111,0.333,0.556)	(0.052,0.052,0.157)	(0.074,0.222,0.370)	(0.262,0.367,0.472)	(0.074,0.074,0.222)	(0.157,0.262,0.367)	(0.074,0.074,0.222)	(0.111,0.111,0.333)
SP 8	(0.483,0.622,0.778)	(0.517,0.586,0.655)	(0.249,0.414,0.580)	(0.074,0.074,0.222)	(0.222,0.370,0.519)	(0.249,0.414,0.580)	(0.222,0.370,0.519)	(0.333,0.556,0.778)	(0.249,0.414,0.580)	(0.414,0.580,0.746)	(0.157,0.262,0.367)	(0.556,0.778,1.000)
SP 9	(0.278,0.389,0.489)	(0.276,0.379,0.483)	(0.11,0.333,0.556)	(0.074,0.074,0.222)	(0.111,0.333,0.556)	(0.074,0.074,0.222)	(0.222,0.370,0.519)	(0.524,0.733,0.943)	(0.157,0.262,0.367)	(0.052,0.157,0.262)	(0.091,0.091,0.272)	(0.778,1.000,1.000)
SP 10	(0.611,0.778,1.000)	(0.793,0.897,1.000)	(0.074,0.222,0.370)	(0.249,0.414,0.580)	(0.091,0.272,0.453)	(0.052,0.157,0.262)	(0.733,0.943,0.943)	(0.333,0.556,0.778)	(0.370,0.519,0.667)	(0.262,0.367,0.472)	(0.083,0.249,0.414)	(0.083,0.249,0.414)

Table 23 Z-Number weighted normalized decision-making matrix

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	(0.077,0.090,0.104)	(0.058,0.067,0.076)	(0.017,0.028,0.040)	(0.038,0.053,0.069)	(0.073,0.093,0.093)	(0.039,0.054,0.070)	(0.008,0.010,0.010)	(0.029,0.048,0.067)	(0.044,0.056,0.056)	(0.019,0.032,0.045)	(0.047,0.061,0.061)	(0.014,0.020,0.025)
SP 2	(0.086,0.109,0.121)	(0.076,0.085,0.094)	(0.005,0.005,0.014)	(0.025,0.032,0.032)	(0.028,0.047,0.066)	(0.009,0.027,0.045)	(0.002,0.002,0.005)	(0.029,0.048,0.067)	(0.006,0.006,0.019)	(0.005,0.005 0.015)	(0.041,0.058,0.074)	(0.009,0.013,0.017)
SP 3	(0.092,0.132,0.152)	(0.089,0.103,0.116)	(0.028,0.040,0.051)	(0.053,0.069,0.069)	(0.010,0.031,0.052)	(0.013,0.022,0.031)	(0.012,0.016,0.021)	(0.073,0.094,0.094)	(0.004,0.004,0.013)	(0.026,0.036,0.046)	(0.007,0.020,0.034)	(0.020,0.025,0.025)
SP 4	(0.038,0.06,0.072)	(0.040,0.049,0.058)	(0.020,0.026,0.026)	(0.005,0.005,0.015)	(0.031,0.052,0.073)	(0.004,0.005,0.013)	(0.011,0.014,0.014)	(0.042,0.054,0.054)	(0.022,0.031,0.040)	(0.028,0.039,0.050)	(0.058,0.074,0.074)	(0.004,0.007,0.009)
SP 5	(0.109,0.125,0.154)	(0.085,0.098,0.112)	(0.042,0.054,0.054)	(0.004,0.004,0.011)	(0.009,0.028,0.047)	(0.009,0.009,0.027)	(0.007,0.012,0.016)	(0.031,0.052,0.073)	(0.049,0.063,0.063)	(0.023,0.029,0.029)	(0.006,0.017,0.028)	(0.008,0.013,0.019)
SP 6	(0.072,0.082,0.098)	(0.045,0.054,0.063)	(0.023,0.031,0.041)	(0.008,0.022,0.038)	(0.063,0.089,0.114)	(0.013,0.022,0.031)	(0.002,0.005,0.008)	(0.018,0.030,0.042)	(0.013,0.022,0.031)	(0.045,0.058,0.058)	(0.006,0.018,0.031)	(0.015,0.019,0.019)
SP 7	(0.087,0.106,0.112)	(0.071,0.080,0.089)	(0.012,0.020,0.028)	(0.006,0.006,0.019)	(0.013,0.038,0.063)	(0.004,0.004,0.013)	(0.002,0.005,0.008)	(0.013,0.013,0.038)	(0.022,0.031,0.040)	(0.005,0.005,0.014)	(0.012,0.019,0.027)	(0.002,0.002,0.006)
SP 8	(0.080,0.103,0.129)	(0.067,0.076,0.085)	(0.014,0.023,0.032)	(0.005,0.005,0.015)	(0.025,0.042,0.059)	(0.021,0.035,0.050)	(0.005,0.008,0.011)	(0.064,0.090,0.115)	(0.028,0.047,0.066)	(0.015,0.026,0.036)	(0.031,0.043,0.055)	(0.004,0.007,0.009)
SP 9	(0.046,0.064,0.081)	(0.036,0.050,0.063)	(0.006,0.018,0.030)	(0.005,0.005,0.015)	(0.013,0.038,0.063)	(0.006,0.006,0.019)	(0.003,0.008,0.011)	(0.090,0.115,0.115)	(0.044,0.062,0.080)	(0.010,0.016,0.023)	(0.004,0.012,0.019)	(0.002,0.002,0.007)
SP 10	(0.101,0.129,0.166)	(0.103,0.116,0.130)	(0.004,0.012,0.020)	(0.017,0.028,0.040)	(0.010,0.031,0.052)	(0.004,0.013,0.022)	(0.016,0.020,0.020)	(0.010,0.029,0.048)	(0.028.047,0.066)	(0.023,0.032,0.041)	(0.019,0.027,0.035)	(0.002,0.006,0.010)

$$(E1)_{normalization} = \begin{bmatrix} \frac{(0.84,0.98,1.13)}{1.8} \\ \frac{(0.93,1.19,1.32)}{1.8} \\ \frac{(1.00,1.43,1.65)}{1.8} \\ \frac{(0.41,0.68,0.78)}{1.8} \\ \frac{(1.18,1.38,1.67)}{1.8} \\ \frac{(0.78,0.89,1.07)}{1.8} \\ \frac{(0.95,1.15,1.22)}{1.8} \\ \frac{(0.87,1.12,1.40)}{1.8} \\ \frac{(0.50,0.70,0.88)}{1.8} \\ \frac{(1.10,1.40,1.80)}{1.8} \end{bmatrix} = \begin{bmatrix} (0.467, 0.544, 0.628) \\ (0.517, 0.661, 0.733) \\ (0.556, 0.794, 0.917) \\ (0.228, 0.378, 0.433) \\ (0.656, 0.767, 0.928) \\ (0.430, 0.494, 0.594) \\ (0.528, 0.639, 0.678) \\ (0.483, 0.622, 0.778) \\ (0.278, 0.389, 0.489) \\ (0.611, 0.778, 1.000) \end{bmatrix}$$

