

Article

A Hybrid Multi-Criteria Decision-Making Framework Based on Interval Type-2 Fuzzy Modelling for Sustainable Investment Project Selection

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Abstract

Selecting sustainable investment projects is a complex decision-making problem because economic, environmental, and social criteria must be considered simultaneously under uncertainty. This study develops a two-stage multi-criteria decision-making (MCDM) framework for sustainable investment project selection in the manufacturing sector, with uncertainty explicitly modelled using interval type-2 fuzzy sets. In the first stage, the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2FAHP) is applied to determine the weights of the sustainability dimensions based on the assessments of multiple decision-makers, while the criteria within each dimension are assumed to be equally important. In the second stage, investment projects are ranked using the Interval Type-2 Fuzzy Multi-Objective Optimization by Ratio Analysis (IT2FMOORA) and Interval Type-2 Fuzzy TODIM (IT2FTODIM) methods. Uncertain assessments are represented using interval type-2 triangular fuzzy numbers (IT2TFNs), and the proposed framework is tested through a real-world case study based on data and expert assessments obtained from a manufacturing company in central Serbia. The results show that both ranking methods identify the same project as the best alternative for forthcoming implementation. Overall, the proposed framework provides a structured decision-support approach for sustainable investment project selection by jointly considering economic, environmental, and social dimensions while explicitly addressing uncertainty in the decision-making process.

Keywords: sustainable investment project selection; multi-criteria decision-making; uncertainty modelling; IT2TFNs; IT2FAHP; IT2FMOORA; IT2FTODIM

Academic Editor: Wei Gao

Received: 19 September 2026

Revised: 1 October 2026

Accepted: 8 October 2026

Published: 9 October 2026

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1. Introduction

Successful investment decision-making involves several stages, including the identification, development, evaluation, selection, and implementation of investment projects. An investment project represents an essential element of the investment process and is aimed at achieving predefined objectives within specific time and resource constraints. According to the Project Management Institute [1], a project is a temporary endeavor undertaken to create a unique product, service, or result. Due to the increasing complexity of investment environments and the numerous factors influencing project success,

selecting the most appropriate investment project represents a complex decision-making problem.

The evaluation and selection of investment projects require the consideration of multiple factors, including financial, technical, strategic, and risk-related aspects. Since investors often face uncertainty and conflicting criteria when making investment decisions, selecting the optimal project represents a challenging managerial task that requires the application of appropriate decision-support methods [2,3]. Investment projects can be selected using either subjective or objective methods. The application of systematic methods, such as multi-criteria decision-making (MCDM) models, can provide more reliable and structured results by reducing the influence of subjective judgments of decision-makers (DMs). The determination of criteria weights represents an important step in the application of MCDM models [4–11].

Traditionally, investment project selection has been primarily based on economic and financial indicators [12–15]. However, contemporary approaches emphasize the need to incorporate broader sustainability-related aspects into the evaluation process. Sustainability considerations enable organizations to assess investment alternatives from multiple perspectives, including economic viability, environmental impact, and social responsibility. Therefore, sustainability dimensions have become increasingly important in investment project selection, as they provide a more comprehensive assessment of project performance [16]. The sustainability dimensions considered in this research are adopted from the framework proposed by [17].

When it comes to the evaluation and selection of investment and other types of projects, the relevant literature includes approaches based on different methodological and conceptual foundations. This diversity stems from the very nature of project selection and its multidimensional character. A common feature of these approaches is the use of MCDM models for project evaluation and selection. Researchers have addressed different aspects of project evaluation and selection. Jurík et al. [18] focused on project selection in accordance with sustainable development goals, while Awasthi et al. [19] analyzed urban mobility projects based on multiple criteria related to their impact on sustainability. A similar sustainability-oriented perspective was adopted by Bhattu et al. [20], who developed an approach for project selection based on socio-technical and environmental consequences. In addition, MCDM models have also been applied to the selection of construction projects [21]. Nevertheless, the evaluation, selection, and ranking of investment projects in the manufacturing sector, particularly when economic, environmental, and social dimensions are considered simultaneously, remain insufficiently explored.

Since sustainability dimensions and criteria are often evaluated using expert judgments, uncertainty and subjectivity are unavoidable in the decision-making process. Fuzzy set theory provides an effective framework for representing imprecise and uncertain information [5,22]. In general, the relative importance of sustainability dimensions, as well as uncertain criterion values, can be more easily expressed using linguistic terms than precise numerical values. The development of fuzzy set theory [23] has made it possible to quantitatively represent linguistic variables. Numerous studies have therefore extended MCDM approaches by incorporating different types of fuzzy sets [24–26]. This research focuses on MCDM methods enhanced with interval type-2 fuzzy sets (IT2FSs), which provide an effective framework for handling uncertainty in decision-making processes [27,28].

Conventional fuzzy sets are capable of handling incomplete information but may not adequately represent the additional uncertainty that can arise in decision-making processes. Type-2 fuzzy sets extend the concept of conventional fuzzy sets by allowing uncertainty to be represented in the membership function itself. In addition to the membership function, the granularity and domain of fuzzy sets represent important aspects of

their definition and application. The granularity is typically determined according to the assessments of DMs and the complexity of the considered problem [22,29–31].

In the first stage of the proposed model, the assessment of the relative importance of sustainability dimensions is formulated as a fuzzy group decision-making problem. The determination of the weights of sustainability dimensions is based on the Analytic Hierarchy Process (AHP) [32], extended by incorporating interval type-2 fuzzy triangular numbers (IT2TFNs), resulting in the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2FAHP) approach. Previous studies have applied AHP integrated with type-2 fuzzy set theory to different decision-making problems [33–37]. These studies demonstrate different approaches to representing uncertain information in terms of both linguistic granularity and the domains of the corresponding type-2 fuzzy numbers. For example, in [37], the authors employed a nine-point linguistic scale, whereas [33] used three linguistic expressions and [34–36] applied five-point linguistic scales. Different domains have also been adopted, including (1–10) by [34], (1–5) by [33], and (1–9) by [35–37].

The analyzed IT2FAHP approaches also differ in the procedures used to process fuzzy assessments. The transformation of fuzzy pairwise comparison matrices containing type-2 fuzzy numbers into crisp pairwise comparison matrices can be performed using the defuzzification procedure proposed by [38]. The consistency of relative importance assessments can subsequently be evaluated according to the principles of conventional AHP. In addition, the fuzzy geometric mean operator combined with fuzzy arithmetic operations can be used to determine the fuzzy weight vector. The application of the fuzzy geometric mean enables the resulting type-2 fuzzy numbers to preserve the required properties of fuzzy sets.

In the second stage of the proposed model, investment projects are ranked using MCDM methods integrated with IT2TFNs. Previous studies have combined Multi-Objective Optimization by Ratio Analysis (MOORA) [39] with IT2FSs, including [40–42], while interval type-2 fuzzy extensions of Interactive and Multicriteria Decision Making method (in Portuguese: Tomada de Decisão Interativa Multicritério; TODIM) [43] have been investigated by [44–47]. The analyzed studies differ in the representation of uncertain alternative values, the number of linguistic expressions, the domains of fuzzy numbers, the aggregation procedures, normalization procedures, and the transformation of fuzzy information into crisp values.

Seven linguistic expressions were used to represent uncertain criterion values in several studies [40,44,45], whereas nine-point scales were applied by [41,46,47], and a five-point scale was used by [42]. Since the investment projects considered in this research are evaluated according to a large number of criteria, a nine-point scale is adopted to enable finer differentiation among their assessed values. Different domains have also been used to model uncertain criterion values. Several studies employed the interval (0,1) [40–42,44,45], while [46,47] used a common measurement scale, as adopted in this research.

The determination of the elements of the fuzzy decision matrix has frequently been formulated as a fuzzy group decision-making problem [40,41,44,45,48]. Different aggregation procedures have been applied, including fuzzy arithmetic operators, the fuzzy geometric mean, and the Fuzzy Ordered Aggregation Operator. In other studies, the assessed values of the fuzzy decision matrix were determined based on the consensus of the DMs [42,46,47], as is the case in the present research. Since decision-making problems generally include both benefit-type and cost-type criteria, appropriate normalization procedures are also required. For example, in papers [42,46], authors applied the normalization procedure presented in [49,50].

In many previous studies, the fuzzy decision matrix was transformed into a crisp decision matrix [40–42,44,46]. Although this approach reduces computational complexity, the transformation may result in a loss of information contained in the original fuzzy

representation. Different defuzzification procedures have therefore been proposed, including the procedure developed by [51] and the approaches proposed by [27,28].

Regarding the ranking procedure, conventional MOORA has been applied in previous studies, while modified variants have also been proposed. In this research, MOORA with a reference point is employed, representing an important distinction from the approaches considered in the analyzed studies. In the case of TODIM, previous studies have applied conventional TODIM or determined preference values using distances between type-2 fuzzy numbers. Different distance measures have been proposed for this purpose. In [45], the authors applied the distance measure developed by [52], whereas in [47] authors employed the distance measure proposed by [53]. In the present research, the Hamming distance is applied.

The motivation for selecting these two methods, MOORA and TODIM, lies in their fundamentally different mathematical foundations and ranking principles. The proposed model therefore incorporates two complementary approaches, providing a basis for comparing the obtained results.

The MOORA method is known for enabling the evaluation of alternatives based on the ratio of criterion values and incorporates a reference-point approach, whereas TODIM determines the relative dominance of alternatives based on preference relations between them.

Therefore, the combined application of these two methods enables decision-makers, particularly in the context of investment project evaluation, to examine the problem and make decisions from two complementary perspectives.

Based on the reviewed literature, the motivation for this research arises from the limited attention given to the ranking of investment projects in the manufacturing sector while simultaneously considering all three sustainability dimensions in an interval type-2 fuzzy environment. Although IT2FAHP has been widely used to determine criteria weights, its application to determining the weights of sustainability dimensions in investment project selection remains insufficiently explored. Furthermore, the prioritization of manufacturing investment projects through the combined application of MCDM methods and type-2 fuzzy set theory has received limited attention.

