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RESEARCH PAPER

Sustainable Project Portfolio Selection Considering Combined Rankings Under Uncertainty: A Case Study

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Abstract

Due to resource limitations such as time, money, and human forces, project-oriented organizations always decide to choose among their candidate projects. In sustainable decision-making, in addition to responding to the internal needs of the organization, responding to social needs and protecting the environment are also taken into consideration. More specifically, in sustainable project selection, projects are selected with a wider view including economic, social, and environmental pillars. In this article, a combined approach has been presented to select investment projects sustainably, determining the ranking of projects based on the combined output of several multi-attribute decision-making methods. Since the data needed in decision-making is often associated with uncertainty, the problem of project selection has been modeled and analyzed in a non-deterministic way using a robust optimization approach. In the studied case, six projects were selected by the deterministic model, while the robust model reduced them to three projects due to the pessimistic modeling approach. It was also observed that by taking into account the uncertainty, the optimal values of three objective functions have been reduced by 28%, 46%, and 28% respectively; but the validity of the answers is guaranteed in non-deterministic real-world situations, which is very important in the investment problems. The main benefits of the proposed approach are: 1) integrating evaluation and selection phases in order to make wise and optimal decisions, 2) combining the results of different MCDM methods which helps the managers with selecting the projects that are generally acceptable by MCDM methods, 3) because a robust optimization model is implemented, the model solutions remain more feasible in resource fluctuations, and 4) the model prevents ignoring high-priority projects which can be outranked by permutations of lower-priority projects.

Keywords:
Project selection; Combined rankings; Project portfolio; Sustainability

Introduction

Project-oriented organizations face a strategic problem called project portfolio selection where they seek to choose projects that firstly meet the strategic goals of the organization and secondly satisfy their limitations; e.g., human resources, cost, equipment, and other resources. Allocating the organizational resources to inappropriate projects leads to the loss of investment opportunities in other projects. Choosing the project portfolio is one of the challenging issues of decision-making in these organizations [1]. In most relevant research, the optimality of projects has been considered from an economic point of view while global issues such as global warming, environmental laws, and damages to the environment have received less attention. Published researches mainly focus on economic, cost, and quality issues and focus less on the

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long-term effects that jeopardize the sustainability of the selected projects [2].

The concept of sustainability has three aspects including economic, environmental, and social dimensions [3] which are considered in this article. A number of development projects in Yazd province have been considered as a case study.

Although several efforts have been made regarding the comprehensive development of Yazd province, the following pieces of evidence show that it is still facing challenges in social and environmental aspects [4] and [5]:

- There has been a high rate of immigration due to the execution of many industrial projects that each require a large number of workers. As a result, Yazd province is the third province in Iran in the rate of accepting immigrants [6]. For this reason, many social and cultural problems have been imposed on the province [7];
- According to published statistics, 12.8% of people in Yazd province who are able to work are currently unemployed. Additionally, nearly 40% of the unemployed in Yazd province are people with high education;
- Although the rapid growth of industries has been aimed at meeting the economic needs and employment of the growing population, it has caused the spread of toxic and polluting substances in the environment [8];
- Another issue that has been raised in the province is the lack of water. The two main factors of rapid population growth and urbanization on one hand and industrial and agricultural development on the other hand, have not only increased the need for water consumption - especially drinking water- but also led to a reduction in water resources [4];
- According to the statistics announced by the meteorological department of Yazd province, the area affected by the drought of the entire province in 2018 is equal to 61.3% [7].

Fig. 1 shows some factors causing the unsustainable development of Yazd province.

