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An MCDM Method with Dynamic Weights for Investment Project Selection

Abstract. *The investment projects evaluation and selection problem is a very important and common decision-making issue for enterprises. In general, enterprises will recruit experts for a committee to review many of the quantitative and qualitative factors in the selection process of investment projects. In the face of uncertain environments, experts may reasonably use interval linguistic variables to express their subjective evaluations of investment projects with respect to each criterion. This study presents a dynamic mechanism to objectively compute the weight of each criterion, and proposes a new MCDM method to determine the ranking order of all investment projects by combining the three indices of performance index, special superior index, and regret index. In order to illustrate the effectiveness of the proposed method, this study compares the project ordering results of the proposed method with the ordering results of other MCDM methods. Based on the results, the proposed model can provide more objective, flexible, and robust results to make decisions for the evaluation of investment projects. Finally, the conclusions and future research directions are discussed in the final section.*

Keywords: *investment project selection, MCDM, interval linguistic variables, dynamic weights.*

JEL Classification: C02, C11, C45, C46, C63.

1. Introduction

When individuals and companies make investment decisions, they expect a satisfactory return on their investment, which depends on selecting the best investment from among many alternatives, thus, the investment project evaluation and selection problem is a very important and common decision-making issue for enterprises. Methods such as net present value (NPV), payback period, and internal rate of return are the common methods used in the evaluation of investment alternatives. It is possible to say that the most preferred method among them is NPV. The net present value of a project can be calculated by deducting the initial

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investment from the present value of the project's cash flows, which have been discounted at a rate equal to the firm's cost of capital (Gitman and Zutter, 2015). The important elements in the NPV calculation are the cash flow amounts and the discount rate. Thus, the result depends on the cash flow estimation and the discount rate. Recently, Brusov et al. (2021) indicated that NPV can also be affected by the number of payments of tax on income and of interest on debt. Later, Filatova et al. (2022) investigated the effect of advanced payments of tax on the profit on effectiveness of investments. These studies evaluated the investment projects from a financial point of view. However, there are also other issues that need to be taken into account, such as the political circumstances, the general condition of the market, and environment issues, which may affect the performance of the investments. Evaluation of investment projects can be applied with multi-criteria decision-making methods. In general, an enterprise will recruit experts for a committee to review the many quantitative and qualitative factors that occur in the selection process for investment projects. Therefore, investment project selection can be regarded as a group multi-criteria decision-making (GMCDM) problem. For this reason, the aim of this paper is to develop a new group MCDM approach to deal with the problems of investment projects selection.

TOPSIS (Hwang and Yoon, 1981), the Analytic hierarchy process (AHP) (Saaty, 1980), and VIKOR (Opricovic, 1998) are the most popular MCDM methods. To date, MCDM methods have a wide range of applications for the risk assessment, selection, and evaluation of various projects and investments. For example, Yong (2006) proposed the fuzzy TOPSIS method for plant location selection. Wang and Liu (2007) conducted a study on logistic centre location selection by combining the fuzzy AHP and TOPSIS methods. Durán and Aguilo (2008) used fuzzy AHP for computer-aided machine tool selection.

Amiri (2010) used the AHP and fuzzy TOPSIS methods to select projects for oil-fields development. Chen (2010) designed a fuzzy AHP methodology for project risk assessment. Torfi and Rashidi (2011) used AHP and fuzzy TOPSIS in project manager selection, where AHP was used to determine the criteria weights and fuzzy TOPSIS was performed to rank the alternatives. Pejić et al. (2013) proposed a method for student project evaluation using the fuzzy TOPSIS method. Walczak and Rutkowska (2017) proposed a modified fuzzy TOPSIS method to rank the projects for a participatory budget, where the authors emphasized the importance of the assigned weights. Anisseh et al. (2018) conducted a study on project portfolio selection using fuzzy Delphi, fuzzy AHP, and fuzzy TOPSIS methods. Jabbarzadeh (2018) applied the AHP and TOPSIS methods in contractor selection. Han et al. (2019) proposed a hybrid method for project selection, where fuzzy AHP was used to determine the weights of the criteria and fuzzy TOPSIS was used to rank the projects. Štirbanović et al. (2019) used the VIKOR and TOPSIS methods for flotation machine selection.