Accordingly, the main contribution of this research is the development of a two-stage fuzzy decision-making model for evaluating and ranking investment projects in the manufacturing sector. The broader objective is achieved through: (a) modeling existing uncertainties using IT2TFNs; (b) formulating the assessment of the relative importance of sustainability dimensions as a fuzzy group decision-making problem and determining their weights using the proposed IT2FAHP; (c) determining the ranking of investment projects in the manufacturing sector using the proposed Interval Type-2 Fuzzy Multi-Objective Optimization by Ratio Analysis (IT2FMOORA) and Interval Type-2 Fuzzy TODIM (IT2FTODIM); and (d) identifying the most appropriate investment project while simultaneously considering all sustainability dimensions, the associated criteria, and their values. The application of the proposed model to real-world data demonstrates that both ranking approaches identify the same investment project as the best alternative for implementation.

2. Materials and Methods

2.1. Proposed Methodology

In this section, the methodology used to solve the considered problem is presented. A two-stage fuzzy model is proposed, in which IT2TFNs are used to model uncertainty, while the algebraic operations required for their manipulation follow [27,28,38]. In the first stage, the determination of the weights of the sustainability dimensions is formulated as a fuzzy group decision-making problem. The weight vector of the sustainability

dimensions is determined using the proposed IT2FAHP. In the second stage, the investment projects are ranked using MOORA and TODIM extended with IT2TFNs. The proposed methodology is presented in Figure 1.

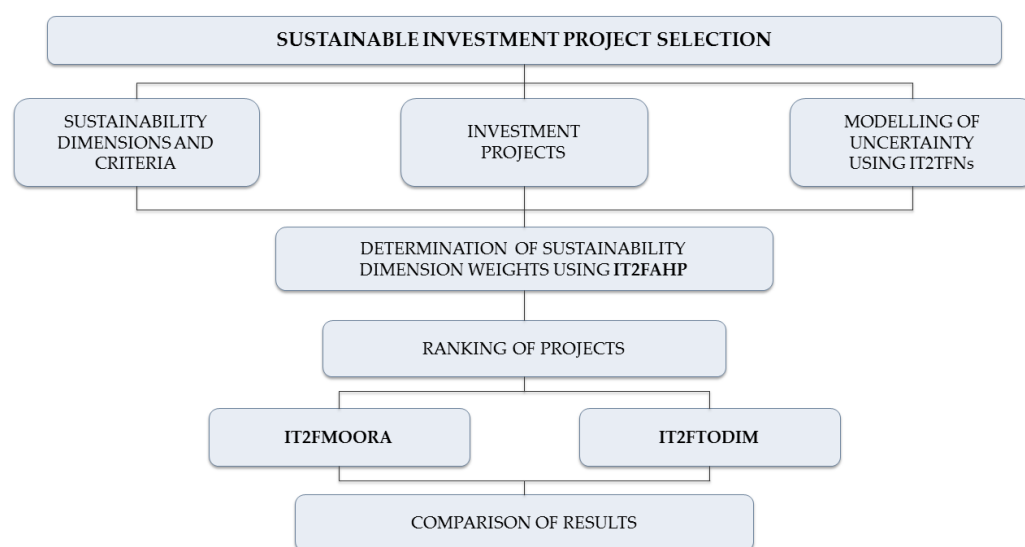


Figure 1. The proposed methodology.

2.1.1. Defining the Set of Decision-Makers

The assessment of the relative importance of the sustainability dimensions used in the evaluation of the considered investment projects is performed by multiple decision-makers.

The decision-makers are formally represented by the corresponding set of indices. The total number of decision-makers is denoted by E , while e denotes the index of an individual decision-maker.

The selection of DMs may itself be regarded as an important decision-making task. The Faculty of Engineering organizes and implements cooperation programs with representatives of companies from the region. In this research, a panel discussion was organized to select the DMs. The panel included experts from different departments of the considered company, including management, quality control, production, and finance. Professors and PhD students whose research focuses on project management and who have participated or are currently participating in numerous projects also took part in the panel discussion.

Based on the panel discussion, three DMs were selected based on their professional expertise and involvement in areas relevant to the economic, social, and managerial aspects of investment project evaluation: the Head of Project Management, the Head of Financial Controlling, and the Human Resources Manager.

The selected expert group was formed in accordance with the established practice within the company, meaning that the DMs who normally participate, together with the CEO, in this type of decision-making were included. At the same time, the three DMs considered cover functional areas that are essential for the evaluation of investment projects. This made it possible to consider the decision-making problem from multiple perspectives. The first perspective concerns project management, the second focuses on the financial aspect, and the third relates to the organization and employees.

2.1.2. Defining the Set of Sustainability Criteria

Numerous studies in the literature evaluate projects according to multiple sustainability dimensions [16–21,54]. Some authors emphasize economic feasibility as the primary consideration in project evaluation, while environmental and social dimensions may receive less attention [20]. Analyses of the relevant literature have also shown that economic, social, and environmental dimensions are frequently examined separately rather than in an integrated manner [54]. Other studies combine two sustainability dimensions when defining the criteria set [19,21]. However, several studies incorporate all three dimensions and develop comprehensive sustainability frameworks for project selection [17,20].

Investment projects in the manufacturing sector represent a specific decision-making problem, as they can affect different aspects of business operations, primarily the production process, but also costs and resource utilization, as well as the environment and employees.

One of the most common and relevant examples in this context is the procurement of new production equipment, installation of a new production line, or process automation, where the decision on project selection is not based solely on economic benefits, but also considers a range of consequences that such a project may have on energy and material consumption, waste generation, and, in general, the social environment.

For this reason, in this research, the idea was to consider the problem holistically from three different but interdependent perspectives, i.e., sustainability dimensions: economic, environmental, and social. The existing set of criteria, i.e., the criteria used for project selection, is defined within these three groups and encompasses different aspects and consequences that an investment decision may have. The sustainability criteria used in this research for evaluating projects in the manufacturing sector are adopted and modified from [17] to reflect the context of manufacturing investment project evaluation (see Table 1).

Table 1. Sustainability criteria.

Economic ($k = 1$)	Environmental ($k = 2$)	Social ($k = 3$)
Initial cost ($j = 1$)	Fossil fuel consumption ($j = 1$)	Territory management ($j = 1$)
Revenues ($j = 2$)	Noise ($j = 2$)	Resource utilization ($j = 2$)
Return on investment ($j = 3$)	Air quality ($j = 3$)	Service provision ($j = 3$)
Duration of project ($j = 4$)	Water resources quality ($j = 4$)	Occupation of public space ($j = 4$)
Production ($j = 5$)	Climate and climate change ($j = 5$)	Land use and transportation ($j = 5$)
Management commitment ($j = 6$)	Environmental management ($j = 6$)	Representation ($j = 6$)
Balance of payment ($j = 7$)	Government regulations ($j = 7$)	Community participation ($j = 7$)
Resource consumption ($j = 8$)	Energy management ($j = 8$)	Household food security ($j = 8$)
Project feasibility ($j = 9$)	Water cycle management ($j = 9$)	Employment opportunities ($j = 9$)
Life cycle costs ($j = 10$)	Materials and waste management ($j = 10$)	Incentives and rewards ($j = 10$)
Willingness to pay ($j = 11$)		Housing ($j = 11$)
Affordability ($j = 12$)		Culture ($j = 12$)
Operational cost ($j = 13$)		Security ($j = 13$)
Financial risk ($j = 14$)		Work pressure ($j = 14$)
Cost-effectiveness ($j = 15$)		Accessibility ($j = 15$)
		Education and training ($j = 16$)
		Healthcare facilities ($j = 17$)
		Demography ($j = 18$)

Risk to human health ($j = 19$)

Public awareness ($j = 20$)

The considered criteria are classified as benefit-type or cost-type criteria according to the direction of preference. For benefit-type criteria, higher values indicate more desirable performance, whereas for cost-type criteria, lower values are preferred. For the economic sustainability dimension ($k = 1$), the benefit-type criteria are $j = 2, 3, 5, 6, 7, 9, 11, 12$, and 15 , while the cost-type criteria are $j = 1, 4, 8, 10, 13$, and 14 . For the environmental sustainability dimension ($k = 2$), the benefit-type criteria are $j = 3, 4, 6, 7, 8, 9$, and 10 , whereas $j = 1, 2$, and 5 are classified as cost-type criteria. For the social sustainability dimension ($k = 3$), all criteria are classified as benefit-type criteria except $j = 5, 14$, and 19 , which are classified as cost-type criteria.

2.1.3. Defining the Set of Investment Projects

In the general case, DMs may consider different investment projects. The set of investment projects is represented by the corresponding index set. The total number of investment projects is denoted by I , while i denotes the index of an individual investment project.

In this study, five investment projects identified by the analyzed company during the previous year for potential future implementation are evaluated: the procurement and installation of a new railcar floor production line for the Desiro HC platform ($i = 1$); the procurement and installation of a new Computer Numerical Control (CNC) machine with a working travel of 30 m for machining railcar floor components ($i = 2$); the procurement and installation of a robot for the automatic welding of railcar floor components ($i = 3$); the procurement and installation of a new railcar floor production line for the Desiro ML platform ($i = 4$); and the procurement and installation of a new railcar floor production line for the Mireo platform ($i = 5$).

2.1.4. Choice of Appropriate Linguistic Variables for Describing the Uncertain Data

It is assumed that the sustainability dimensions do not have equal importance and that their relative importance is assessed by the DMs. The relative importance of the sustainability dimensions can be more appropriately expressed using linguistic terms than precise numerical values. The number and type of linguistic terms were selected for the considered problem by taking into account the complexity of the decision-making process and the ability of the DMs to distinguish between different assessment levels.

In this study, the criteria within each sustainability dimension are considered to have equal importance. The main reason for this assumption is the large number of criteria included in the model. Determining separate weights for all 45 criteria would require a considerable number of pairwise comparisons and would place an additional burden on the decision-makers. There is also another issue related to the different numbers of criteria within the three dimensions. The economic dimension includes 15 criteria, the environmental dimension includes 10 criteria, whereas the social dimension includes 20 criteria. If the weights of all criteria were determined directly, the number of criteria within a dimension would affect the individual weight assigned to each criterion. Under an equal-weight assumption, for example, the average weight of a criterion would be $1/15$ in the economic dimension, $1/10$ in the environmental dimension, and $1/20$ in the social dimension. Thus, a criterion from the environmental dimension would have a higher individual weight simply because fewer criteria are included in that dimension. To avoid such an effect, the model first determines the weights of the three sustainability dimensions and then distributes the weight of each dimension equally among its criteria. This allows the

relative importance of the dimensions to be determined independently of the number of criteria included in each dimension.