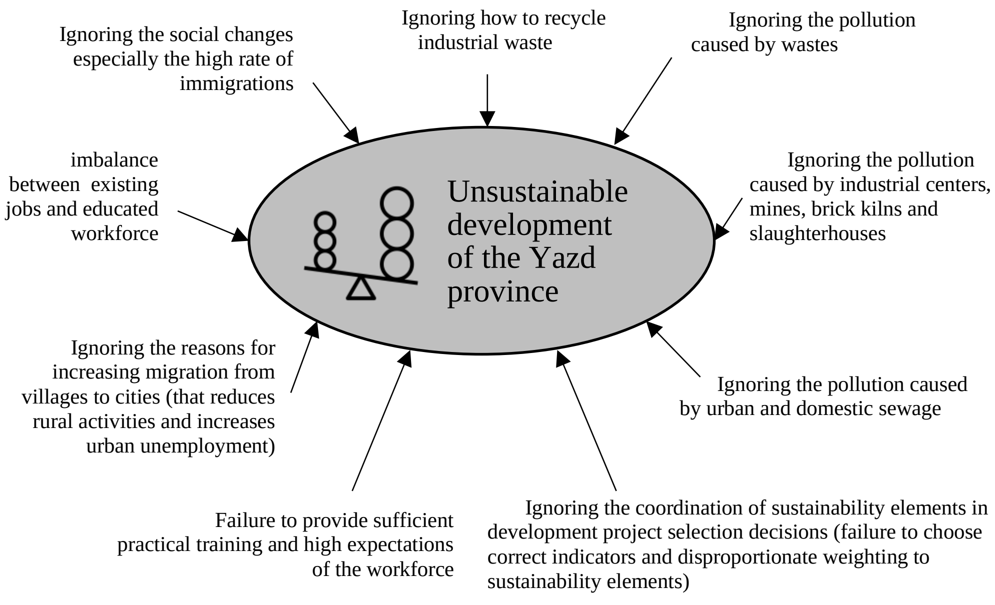

Figure 1. Some of the issues shaping the unsustainable development of Yazd province.

Among the problems shown in Fig. 1, the focus of this article is on the problem of "Ignoring the coordination of sustainability elements in development project selection decisions". This paper suggests several sustainability indicators that can be used in the selection of investment projects and proposes a combined MCDM approach for ranking candidate projects based on these criteria. Then, a robust optimization model is formulated for selecting the optimal combination of candidate projects.

The rest of this paper is organized as follows: The second section reviews the relevant literature. The third section introduces the proposed method and the results are presented in the fourth section. Finally, the resulting managerial insights and conclusions are presented in the fifth and sixth sections.

Problem Definition

In the project selection problem, the objective is to identify the most suitable projects to pursue given limited resources and industry standards. This challenge is particularly complex as it involves making decisions based on multiple criteria and balancing various factors. The selection process typically involves evaluating projects based on a set of indicators or criteria. By considering a wide range of indicators, decision-makers aim to gain a comprehensive understanding of each project's strengths and weaknesses and make informed choices. Sustainability considerations play a crucial role in the project selection process. They encompass economic, social, and environmental aspects, reflecting a broader perspective beyond immediate financial gains. Economic sustainability involves assessing the long-term financial viability and potential profitability of a project. Social sustainability considers the impact on communities, stakeholders, and society at large, focusing on aspects such as job creation, social equity, and community development. Environmental sustainability evaluates the project's ecological impact, including factors like resource consumption, pollution, and carbon emissions. To incorporate these sustainability considerations into the project selection process, evaluation indicators must be derived. These indicators serve as measurable metrics that capture the performance and alignment of each project with sustainability goals. By employing a comprehensive set of evaluation indicators, decision-makers can effectively compare and prioritize projects based on their sustainability performance. The goal is to select projects that not only align with industry standards and resource limitations but also demonstrate a commitment to sustainable development and positive societal and environmental outcomes. This approach helps organizations and stakeholders make informed decisions that balance the present needs with the long-term well-being of society and the environment.

Literature Review

Several researches have been conducted in the field of sustainable project selection and some of the most important of them are reviewed here. Frini & BenAmor have used a multi-period multi-criteria decision-making method for the sustainable project selection problem [9]. The weight of sustainability indicators in this article is done through pairwise comparisons and ranking of projects by the TOPSIS method. The sustainability indicators examined in this article are the volume of 5-year exploitation of projects, the amount of carbon dioxide left in the environment, preventing the destruction of old forest areas, and economic issues. Kudratova et al. have examined sustainability criteria from two environmental and economic perspectives. Kudratova et al. have discussed a method for robustness evaluation in the performance evaluation issues of low-energy buildings using scenario analysis [10].

They have presented a quantitative approach to reach a framework for sustainable project selection. The economic dimension of sustainability is considered a competitive advantage booster. The environmental dimension also emphasizes protecting the environment and reducing the use of energy, raw materials, and land. A multi-criteria decision-making approach is used to combine different economic and environmental dimensions and obtain a quantitative output. The mentioned study has been used in a financial institution to choose the best area for investment concentration. Khalili-Damghani & Sadi-Nezhad designed a decision support system for sustainable multi-objective project selection problems with multiple time horizons

[11]. They used the TOPSIS method based on fuzzy programming to consider the uncertainty of decision-making on the priority of goals. Two main modules are used: the first module specifically considers economic indicators such as cost, profit, budget, availability of resources, utilization of resources, and rate of return on investment. The result obtained from economic issues and effective factors such as social issues, environmental issues, investor risk, alignment with strategy, and organizational readiness has been used as the input of a fuzzy system to estimate the investor's risk fitness function in the second module. In another article, Khalili-Damghani & Sadi-Nezhad presented a combined decision-making approach where weights of criteria are obtained with a fuzzy method and preference rate is obtained using the fuzzy TOPSIS method, and finally, a combined method is presented for ranking the projects by considering the sustainability. The main criteria of sustainability include economic, social, and environmental issues, investor risk, alignment with strategy, and organizational readiness [12]. Mavrotas et al. presented an approach to investigate the robustness of the solutions in sustainable project selection problems [13]. Jalili Bal et al. [14] used quality control methods for identifying effective factors of sustainability in the selection of project portfolios. The economic, social, and environmental factors have been identified, and then the relationships between the identified factors have been determined using the DIMATEL method.