Then, the importance weights of sustainability criteria obtained in the previous step utilizing the AHP approach are multiplied in the columns related to the criterion in the normalized decision matrix. Table 23 is the weighted normalized decision matrix. For instance, the first column is calculated as follows:

$$W_1^z \times (E1)_{normalization} = 0.166 \times \begin{bmatrix} (0.467, 0.544, 0.628) \\ (0.517, 0.661, 0.733) \\ (0.556, 0.794, 0.917) \\ (0.228, 0.378, 0.433) \\ (0.656, 0.767, 0.928) \\ (0.430, 0.494, 0.594) \\ (0.528, 0.639, 0.678) \\ (0.483, 0.622, 0.778) \\ (0.278, 0.389, 0.489) \\ (0.611, 0.778, 1.000) \end{bmatrix} = \begin{bmatrix} (0.077, 0.090, 0.104) \\ (0.086, 0.109, 0.121) \\ (0.092, 0.132, 0.152) \\ (0.038, 0.063, 0.072) \\ (0.109, 0.125, 0.154) \\ (0.072, 0.082, 0.098) \\ (0.087, 0.106, 0.112) \\ (0.080, 0.103, 0.129) \\ (0.046, 0.064, 0.081) \\ (0.101, 0.129, 0.166) \end{bmatrix}$$

According to Table 23 of the second step, this table is the input table (parameters) of the AP-DEA model in Z-Number condition and then using GAMS software, solves the linear model, and has extracted its results in the form of project efficiency and project ranking. Similar to the Z-Number scenario, the AHP-DEA model is solved in certain and fuzzy

Table 24 Ranking of sustainable projects

Sustainable Project	Z-DEA	Ranking	Z-AHP-DEA	Ranking
SP 1	2.97	9	3.22	3
SP 2	8.35	3	8.05	4
SP 3	15.26	1	16.72	10
SP 4	4.15	8	4.15	1
SP 5	10.29	2	9.45	5
SP 6	5.96	6	6.15	2
SP 7	5.76	7	5.56	8
SP 8	7.18	5	7.4	6
SP 9	7.25	4	7.27	7
SP 10	2.21	10	2.22	9

Table 25 Comparison of rankings in certainty, fuzzy, and Z-Number conditions for DEA and AHP-DEA approaches

Sustainable Project	DEA	Ranking	F-DEA	Ranking	Z-DEA	Ranking	T-AHP-DEA	Ranking	F-AHP-DEA	Ranking	Z-AHP-DEA	Ranking
SP 1	1.82	9	3.18	9	2.97	9	1.83	9	3.12	9	3.22	9
SP 2	5.2	2	8.05	2	8.35	3	5.45	2	8.04	2	8.05	3
SP 3	5.77	1	10.74	1	15.26	1	5.86	1	10.9	1	16.72	1
SP 4	2.31	7	4.49	7	4.15	8	2.33	6	4.41	7	4.15	8
SP 5	2.36	5	4.98	6	10.29	2	2.34	5	5.03	6	9.45	2
SP 6	2.33	6	5.11	5	5.96	6	2.31	7	5.16	5	6.15	6
SP 7	4.45	3	6.88	3	5.76	7	4.54	3	6.76	3	5.56	7
SP 8	3.12	4	6.41	4	7.18	5	3.12	4	6.33	4	7.4	4
SP 9	2.25	8	4.33	8	7.25	4	2.24	8	4.37	8	7.27	5
SP 10	1.1	10	1.93	10	2.21	10	1.1	10	1.95	10	2.22	10

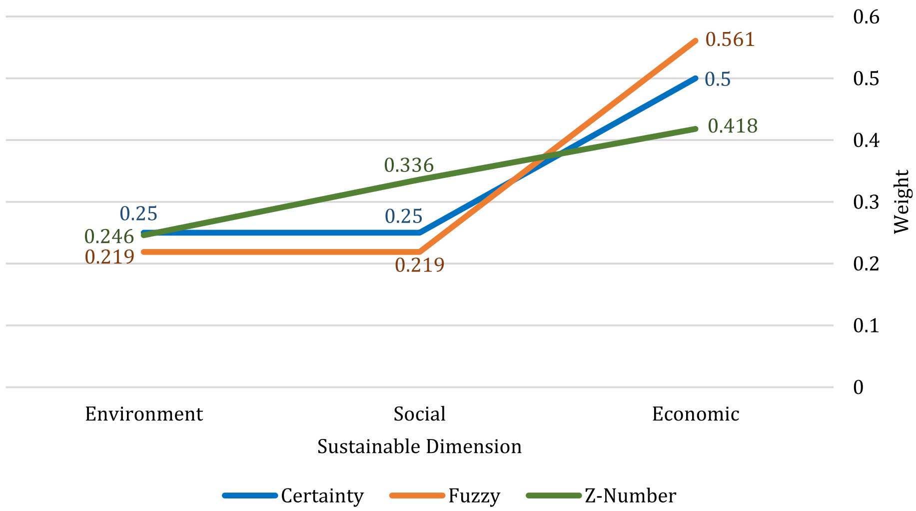
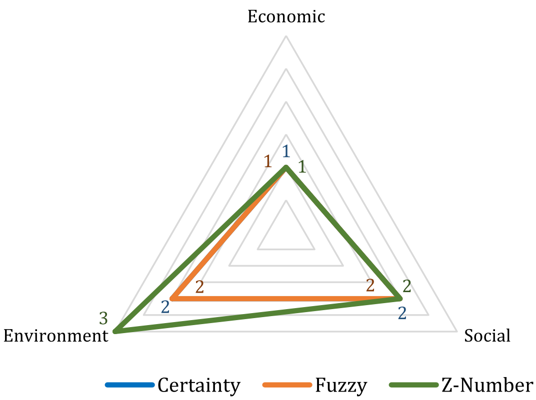


Fig. 6 Comprasion of Sustainable Dimension Weight

Fig. 7 Comprasion of sustainable dimension weight ranking



scenario. The data of these certain and fuzzy scenarios are given in Appendix 1 and 2, and then in Table 25, the results of different scenarios are summarized.

Calculations related to certain and fuzzy numbers are given in the appendix section (appendix 1 and 2).

Then, we rank the sustainable projects once with the DEA approach (i.e., Table 24), and once with the AHP-DEA approach (i.e., Table 25).