Different measurement scales are used to define the domains of IT2TFNs used to model the predefined linguistic expressions.

In this research, the DMs assess the relative importance of the sustainability dimensions using the following five linguistic variables:

- low importance (A1): $((1,2,3; 1), (1.5,2,2.5; 0.8))$
- medium low importance (A2): $((2,3.5,5; 1), (2.5,3.5,4.5; 0.8))$
- medium importance (A3): $((4,5.5,7; 1), (4.5,5.5,6.5; 0.8))$
- medium high importance (A4): $((5,7.5,9; 1), (5.5,7.5,8.5; 0.8))$
- high importance (A5): $((7,9,9; 1), (7.5,9,9; 0.8))$

The values of the sustainability criteria are described using nine linguistic variables modeled by IT2TFNs:

- extremely low value (V1): $((1,1,2.5; 1), (1,1,2; 0.75))$
- low value (V2): $((1,2,3; 1), (1.5,2,2.5; 0.75))$
- fairly low value (V3): $((1.5,3,4.5; 1), (2,3,4; 0.75))$
- medium low value (V4): $((2.5,4,5.5; 1), (2,4,5; 0.75))$
- medium value (V5): $((3.5,5,6.5; 1), (4,5,6; 0.75))$
- fairly high value (V6): $((4.5,6,7.5; 1), (5,6,7; 0.75))$
- medium high value (V7): $((5.5,7,8.5; 1), (6,7,8; 0.75))$
- high value (V8): $((7,8,9; 1), (7.5,8,8.5; 0.75))$
- extremely high value (V9): $((7.5,9,9; 1), (7,9,9; 0.75))$

The domain values of these IT2TFNs are defined on the real line in the interval (1–9). Values of 1 and 9 represent the lowest and highest levels, respectively.

2.1.5. The Proposed IT2FAHP for the Determination of the Weight Vector of Sustainability Dimensions

The proposed IT2FAHP is implemented through the following steps:

Step 1. Each DM assesses the relative importance of the sustainability dimensions using the predefined linguistic expressions modeled by IT2TFNs.

$$[\tilde{A}_{kk'}^e]_{K \times K} \quad (1)$$

Step 2. The fuzzy pairwise comparison matrix is transformed into a crisp pairwise comparison matrix using the defuzzification procedure proposed by [38]. The consistency ratio (CR) is then calculated for the resulting crisp matrix using the standard Saaty procedure of the conventional AHP.

$$[A_{kk'}]_{K \times K} \quad (2)$$

Step 3. The weight vector of the sustainability dimensions is determined at the level of each DM.

$$[\tilde{W}_k^e]_{1 \times K} \quad (3)$$

Step 4. The aggregated weight vector of the sustainability dimensions is determined using the fuzzy geometric operator.

$$[\tilde{W}_k]_{1 \times K} \quad (4)$$

where:

$$\tilde{W}_k = \sqrt[E]{\prod_{e=1,\dots,E} \tilde{W}_k^e} \quad (5)$$

Step 5. The normalized fuzzy weight vector of the sustainability dimensions is determined.

$$[\tilde{\omega}_k]_{1 \times K} \quad (6)$$

where:

$$\tilde{\omega}_k = \frac{\tilde{W}_k}{\sum_{k=1,\dots,K} \tilde{W}_k} \quad (7)$$

2.1.6. The Proposed IT2FMOORA for Determining the Rank of Investment Projects

The proposed IT2FMOORA extends the MOORA method by incorporating IT2TFNs and is implemented through the following steps:

Step 1. The fuzzy decision matrix at the level of each sustainability criterion is defined as:

$$[\tilde{x}_{ij}]_{I \times J_k} \quad (8)$$

The values of the sustainability criteria may be represented either as crisp numerical data, when objective measurements are available, or as uncertain values expressed using IT2TFNs when the assessment is based on linguistic evaluations.

The elements of the fuzzy decision matrix are defined as criteria values, $j, j = 1, \dots, J_k, k = 1, \dots, K$ for each investment project $i, i = 1, \dots, I$.

Step 2. The normalized fuzzy decision matrix is obtained using the linear normalization procedure [27,28,55]:

$$[\tilde{r}_{ij}]_{I \times J_k} \quad (9)$$

- For benefit-type criteria:

$$\tilde{r}_{ij} = \frac{\tilde{x}_{ij}}{\tilde{x}_{\max}} \quad (10)$$

$$\tilde{x}_{\max} = \max_{i=1,\dots,I} \tilde{x}_{ij} \quad (11)$$

- For cost-type criteria

$$\tilde{r}_{ij} = \frac{\tilde{x}_{\min}}{x_{ij}} \quad (12)$$

$$\tilde{x}_{\min} = \min_{i=1,\dots,I} \tilde{x}_{ij} \quad (13)$$

Step 3. The aggregated fuzzy decision matrix is determined at the level of each sustainability dimension:

$$[\tilde{y}_{ik}]_{I \times J} \quad (14)$$

where:

$$\tilde{y}_{ik} = \sqrt[J_k]{\prod_{j=1,\dots,J_k} \tilde{r}_{ij}} \quad (15)$$

Step 4. The weighted fuzzy decision matrix is determined as follows:

$$[\tilde{z}_{ik}]_{I \times K} \quad (16)$$

where:

$$\tilde{z}_{ik} = \tilde{\omega}_k \cdot \tilde{y}_{ik} \quad (17)$$

The values of $\tilde{z}_{ik}$, $i = 1, \dots, I$; $k = 1, \dots, K$ are presented by IT2TFNs according to the fuzzy algebra rules [27,28].

Step 5. The reference point is determined at the level of each sustainability dimension, f_j^* :

$$f_k^* = \max_{i=1, \dots, I} \tilde{z}_{ik} \quad (18)$$

The comparison of IT2TFNs is performed using the corresponding procedure [56].

Step 6. The following matrix is constructed:

$$[m_{ik}]_{I \times K} \quad (19)$$

$$m_{ik} = \frac{1}{K} \cdot d(\tilde{f}_k^*, \tilde{z}_{ik}) \quad (20)$$

where:

$d(\tilde{f}_k^*, \tilde{z}_{ik})$ where the Hamming distance represents the distance between two IT2TFNs.

Step 7. The coefficient for each investment project is determined as follows:

$$\delta_i = \max_{k=1, \dots, K} m_i \quad (21)$$

Step 8. The obtained coefficient values are arranged in ascending order. The investment project with the lowest coefficient value is ranked first and represents the best alternative.

2.1.7. The Proposed IT2FTODIM for Determining the Rank of Investment Projects

The first four steps of the proposed IT2FTODIM are identical to those of IT2FMOORA presented in the previous subsection.

Step 5. The preference values of each considered investment project within each sustainability dimension are determined as follows:

$$d_{ii'}^k = \begin{cases} \sqrt{d(\tilde{z}_{ik}, \tilde{z}_{i'k})} & \tilde{z}_{ik} > \tilde{z}_{i'k} \\ 0 & \tilde{z}_{ik} = \tilde{z}_{i'k} \\ -\sqrt{d(\tilde{z}_{ik}, \tilde{z}_{i'k})} & \tilde{z}_{ik} < \tilde{z}_{i'k} \end{cases} \quad (22)$$

Step 6. The dominance degree of each considered investment project is determined as follows:

$$\delta_i = \sum_{k=1, \dots, K} d_{ii'}^k \quad (23)$$

Step 7. The overall dominance degree for each investment project is determined as follows:

$$\xi_i = \frac{\delta_i - \delta^{\min}}{\delta^{\max} - \delta^{\min}} \quad (24)$$

where:

$$\delta^{\min} = \min_{i=1, \dots, I} \delta_i \quad (25)$$

$$\delta^{max} = \max_{i=1,...,I} \delta_i \quad (26)$$

Step 8. The overall dominance values are arranged in descending order. The investment project with the highest overall dominance value is ranked first and represents the best alternative.

2.2. Case Study

The proposed model was tested using data obtained from a manufacturing company operating in central Serbia. The company produces aluminum components for railcars used in urban and regional trains. Due to the expected increase in demand for its products in the coming years, the company's management is evaluating investment projects aimed at increasing its production capacity.

The considered alternatives, i.e., investment projects, include the introduction or upgrading of production lines, acquisition of new CNC equipment, and automation of the welding process. However, these alternatives may also differ in terms of resource utilization, environmental impact, and consequences for employees, rather than solely from the perspective of economic benefits.

For this reason, the problem considered in this case study was evaluated through the aforementioned dimensions, namely economic, environmental, and social, which fully corresponds to the structure of the proposed model.

The required data were collected using two questionnaires developed for this study. The first questionnaire consisted of five predefined linguistic expressions used by the DMs to perform pairwise comparisons and assess the relative importance of the sustainability dimensions. The second questionnaire consisted of nine predefined linguistic expressions used to assess uncertain criterion values. Both questionnaires were distributed to the selected DMs by e-mail. Unlike the assessment of the relative importance of the sustainability dimensions, which was performed individually by each DM, the criterion values were determined through a joint assessment and expressed as a single consensus-based linguistic evaluation for each investment project and criterion. The DMs discussed their assessments together and, whenever possible, agreed on a common linguistic evaluation. When they could not reach an agreement, each DM gave an individual assessment, and the final evaluation was obtained by averaging these assessments.

The DMs received clear information about the purpose of the study, their role in the process, and clear instructions for providing their assessments. The selection of the DMs was carried out through a panel discussion, while the questionnaires used to collect their assessments were distributed by e-mail. Their participation was voluntary, and oral consent was obtained from all DMs. For ethical reasons, the names of the DMs and the company name are not reported in the study. In addition, the research did not involve experiments with human participants or the processing of personal or sensitive data; therefore, the authors considered that formal approval from an ethics committee was not required.