Nguyen et al. (2020) collected data from 13 companies between 2016 and 2019 in the Vietnam Stock Exchange Market, and integrated the analytical hierarchy process (AHP) with grey relational analysis (GRA) and the multi-objective optimisation ratio analysis (MOORA) technique to determine the order performance through the similarity to the ideal solution (TOPSIS) method to acquire the final ranking of each enterprise. Li et al. (2021) applied probabilistic linguistic-VIKOR to evaluate technological innovation project risk. Xu et al. (2021) applied the entropy and the TOPSIS methods to evaluate the competitiveness of each city in China. Prasetyo et al. (2021) the applied analytic network process (ANP) to determine how to choose an Islamic capital market investment instrument. Ghoni and Mutiara (2022) use the fuzzy analytic network process (FANP) to pick up Islamic stocks based on criteria such as return on assets (ROA), return on equity (ROE), return on investment (ROI), and net profit margin (NPM). Wang and Li (2022) integrated the intuitionistic fuzzy set with VIKOR to build an investment project decision-making model, and based on the experimental results, their method can choose sustainable and practical investment projects. Dinçer et al. (2022) integrates multi-stepwise weight assessment ratio analysis (M-SWARA) with TOPSIS to select microgeneration energy technology investment alternatives. Meng and Shaikh (2023) analysed environmental, social, and governance (ESG) criteria, and ranked green finance investment strategies using the fuzzy AHP and fuzzy WASPAS methods. Činčikaitė and Meidute-Kavaliauskiene (2023) apply TOPSIS to analyse the competitiveness of each country for implementing the projects of foreign direct investment.

Some studies indicated that rank investments projects with MCDM methods will be influenced by the weights of the criteria (Amiri,2010; Walczak and Rutkowska, 2017; Štirbanović et al., 2019); thus, the best alternative can be seen as the worst one if wrong weights are assigned to the criteria. Therefore, if the decision-makers are truly experts in their fields and express their views correctly, the only obstacle to the correct selection is the way to determine the weights of the criteria. To handle this issue, this study presents a dynamic mechanism to compute the weight of each criterion, as based on the evaluation opinions of experts. In addition, many uncertain conditions, as well as the subjective judgement of experts, must be considered when dealing with investment evaluation and selection. When facing uncertain environments, it can be difficult for experts to express their judgements using crisp values, thus, experts often use reasonable linguistic variables to express their evaluations for investment projects with respect to each criterion. Then, the new group MCDM method is proposed to determine the ranking order of all investment projects by combining the three indices, namely the performance index, the special superior index, and the regret index. In order to illustrate the effectiveness of the proposed method, this paper compared the results of projects ordering by the proposed method with the ordering of other MCDM methods. We think that this paper will fill the gap in the present literature and make a good contribution.

The remainder of this study is structured, as follows. The definitions of fuzzy numbers and interval linguistic variables are illustrated in Section 2. The novel methodology to evaluate investment projects is developed in Section 3. Section 4 provides a numerical example regarding the investment project evaluation and selection problem and implements the proposed method. Finally, discussions and conclusions are presented in Section 5 and 6, respectively.

2. Fuzzy number and interval linguistic variable

Definition 1. Positive triangular fuzzy number (PTFN) can be defined as $\tilde{T} = (l, m, u)$, where $0 \leq l \leq m \leq u$ (Dubois and Prade, 1980; Zimmerman, 1991). The membership function of $\tilde{T}$ can be defined, as shown in Figure 1.

$$\mu_{\tilde{T}}(x) = \begin{cases} \dfrac{x-l}{m-l}, & l \leq x \leq m \\ \dfrac{u-x}{u-m}, & m \leq x \leq u \\ 0, & otherwise \end{cases} \quad (1)$$

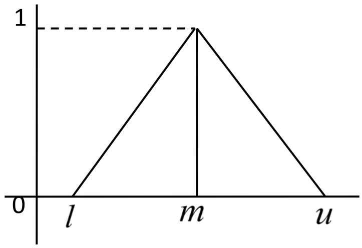

Figure 1. Positive TFN $\tilde{T}$
Source: Zimmerman (1991).

Definition 2. Suppose that $S^t = \{s_0^t, s_1^t, \dots, s_{t-1}^t\}$ is a finite and totally ordered linguistic term set. The membership function of each linguistic variable can be represented as a positive triangular fuzzy number. An interval linguistic variable can be expressed as $l_u^t = (\lambda s_u^t, (1-\lambda) s_{u+1}^t)$. The s_u^t and s_{u+1}^t are u-th and u+1-th linguistic terms separately in S^t. The λ is a numerical value, which represents the ratio of the u-th linguistic term s_u^t and u+1-th linguistic term s_{u+1}^t (Herrera and Martinez, 2001).