Jalili Bal et al. [15] presented a combined decision-making method for prioritizing the portfolio of construction projects considering sustainable criteria which the lexicographic method is first used for weighting the sustainability criteria and pairwise comparisons are considered in intervals. The sustainability criteria and the weight obtained from the lexicographic method are used to prioritize construction projects using the VICOR method. His proposed method has been implemented in a study of several refinery projects.

Several researchers have also used multi-criteria decision-making methods to select projects, the most important of which have been reviewed here. Ferreira et al. have used the combination of Fuzzy ELECTRE and Fuzzy TOPSIS methods to select investment projects for the industrial reconstruction of a small oil company in Brazil [16]. Lee & Chang [17] have used multi-criteria decision-making methods and presented a comparative analysis of the ranking of renewable energy sources for electricity generation in Taiwan. In order to evaluate the weight of each criterion in decision-making, Shannon's entropy method was used and to prioritize the projects, several multi-criteria decision-making methods such as WSM VIKOR, TOPSIS, and ELECTRE were used. Yazdani & Hasanpour [18] have studied the prioritization and selection of projects in a private joint-stock company using the ANP model where a field study of the criteria is conducted and the necessary sub-criteria for prioritizing and selecting the projects from economic and social aspects were obtained, and then the process of network analysis is used to prioritize the projects. Naderi & Qodsipour selected projects using several multi-criteria decision-making methods [19]. Naderi et al. [20] have determined the optimal portfolio of Dana Industrial Group projects. A multi-criteria decision-making method has been used to select their projects. Behravesh et al. [21] used the AHP method to focus on the internal and external risks of the portfolio and determine criteria weights using experts' opinions. Then, projects have been selected and prioritized by using the TOPSIS method in Fanap Holding.

Babazadeh & Ajrian considered mutual effects between projects in a linear programming model under uncertainty [22]. The obtained results show that considering the mutual effects of projects on each other has created better performance in project selection problems which increases synergy and prevents the selection of projects that conflict with each other.

Ebnerasoul et al. [23] proposed a two-objective sustainable optimization model with two objective functions and a series of constraints that help organizations choose the best portfolio in terms of efficiency, risk, and criticality compared to other possible portfolios. Jurík et al. [24] implemented the AHP MCDA method to select projects considering sustainable perspectives. Mohagheghi et al. [25] proposed a sustainable project portfolio selection and optimization model with considerations of outsourcing decisions, financing options, and staff assignment under uncertainty. Swarnakar et al. [26] used the best-worst MCDA method for sustainable project selection in manufacturing environments.

Table 1 summarizes the reviewed research papers and their main characteristics compared to the present paper.

The identified research gaps are:

- None of the reviewed research papers compared different MCDM methods and combined the ranks obtained from them;
- None of the reviewed research papers tackled both MCDM and optimization phases;
- None of the reviewed research papers considered augmented scores in order to prevent selecting permutations including less-desirable projects instead of high-priority projects;
- Indicators such as taxes due to environmental pollution and sustainable development discounts have not been investigated in the previously published research papers.

Compared to the reviewed research papers, the contributions of this research are as follows:

- A large number of ranking methods have been examined and a combined ranking method has been proposed;
- To ensure the selection of high-priority projects, first the ranks were calculated in an augmented form and then they were fed as input to the optimization model;
- Sustainable development discount is considered in model formulation.

Proposed Method

The implemented research method includes the following phases:

1. Calculating initial ranks of projects based on different MCDM methods;
2. Providing combined ranks;
3. Calculating augmented ranks;
4. Choosing the optimal sustainable project portfolio considering the uncertainty.

The details of each of these steps are illustrated in Fig. 2.

To investigate the problem in a real-world situation, 10 investment projects in Yazd province were tested, which were proposed by one of the government organizations of the province and were under consideration, then as shown in Table 2, the criteria and sub-criteria for the evaluation of the projects from the perspective of sustainability were selected with the participation of the following experts:

- Vice president of management and planning organization of Yazd province, Head of planning, budgeting, organization, and administrative modernization department of Yazd governorate,
- President of Yazd Science and Technology Park,
- Strategic management consultant of Yazd municipality and member of Yazd province development steering council, and
- Some members of the productivity promotion working group of Yazd province.