As the company does not have an established decision-support tool, the company representatives who participated in this research expressed interest in applying the proposed model to the evaluation of future investment projects, as well as to other problems, such as supplier and raw material selection. As a practical advantage of the model, they highlighted the simultaneous consideration of economic, environmental, and social aspects, while, with certain modifications, the model could also be applied to other decision-making problems within the company.

3. Results

3.1. Application of the Proposed IT2FAHP for Determining the Weights of Sustainability Dimensions

The assessments of the relative importance of the sustainability dimensions provided by the selected DMs are presented below. Based on these assessments, the corresponding fuzzy pairwise comparison matrices were constructed, and the individual weight vectors were determined according to Steps 1–3 of the proposed algorithm.

Head of Project Management:

$$\begin{bmatrix} \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} & A2 & A1 \\ & \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} & 1/A1 \\ & & \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} \end{bmatrix} \begin{bmatrix} 1 & 3.40 & 1.95 \\ & 1 & 0.55 \\ & & 1 \end{bmatrix}, CR = 0$$

$$\tilde{W}_k^1 = \left[\begin{pmatrix} (4.6500, 9; 1), \\ (5.65, 8; 0.8) \end{pmatrix} \quad \begin{pmatrix} (1.533, 1.786, 2.500; 1), \\ (1.622, 1.786, 2.067; 0.8) \end{pmatrix} \quad \begin{pmatrix} (2.333, 3.500, 5; 1), \\ (2.900, 3.500, 4.167; 0.8) \end{pmatrix} \right]$$

The fuzzy pairwise comparison matrices of the relative importance of the sustainability dimensions for the other DMs, namely the Head of Financial Controlling and the Human Resources Manager, are presented below.

Head of Financial Controlling:

$$\begin{bmatrix} \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} & A3 & A5 \\ & \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} & A1 \\ & & \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} \end{bmatrix}, CR = 0.01$$

Human Resources Manager:

$$\begin{bmatrix} \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} & 1/A4 & 1/A5 \\ & \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} & 1/A1 \\ & & \begin{pmatrix} (1,1,1; 1) \\ (1,1,1; 1) \end{pmatrix} \end{bmatrix}, CR = 0.03$$

The individual weight vectors of the sustainability dimensions for the Head of Financial Controlling and the Human Resources Manager were calculated as follows:

$$\tilde{W}_k^2 = \left[\begin{pmatrix} (12, 15.500, 17; 1), \\ (13, 15.500, 16.500; 0.8) \end{pmatrix} \quad \begin{pmatrix} (2.143, 3.182, 4.250; 1), \\ (2.654, 3.182, 3.722; 0.8) \end{pmatrix} \quad \begin{pmatrix} (1.444, 1.611, 2.143; 1), \\ (1.511, 1.611, 1.800; 0.8) \end{pmatrix} \right]$$

$$\tilde{W}_k^3 = \left[\begin{pmatrix} (1.222, 1.244, 1.343; 1), \\ (1.229, 1.244, 1.315; 0.8) \end{pmatrix} \quad \begin{pmatrix} (6.333, 9, 11; 1), \\ (6.900, 9, 10.167; 0.8) \end{pmatrix} \quad \begin{pmatrix} (9, 12, 13; 1), \\ (10, 12, 12.500; 0.8) \end{pmatrix} \right]$$

The aggregated weight vector of the sustainability dimensions was determined using the fuzzy geometric mean operator according to Step 4 of the proposed algorithm:

$$\tilde{W} = \left[\begin{pmatrix} (3.885, 5.004, 5.901; 1), \\ (4.472, 5.004, 5.577; 0.8) \end{pmatrix} \quad \begin{pmatrix} (2.750, 3.712, 4.888; 1), \\ (3.097, 3.712, 4.276; 0.8) \end{pmatrix} \quad \begin{pmatrix} (3.118, 4.074, 5.183; 1), \\ (3.525, 4.074, 4.377; 0.8) \end{pmatrix} \right]$$

Finally, the normalized fuzzy weight vector of the sustainability dimensions was determined according to Step 5 of the proposed algorithm:

$$\tilde{\omega} = \left[\begin{pmatrix} (0.243, 0.391, 0.605; 1), \\ (0.314, 0.391, 0.503; 0.8) \end{pmatrix} \quad \begin{pmatrix} (0.172, 0.290, 0.501; 1), \\ (0.279, 0.290, 0.385; 0.8) \end{pmatrix} \quad \begin{pmatrix} (0.195, 0.319, 0.531; 1), \\ (0.248, 0.319, 0.395; 1) \end{pmatrix} \right]$$

3.2. Application of the Proposed IT2FMOORA for Ranking Investment Projects

The assessed criterion values for each considered investment project were determined according to Step 1 of the proposed algorithm. The assessed values under the economic, environmental, and social sustainability dimensions are presented in Table 2, Table 3 and Table 4, respectively.

Table 2. Assessed criterion values under the economic dimension.

	<i>i</i> = 1	<i>i</i> = 2	<i>i</i> = 3	<i>i</i> = 4	<i>i</i> = 5
<i>j</i> = 1	0.95	1.70	0.75	0.69	0.80
<i>j</i> = 2	203%	114%	43%	134%	110%
<i>j</i> = 3	4.92	13.11	4.46	7.48	9.09
<i>j</i> = 4	V3	V4	V5	V6	V5
<i>j</i> = 5	V2	V3	V4	V5	V6
<i>j</i> = 6	V4	V3	V3	V5	V4
<i>j</i> = 7	V6	V5	V5	V3	V2
<i>j</i> = 8	V5	V3	V3	V2	V2
<i>j</i> = 9	V7	V6	V4	V3	V2
<i>j</i> = 10	V4	V3	V3	V3	V2
<i>j</i> = 11	V7	V7	V6	V5	V5
<i>j</i> = 12	V8	V7	V7	V5	V4
<i>j</i> = 13	V3	V5	V6	V7	V8
<i>j</i> = 14	V2	V3	V4	V5	V7
<i>j</i> = 15	V6	V7	V8	V6	V5

Table 3. Assessed criterion values under the environmental dimension.

	<i>i</i> = 1	<i>i</i> = 2	<i>i</i> = 3	<i>i</i> = 4	<i>i</i> = 5
<i>j</i> = 1	V6	V3	V2	V6	V5
<i>j</i> = 2	V3	V6	V2	V3	V3
<i>j</i> = 3	V4	V6	V3	V4	V4
<i>j</i> = 4	V2	V2	V2	V2	V2
<i>j</i> = 5	V1	V1	V1	V1	V1
<i>j</i> = 6	V2	V2	V2	V2	V2
<i>j</i> = 7	V3	V3	V2	V3	V3
<i>j</i> = 8	V3	V5	V2	V3	V3
<i>j</i> = 9	V2	V2	V2	V2	V2
<i>j</i> = 10	V4	V2	V5	V3	V4

Table 4. Assessed criterion values under the social dimension.

	<i>i</i> = 1	<i>i</i> = 2	<i>i</i> = 3	<i>i</i> = 4	<i>i</i> = 5
<i>j</i> = 1	V8	V5	V3	V7	V9
<i>j</i> = 2	V4	V3	V6	V3	V3
<i>j</i> = 3	V2	V2	V2	V2	V2
<i>j</i> = 4	V3	V3	V3	V3	V3
<i>j</i> = 5	V7	V6	V5	V7	V6
<i>j</i> = 6	V6	V9	V5	V7	V9
<i>j</i> = 7	V7	V5	V2	V6	V5
<i>j</i> = 8	V2	V2	V2	V2	V2
<i>j</i> = 9	V7	V6	V5	V6	V8
<i>j</i> = 10	V5	V5	V6	V5	V4
<i>j</i> = 11	V3	V2	V4	V3	V3
<i>j</i> = 12	V3	V3	V3	V3	V3

$j = 13$	V3	V3	V7	V4	V4
$j = 14$	V5	V2	V7	V4	V5
$j = 15$	V4	V7	V2	V6	V5
$j = 16$	V5	V2	V6	V4	V5
$j = 17$	V2	V5	V4	V3	V4
$j = 18$	V2	V3	V1	V2	V2
$j = 19$	V4	V5	V3	V4	V4
$j = 20$	V4	V5	V6	V3	V4

By applying Step 2 of the proposed algorithm, the normalized fuzzy decision matrices were constructed. The normalized criterion values under the economic, environmental, and social sustainability dimensions are presented in Table 5, Table 6 and Table 7, respectively.

Table 5. Normalized criterion values under the economic dimension.

	$i = 1$	$i = 2$	$i = 3$	$i = 4$	$i = 5$
$j = 1$	0.726	0.406	0.920	1	0.862
$j = 2$	1	0.562	0.212	0.660	0.542
$j = 3$	0.375	1	0.340	0.571	0.693
$j = 4$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.182, 0.250, 1; 1), (0.200, 0.259, 1; 0.8))$	$((0.154, 0.200, 0.714; 1), (0.167, 0.200, 0.444; 0.8))$	$((0.133, 0.167, 0.556; 1), (0.143, 0.167, 0.400; 0.8))$	$((0.154, 0.200, 0.714; 1), (0.167, 0.200, 0.444; 0.8))$
$j = 5$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$	$((0.500, 0.667, 1; 1), (0.556, 0.667, 1; 0.8))$
$j = 6$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$
$j = 7$	$((0.500, 0.667, 1; 1), (0.556, 0.667, 1; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$
$j = 8$	$((0.154, 0.200, 0.714; 1), (0.167, 0.200, 0.444; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.333, 0.500, 2.500; 1), (0.400, 0.500, 1.333; 0.8))$	$((0.333, 0.500, 2.500; 1), (0.400, 0.500, 1.333; 0.8))$
$j = 9$	$((0.611, 0.778, 1.133; 1), (0.667, 0.778, 1.143; 0.8))$	$((0.500, 0.667, 1; 1), (0.556, 0.667, 1; 0.8))$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$
$j = 10$	$((0.182, 0.250, 1; 1), (0.200, 0.259, 1; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.333, 0.500, 2.500; 1), (0.400, 0.500, 1.333; 0.8))$
$j = 11$	$((0.611, 0.778, 1.133; 1), (0.667, 0.778, 1.143; 0.8))$	$((0.611, 0.778, 1.133; 1), (0.667, 0.778, 1.143; 0.8))$	$((0.500, 0.667, 1; 1), (0.556, 0.667, 1; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$
$j = 12$	$((0.778, 0.889, 1.200; 1), (0.833, 0.889, 1.214; 0.8))$	$((0.611, 0.778, 1.133; 1), (0.667, 0.778, 1.143; 0.8))$	$((0.611, 0.778, 1.133; 1), (0.667, 0.778, 1.143; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$
$j = 13$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.154, 0.200, 0.714; 1), (0.167, 0.200, 0.444; 0.8))$	$((0.133, 0.167, 0.556; 1), (0.143, 0.167, 0.400; 0.8))$	$((0.118, 0.143, 0.455; 1), (0.125, 0.143, 0.333; 0.8))$	$((0.111, 0.125, 0.357; 1), (0.118, 0.125, 0.267; 0.8))$
$j = 14$	$((0.333, 0.500, 2.500; 1), (0.400, 0.500, 1.333; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.182, 0.250, 1; 1), (0.200, 0.259, 1; 0.8))$	$((0.154, 0.200, 0.714; 1), (0.167, 0.200, 0.444; 0.8))$	$((0.118, 0.143, 0.455; 1), (0.125, 0.143, 0.333; 0.8))$
$j = 15$	$((0.500, 0.667, 1; 1), (0.556, 0.667, 1; 0.8))$	$((0.611, 0.778, 1.133; 1), (0.667, 0.778, 1.143; 0.8))$	$((0.778, 0.889, 1.200; 1), (0.833, 0.889, 1.214; 0.8))$	$((0.500, 0.667, 1; 1), (0.556, 0.667, 1; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$