Definition 3. Let $\boldsymbol{\phi}$ be a linguistic transfer function. The $\boldsymbol{\phi}$ could translate the linguistic variable into a crisp value, as follows (Tai and Chen, 2009).

$$\boldsymbol{\phi}(s_u^t) = u/(t-1) \quad (2)$$

where t is the scale of linguistic term and u=0,1,2,…,t-1.

Definition 4. Let △ be a symbolic translation function, which could translate crisp value β (β∈ [0, 1]) into an interval linguistic variable as follows (Liu et al., 2014).

$$\triangle(\beta) = (\lambda s_u^t, (1-\lambda) s_{u+1}^t) \quad (3)$$

where $\boldsymbol{\phi}(s_u^t) \leq \beta \leq \boldsymbol{\phi}(s_{u+1}^t)$ and λ=(t-1)*($\phi(s_{u+1}^t) - \beta$).

Definition 5. Let $\triangle^{-1}$ be a reverse symbolic translation function, which can translate the interval linguistic variable l_u^t=$(\lambda s_u^t, (1-\lambda)s_{u+1}^t)$ into a crisp value, as follows (Liu et al., 2014).

$$\triangle^{-1}(l_u^t) = \lambda * \boldsymbol{\phi}(s_u^t) + (1-\lambda) * \boldsymbol{\phi}(s_{u+1}^t) \quad (4)$$

3. The proposed method

Generally, an m-element set of investment projects is considered, from which the most advantageous one should be selected for a given purpose. Each project is evaluated by K experts or evaluators according to n different criteria, and the initial problem specification is recorded in Table 1. The conceptual scheme of the proposed method is shown in Figure 2, which involves the execution of a total of eleven consecutive steps.

Table 1. Notations and descriptions of proposed method

Elements	Notations	Descriptions
Decision-makers (evaluators) set D		K means the number of decision maker.
Investment project set P	$\text{P} = \{P_1, P_2, \ldots, P_m\}$	m means the number of investment project. n means the number of criteria.
Criteria set C	$\text{C} = \{C_1, C_2, \ldots, C_n\}$	
Criteria importance set W	$\text{W} = \{w, w_2, \ldots, w_n\}$	

Source: The research creation.