We similarly have:

5 Discussion

In this section, the results of the AHP, DEA, and AHP-DEA approaches in certain, fuzzy, and Z-Number conditions have been analyzed and compared; it shows, as it shifts from certainty to fuzzy and Z-NUMBER conditions, the results change, and the more we consider uncertainty the more reliable results will be obtained. In the second part, the results

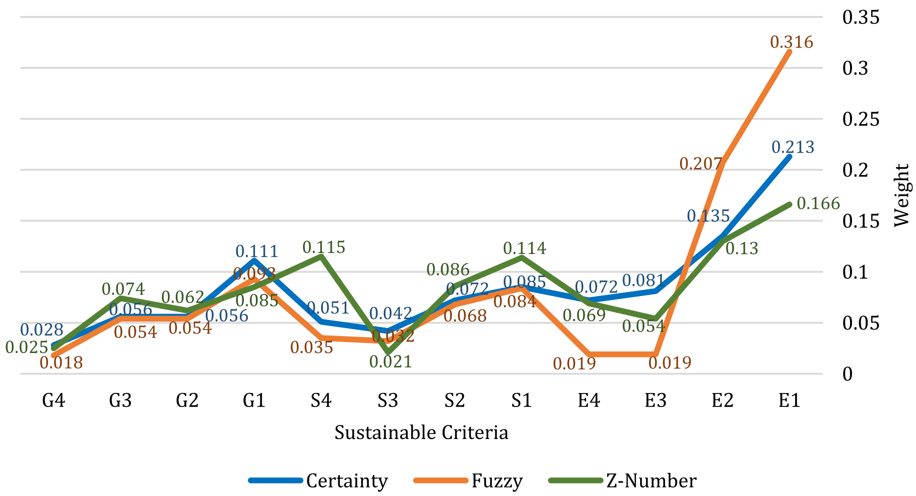
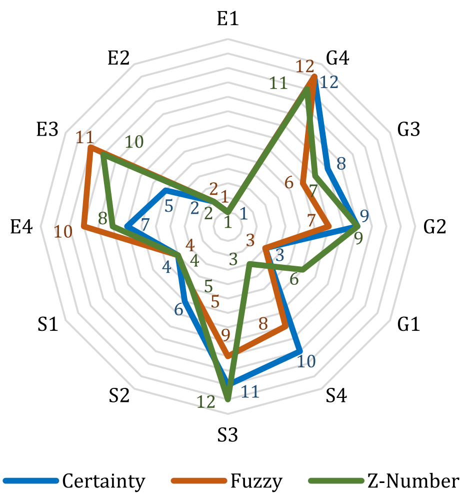


Fig. 8 Comprasion of sustainable criteria weight

Fig. 9 Comprasion of Sustainable Criteria Weight Ranking



of DEA and AHP-DEA have been analyzed and compared; it shows, when the importance weights of criteria are determined by experts and considered in the decision-making matrix, the ranking of sustainable projects will be different. This indicates that by considering the expert mental judgment to weigh the criteria and include them in the DEA model, more reliable results will be obtained for the organization.

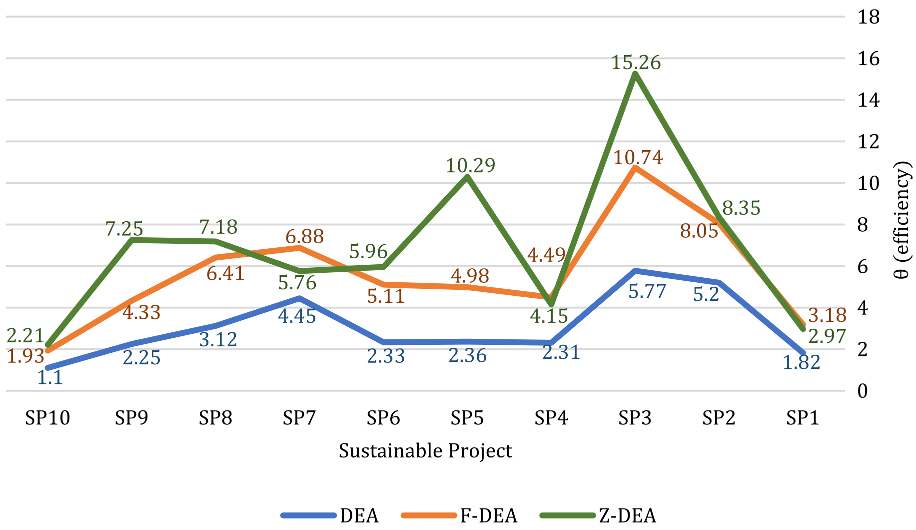
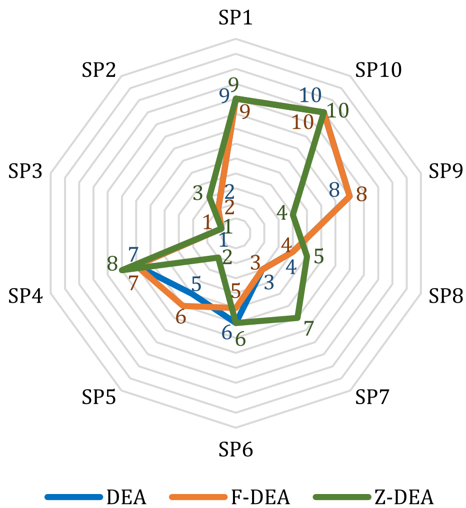


Fig. 10 Comprasion of Sustainable Projects Teta (DEA)

Fig. 11 Comprasion of Sustainable Projects Ranking (DEA)



5.1 Comparison of the results obtained by the proposed approaches: (Certainty & Fuzzy & Z-Number)

In this section, the results obtained from the different approaches used in certainty, fuzzy and Z-Number conditions have been analyzed. In the first part, according to Figs. 6 and 8 (comparison of the obtained importance weights of sustainability dimensions and criteria), it shows that the results will be different in each condition which can affect our decision making. Also, in Figs. 7 and 9, where the ranking of sustainability dimensions and criteria is based on their weights, it also demonstrates that in different