Table 6. Normalized criterion values under the environmental dimension.

	$i = 1$	$i = 2$	$i = 3$	$i = 4$	$i = 5$
$j = 1$	$((0.133, 0.167, 0.556; 1), (0.143, 0.167, 0.400; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.333, 0.500, 2.500; 1), (0.400, 0.500, 1.333; 0.8))$	$((0.133, 0.167, 0.556; 1), (0.143, 0.167, 0.400; 0.8))$	$((0.154, 0.200, 0.714; 1), (0.167, 0.200, 0.444; 0.8))$
$j = 2$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.133, 0.167, 0.556; 1), (0.143, 0.167, 0.400; 0.8))$	$((0.333, 0.500, 2.500; 1), (0.400, 0.500, 1.333; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1), (0.250, 0.333, 1; 0.8))$
$j = 3$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$	$((0.500, 0.667, 1; 1), (0.556, 0.667, 1; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$	$((0.278, 0.444, 0.733; 1), (0.222, 0.444, 0.714; 0.8))$
$j = 4$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$
$j = 5$	$((0.400, 1.2500; 1), (0.500, 1.2; 0.8))$	$((0.400, 1.2500; 1), (0.500, 1.2; 0.8))$	$((0.400, 1.2500; 1), (0.500, 1.2; 0.8))$	$((0.400, 1.2500; 1), (0.500, 1.2; 0.8))$	$((0.400, 1.2500; 1), (0.500, 1.2; 0.8))$
$j = 6$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$
$j = 7$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$
$j = 8$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.389, 0.556, 0.867; 1), (0.444, 0.556, 0.857; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1), (0.222, 0.333, 0.571; 0.8))$
$j = 9$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1), (0.167, 0.222, 0.357; 0.8))$

	$i = 1$	$i = 2$	$i = 3$	$i = 4$	$i = 5$
$j = 10$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$

Table 7. Normalized criterion values under the social dimension.

	$i = 1$	$i = 2$	$i = 3$	$i = 4$	$i = 5$
$j = 1$	$((0.778, 0.889, 1.200; 1),$ $(0.833, 0.889, 1.214; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.611, 0.778, 1.133; 1),$ $(0.667, 0.778, 1.143; 0.8))$	$((0.833, 1.1, 1.200; 1),$ $(0.778, 1.1, 1.287; 0.8))$
$j = 2$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$
$j = 3$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$
$j = 4$	$((0.222, 0.333, 1.667; 1),$ $(0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1),$ $(0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1),$ $(0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1),$ $(0.250, 0.333, 1; 0.8))$	$((0.222, 0.333, 1.667; 1),$ $(0.250, 0.333, 1; 0.8))$
$j = 5$	$((0.118, 0.143, 0.455; 1),$ $(0.125, 0.143, 0.333; 0.8))$	$((0.133, 0.167, 0.556; 1),$ $(0.143, 0.167, 0.400; 0.8))$	$((0.154, 0.200, 0.714; 1),$ $(0.167, 0.200, 0.444; 0.8))$	$((0.118, 0.143, 0.455; 1),$ $(0.125, 0.143, 0.333; 0.8))$	$((0.133, 0.167, 0.556; 1),$ $(0.143, 0.167, 0.400; 0.8))$
$j = 6$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.833, 1.1, 1.200; 1),$ $(0.778, 1.1, 1.287; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.611, 0.778, 1.133; 1),$ $(0.667, 0.778, 1.143; 0.8))$	$((0.833, 1.1, 1.200; 1),$ $(0.778, 1.1, 1.287; 0.8))$
$j = 7$	$((0.611, 0.778, 1.133; 1),$ $(0.667, 0.778, 1.143; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$
$j = 8$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$
$j = 9$	$((0.611, 0.778, 1.133; 1),$ $(0.667, 0.778, 1.143; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.778, 0.889, 1.200; 1),$ $(0.833, 0.889, 1.214; 0.8))$
$j = 10$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$
$j = 11$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$
$j = 12$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$
$j = 13$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.611, 0.778, 1.133; 1),$ $(0.667, 0.778, 1.143; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$
$j = 14$	$((0.154, 0.200, 0.714; 1),$ $(0.167, 0.200, 0.444; 0.8))$	$((0.333, 0.500, 2.500; 1),$ $(0.400, 0.500, 1.333; 0.8))$	$((0.118, 0.143, 0.455; 1),$ $(0.125, 0.143, 0.333; 0.8))$	$((0.182, 0.250, 1; 1),$ $(0.200, 0.259, 1; 0.8))$	$((0.154, 0.200, 0.714; 1),$ $(0.167, 0.200, 0.444; 0.8))$
$j = 15$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.611, 0.778, 1.133; 1),$ $(0.667, 0.778, 1.143; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$
$j = 16$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$
$j = 17$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$
$j = 18$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.111, 0.111, 0.333; 1),$ $(0.111, 0.111, 0.286; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$	$((0.111, 0.222, 0.400; 1),$ $(0.167, 0.222, 0.357; 0.8))$
$j = 19$	$((0.182, 0.250, 1; 1),$ $(0.200, 0.259, 1; 0.8))$	$((0.154, 0.200, 0.714; 1),$ $(0.167, 0.200, 0.444; 0.8))$	$((0.222, 0.333, 1.667; 1),$ $(0.250, 0.333, 1; 0.8))$	$((0.182, 0.250, 1; 1),$ $(0.200, 0.259, 1; 0.8))$	$((0.182, 0.250, 1; 1),$ $(0.200, 0.259, 1; 0.8))$
$j = 20$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$	$((0.389, 0.556, 0.867; 1),$ $(0.444, 0.556, 0.857; 0.8))$	$((0.500, 0.667, 1; 1),$ $(0.556, 0.667, 1; 0.8))$	$((0.167, 0.333, 0.600; 1),$ $(0.222, 0.333, 0.571; 0.8))$	$((0.278, 0.444, 0.733; 1),$ $(0.222, 0.444, 0.714; 0.8))$

According to Step 3 of the proposed algorithm, the aggregated fuzzy decision matrix was determined. The obtained matrix is presented in Table 8.

Table 8. Aggregated fuzzy decision matrix.

	$k = 1$	$k = 2$	$k = 3$
$i = 1$	$((0.366, 0.448, 0.968; 1),$ $(0.397, 0.448, 0.834; 0.8))$	$((0.179, 0.325, 0.705; 1),$ $(0.214, 0.325, 0.600; 0.8))$	$((0.249, 0.368, 0.719; 1),$ $(0.269, 0.368, 0.641; 0.8))$
$i = 2$	$((0.338, 0.458, 0.931; 1),$ $(0.376, 0.458, 0.810; 0.8))$	$((0.189, 0.333, 0.889; 1),$ $(0.244, 0.333, 0.603; 0.8))$	$((0.240, 0.383, 0.755; 1),$ $(0.293, 0.383, 0.664; 0.8))$
$i = 3$	$((0.300, 0.398, 0.788; 1),$ $(0.315, 0.398, 0.693; 0.8))$	$((0.186, 0.347, 0.780; 1),$ $(0.252, 0.347, 0.631; 0.8))$	$((0.288, 0.424, 0.739; 1),$ $(0.329, 0.424, 0.670; 0.8))$
$i = 4$	$((0.308, 0.419, 0.827; 1),$ $(0.346, 0.419, 0.704; 0.8))$	$((0.171, 0.316, 0.687; 1),$ $(0.214, 0.316, 0.587; 0.8))$	$((0.309, 0.455, 0.792; 1),$ $(0.311, 0.455, 0.742; 0.8))$
$i = 5$	$((0.280, 0.384, 0.756; 1),$ $(0.306, 0.384, 0.634; 0.8))$	$((0.182, 0.331, 0.719; 1),$ $(0.217, 0.331, 0.606; 0.8))$	$((0.325, 0.469, 0.795; 1),$ $(0.353, 0.469, 0.732; 0.8))$

In Step 4 of the proposed algorithm, the weighted normalized fuzzy decision matrix was constructed using the previously determined weights of the sustainability dimensions. The obtained weighted normalized fuzzy decision matrix is presented in Table 9.

Table 9. Weighted normalized fuzzy decision matrix.