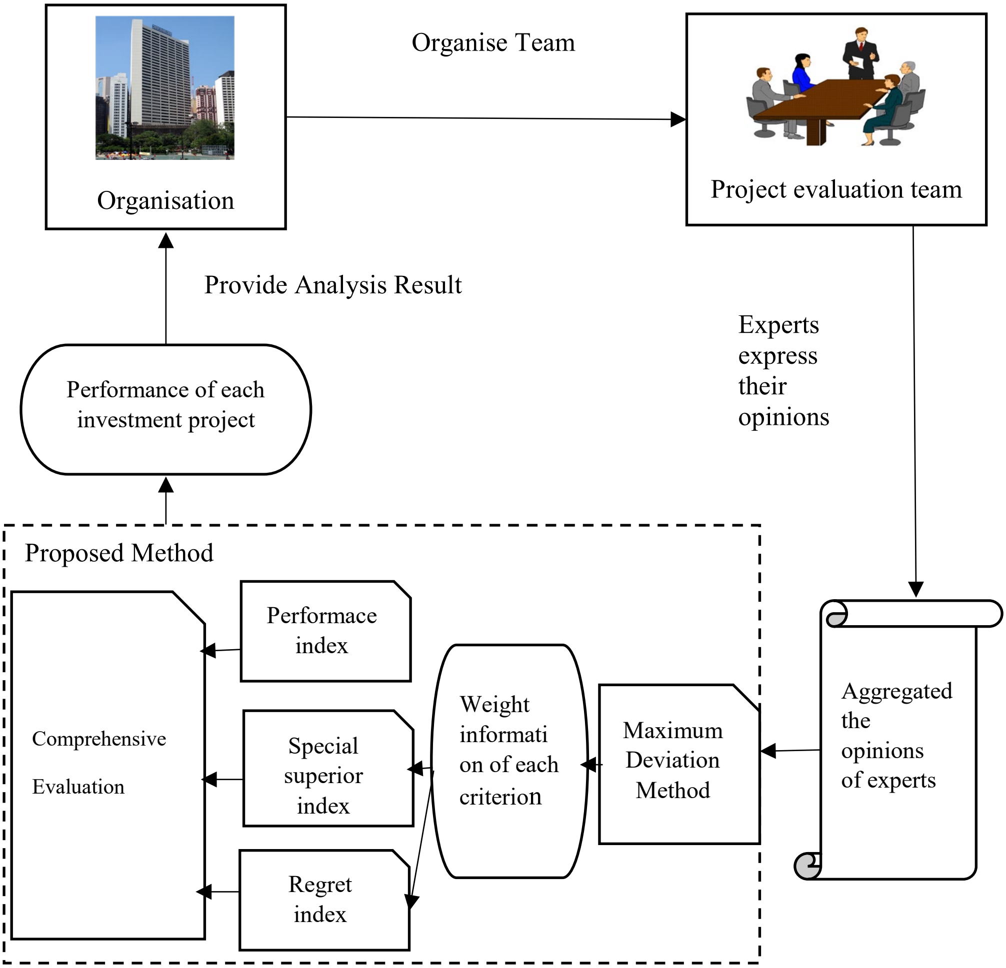

Figure 2. Conceptual process of proposed method
Source: The research creation.

The execution process of proposed method can be illustrated as following steps.

Step 1. According to the decision-making problem, the qualified experts should be invited to organise as an investment project evaluation team.

Step 2. Initially, organisation efforts should prepare investment projects for the evaluation team to analyse and evaluate which one is the best project for investment.

Step 3. The experts will determine the appropriate criteria to evaluate investment projects.

Step 4. In this step, experts should express their opinions about the performance of each investment project with respect to each criterion. The performance of the i-th project with respect to the j-th criterion by the k-th decision maker can be represented as an interval linguistic variable $\tilde{x}_{ijk}$.

Step 5. Aggregate the opinions of experts, as follows.

$$\tilde{x}_{ij} = \triangle\left(\sum_{z=1}^{K} \triangle^{-1}\left(\tilde{x}_{ijk}\right)/K\right) \tag{5}$$

Step 6. According to the maximising deviation method (Wu and Chen, 2007), the weight of criterion C_j can be calculated as

$$w_j = \frac{\sum_{k=1}^{K} R_k \sum_{i=1}^{n} \sum_{l=1}^{n} \left(\triangle^{-1}\left(\tilde{x}_{ijk}\right) - \triangle^{-1}\left(\tilde{x}_{ljk}\right)\right)^2}{\sum_{j=1}^{m} \sum_{k=1}^{K} R_k \sum_{i=1}^{n} \sum_{l=1}^{n} \left(\triangle^{-1}\left(\tilde{x}_{ijk}\right) - \triangle^{-1}\left(\tilde{x}_{ljk}\right)\right)^2} \tag{6}$$

where R_k means the importance of decision maker k.

Step 7. Calculate performance index (P_i) of investment project *i*, as follows.

$$P_i = \sum_{j=1}^{n} w_j * \triangle^{-1}\left(\tilde{x}_{ij}\right) \tag{7}$$

The performance index of an investment project represents the overall performance of this investment project, and will reflect the entire advantage of this investment project.

Step 8. Calculate the special superior index (S_i) of investment project i, as follows.

$$S_i = max_j\left(w_j * \triangle^{-1}\left(\tilde{x}_{ij}\right)\right) \tag{8}$$

The special superior index of an investment project represents the maximum satisfactory degree of the organisation in one dimension if the organisation chooses this project as the investment target.

Step 9. Calculate the regret index (R_i) of investment project i, as follows.

$$R_i = max_j\left(w_j * \left(max_y\left(\triangle^{-1}\left(\tilde{x}_{yj}\right)\right) - \triangle^{-1}\left(\tilde{x}_{ij}\right)\right)\right) \tag{9}$$

The regret index of an investment project represents the maximum regret degree of organisation in one dimension if the organisation selects this project for investment.

Step 10. The performance index, the special superior index, and the regret index are normalised for a reasonable comparison. The normalised formula can be computed, as follows.

$$P_i^* = \frac{P_i - min_i(P_i)}{max_i(P_i) - min_i(P_i)} \tag{10}$$

$$S_i^* = \frac{S_i - min_i(S_i)}{max_i(S_i) - min_i(S_i)} \tag{11}$$

$$R_i^* = \frac{max_i(R_i) - R_i}{max_i(R_i) - min_i(R_i)} \tag{12}$$

Step11. Calculate the overall index (Ψ_i) of the investment project.