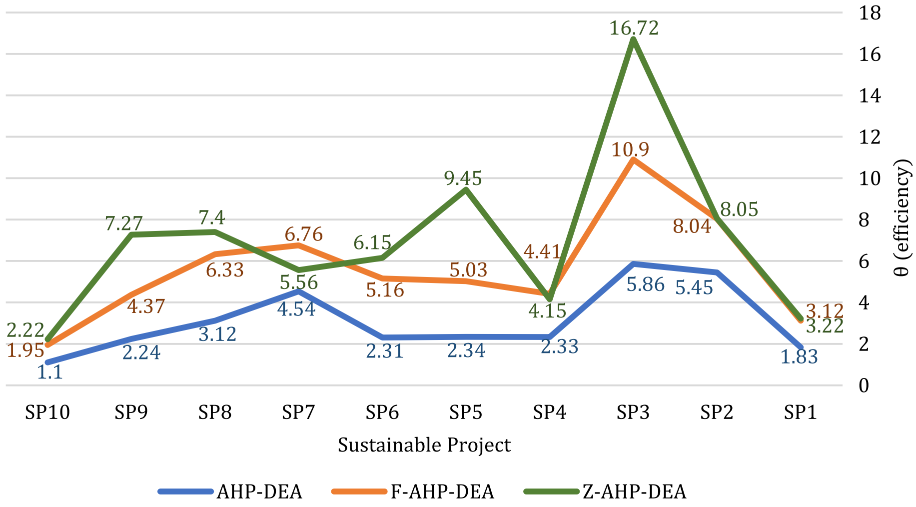
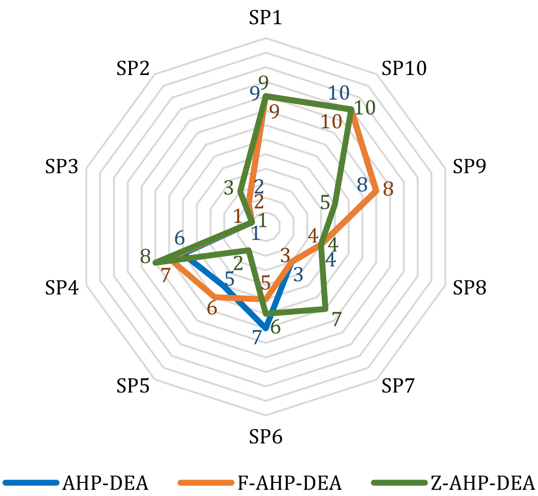


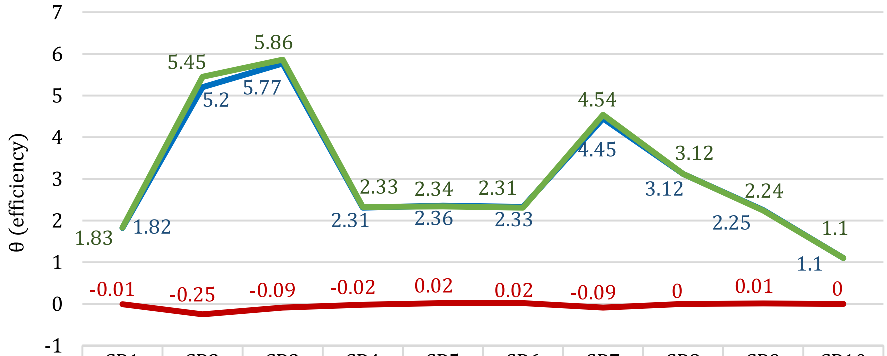
Fig. 12 Comprasion of Sustainable Projects Teta (AHP-DEA)

Fig. 13 Comprasion of Sustainable Projects Ranking (AHP-DEA)



situations the ranking of the weights will differ. In general, given the uncertainties in the opinions and judgments of experts, the more it shifts from certainty condition to fuzzy and Z-Number conditions, the closer it gets to the real world and the credible answers. Therefore, Z-Number condition can provide more reliable results and closer to reality, considering the probability of confidence in expert judgment on their fuzzy views.

Similarly, according to Figs. 10 and 12, which are the amount of obtained efficiencies (θ), and also Figs. 11 and 13, which represent the ranking of the projects through the DEA and AHP-DEA approaches, it can be seen that as it shifts from certainty to fuzzy condition and Z-Number, it will affect the ranking of projects. Therefore, because experts' opinions contain uncertainty, the Z-Number approach, which considers both the fuzzy linguistic scale and the probability of expert confidence in opinions, provides more effective and reliable answers.

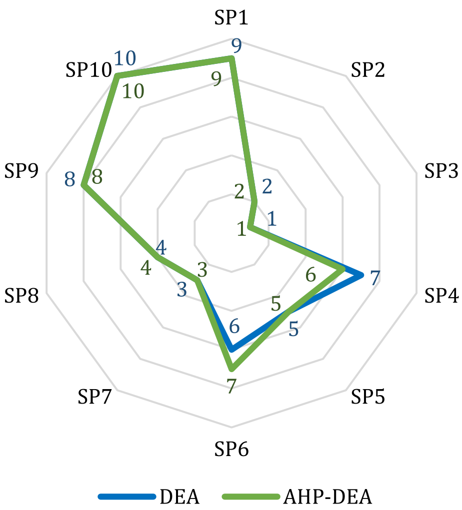


	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
DEA	1.82	5.2	5.77	2.31	2.36	2.33	4.45	3.12	2.25	1.1
AHP-DEA	1.83	5.45	5.86	2.33	2.34	2.31	4.54	3.12	2.24	1.1
Difference	-0.01	-0.25	-0.09	-0.02	0.02	0.02	-0.09	0	0.01	0

DEA AHP-DEA Difference

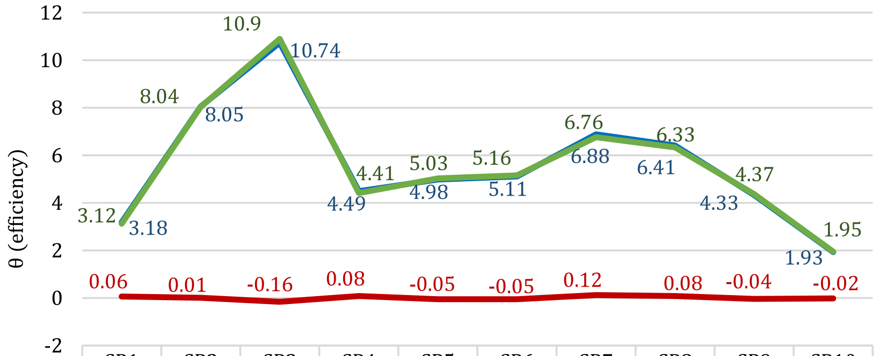
Fig. 14 Comprasion of DEA & AHP-DEA Teta