At the same time, their weighting was determined via pairwise comparisons by the above experts. Having K experts, a weight w_k was considered for each of the experts based on their knowledge and experience level from 1 to 3, i.e., moderate to high experience levels, and the opinions of the experts were combined using Eq. (1) where a_{ik} is the k^{th} expert's opinion regarding the i^{th} index.

$$a_i = \sqrt[\sum_{k=1}^{K} w_k]{\prod_{k=1}^{K} a_{ik}^{w_k}} \; \forall i \tag{1}$$

Table 1. Summary of reviewed research

Ref. #	Author(s)	Year	Tackled phases: MCDA	Tackled phases: Opt.	MCDA method	Opt. method	Uncertainty	Case study	Projects type	Country / Region
[9]	Frini & BenAmor	2015	✓	×	TOPSIS	Not considered	×	Forest mgmt.	Alternative decisions	Canada
[10]	Kudratova et al.	2020	×	✓	Not considered	Linear programming	✓	Asian Dev. Bank	Development	Asia
[11]	Khalili-Damghani & Sadi-Nezhad	2013	✓	✓	Fuzzy TOPSIS	Fuzzy optimization	✓	Financial and credit	Investment chances	Iran
[12]	Khalili-Damghani & Sadi-Nezhad	2013	✓	×	Fuzzy TOPSIS	Goal programming	✓	Financial and credit	Investment chances	Iran
[13]	Mavrotas et al.	2016	×	✓	Not considered	Robust optimization	✓	Not considered	-	-
[14]	Jalili Bal et al.	2016	✓	✓	AHP	Linear programming	×	Oil refinery	Construction	Iran
[15]	Jalili Bal et al.	2018	✓	×	VIKOR	Not considered	×	Not mentioned	Not mentioned	Iran
[16]	Ferreira et al.	2016	✓	×	Fuzzy-ELECTRE & Fuzzy-TOPSIS	Not considered	✓	Oil refinery	Restructuring alternatives	Brazil
[17]	Lee & Chang	2018	✓	×	WSM, VIKOR, TOPSIS, & ELECTRE	Not considered	×	Renewable energy development	Renewable energy sources	Taiwan
[18]	Yazdani & Hasanpour	2016	✓	×	ANP	Not considered	×	Power distribution	Power supply	Iran
[19]	Naderi & Qodsipour	2018	✓	×	TOPSIS	Not considered	×	Education ministry	Monitoring plans	Iran
[20]	Naderi et al.	2019	✓	×	TOPSIS	Not considered	×	ICT holding	New product dev.	Iran
[21]	Behravesh et al.	2018	✓	×	AHP & TOPSIS	Not considered	×	Telecommunication	IT & Marketing	Iran
[22]	Babazadeh & Ajrian	2016	✓	✓	MAUT	Integer programming	✓	Not considered	-	-
[23]	Ebnerasoul et al.	2022	×	✓	Not considered	DEA + Bi-objective approach	✓	Accelerator company	New ideas	Iran
[24]	Jurík et al.	2022	✓	×	AHP	Not considered	×	Not mentioned	Production	Slovakia
[25]	Mohagheghi et al.	2022	×	✓	Not considered	Fuzzy optimization	✓	Not considered	-	Iran
[26]	Swarnakar et al.	2023	✓	×	Best-worst method	Not considered	×	Automotive manufacturing	Assembly lines	India
	This paper		✓	✓	AHP, VIKOR, TOPSIS, PROMETHEE, and their aggregations	Robust optimization	✓	Yazd province	Development	Iran

Table 2. Selected criteria and sub-criteria of sustainability in the problem of project selection.

Criteria	Sub-criteria
Economic	Project Net Present Value (NPV) Internal Rate of Return (IRR) The total investment in Riyals Total foreign exchange investment
Environmental	Annual water consumption Annual electricity consumption Annual gas consumption Pollution level
Social	Forecasting direct employment Indirect employment forecast