	$k = 1$	$k = 2$	$k = 3$
$i = 1$	$((0.089, 0.175, 0.586; 1),$ $(0.125, 0.175, 0.419; 0.8))$	$((0.031, 0.094, 0.353; 1),$ $(0.060, 0.094, 0.231; 0.8))$	$((0.049, 0.117, 0.382; 1),$ $(0.067, 0.117, 0.253; 0.8))$
$i = 2$	$((0.082, 0.179, 0.563; 1),$ $(0.118, 0.179, 0.407; 0.8))$	$((0.033, 0.097, 0.445; 1),$ $(0.068, 0.097, 0.232; 0.8))$	$((0.047, 0.122, 0.401; 1),$ $(0.073, 0.122, 0.262; 0.8))$
$i = 3$	$((0.073, 0.156, 0.477; 1),$ $(0.099, 0.156, 0.349; 0.8))$	$((0.032, 0.101, 0.391; 1),$ $(0.070, 0.101, 0.243; 0.8))$	$((0.056, 0.135, 0.392; 1),$ $(0.082, 0.135, 0.265; 0.8))$
$i = 4$	$((0.075, 0.164, 0.500; 1),$ $(0.109, 0.164, 0.354; 0.8))$	$((0.029, 0.092, 0.344; 1),$ $(0.060, 0.092, 0.226; 0.8))$	$((0.060, 0.145, 0.421; 1),$ $(0.077, 0.145, 0.293; 0.8))$
$i = 5$	$((0.068, 0.150, 0.457; 1),$ $(0.096, 0.150, 0.319; 0.8))$	$((0.031, 0.096, 0.360; 1),$ $(0.061, 0.096, 0.233; 0.8))$	$((0.063, 0.150, 0.422; 1),$ $(0.088, 0.150, 0.289; 0.8))$

The reference point for each sustainability dimension was determined according to Step 5 of the proposed algorithm:

$$\begin{aligned}\tilde{f}_1^* &= ((0.089, 0.179, 0.586; 1), (0.125, 0.179, 0.419; 0.8)), & \tilde{f}_2^* &= ((0.033, 0.101, 0.445; 1), (0.070, 0.101, 0.243; 0.8)), \\ \tilde{f}_3^* &= ((0.063, 0.150, 0.422; 1), (0.088, 0.150, 0.293; 0.8))\end{aligned}$$

Finally, Steps 6–8 of the proposed algorithm were applied to calculate the ranking coefficients of the considered investment projects. The obtained coefficient values and the final ranking of the investment projects are presented in Table 10.

Table 10. Ranking of the considered investment projects obtained using IT2FMOORA.

	$k = 1$	$k = 2$	$k = 3$	δ_i	Rank
$i = 1$	0.001	0.022	0.030	0.030	2
$i = 2$	0.016	0.003	0.023	0.023	1
$i = 3$	0.044	0.009	0.017	0.044	4
$i = 4$	0.035	0.025	0.004	0.035	3
$i = 5$	0.056	0.019	0.001	0.056	5

3.3. Application of the Proposed IT2FTODIM for Ranking Investment Projects

By applying Step 5 of the proposed IT2FTODIM algorithm, the preference matrices for the five considered investment projects were constructed. The obtained preference matrices are presented in Tables 11–15.

Table 11. Preference matrix for the first considered investment project.

	$k = 1$	$k = 2$	$k = 3$
$i = 1 - 2$	−0.289	−0.233	−0.152
$i = 1 - 3$	0.129	−0.194	−0.200
$i = 1 - 4$	0.319	0.095	−0.279
$i = 1 - 5$	0.406	−0.084	−0.297

$$\delta_1 = -0.779$$

Table 12. Preference matrix for the second considered investment project.

	$k = 1$	$k = 2$	$k = 3$
$i = 2 - 1$	0.289	0.233	0.152
$i = 2 - 3$	0.330	−0.195	−0.167
$i = 2 - 4$	0.285	0.254	−0.239
$i = 2 - 5$	0.379	0.220	−0.259

$$\delta_2 = 1.282$$

Table 13. Preference matrix for the third considered investment project.

	<i>k</i> = 1	<i>k</i> = 2	<i>k</i> = 3
<i>i</i> = 3 – 1	−0.129	0.194	0.200
<i>i</i> = 3 – 2	−0.330	0.195	0.167
<i>i</i> = 3 – 4	−0.167	0.218	−0.239
<i>i</i> = 3 – 5	0.187	0.175	−0.259

$$\delta_3 = 0.212$$

Table 14. Preference matrix for the fourth considered investment project.

	<i>k</i> = 1	<i>k</i> = 2	<i>k</i> = 3
<i>i</i> = 4 – 1	−0.319	−0.095	0.279
<i>i</i> = 4 – 2	−0.285	−0.254	0.239
<i>i</i> = 4 – 3	0.167	−0.218	0.207
<i>i</i> = 4 – 5	0.251	−0.130	−0.120

$$\delta_4 = -0.279$$

Table 15. Preference matrix for the fifth considered investment project.

	<i>k</i> = 1	<i>k</i> = 2	<i>k</i> = 3
<i>i</i> = 5 – 1	−0.406	0.084	0.297
<i>i</i> = 5 – 2	−0.379	−0.220	0.259
<i>i</i> = 5 – 3	−0.187	−0.175	0.220
<i>i</i> = 5 – 4	−0.251	0.130	0.120

$$\delta_5 = -0.508$$

After applying the remaining steps of the proposed IT2FTODIM algorithm, the overall dominance values and the final ranking of the considered investment projects were determined. The obtained results are presented in Table 16.

Table 16. Ranking of the considered investment projects obtained using IT2FTODIM.

	ξ_i	Rank
<i>i</i> = 1	0	5
<i>i</i> = 2	1	1
<i>i</i> = 3	0.481	2
<i>i</i> = 4	0.241	3
<i>i</i> = 5	0.131	4

3.4. Sensitivity Analysis

To examine the stability of the ranking of the considered investment projects, and consequently the stability of the obtained solution, a sensitivity analysis was conducted. The analysis was performed by varying the relative importance of the considered sustainability dimensions across four scenarios. In three scenarios, one of the three sustainability

dimensions is treated as dominant and assigned a weight of 0.6, while the other two dimensions are assigned weights of 0.2 each. The fourth scenario considers all three sustainability dimensions to be equally important. The four considered scenarios are presented in Table 17.

Table 17. Weighting scenarios considered in the sensitivity analysis.

	Economic	Environmental	Social
Baseline model	Weights obtained by IT2FAHP		
Scenario 1 Economic dominant	0.60	0.20	0.20
Scenario 2 Environmental dominant	0.20	0.60	0.20
Scenario 3 Social dominant	0.20	0.20	0.60
Scenario 4 Equal dimensions	1/3	1/3	1/3

For each considered scenario, the proposed model remained completely unchanged, with the only changes being made to the weights of the sustainability dimensions. All other aspects of the ranking procedure remained unchanged for both applied methods. The obtained rankings for the considered scenarios are presented in Table 18 for IT2FMOORA and Table 19 for IT2FTODIM.

Table 18. Sensitivity analysis of investment-project rankings using IT2FMOORA.

	Baseline Model	Scenario 1 Economic Dominant	Scenario 2 Environmental Dominant	Scenario 3 Social Dominant	Equal Dimensions
$i = 1$	2	4	4	3	3
$i = 2$	1	1	1	1	1
$i = 3$	4	3	2	4	4
$i = 4$	3	2	3	2	2
$i = 5$	5	5	5	5	5

Table 19. Sensitivity analysis of investment-project rankings using IT2FTODIM.

	Baseline Model	Scenario 1 Economic Dominant	Scenario 2 Environmental Dominant	Scenario 3 Social Dominant	Equal Dimensions
$i = 1$	5	5	5	5	5
$i = 2$	1	1	1	1	1
$i = 3$	2	3	2	2	2
$i = 4$	3	2	3	3	3
$i = 5$	4	4	4	4	4

The results of the conducted sensitivity analysis showed that the ranking of the investment projects is relatively stable and that there are no significant changes despite variations in the weights of the sustainability dimensions.

Specifically, it was shown that investment project ($i = 2$) remains the top-ranked alternative in all four additional scenarios analyzed for both applied methods. For IT2FMOORA, the rankings of all other projects vary depending on the considered scenario, to a greater or lesser extent, whereas IT2FTODIM produces more stable rankings of the considered investment projects. Overall, the sensitivity analysis indicates that

investment project ($i = 2$) remains the highest-priority alternative in all considered cases, demonstrating the stability of the obtained solution with respect to changes in the sustainability-dimension weights.

4. Discussion

The results obtained using IT2FMOORA and IT2FTODIM show that investment project ($i = 2$) is ranked first by both methods and can therefore be considered the most suitable alternative for implementation in the forthcoming period. This agreement is particularly important because the two methods employ different ranking procedures. The results obtained using the two methodologically different ranking approaches are consistent with respect to the top-ranked alternative. Although the ranking positions of the remaining investment projects differ between the two methods, both IT2FMOORA and IT2FTODIM identify the same project as the first-ranked alternative. For example, investment project ($i = 3$) was ranked fourth by IT2FMOORA and second by IT2FTODIM, representing a difference of two ranking positions. This finding is also supported by the sensitivity analysis, where the same project retained the first position under all considered weighting scenarios for both methods.

Based on the obtained results, investment project ($i = 5$), which was ranked last by IT2FMOORA and fourth by IT2FTODIM, appears to be less suitable for implementation in the forthcoming period, while the remaining investment projects may continue to be considered by strategic management in subsequent planning periods.

Previous studies have demonstrated the applicability of interval type-2 fuzzy extensions of MOORA and TODIM in different MCDM problems. IT2FMOORA-based approaches have been applied by [40–42], while interval type-2 fuzzy TODIM approaches have been considered by [44–47]. The present study extends this body of research to sustainable investment project selection in the manufacturing sector while simultaneously considering economic, environmental, and social dimensions. An additional methodological distinction is that the considered criteria may be either crisp or uncertain, while uncertain criterion values are represented using IT2TFNs. Furthermore, the proposed IT2FMOORA employs a reference-point-based ranking procedure, whereas the IT2FTODIM approach determines preference relations using the distance between IT2TFNs, with the Hamming distance applied in this study.