Fig. 15 Comprasion of DEA & AHP-DEA Teta



5.2 Comparison of DEA and AHP-DEA approaches

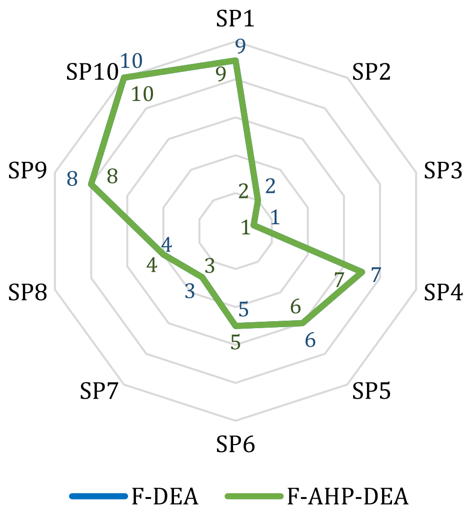
Given the importance weights of sustainability input and output criteria that can have different effects on the efficiency and selection of the projects, the AHP approach in different situations to calculate the weights of the sustainability dimensions and criteria have been used. According to Figs. 14, 16 and 18, it can be seen that the resulted efficiencies through DEA and AHP-DEA approaches will be different in each condition. Figures 15, 17 and 19 illustrate the difference in rankings. In the DEA method, the importance weights of sustainability criteria are calculated according to the decision



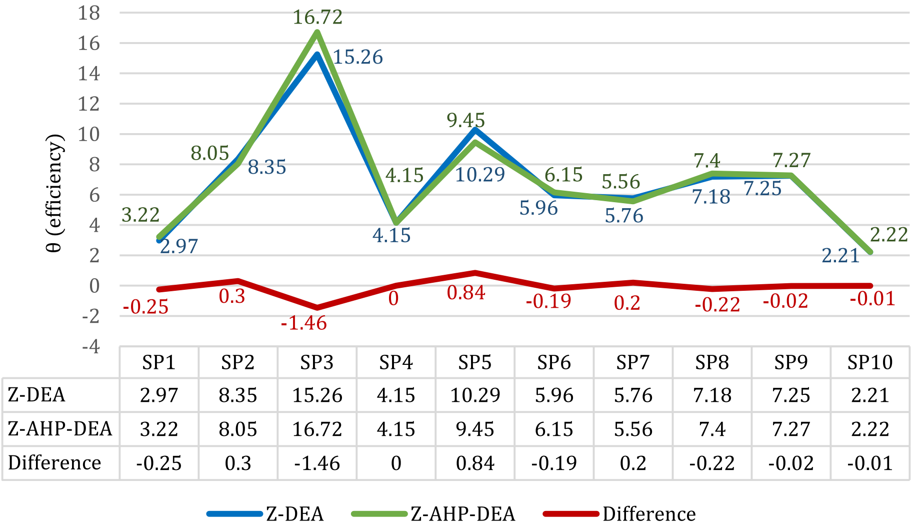
	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
F-DEA	3.18	8.05	10.74	4.49	4.98	5.11	6.88	6.41	4.33	1.93
F-AHP-DEA	3.12	8.04	10.9	4.41	5.03	5.16	6.76	6.33	4.37	1.95
Difference	0.06	0.01	-0.16	0.08	-0.05	-0.05	0.12	0.08	-0.04	-0.02

Fig. 16 Comprasion of F-DEA & F-AHP-DEA Teta

Fig. 17 Comprasion Of F-DEA & F-AHP-DEA Ranking



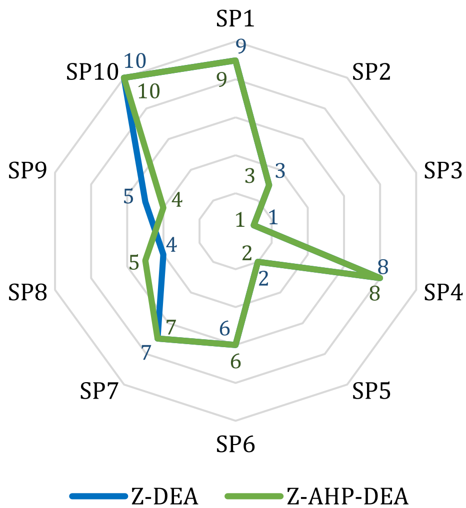
matrix but in the AHP-DEA method, obtained according to the opinions of experts, and will be effective in DEA calculations so that in the AHP-DEA approach, the output of the results will be obtained as a modified weight (weight obtained according to the opinions of experts). Therefore, it will achieve more reliable results by involving the opinions of experts in the AHP-DEA approach. And given that experts mental judgments, both in the pairwise comparison and in the decision-making matrices, always contain uncertainties, so as it shifts from certain approaches to fuzzy and Z-Number, inaccuracy decreases and the level of reliability and confidence in the results Increase. Hence, the Z-AHP-DEA approach can be a suitable and reliable method for calculating



	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
Z-DEA	2.97	8.35	15.26	4.15	10.29	5.96	5.76	7.18	7.25	2.21
Z-AHP-DEA	3.22	8.05	16.72	4.15	9.45	6.15	5.56	7.4	7.27	2.22
Difference	-0.25	0.3	-1.46	0	0.84	-0.19	0.2	-0.22	-0.02	-0.01

Fig. 18 Comprasion Of Z-DEA & Z-AHP-DEA Ranking

Fig. 19 Comprasion Of F-DEA & F-AHP-DEA Ranking



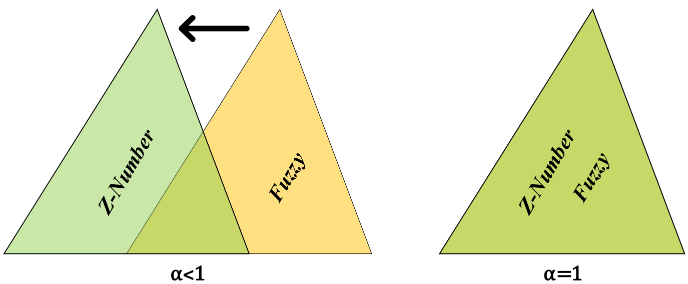


Fig. 20 The situation where $\tilde{A}^z < \tilde{A}$ & $\tilde{A}^z = \tilde{A}$

the efficiency and ranking of projects (according to the level of uncertainty and modified weights of experts).

To validate the proposed Z-AHP-DEA approach, we will validate the following:

1. Z-number
2. Z-AHP
3. Z-DEA
4. Z-AHP-DEA

5.2.1 Z-Number Validation

Z-Number information considers the probability and reliability of fuzzy numbers.

$$\tilde{A}^z = \sqrt{\alpha} \times \tilde{A} = \left[\sqrt{\alpha}d, \sqrt{\alpha}e, \sqrt{\alpha}f\right] = \left[d', e', f'\right]$$

Figure 20 illustrates the situation where $\tilde{A}^z < \tilde{A}$. This situation indicates that, some (or only one) possibility components were less than 1.00, e.g. ([2, 4, 7, 9.5], [0.8, 0.8, 0.9, 1]). It means, the α obtained by $\alpha = \frac{\int x\mu_{\tilde{B}}(x)d_x}{\int \mu_{\tilde{B}}(x)d_x}$ is less than 1.00 ($\alpha < 1$). Obviously, the converted Z-Number will be less than the source. There is also a situation that all possibilities are deterministic and equal to 1.00 e.g. ([2, 4, 7, 9.5], [1, 1, 1, 1]). In similar cases, the Z-Number can be defined as a simple fuzzy set ($\alpha \leq 1$).