The performance index, the special superior index, and the regret index can be used to evaluate the investment project based on different conditions. The overall index (Ψ_i) of investment project i can be computed by integrating the performance index, special superior index, and regret index as

$$\Psi_i = \Lambda_a{*}P_i^* + \Lambda_b{*}S_i^* + \Lambda_c{*}R_i^* \tag{13}$$

where Λ_a, Λ_b, Λ_c is between 0 and 1. Λ_a+ Λ_b+ Λ_c=1.

The overall index Ψ_i represents the total performance value of project *i*. If Ψ_i>Ψ_j, the total performance of investment project *i* is better than project *j*.

4. Numerical example

In order to meet market demands, a manufacturing company intends to expand its production capacity, and first assembles a team of four experts to assist with the process. Through preliminary screening of a large number of options, the experts identify five potentially suitable investment projects, from which the most advantageous one is to be selected. According to the relevant literature sources A to I (as shown in the columns of Table 2), they select the six most frequent partial criteria to evaluate the five considered investment projects (rows of Table 2), and then, apply the proposed method to select a suitable factory, which is illustrated, as follows.

Step 1. This manufacturing company invited four suitable experts to organise a project evaluation team. Four experts come from industry, government, and academia. The first expert is the senior director of the manufacturing department in a manufacturing company. The second expert is the staff in the economic department of the government. The third expert is the professor of information management department in a public university. The fourth expert is the professor of business management department in a private university.

Step 2. This manufacturing company received a huge amount for a factory investment project. After preliminary screening, five factory investment projects were considered, and a detailed evaluation was executed to select the most suitable investment project.

Step 3. The experts collected the relative literature and selected suitable criteria (refer to Table 2) to deal with the investment project selection problem. After screening the literature, they determined six criteria to evaluate five projects, such as expansion possibility (C_1), management considerations (C_2), financial considerations (C_3), market considerations (C_4), political considerations (C_5), and environment considerations (C_6).

Step 4. In order to express their subjective opinions, the experts utilised three different types of interval linguistic variables (see Table 3 and Figures 3 to 5).

Experts 1 and 2 used type I, expert 3 used type II, and expert 4 used type III. The evaluation results of each project by each expert for each of the six partial criteria are shown in Table 4.

Table 2. Literatures and evaluation criteria collections

	A	B	C	D	E	F	G	H	sum
Skilled Workers	v								1
Expansion Possibility	v	v	v						3
Availability of acquirement material	v								1
Resource Consideration		v							1
Economic Consideration		v		v					2
Social Consideration		v			v				2
Transportation		v							1
Operation Easiness			v				v		2
Reliability			v						1
Quality			v			v			2
Implementation Easiness			v						1
Maintainability			v						1
Management Consideration				v			v	v	4
Financial Consideration				v		v	v	v	5
Market Consideration				v				v	3
Political Consideration				v					2
Product Consideration					v				2
Environment Consideration							v	v	3
System risks Consideration				v	v				2
Effect of existing project portfolio					v				1
Project specifications					v				1
Organisational considerations					v				1
Experience						v			1
Manpower resources						v			1
Equipment resources						v			1
Current workload						v			1
Technology							v	v	2
Legality							v		1
Manufacture								v	1

A: Yong (2006), B: Wang and Liu (2007), C: Duran and Aguilo (2008), D: Chen (2010), E: Anisseh et al. (2018), F: Jabbarzadeh (2018), G: Han et al.(2019), H: Li et al. (2021).

Source: The research creation.

Table 3. Different types of linguistic variables

	Linguistic variable	Fig.
Type I	Extremely Poor($1s_0^5$,$0s_1^5$), Poor($1s_1^5$,$0s_2^5$), Fair($1s_2^5$,$0s_3^5$), Good($1s_3^5$,$0s_4^5$), Extremely Good($0s_3^5$,$1s_4^5$)	Figure. 3
Type II	Extremely Poor($1s_0^7$,$0s_1^7$), Poor($1s_1^7$,$0s_2^7$), Medium Poor($1s_2^7$,$0s_3^7$), Fair($1s_3^7$,$0s_4^7$), Medium Good($1s_4^7$,$0s_5^7$), Good($1s_5^7$,$0s_6^7$), Extremely Good($0s_5^7$,$1s_6^7$)	Figure. 4
Type III	Extremely Poor($1s_0^9$,$0s_1^9$),Very Poor($1s_1^9$,$0s_2^9$), Poor($1s_2^9$,$0s_3^9$), Medium Poor($1s_3^9$,$0s_4^9$), Fair($1s_4^9$,$0s_5^9$), Medium Good($1s_5^9$,$0s_6^9$), Good($1s_6^9$,$0s_7^9$), Very Good($1s_7^9$,$0s_8^9$), Extremely Good($0s_7^9$,$1s_8^9$)	Figure.5

Source: The research creation.