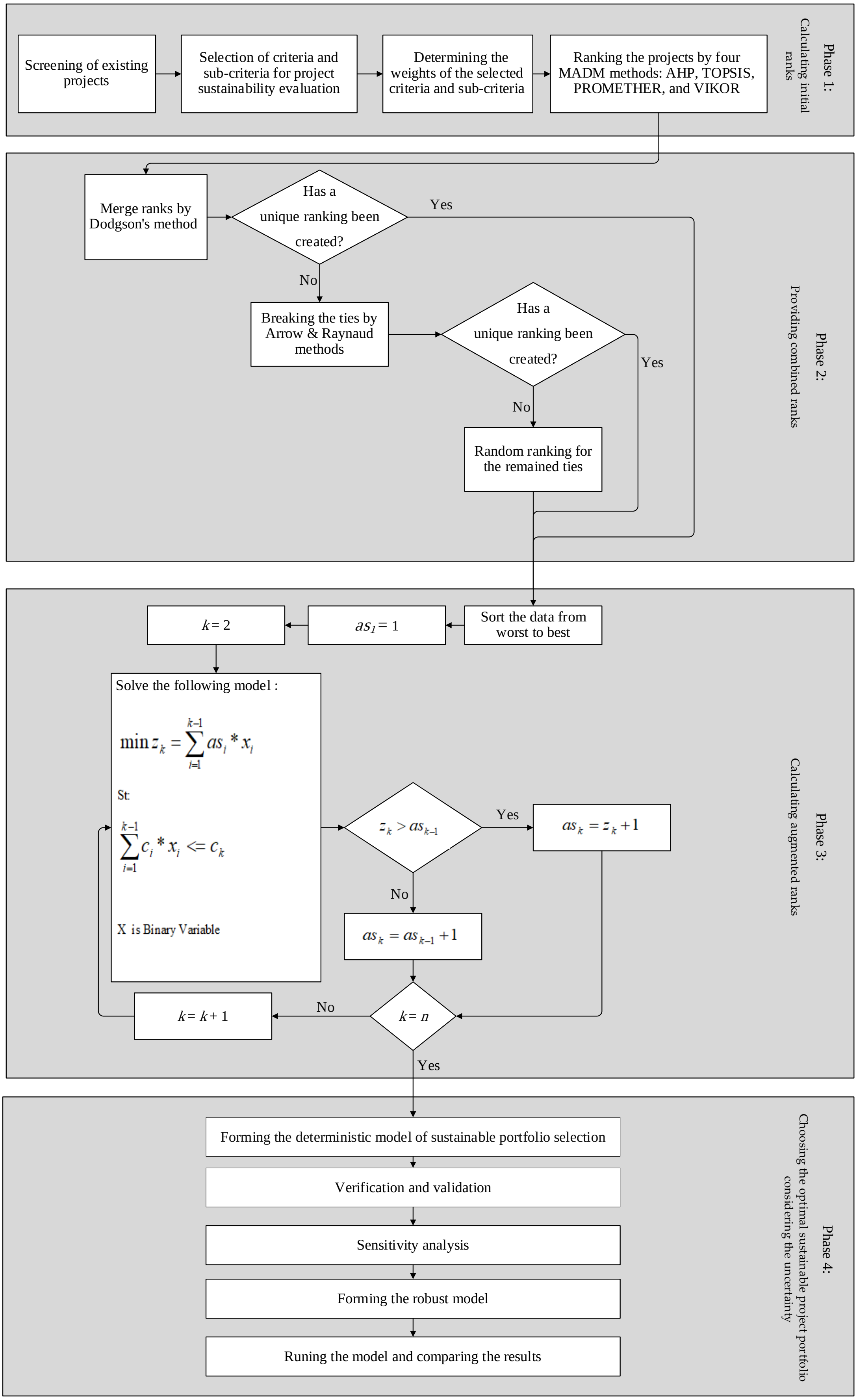

Figure 2. Framework of research method.

Table 3 shows the final weights considered for each of the evaluation indicators.

Table 3. Criteria weight and sub-criteria of sustainability of the project selection problem.

Criteria	Weight of criteria	Sub-criteria	Weight of sub-criteria
Economic	0.202679924	NPV	0.039857230
		IRR	0.046175988
		Total fixed capital	0.058323353
		Total working capital	0.058323353
Environmental	0.428401625	Annual water consumption	0.256868783
		Annual electricity consumption	0.055058764
		Annual gas consumption	0.024330573
		Pollution level	0.092143505
Social	0.368918451	Direct employment opportunities	0.262485710
		Indirect employment opportunities	0.106432741

The projects were ranked based on AHP, VIKOR, TOPSIS, and PROMETHEE MADM methods where their results are described in the next section. It should be mentioned that these MCDM methods are the most popular MCDM methods in reviewed project selection papers.

Different MADM methods may result in different ranks. So, after determining the ranks via four MADM methods, several combination methods including arithmetic mean, Borda [27], Copeland [28], Kemeny [29], Maximum, Dodgson [30], Köhler [31], and Arrow & Raynaud [32] were tested for combining the resulted ranks.