Differences in the rankings obtained by IT2FMOORA and IT2FTODIM may potentially, and indeed are even expected to, arise as a result of the different mathematical foundations of the two methods [57]. IT2FMOORA evaluates and ranks alternatives according to their distance from a reference point, whereas IT2FTODIM is based on the direct comparison of alternatives and the preference relations between them. For this reason, changes in the weights of the sustainability dimensions, the introduction of criterion weights, or changes in the assessments provided by the decision-makers may be reflected differently in the results obtained using these two approaches. If the best alternative differs between the two approaches, decision-makers should examine the position of the top-ranked alternative under the other approach and investigate the criteria and sustainability dimensions contributing to the divergence. In addition, sensitivity analysis through changes in the weights may contribute to the selection of an appropriate solution. It should be emphasized that the proposed model represents a decision-support tool rather than necessarily providing a strict solution to the problem. The decision-makers bear full responsibility for the final selection of the alternative. The proposed approach is based on a complementary analysis of the solutions from two different perspectives, which can further support this process.

It should be emphasized that the methodological contribution of this study does not lie in introducing new MCDM methods, but in integrating existing approaches into a two-stage framework for sustainable investment project selection.

From a practical perspective, the proposed framework can support strategic management in evaluating investment projects whose implementation may directly influence the future growth and development of a manufacturing company. By considering economic, environmental, and social dimensions simultaneously, the model provides a broader basis for investment decision-making than approaches focused primarily on financial indicators. The resulting ranking enables decision-makers to identify the investment project that best reflects the combined sustainability considerations included in the evaluation process. In this sense, the proposed framework can serve as a decision-support tool for selecting projects intended to contribute to the achievement of strategic objectives and the improvement of long-term business performance.

The proposed framework is subject to several limitations. Only three experts participated in the case study. Although the experts were selected to represent business areas relevant to the evaluation of investment projects, involving a larger number of experts could provide a broader range of perspectives and reduce the influence of individual assessments. Accordingly, future studies in the same domain could include additional experts to ensure a broader expert panel, such as specialists in environmental and sustainability issues, occupational safety, and other relevant aspects.

A certain degree of subjectivity is also inherent in assessing the relative importance of the sustainability dimensions and the uncertain criterion values, as these assessments depend on the knowledge and experience of the selected DMs. The use of interval type-2 fuzzy numbers also increases the computational complexity of the decision-making procedure compared with simpler decision-making approaches.

An additional limitation is that the criteria within each sustainability dimension are assumed to have equal importance. Although this assumption was adopted to avoid the additional burden of determining the criterion weights and to prevent the number of criteria within a dimension from affecting their relative weights, some alternative approaches to weight determination could lead to somewhat different results. Another limitation is that the proposed framework was applied only to a single company. Therefore, the obtained results cannot be generalized. However, since the case study concerns a single company and a specific decision-making problem, the study does not aim to generalize the obtained results and conclusions.

Although operations with interval type-2 fuzzy numbers increase the computational complexity of the proposed approach, in practice, DMs would not be required to perform these operations manually, as the development of a user-friendly software solution could facilitate the practical implementation of the proposed two-stage fuzzy model. The proposed model can also be extended to other industrial contexts, such as the process and automotive industries, in order to examine its applicability under different decision-making conditions. Overall, the proposed framework provides a structured approach for supporting sustainable investment project selection under uncertainty and can serve as a basis for strategic decision-making in manufacturing companies.

5. Conclusions

Investments represent an important prerequisite for development, both at the level of the overall economy and individual business entities, as they contribute to continuous growth and the improvement of future business performance. However, the selection of an appropriate investment project is a complex decision-making problem, particularly when economic, environmental, and social aspects must be simultaneously considered

under uncertainty. In this research, a hybrid two-stage fuzzy model was proposed for the ranking of investment projects under interval type-2 uncertainty.

The proposed model was tested using real-world data obtained from a manufacturing company operating in central Serbia. The assessments required for determining the relative importance of the sustainability dimensions were provided by selected decision-makers based on their knowledge and professional experience. The application of both ranking methods resulted in the identification of the same investment project as the most preferable alternative for implementation in the forthcoming period.

The main contributions of the presented research are as follows: (1) uncertainty in the decision-making process is modelled using IT2TFNs; (2) the determination of the relative importance of the sustainability dimensions is formulated as a fuzzy group decision-making problem; (3) the weight vector of the sustainability dimensions is determined using the proposed IT2FAHP, enabling the subjective assessments of multiple decision-makers to be incorporated into the weighting process; (4) the individual fuzzy weight vectors are aggregated using a fuzzy geometric mean operator to obtain the overall weight vector of the sustainability dimensions; (5) the investment projects are ranked using two interval type-2 fuzzy multi-criteria decision-making approaches: (i) IT2FMOORA, based on the reference point approach, Hamming distance, and fuzzy algebraic operations, and (ii) IT2FTODIM, in which preference values are determined by applying the Hamming distance for type-2 fuzzy numbers within the conventional TODIM procedure.

The practical implications of the proposed methodology are primarily related to strategic decision-making in manufacturing companies. The proposed framework enables investment projects to be evaluated and ranked by simultaneously considering economic, environmental, and social criteria and the relative importance of the corresponding sustainability dimensions. The investment project ranked first represents the most preferable alternative and may therefore be considered for implementation in the forthcoming period to support the achievement of the established strategic objectives.

The main advantage of the proposed two-stage fuzzy model lies in the integration of fuzzy group decision-making, interval type-2 fuzzy modelling, and two complementary MCDM ranking methods within a unified framework. In this way, the obtained results can provide decision support to strategic management in selecting the most appropriate investment project. Although the proposed model was tested in the manufacturing sector, its application can be extended to other industries, such as the process and automotive industries.

The proposed methodology is subject to certain limitations. First, the determination of the relative importance of the sustainability dimensions relies on the subjective assessments of the decision-makers, while some criterion values are characterized by uncertainty. Second, the use of interval type-2 fuzzy sets increases the complexity of the calculations compared with conventional decision-making approaches.

Future research could address the development of a software solution for implementing the proposed model. The model could also be applied to investment project selection problems in other industries, such as the process and automotive industries.

Author Contributions: Conceptualization, T.P. and D.T.; methodology, D.T.; validation, N.K., J.D. and T.P.; formal analysis, D.T. and J.D.; investigation, T.P. and J.D.; resources, T.P.; data curation, J.D. and M.M.; writing—original draft preparation, T.P.; writing—review and editing, D.T., N.K. and M.M.; visualization, N.K.; supervision, D.T. and M.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AHP	Analytic Hierarchy Process
CNC	Computer Numerical Control
CR	Consistency Ratio
DMs	Decision-Makers
IT2FAHP	Interval Type-2 Fuzzy Analytic Hierarchy Process
IT2FMOORA	Interval Type-2 Fuzzy Multi-Objective Optimization by Ratio Analysis
IT2FSs	Interval Type-2 Fuzzy Sets
IT2FTODIM	Interval Type-2 Fuzzy TODIM
IT2TFNs	Interval Type-2 Triangular Fuzzy Numbers
MCDM	Multi-Criteria Decision-Making
MOORA	Multi-Objective Optimization by Ratio Analysis
TODIM	Tomada de Decisão Interativa Multicritério (in Portuguese)

References

1. ANSI/PMI 99-001-2008; A Guide to the Project Management Body of Knowledge: (PMBOK® Guide), Global Standard, 4 ed.; Project Management Institute: Newtown Square, PA, USA, 2008; ISBN 978-1-933890-51-7.
2. Chakraborty, S.; Saha, A.K. Selection of Forklift Unit for Transport Handling Using Integrated MCDM under Neutrosophic Environment. *Facta Univ. Ser. Mech. Eng.* **2024**, *22*, 235–256. <https://doi.org/10.22190/FUME220620039C>.
3. Arsić, D.; Lazić, V.; Nikolić, R.R.; Sczygiol, N.; Krstić, B.; Ivković, D.; Hadzima, B.; Pastorek, F.; Ulewicz, R. Weldability Assessment of Various Steels by Hard-Facing. *Materials* **2022**, *15*, 3082. <https://doi.org/10.3390/ma15093082>.
4. Božanić, D.; Pamučar, D.; Milić, A.; Marinković, D.; Komazec, N. Modification of the Logarithm Methodology of Additive Weights (LMAW) by a Triangular Fuzzy Number and Its Application in Multi-Criteria Decision Making. *Axioms* **2022**, *11*, 89. <https://doi.org/10.3390/axioms11030089>.
5. Więckowski, J.; Sałabun, W. Making More Informed Decisions in Multi-Criteria Problems under Uncertain Conditions of Criteria Weights: Drone Selection Study Case. *Facta Univ. Ser. Mech. Eng.* **2025**, *Epub ahead of printing*. <https://doi.org/10.22190/FUME240930019W>.
6. Stevic, Z.; Ulutas, A.; Topal, A.; Marinkovic, D.; Cavoski, S. A New Objective Method for Determining Criteria Weights in MCDM Models—LOGSTA. *Int. J. Simul. Model.* **2025**, *24*, 589–600. <https://doi.org/10.2507/IJSIMM24-4-738>.
7. Arsić, D.; Ivković, D.; Sudžum, R.; Marinković, D.; Komatina, N. Selection of Base Materials for Repair Welding Using BWM-TOPSIS and BWM-RADAR Approaches. *Materials* **2025**, *18*, 5696. <https://doi.org/10.3390/ma18245696>.
8. Komatina, N. A Compromise-Based MADM Approach for Prioritizing Failures: Integrating the RADAR Method within the FMEA Framework. *J. Sist. Dan Manaj. Ind.* **2024**, *8*, 73–88. <https://doi.org/10.30656/jsmi.v8i2.9283>.
9. Mandal, N.; Sarkar, P.; Petrović, N. Multi-Criteria Decision-Making for Ranking Renewable Energy Sources: A Case Study from the Republic of Serbia. *J. Eng. Manag. Syst. Eng.* **2025**, *4*, 109–121. <https://doi.org/10.56578/jemse040203>.
10. Kawecka, E.; Perec, A.; Radomska-Zalas, A. Use of the Simple Multicriteria Decision-Making (MCDM) Method for Optimization of the High-Alloy Steel Cutting Process by the Abrasive Water Jet. *Spectr. Mech. Eng. Oper. Res.* **2024**, *1*, 111–120. <https://doi.org/10.31181/smeor11202411>.
11. Kizielewicz, B.; Sałabun, W. SITW Method: A New Approach to Re-Identifying Multi-Criteria Weights in Complex Decision Analysis. *Spectr. Mech. Eng. Oper. Res.* **2024**, *1*, 215–226. <https://doi.org/10.31181/smeor11202419>.
12. Lazić, V.; Cukic, R.; Aleksandrović, S.; Milosavljević, D.; Arsić, D.; Nedeljković, B.; Djordjević, M. Techno-Economic Justification of Reparatory Hard Facing of Various Working Parts of Mechanical Systems. *Tribol. Ind.* **2014**, *36*, 287.
13. Aqlan, F.; Al-Fandi, L. Prioritizing Process Improvement Initiatives in Manufacturing Environments. *Int. J. Prod. Econ.* **2018**, *196*, 261–268. <https://doi.org/10.1016/j.ijpe.2017.12.004>.