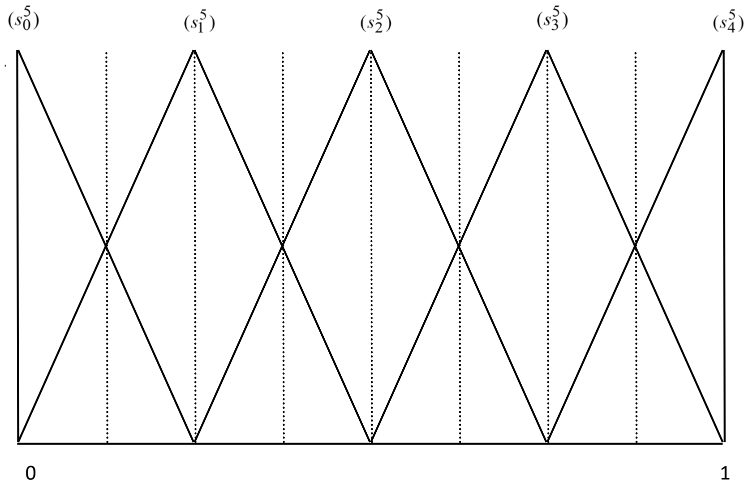

Figure 3. Membership functions of linguistic variables at type I
Source: Herrera and Martinez (2001).

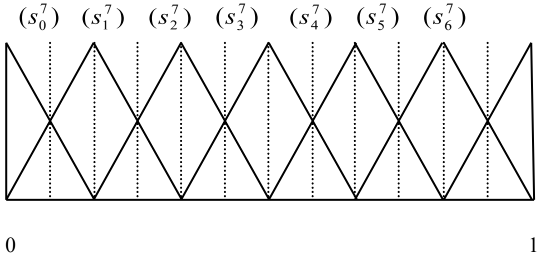

Figure 4. Membership functions of linguistic variables at type II
Source: Herrera and Martinez (2001).

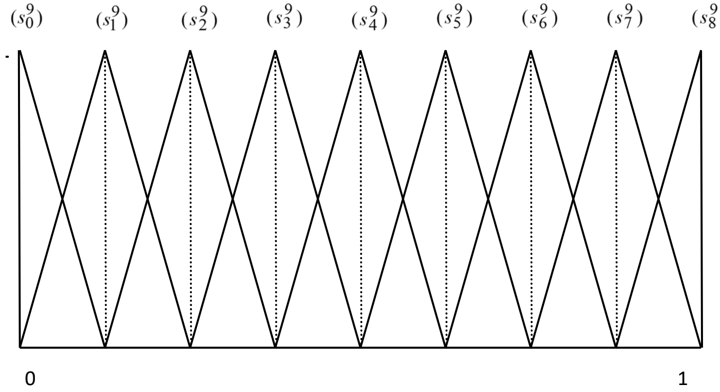

Figure 5. Membership functions of linguistic variables at type III
Source: Herrera and Martinez (2001).