Because different combination methods may also produce different results, another combination method should also be used for integrating the results of combination methods. As shown in Fig. 2, final rankings have been determined firstly via the Dodgson method based on the following reasons:

Dodgson's method is an improvement of Copeland's method, which is itself an improvement of Borda's method among the methods of providing combined ranks;

Dodgson's method behaves more moderately compared to methods such as Kohler and Arrow and Raynaud because Kohler's method has an optimistic view and Arrow and Raynaud's methods have a strict view, but Dodgson's method has a more balanced approach than these approaches.

Then, if the same ranking is obtained by Dodgson’s method, the Arrow & Raynaud method is used to generate the final rankings, because the Arrow and Raynaud method has a stricter view compared to other methods.

Finally, if still there are duplicate rankings, the random rankings are calculated for duplicate values.

After ranking the projects based on the proposed framework, the augmented rankings of the projects have been calculated. The augmented rankings are based on an optimization model developed by Mavrotas et al. [33] as shown in Fig. 2. The augmented rankings ensure that high-priority projects are selected and different permutations of less desirable projects cannot prevent them from being selected.

The optimization model of this research utilizes the backpack model used by Mavrotas et al. [33] which is described below where the objective functions and constraints are adopted from the original model.

The notations used in the optimization model are as follows:

Sets

i All candidate projects (i=1, 2, …, 10)

SA hotel projects ($SA \in i$)

SB food industry projects ($SB \in i$)

Parameters

$TNCF_i$ Income from the product of project i

$BUDG_i$ Total costs during the project i

TGT_i The amount of green tax in project i (caused by electricity and gas consumption)

TW_i Tax discount in project i (due to the creation of direct and indirect employment)

AS_i Augmented rank of the project i

W The total available budget for investment in all projects

Decision variables

x_i Binary variable indicating project i is selected (equal to 1) or not (equal to zero)

npv Total net worth of selected portfolio

tr Total score of portfolio projects

ts Green tax discount of the selected portfolio

In the proposed model, three objectives are defined for the problem, which include: 1) increasing the net investment value of the portfolio of projects, 2) increasing the enhanced total score of the selected projects in the portfolio, and 3) reducing the amount of green tax of the project portfolio. As for objective (2), the goal is to maximize the net value of the portfolio investment, which is obtained from the difference between the income and expenses of the projects.

$$\text{maximize}\, npv = \sum_i TNCF_i\, x_i - \sum_i BUDG_i\, x_i \tag{2}$$

Eq. (3) tries to select projects with higher augmented scores proposed by Mavrotas et al. [33].

$$\text{maximize}\, tr = \sum_i AS_i\, x_i \tag{3}$$

Eq. (4) is to increase the difference between the sustainable development discount and the amount of green tax paid in the project.

$$\text{maximize}\, ts = \sum_i TW_i\, x_i - \sum_i TGT_i\, x_i \tag{4}$$

The constraints of the problem are shown in Eqs. (5) to (7) based on Mavrotas et al. [33]. In Eq. (5), the available budget limit for the execution of projects is imposed.

$$\sum_i BUDG_i\, x_i \le W \tag{5}$$

Because of a legal restriction set by the local government, a maximum of 20% of the total available budget must be assigned to type-A projects. Eq. (6) sets a budget-based limit for the selection of type-A projects based on this restriction.

$$\sum_{i \in S_A} BUDG_i \, x_i \leq 0.2W \tag{6}$$

Eq. (7) restricts the selection of type B projects to make up at least 30% of the total number of selected projects.

$$\sum_{i \in S_B} x_i \geq 0.3 \sum_i x_i \tag{7}$$

As mentioned before, because of uncertainty in some parameters, the problem is modeled as non-deterministic. According to the opinion of the experts in the investigated case sample, a percentage of fluctuation is determinable for each uncertain parameter. So, the method of Bertsimas & Sim [34] with an interval limit has been used.

A sensitivity analysis has been conducted and according to its results which are presented in the fourth section, the parameters $TNCF_i$, $BUDG_i$, TW_i, and TGT_i are considered non-deterministic parameters. Therefore, Eqs. (2), (4), (5), and (6), which contain the above-mentioned parameters, are transformed into non-deterministic Eqs. (8) to (11), respectively:

$$\text{maximize } npv = \sum_i TNCF_i \, x_i - \sum_i \text{BUDG}_i \, x_i \tag{8}$$

$$\text{maximize } ts = \sum_i TW_i \, x_i - \sum_i TGT_i \, x_i \tag{9}$$

$$\sum_i BUDG_i \, x_i \leq W \tag{10}$$

$$\sum_{i \in S_A} BUDG_i \, x_i \leq 0.2W \tag{11}$$

The resulting non-deterministic model includes Eqs. (3), (7), and (8) -(11). In order to solve this model, it is necessary to form the counterpart deterministic model for Eqs. (8) to (11).