Therefore, Z-Number is always less than or equal to its corresponding fuzzy numbers, and because they also take into account the probability of fuzzy numbers, they will therefore be more accurate and reliable. But eventually it becomes fuzzy numbers and they are treated like fuzzy numbers.

5.2.2 Z-AHP Validation

To validate Z-AHP, we review the both approaches and their results. Hence the F-AHP approach according to the article (D.-Y. Chang, 1996) is validation and also according to what is said in the validation section z-number, which treats z-number as fuzzy numbers, so the Z-AHP approach is also validation. Since the incompatibility rate of all questionnaires is below 10%, the results of Z-AHP are also validation.

5.2.3 Z-DEA Validation:

Hence the F-DEA approach according to the article (Lertworasirikul et al., 2003) is validation and also according to what is said in the validation section z-number, which treats z-number as fuzzy numbers, so the Z-DEA approach is also validation.

5.2.4 Z-AHP-DEA Validation

Since in the proposed Z-AHP-DEA approach, the weights of importance DE fuzzed from the Z-AHP approach are multiplied in the decision matrix by Z-Number data, so the result of the decision matrix is multiplied by Z-Number data, which according to what is said in

Table 26 Z-AHP-DEA Validation

Approach	Z-Number	Z-AHP Result	Z-AHP Approach	Z-DEA	Z-AHP-DEA
Validation	behaves like fuzzy Number	incompatibility rate < 10%	Same as F-AHP approach	Same as F-DEA approach	Same as Z-DEA approach

the validation section. Z-number, which treats z-number as fuzzy numbers, so the Z-AHP-DEA approach is also validation (Table 26).

6 Conclusion and future recommendations

6.1 Managerial insight

Organizations and investors are faced with a host of projects and investment opportunities that are a key factor in their growth and survival. Certainly, dynamic economic conditions have made most investors sensitive to the issue of selecting a project portfolio in order to avoid potential losses. Given the limited resources of organizations (capital, manpower, time, etc.), selecting the best project portfolio that meets the goals of organizations (increasing profitability, reducing risk, how to allocate resources, etc.) is one of the challenges which most organizations and investors face it. Selecting a subset of projects in such a situation is a multi-attribute problem, given the priorities, organizational constraints, and interaction between depending projects So that the decision-maker has to select a portfolio of the best projects, taking the various criteria and aspects into account. Dimensions and criteria of sustainability are one of the most important challenges of the present time. Concerns about sustainability suggest that the current way of producing, organizing, consuming, living, etc. may have negative effects on the future. Concisely, the current approach to conduct procedure is not sustainable, so some of it needs to change. Change in organizations, whether, a new manufacturing plant, a new product, a new business process, or a new resource, is often organized as a project; Therefore, it can be concluded that a sustainable society needs projects, and sustainability is related to the project; to have sustainable projects, the principles of sustainability must be considered in the project selection process. Researchers have used a variety of methods to make decisions about choosing sustainable projects. One of the methods that has been considered by researchers in this field is multi-attribute fuzzy decision-making methods that have been developed to deal with complex engineering issues. In such methods, various criteria, multiple decision-makers, as well as environmental uncertainty and mental disabilities of decision-makers have been considered. The Fuzzy logic has many applications in various sciences, one of the most important of which is the interpretation that this science is the structure of intelligent beings' decisions and, above all, human intelligence. Thus, linguistic variables can be better implemented with fuzzy set theory. Fuzzy set theory provides the flexibility needed to demonstrate the uncertainty caused by lack of knowledge and can apply to manage the issue of uncertainty, and inaccurate information in real-world decision-making issues where the value of criteria, options, etc. are not precisely determined. Therefore, under decision-making environment where the value of research criteria and projects has been expressed vaguely and indefinitely, it is possible to use decision-making methods with multiple fuzzy criteria to solve the problem of ranking and selecting research projects. One of these approaches is the AHP method, through which, according to the experts' opinions, we can calculate the importance weight of the criteria and get a mental judgment by experts. Data envelopment analysis, on the other hand, is a useful tool for calculating the efficiency of alternatives and at the same time calculating the weight of criteria, which does not lose its efficiency by increasing the number of alternatives and criteria. DEA approach, which is one of the multi-criteria decision-making methods, is a non-parametric technique for measuring and evaluating the relative efficiency of a set of phenomena (organizations, projects, etc.) with similar inputs and outputs. The reason for the wider acceptance of the DEA method compared to other methods is the possibility of examining the complex and often unknown relationships between several inputs and outputs. Due to the capability of data envelopment analysis method in facing multiple criteria, in several studies, DEA technique has been used to solve financial problems and select stock portfolio and project. Many methods for project selection and evaluation have been proposed using multi-attribute decision making, but the method that can combine the advantages of both DEA and MADM approaches in uncertainty conditions has not yet been studied.

Summary of the results will be as follows:

Selecting and filtering appropriate sustainable criteria for mass and infrastructure companies to select appropriate projects in line with strategic organizational goals.

The importance weights of sustainability criteria obtained by the expert judgments and the pairwise comparison matrix of the AHP approach, considering in the decision-making matrix, will be effective in evaluating and ranking the projects. Therefore, the integrated AHP-DEA approach will have results in line with the judgments of experts compared to the DEA approach.

The results of the AHP-DEA approach under different scenarios including certainty, fuzzy, and Z-Number show different results. Given the uncertainty in judgments of experts, as it moves from certainty to fuzzy and the Z-Number scenario, better demonstration of uncertainty in judgments will emerge. Since the Z-Number approach also takes the reliability of fuzzy numbers into account, it can better demonstrate the uncertain environment and the results obtained from it will be more reliable and closer to the real world. Therefore, the Z-AHP-DEA approach will provide more reliable results.

The limitations of this research can be: 1. Limitation in the number of experts for interviewing and preparing questionnaires and not using group decision-making due to the limitations of the company (only one senior expert has been used) 2. Limitation of expert time to answer the questionnaires Due to the large number of questionnaires, which affected the accuracy of expert answers. 3. Restrictions on access to information and data Candidate projects 4. In this study, a questionnaire was used to apply the proposed approach, so the expert may refuse to provide a real answer and give an unreal answer.

What is important in this research is the proposed Z-AHP-DEA approach and the advantages of using this approach that can be used in project-oriented companies to rank and evaluate their projects based on sustainable criteria and this proposed approach of this research would be suitable tool for decision making in order to select appropriate projects in line with the goals and prospects of that company.