Table 4. Opinions of experts for the linguistic ratings of each project

Expert 1		Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6
	Project 1	$(1s^5_0,0s^5_1)$	$(1s^5_2,0s^5_3)$	$(1s^5_0,0s^5_1)$	$(1s^5_1,0s^5_2)$	$(1s^5_1,0s^5_2)$	$(1s^5_3,0s^5_4)$
	Project 2	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$	$(1s^5_0,0s^5_1)$	$(1s^5_0,0s^5_1)$	$(1s^5_3,0s^5_4)$
	Project 3	$(1s^5_3,0s^5_4)$	$(1s^5_1,0s^5_2)$	$(1s^5_1,0s^5_2)$	$(1s^5_0,0s^5_1)$	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$
	Project 4	$(1s^5_0,0s^5_1)$	$(1s^5_2,0s^5_3)$	$(1s^5_1,0s^5_2)$	$(1s^5_0,0s^5_1)$	$(1s^5_1,0s^5_2)$	$(1s^5_3,0s^5_4)$
	Project 5	$(1s^5_0,0s^5_1)$	$(1s^5_2,0s^5_3)$	$(1s^5_1,0s^5_2)$	$(1s^5_0,0s^5_1)$	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$
Expert 2		Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6
	Project 1	$(1s^5_1,0s^5_2)$	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$
	Project 2	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$
	Project 3	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$	$(1s^5_2,0s^5_3)$	$(0s^5_3,1s^5_4)$	$(0s^5_3,1s^5_4)$	$(0s^5_3,1s^5_4)$
	Project 4	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$	$(0s^5_3,1s^5_4)$	$(0s^5_3,1s^5_4)$	$(0s^5_3,1s^5_4)$
	Project 5	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$	$(1s^5_3,0s^5_4)$	$(0s^5_3,1s^5_4)$	$(1s^5_3,0s^5_4)$	$(1s^5_3,0s^5_4)$
Expert 3		Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6
	Project 1	$(1s^7_1,0s^7_2)$	$(1s^7_5,0s^7_6)$	$(1s^7_4,0s^7_5)$	$(1s^7_3,0s^7_4)$	$(1s^7_0,0s^7_1)$	$(1s^7_4,0s^7_5)$
	Project 2	$(1s^7_2,0s^7_3)$	$(1s^7_2,0s^7_3)$	$(1s^7_5,0s^7_6)$	$(1s^7_2,0s^7_3)$	$(1s^7_3,0s^7_4)$	$(1s^7_5,0s^7_6)$
	Project 3	$(1s^7_3,0s^7_4)$	$(1s^7_5,0s^7_6)$	$(1s^7_1,0s^7_2)$	$(1s^7_3,0s^7_4)$	$(1s^7_5,0s^7_6)$	$(1s^7_4,0s^7_5)$
	Project 4	$(1s^7_2,0s^7_3)$	$(1s^7_5,0s^7_6)$	$(1s^7_2,0s^7_3)$	$(1s^7_2,0s^7_3)$	$(1s^7_4,0s^7_5)$	$(1s^7_5,0s^7_6)$
	Project 5	$(1s^7_1,0s^7_2)$	$(1s^7_3,0s^7_4)$	$(1s^7_4,0s^7_5)$	$(1s^7_2,0s^7_3)$	$(1s^7_5,0s^7_6)$	$(1s^7_5,0s^7_6)$
Expert 4		Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6
	Project 1	$(1s^9_4,0s^9_5)$	$(1s^9_6,0s^9_7)$	$(1s^9_4,0s^9_5)$	$(1s^9_6,0s^9_7)$	$(1s^9_2,0s^9_3)$	$(1s^9_5,0s^9_6)$
	Project 2	$(1s^9_6,0s^9_7)$	$(1s^9_6,0s^9_7)$	$(1s^9_7,0s^9_8)$	$(1s^9_4,0s^9_5)$	$(1s^9_2,0s^9_3)$	$(1s^9_6,0s^9_7)$
	Project 3	$(1s^9_6,0s^9_7)$	$(1s^9_6,0s^9_7)$	$(1s^9_2,0s^9_3)$	$(1s^9_6,0s^9_7)$	$(1s^9_6,0s^9_7)$	$(1s^9_6,0s^9_7)$
	Project 4	$(1s^9_5,0s^9_6)$	$(1s^9_6,0s^9_7)$	$(1s^9_2,0s^9_3)$	$(1s^9_4,0s^9_5)$	$(1s^9_2,0s^9_3)$	$(1s^9_6,0s^9_7)$
	Project 5	$(1s^9_6,0s^9_7)$	$(1s^9_6,0s^9_7)$	$(1s^9_3,0s^9_4)$	$(1s^9_3,0s^9_4)$	$(1s^9_6,0s^9_7)$	$(1s^9_7,0s^9_8)$

Source: The research creation.

Step 5. The opinions of the individual experts were appropriately integrated using equation (5).

Step 6. By applying equation (6), the weight of each criterion were obtained (see Table 5). According to the results, the weighted rank of each criterion for the factory investment project selection were expansion possibility (C_1) > political considerations (C_5) > financial considerations (C_3) > management considerations (C_2) > market considerations (C_4) > environment considerations (C_6).

Table 5. Weight of each criterion

	C_1	C_2	C_3	C_4	C_5	C_6
Weight	0.2511	0.1448	0.2016	0.0986	0.2068	0.0970

Source: The research creation.

Step 7. From these integrated values and weights, the triplets of the indices (performance index, special superior index, regret index) for all projects were calculated according to equations (7) to (9). For the purpose of comparability, these indices were normalised according to equations (10) to (12), and from these normalised triplet indices, the overall indices were obtained based on equation (13), which assumes that the partial indices have equal importance (see Table 6).