The robust counterpart of the above Eqs. based on Bertsimas and Sim [34] will be equivalent to each of the above four equations. For this purpose, Eq. (8) will be replaced by Eqs. (16) to (19).

$$\sum_i TNCF_i x_i + \Gamma q + \sum_i p_1^i - \sum_i BUDG_i x_i + \Gamma q + \sum_i p_2^i \geq npv \tag{12}$$

$$p_1^i + q \leq TNCF_i x_i \forall\, i \tag{13}$$

$$p_2^i + q \leq BUDG_i x_i \forall\, i \tag{14}$$

$$p_1^t . p_2^t . q \geq 0 \tag{15}$$

Similarly, Eq. (9) will also be replaced by Eqs. (16) to (19).

$$\sum_i TW_i x_i + \Gamma q1 + \sum_i \text{p}_{1\_2}^i - \sum_i TGT_i x_i + \Gamma q2 + \sum_i \text{p}_{2\_2}^i \geq ts \tag{16}$$

$$p_{1\_2}^i + q1 \leq TW_i x_i \forall\, i \tag{17}$$

$$p_{2\_2}^i + q2 \leq TGT_i x_i \forall\, i \tag{18}$$

$$p_{1\_2}^t . p_{2\_2}^t . q \geq 0 \tag{19}$$

Eq. (10) will also be replaced by Eq. (20).

$$\sum_i BUDG_i x_i + \Gamma q + \sum_i p_2^i \leq W \tag{20}$$

Finally, Eq. (11) is equated with Eq. (21).

$$\sum_{i \in S_A} BUDG_i x_i + \Gamma q + \sum_i p_2^i \leq 0.2W \tag{21}$$

With these explanations, the counterpart deterministic model for the non-deterministic model of the problem is in the form of Eqs. (3), (7) and (12)-(21).

Results

After applying various multi-attribute decision-making methods, the ranks of the candidate projects were obtained as described in Table 4. As shown in this table, the ranks obtained from different methods are different, and this issue shows the necessity of combining the resulting rankings.

Table 4. Ranking of projects based on four MADM methods.

Project Name	PROMETHEE	AHP	TOPSIS	VIKOR
Korshid Yazd hotel	4	4	2	4
Jahanfar hotel	7	7	10	7
Yazd chicken production, processing, and supply chain	3	3	1	3
Yazd packaging and processing of dates	5	5	6	5
Yazd hybrid seeds of vegetables and legumes	10	10	3	10
Yazd hydroponics greenhouse	8	8	4	8
Yazd specific software	2	2	5	2
Production of ATM machines	6	6	9	6
Omid Yasin Hospital	1	1	7	1
Yazd electrical-medical equipment	9	9	8	9

After applying the proposed combined ranking shown in Fig. 2, the results are obtained as described in Table 5.

Table 5. Final rankings based on the proposed integrated method.

Row	Name of the project	Final rating
1	Korshid Yazd hotel	4
2	Jahanfar hotel	6
3	Yazd chicken production, processing, and supply chain	2
4	Yazd packaging and processing of dates	7
5	Yazd hybrid seeds of vegetables and legumes	10
6	Yazd hydroponics greenhouse	8
7	Yazd specific software	3
8	Production of ATM machines	5
9	Omid Yasin Hospital	1
10	Yazd electrical-medical equipment	9

In order to identify the parameters that should be modeled non-deterministically, the sensitivity analysis of the parameters was done. As an example, the results for the income parameter are shown in Table 6.

Table 6. Results of the sensitivity analysis for income parameter.

Status	Optimum value of:		
	npv	*tr*	*ts*
Most-likely income values	4.65240E+13	78000	2.32562E+11
Optimistic income values	6.25458E+13	78000	2.32562E+11
Pessimistic income values	3.13200E+13	78000	2.32562E+11

According to Table 7, the increase and decrease of approximately 30% in the project's income parameter has led to a 34% increase and a 32% decrease in the value of the first objective function, respectively. Therefore, the parameter is modeled non-deterministically.

After determining the augmented scores, the deterministic optimization model equivalent to the robust model including Eqs. (3), (7), and (12) -(21) is solved by the augmented epsilon-constrained method [33]. The resulting efficient frontier is obtained in the form of points shown in Fig. 3.