6.2 Findings and future recommendations

Therefore, in this paper considering the importance of the mentioned issues, first, the sustainability criteria were filtered through the questionnaire, and then importance weights were calculated according to the pairwise comparison matrix. Then, according to the decision-making matrix of sustainability indicators, the efficiency of the projects was calculated through the DEA and AHP-DEA approach in certainty, fuzzy and Z-Number conditions, and it established different results and rankings. Based on the obtained results, it can be seen that the more it shifts from certain conditions to fuzzy conditions, and fuzzy conditions by considering the probabilities (Z-Number), the more accurate results are. Using the AHP approach, importance weights of sustainability criteria can be calculated using expert opinions and the obtained results can be used to calculate the efficiency of projects in a modified way to achieve more reliable results. Therefore, the Z-AHP-DEA approach can be a suitable and reliable for calculating the efficiency and ranking of sustainable projects.

In the end, the following topics are suggested as future suggestions:

Considering the internal and external dependencies between the sustainability criteria and calculating importance weights through the Z-ANP approach, as well as calculating the efficiency of projects and ranking them through the Z-ANP-DEA

Taking other criteria such as supplier lifetime value into account along with sustainability criteria

Applying gray numbers to proposed approach and making a comparison with fuzzy and Z-Numbers

Appendix 1

Tables 27, 28, 29, 30, 31, 32, 33, 34.35, 36, 37, 38.

Table 27 Pairwise comparison matrix of the sustainability dimensions with respect to the Goal

Goal	Economic	Social	Environment
Economic		WA	WA
Social			E
Environment			

Table 28 Pairwise comparison matrix for the criteria with respect to the economic dimension

Economic	E1	E2	E3	E4
E1		WA	NB	NB
E2			WA	WA
E3				E
E4				

Table 29 Pairwise comparison matrix for the criteria with respect to the social dimension

Social	S1	S2	S3	S4
S1		E	WA	WA
S2			WA	E
S3				E
S4				

Table 30 Pairwise comparison matrix for the criteria with respect to the environment dimension

Environment	G1	G2	G3	G4
G1		WA	WA	P
G2			E-W	WA
G3				WA
G4				

Table 31 Fuzzy pairwise comparison matrix of the sustainability dimensions with respect to the Goal

Goal	Economic	Social	Environment	Weight
Economic	1	2	2	0.500
Social	0.5	1	1	0.250
Environment	0.5	1	1	0.250

Table 32 Fuzzy pairwise comparison matrix for the criteria with respect to the economic dimension

Economic	E4	E2	E3	E4	Weight
E1	1	2	3	3	0.213
E2	0.5	1	2	2	0.135
E3	0.33	0.5	1	1	0.081
E4	0.33	0.5	1	1	0.072

Table 33 Fuzzy Pairwise comparison matrix for the criteria with respect to the social dimension

social	S1	S2	S3	S4	Weight
S1	1	1	2	2	0.085
S2	1	1	2	1	0.072
S3	0.5	0.5	1	1	0.042
S4	0.5	1	1	1	0.051

Table 34 Fuzzy pairwise comparison matrix for the criteria with respect to the environment dimension

Environment	G1	G2	G3	G4	Weight
G1	1	2	2	4	0.111
G2	0.5	1	1	2	0.056
G3	0.5	1	1	2	0.056
G4	0.25	0.5	0.5	1	0.028
G4					

Table 35 Fuzzy pairwise comparison matrix of the sustainability dimensions with respect to the Goal

Goal	Economic	Social	Environment	Weight
Economic	(1,1,1)	(1,2,3)	(1,2,3)	0.561
Social		(1,1,1)	(1,1,1)	0.219
Environment			(1,1,1)	0.219

Table 36 Fuzzy pairwise comparison matrix for the criteria with respect to the economic dimension

Weight	E4	E3	E2	E1	Economic
0.316	(2,3,4)	(2,3,4)	(1,2,3)	(1,1,1)	E1
0.207	(1,2,3)	(1,2,3)	(1,1,1)		E2
0.019	(1,1,1)	(1,1,1)			E3
0.019	(1,1,1)				E4

Table 37 Fuzzy Pairwise comparison matrix for the criteria with respect to the social dimension

social	S1	S2	S3	S4	Weight
S1	(1,1,1)	(1,1,1)	(1,2,3)	(1,2,3)	0.084
S2		(1,1,1)	(1,2,3)	(1,1,1)	0.068
S3			(1,1,1)	(1,1,1)	0.032
S4				(1,1,1)	0.035

Table 38 Fuzzy pairwise comparison matrix for the criteria with respect to the environment dimension

Environment	G1	G2	G3	G4	Weight
G1	(1,1,1)	(1,2,3)	(1,2,3)	(3,4,5)	0.093
G2		(1,1,1)	(1,1,1)	(1,2,3)	0.054
G3			(1,1,1)	(1,2,3)	0.054
G4				(1,1,1)	0.018

Appendix 2

See Tables 39, 40,41, 42,43, 44

Table 39 Deterministic decision matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	0.98	15	M	H	VH	H	VH	M	VH	M	VH	H
SP 2	1.19	19	VL	VH	M	L	VL	M	VL	VL	H	H
SP 3	1.43	23	H	V H	L	M	H	VH	VL	H	L	VH
SP 4	0.68	11	VH	VL	M	VL	VH	VH	H	H	VH	M
SP 5	1.38	22	VH	VL	L	VL	M	M	VH	VH	L	M
SP 6	0.89	12	H	L	H	M	L	M	M	VH	L	VH
SP 7	1.15	18	M	VL	L	VL	L	VL	H	VL	M	VL
SP 8	1.12	17	M	VL	M	M	M	H	M	M	H	M
SP 9	0.7	11	L	VL	L	VL	M	VH	H	M	L	VL
SP 10	1.4	26	L	M	L	L	VH	L	M	H	H	L

Table 40 Deterministic quantitative decision-making matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	0.98	15	5	7	9	7	9	5	9	5	9	7
SP 2	1.19	19	1	9	5	3	1	5	1	1	7	7
SP 3	1.43	23	7	9	3	5	7	9	1	7	3	9
SP 4	0.68	11	9	1	5	1	9	9	7	7	9	5
SP 5	1.38	22	9	1	3	1	5	5	9	9	3	5
SP 6	0.89	12	7	3	7	5	3	5	5	9	3	9
SP 7	1.15	18	5	1	3	1	3	1	7	1	5	1
SP 8	1.12	17	5	1	5	5	5	7	5	5	7	5
SP 9	0.7	11	3	1	3	1	5	9	7	5	3	1
SP 10	1.4	26	3	5	3	3	9	3	5	7	7	3