Step 8. The ordering of the five considered investment projects, as based on the overall indices (p_3> p_2> p_5> p_4> p_1), is consistent with the ordering of the projects according to their desirability. Therefore, project 3 is the most advantageous.

Table 6. The computational results

	P_i	S_i	R_i	Ψ_i	Rank
Project 1	0.5282	0.1203	0.0425	0.0457	5
Project 2	0.5814	0.1491	0.0286	0.5874	2
Project 3	0.6257	0.1726	0.0195	1.0000	1
Project 4	0.5403	0.1120	0.0396	0.0834	4
Project 5	0.5837	0.1465	0.0310	0.5462	3

Source: The research creation.

5. Discussions

In order to justify the usefulness of the proposed method, this study executed “Maximum deviation method +TOPSIS”, “Maximum deviation method +VIKOR” and “Maximum deviation method +SWA” in accordance with the same data. According to experiment results and the proposed method, the best investment project is consistent with other traditional multi-criteria methods. Table 7 compares this obtained project ordering with the ordering obtained by other MCDM methods. Table 8 presents the results of the robustness analysis of the proposed method with different values Λ_a, Λ_b and Λ_c. According to computational results, most of the ranking order was p_3> p_2> p_5> p_4> p_1 when we used the different values of Λ_a, Λ_b and Λ_c. Therefore, the results present the robustness of the proposed method.

Table 7. Compared the project ordering with other MCDM methods

	P_1	P_2	P_3	P_4	P_5
Proposed Method	5	2	1	4	3
Maximum deviation method +TOPSIS	5	3	1	4	2
Maximum deviation method +VIKOR	5	2	1	4	3
Maximum deviation method +SWA	5	3	1	4	2

p. s. The decision parameter in VIKOR set up as 0.5

Source: The research creation.

Table 8. Presents the results of the robustness analysis of the proposed method

Weight			Project				
Λ_a	Λ_b	Λ_c	P_1	P_2	P_3	P_4	P_5
0	0/6	6/6	5	2	1	4	3
	1/6	5/6	5	2	1	4	3
	2/6	4/6	5	2	1	4	3
	3/6	3/6	5	2	1	4	3
	4/6	2/6	5	2	1	4	3
	5/6	1/6	4	3	1	5	2
	6/6	0/6	4	3	1	5	2
1/6	0/6	5/6	5	2	1	4	3
	1/6	4/6	5	2	1	4	3
	2/6	3/6	5	2	1	4	3
	3/6	2/6	5	2	1	4	3
	4/6	1/6	5	2	1	4	3
	5/6	0/6	4	3	1	5	2
2/6	0/6	4/6	5	2	1	4	3
	1/6	3/6	5	2	1	4	3
	2/6	2/6	5	2	1	4	3
	3/6	1/6	5	2	1	4	3
	4/6	0/6	5	2	1	4	3
3/6	0/6	3/6	5	2	1	4	3
	1/6	2/6	5	2	1	4	3
	2/6	1/6	5	2	1	4	3
	3/6	0/6	5	2	1	4	3
4/6	0/6	2/6	5	2	1	4	3
	1/6	1/6	5	2	1	4	3
	2/6	0/6	5	2	1	4	3
5/6	0/6	1/6	5	3	1	4	2
	1/6	0/6	5	3	1	4	2
6/6	0/6	0/6	5	3	1	4	2

Source: The research creation.

6. Conclusions

The evaluation of investment projects is one of the most important problems of enterprises, as a wrong decision can have devastating consequences. These results can sometimes cause an unnecessary cash outflow or even lead the company to failure. According to the MCDM literature on investment project selection, it can be seen that the biggest obstacle is about the selection of the right alternative under an uncertain environment. In other words, when the experts have mastered their subjects, and well and correctly expressed their thoughts linguistically, the wrong weighting of the criteria will not prevent the right selection.

To eliminate this problem, this study presents a dynamic mechanism to compute the weights of criteria. In addition, this paper proposed a novel MCDM method to rank the investment projects by combining three indices, namely the performance index, special superior index, and regret index. Based on the comparison results, this study proved that the proposed method is robust and effective for dealing with the investment project selection problem. In future studies, the proposed method can be integrated with various tools, including social network analysis and knowledge mapping, to efficiently address decision-making problems. In addition, a decision support system can be developed based on the proposed method to enhance its computational ability.

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