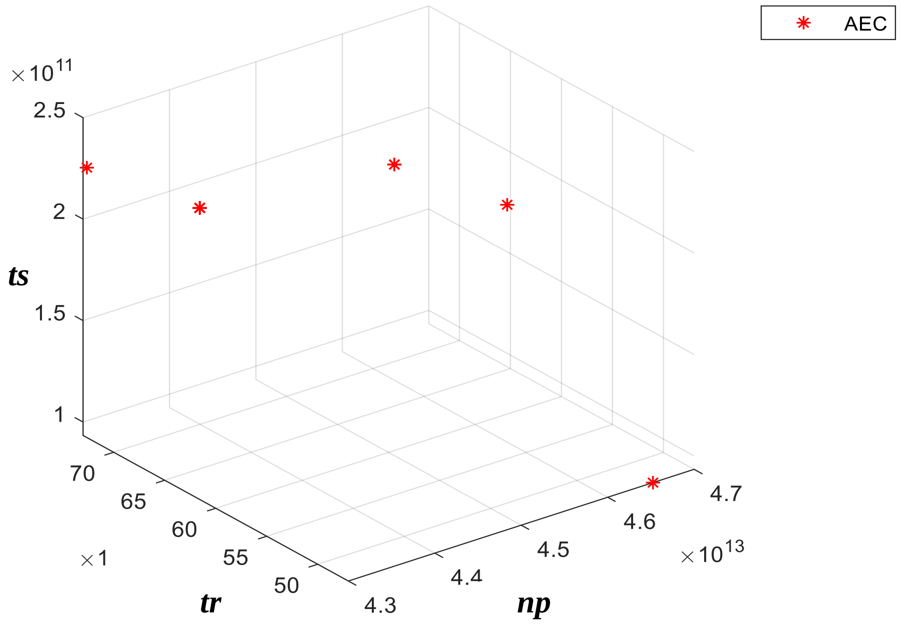

Figure 3. The Pareto-optimal (efficient) results.

After finding the efficient frontier shown in Fig. 3, it is possible to propose the optimal solutions desired by each decision-maker. For this purpose, the chart of efficient points is presented to the decision-maker, according to the priorities of the objective functions. Then the selected projects corresponding to his/her desired point are considered for execution. For example, projects 1, 4, 7, 8, 9, and 10 have been selected in the project basket equivalent to point A in Fig. 3, and the corresponding objective function of the deterministic model is shown in Table 7.

Table 7. Values of objective functions for deterministic model equivalent to point A.

Objective function variable	*npv*	*tr*	*ts*
Optimal value	4.63654E+13	71	1.86114E+11

Applying the same preferences, the optimal solution of the robust model consists of projects 4, 8, and 10 and the related objective function values are shown in Table 8.

Table 8. Objective function values of the robust model.

Objective function variable	*npv*	*tr*	*ts*
Optimal value	3.36001E+13	38	1.33285E+11

Managerial Insights

The managerial insights of this research can be reported as follows:

- In sustainable project selection in organizations, it is possible that some suitable indicators be ignored and will show their impact in the future. In this research, the relevant research in the project selection problem has been reviewed and several indicators have been suggested for sustainable project selection;

- Different MADM methods lead to the confusion of managers when choosing a final prioritization. In this research, a combined approach is presented that calculates combined rankings;
- The available budget, cost, and income of the project cannot always be predicted with certainty and sometimes fluctuates due to the economic conditions prevailing in society. In this research, the available budget, costs, and revenues of the projects have been considered non-deterministic. This approach provides a higher compatibility with the real conditions of the project selection problem;
- Traditional project selection methods have a common weakness in that the combination of several undesirable projects can outperform one or more desirable project(s) due to lower cost bias. In this paper, augmented scores [33] are used, which overcomes the above-mentioned weakness.

Conclusions

Although paying attention to the environmental and social issues of the projects are important in the selection of development projects; they have received less attention in most of the published papers. In this article, an approach is proposed for choosing investment projects with a sustainability perspective and also considering the uncertainty in the given data. The most important contributions of this research are as follows:

- A combined rankings method is proposed with a logical combination of the obtained results;
- A multi-objective robust optimization model is proposed for sustainable project selection problem;
- Several indicators have been suggested for sustainable project scheduling problem;
- Augmented scores of candidate projects are calculated and fed into the robust optimization model;
- Sustainable development discounts and taxes due to environmental pollution are considered in the project selection.

The main research limitations were about the required data including the effect of pollution on green taxes and also the pollution that will be emitted by different projects that have been considered relatively in this research.

Several future research opportunities are possible: 1) The data related to the projects can be examined in the form of uncertain scenarios. 2) The problem can be compared with other robust optimization methods such as Mulvey et al. [35] which is used for scenario-based data. 3) it is suggested that the amount of water consumption during the construction of the project be estimated and included in the calculation of the green tax of the projects, and 4) specific industry-related indicators can be included in the ranking of projects like pharmacy, hoteling, agriculture, and etc., and 5) other MCDM rank combining algorithms can be tested.

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