Table 41 Normalized Deterministic decision-making matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	0.685	0.577	0.556	0.778	1.000	1.000	1.000	0.556	1.000	0.556	1.000	0.778
SP 2	0.832	0.731	0.111	1.000	0.556	0.429	0.111	0.556	0.111	0.111	0.778	0.778
SP 3	1.000	0.885	0.778	1.000	0.333	0.714	0.778	1.000	0.111	0.778	0.333	1.000
SP 4	0.476	0.423	1.000	0.111	0.556	0.143	1.000	1.000	0.778	0.778	1.000	0.556
SP 5	0.965	0.846	1.000	0.111	0.333	0.143	0.556	0.556	1.000	1.000	0.333	0.556
SP 6	0.622	0.462	0.778	0.333	0.778	0.714	0.333	0.556	0.556	1.000	0.333	1.000
SP 7	0.804	0.692	0.556	0.111	0.333	0.143	0.333	0.111	0.778	0.111	0.556	0.111
SP 8	0.783	0.654	0.556	0.111	0.556	0.714	0.556	0.778	0.556	0.556	0.778	0.556
SP 9	0.490	0.423	0.333	0.111	0.333	0.143	0.556	1.000	0.778	0.556	0.333	0.111
SP 10	0.979	1.000	0.333	0.556	0.333	0.429	1.000	0.333	0.556	0.778	0.778	0.333

Table 42 Deterministic weighted normalized decision-making matrix

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	0.146	0.078	0.045	0.056	0.085	0.072	0.042	0.028	0.111	0.031	0.056	0.022
SP 2	0.177	0.099	0.009	0.072	0.047	0.031	0.005	0.028	0.012	0.006	0.043	0.022
SP 3	0.213	0.119	0.063	0.072	0.028	0.051	0.033	0.051	0.012	0.043	0.019	0.028
SP 4	0.101	0.057	0.081	0.008	0.047	0.010	0.042	0.051	0.086	0.043	0.056	0.015
SP 5	0.205	0.114	0.081	0.008	0.028	0.010	0.023	0.028	0.111	0.056	0.019	0.015
SP 6	0.132	0.062	0.063	0.024	0.066	0.051	0.014	0.028	0.062	0.056	0.019	0.028
SP 7	0.171	0.093	0.045	0.008	0.028	0.010	0.014	0.006	0.086	0.006	0.031	0.003
SP 8	0.166	0.088	0.045	0.008	0.047	0.051	0.023	0.040	0.062	0.031	0.043	0.015
SP 9	0.104	0.057	0.027	0.008	0.028	0.010	0.023	0.051	0.086	0.031	0.019	0.003
SP 10	0.208	0.135	0.027	0.040	0.028	0.031	0.042	0.017	0.062	0.043	0.043	0.009

Table 43 Fuzzy decision matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	(0.84,0.98,1.13)	(13,15,17)	M	H	VH	H	VH	M	VH	M	VH	H
SP 2	(0.93,1.19,1.32)	(17,19,21)	VL	VH	M	L	VL	M	VL	VL	H	H
SP 3	(1,1.43,1.65)	(20,23,26)	H	V H	L	M	H	VH	VL	H	L	VH
SP 4	(0.41,0.68,0.78)	(9,11,13)	VH	VL	M	VL	VH	VH	H	H	VH	M
SP 5	(1.18,1.38,1.67)	(19,22,25)	VH	VL	L	VL	M	M	VH	VH	L	M
SP 6	(0.78,0.89,1.07)	(10,12,14)	H	L	H	M	L	M	M	VH	L	VH
SP 7	(0.95,1.15,1.22)	(16,18,20)	M	VL	L	VL	L	VL	H	VL	M	VL
SP 8	(0.87,1.12,1.4)	(15,17,19)	M	VL	M	M	M	H	M	M	H	M
SP 9	(0.5,0.7,0.88)	(8,11,14)	L	VL	L	VL	M	VH	H	M	L	VL
SP 10	(1.1,1.4,1.8)	(23,26,29)	L	M	L	L	VH	L	M	H	H	L

Table 44 Fuzzy quantitative decision-making matrix of sustainability criteria

SPs	E1	E2	E3	E4	S1	S2	S3	S4	G1	G2	G3	G4
SP 1	(0.84,0.98,1.13)	(13,15,17)	(3,5,7)	(5,7,9)	(7,9,9)	(5,7,9)	(7,9,9)	(3,5,7)	(7,9,9)	(3,5,7)	(7,9,9)	(5,7,9)
SP 2	(0.93,1.19,1.32)	(17,19,21)	(1,1,3)	(7,9,9)	(3,5,7)	(1,3,5)	(1,1,3)	(3,5,7)	(1,1,3)	(1,1,3)	(5,7,9)	(5,7,9)
SP 3	(1,1.43,1.65)	(20,23,26)	(5,7,9)	(7,9,9)	`	(3,5,7)	(5,7,9)	(7,9,9)	(1,1,3)	(5,7,9)	(1,3,5)	(7,9,9)
SP 4	(0.41,0.68,0.78)	(9,11,13)	(7,9,9)	(1,1,3)	(3,5,7)	(1,1,3)	(7,9,9)	(7,9,9)	(5,7,9)	(5,7,9)	(7,9,9)	(3,5,7)
SP 5	(1.18,1.38,1.67)	(19,22,25)	(7,9,9)	(1,1,3)	(1,3,5)	(1,1,3)	(3,5,7)	(3,5,7)	(7,9,9)	(7,9,9)	(1,3,5)	(3,5,7)
SP 6	(0.78,0.89,1.07)	(10,12,14)	(5,7,9)	(1,3,5)	(5,7,9)	(3,5,7)	(1,3,5)	(3,5,7)	(3,5,7)	(7,9,9)	(1,3,5)	(7,9,9)
SP 7	(0.95,1.15,1.22)	(16,18,20)	(3,5,7)	(1,1,3)	(1,3,5)	(1,1,3)	(1,3,5)	(1,1,3)	(5,7,9)	(1,1,3)	(3,5,7)	(1,1,3)
SP 8	(0.87,1.12,1.4)	(15,17,19)	(3,5,7)	(1,1,3)	(3,5,7)	(3,5,7)	(3,5,7)	(5,7,9)	(3,5,7)	(3,5,7)	(5,7,9)	(3,5,7)
SP 9	(0.5,0.7,0.88)	(8,11,14)	(1,3,5)	(1,1,3)	(1,3,5)	(1,1,3)	(3,5,7)	(7,9,9)	(5,7,9)	(3,5,7)	(1,3,5)	(1,1,3)
SP 10	(1.1,1.4,1.8)	(23,26,29)	(1,3,5)	(3,5,7)	(1,3,5)	(1,3,5)	(7,9,9)	(1,3,5)	(3,5,7)	(5,7,9)	(5,7,9)	(1,3,5)

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