14. Brauers, W.K.M.; Zavadskas, E.K. Project Management by MULTIMOORA as an Instrument for Transition Economies. *Technol. Econ. Dev. Econ.* **2010**, *16*, 5–24. <https://doi.org/10.3846/tede.2010.01>.
15. Zavadskas, E.K.; Turskis, Z.; Tamošaitienė, J. Multicriteria Selection of Project Managers by Applying Grey Criteria. *Technol. Econ. Dev. Econ.* **2008**, *14*, 462–477. <https://doi.org/10.3846/1392-8619.2008.14.462-477>.
16. Ervural, B.C. Evaluating the Sustainable Development Performance of G20 Economies Using an Integrated Decision-Making Framework. *J. Eng. Manag. Syst. Eng.* **2026**, *5*, 63–84. <https://doi.org/10.56578/jemse050105>.
17. Swarnakar, V.; Jaradat, R.; Khalfan, M.; Maalouf, M.; Eltoukhy, A.E.E.; Hossain, N.U.I. Sustainable Project Choice: Integrating Must-Be Kano and Fuzzy Logic for Optimal Project Selection. *J. Open Innov. Technol. Mark. Complex.* **2025**, *11*, 100610. <https://doi.org/10.1016/j.joitmc.2025.100610>.
18. Jurík, L.; Horňáková, N.; Šantavá, E.; Cagánová, D.; Sablik, J. Application of AHP Method for Project Selection in the Context of Sustainable Development. *Wirel. Netw.* **2022**, *28*, 893–902. <https://doi.org/10.1007/s11276-020-02322-2>.
19. Awasthi, A.; Omrani, H.; Gerber, P. Investigating Ideal-Solution Based Multicriteria Decision Making Techniques for Sustainability Evaluation of Urban Mobility Projects. *Transp. Res. Part A Policy Pract.* **2018**, *116*, 247–259. <https://doi.org/10.1016/j.tra.2018.06.007>.
20. Bhattu, B.; Barkdoll, B.D.; Breffle, W.S. A Sustainability-Based Socio-Technical-Environmental Project Selection Algorithm. *Sustain. Water Resour. Manag.* **2018**, *4*, 117–128. <https://doi.org/10.1007/s40899-017-0149-9>.
21. Fallahpour, A.; Wong, K.Y.; Rajoo, S.; Olugu, E.U.; Nilashi, M.; Turskis, Z. A Fuzzy Decision Support System for Sustainable Construction Project Selection: An Integrated FPP-FIS Model. *J. Civ. Eng. Manag.* **2020**, *26*, 247–258. <https://doi.org/10.3846/jcem.2020.12183>.
22. Komatina, N.; Djapan, M.; Ristić, I.; Aleksić, A. Fulfilling External Stakeholders' Demands—Enhancement Workplace Safety Using Fuzzy MCDM. *Sustainability* **2021**, *13*, 2892. <https://doi.org/10.3390/su13052892>.
23. Zadeh, L.A. The Concept of a Linguistic Variable and Its Application to Approximate Reasoning—I. *Inf. Sci.* **1975**, *8*, 199–249. [https://doi.org/10.1016/0020-0255\(75\)90036-5](https://doi.org/10.1016/0020-0255(75)90036-5).
24. Božanić, D.; Puška, A.; Tešić, D.; Štilić, A.; Ullah, K.; Muhsen, Y.R.; Hezam, I.M. Fuzzy AHP-Fuzzy MABAC Model for Ranking a Combined Construction Machine-Backhoe Loader. *Facta Univ. Ser. Mech. Eng.* **2025**, *23*, 605–625. <https://doi.org/10.22190/FUME250801030B>.
25. Więckowski, J.; Kizielewicz, B.; Shekhovtsov, A.; Sałabun, W. How Do the Criteria Affect Sustainable Supplier Evaluation?—A Case Study Using Multi-Criteria Decision Analysis Methods in a Fuzzy Environment. *J. Eng. Manag. Syst. Eng.* **2023**, *2*, 37–52. <https://doi.org/10.56578/jemse020102>.
26. Mishra, A.R.; Rani, P. Evaluating and Prioritizing Blockchain Networks Using Intuitionistic Fuzzy Multi-Criteria Decision-Making Method. *Spectr. Mech. Eng. Oper. Res.* **2025**, *2*, 78–92. <https://doi.org/10.31181/smeor21202527>.
27. Karnik, N.N.; Mendel, J.M. Centroid of a Type-2 Fuzzy Set. *Inf. Sci.* **2001**, *132*, 195–220. [https://doi.org/10.1016/S0020-0255\(01\)00069-X](https://doi.org/10.1016/S0020-0255(01)00069-X).
28. Mendel, J.M. *Uncertain Rule-Based Fuzzy Systems: Introduction and New Directions*, 2nd ed.; Springer International Publishing: Cham, Switzerland, 2017; ISBN 978-3-319-51369-0.
29. Komatina, N.; Tadić, D.; Đurić, G.; Aleksić, A. Determination of Manufacturing Process Failures Priority under Type 2 Fuzzy Environment: Application of Genetic Algorithm and Variable Neighborhood Search. *Proc. Inst. Mech. Eng. Part E J. Process Mech. Eng.* **2024**, *238*, 2427–2437. <https://doi.org/10.1177/09544089231160510>.
30. Aleksić, A.; Tadić, D. Industrial and Management Applications of Type-2 Multi-Attribute Decision-Making Techniques Extended with Type-2 Fuzzy Sets from 2013 to 2022. *Mathematics* **2023**, *11*, 2249. <https://doi.org/10.3390/math11102249>.
31. Yalçın, G.C.; Kara, K.; Gürol, P.; Babić, M. A Fermatean Fuzzy MCDM Framework for Green Port Transformation and Heavy-Duty Forklift Selection. *J. Eng. Manag. Syst. Eng.* **2025**, *4*, 269–283. <https://doi.org/10.56578/jemse040404>.
32. Saaty, T.L. The Modern Science of Multicriteria Decision Making and Its Practical Applications: The AHP/ANP Approach. *Oper. Res.* **2013**, *61*, 1101–1118. <https://doi.org/10.1287/opre.2013.1197>.
33. Đurić, G.; Mitrović, Č.; Komatina, N.; Tadić, D.; Vorotović, G. The Hybrid MCDM Model with the Interval Type-2 Fuzzy Sets for the Software Failure Analysis. *J. Intell. Fuzzy Syst.* **2019**, *37*, 7747–7759. <https://doi.org/10.3233/JIFS-182541>.
34. Celik, E.; Akyuz, E. An Interval Type-2 Fuzzy AHP and TOPSIS Methods for Decision-Making Problems in Maritime Transportation Engineering: The Case of Ship Loader. *Ocean. Eng.* **2018**, *155*, 371–381. <https://doi.org/10.1016/j.oceaneng.2018.01.039>.
35. Ecer, F. Multi-Criteria Decision Making for Green Supplier Selection Using Interval Type-2 Fuzzy AHP: A Case Study of a Home Appliance Manufacturer. *Oper. Res. Int. J.* **2022**, *22*, 199–233. <https://doi.org/10.1007/s12351-020-00552-y>.

36. Kiracı, K.; Akan, E. Aircraft Selection by Applying AHP and TOPSIS in Interval Type-2 Fuzzy Sets. *J. Air Transp. Manag.* **2020**, *89*, 101924. <https://doi.org/10.1016/j.jairtraman.2020.101924>.
37. Andalib Ardakani, D.; Kiani, M.; Saffari Darberazi, A.; Zamzam, F.; Mofatehzadeh, E. An Interval Type-2 Fuzzy AHP Approach for Success Factors of Green Supply Chain Management. *Int. J. Res. Ind. Eng.* **2024**, *13*, 237–256. <https://doi.org/10.22105/riej.2024.441073.1416>.
38. Kahraman, C.; Öztayşi, B.; Uçal Sarı, İ.; Turanoğlu, E. Fuzzy Analytic Hierarchy Process with Interval Type-2 Fuzzy Sets. *Knowl.-Based Syst.* **2014**, *59*, 48–57. <https://doi.org/10.1016/j.knosys.2014.02.001>.
39. Brauers, W.K.; Zavadskas, E.K. The MOORA Method and Its Application to Privatization in a Transition Economy. *Control Cybern.* **2006**, *35*, 445–469.
40. Bera, A.K.; Jana, D.K.; Banerjee, D.; Nandy, T. Supplier Selection Using Extended IT2 Fuzzy TOPSIS and IT2 Fuzzy MOORA Considering Subjective and Objective Factors. *Soft Comput.* **2020**, *24*, 8899–8915. <https://doi.org/10.1007/s00500-019-04419-z>.
41. Dinçer, H.; Yüksel, S. Selecting Investment Strategies for European Tourism Industry Using the Hybrid Decision Making Approach Based on Interval Type-2 Fuzzy Sets. *J. Intell. Fuzzy Syst.* **2019**, *37*, 1343–1356. <https://doi.org/10.3233/JIFS-182773>.
42. Öztürk, M. Post-earthquake relief logistics center location selection: A novel hybrid IT2 F-RANCOM + IT2 F-MOORA approach. *Mühendis. Bilim. Tasar. Derg.* **2026**, *14*, 11–32. <https://doi.org/10.21923/jesd.1729763>.
43. Autran Monteiro Gomes, L.F.; Duncan Rangel, L.A. An Application of the TODIM Method to the Multicriteria Rental Evaluation of Residential Properties. *Eur. J. Oper. Res.* **2009**, *193*, 204–211. <https://doi.org/10.1016/j.ejor.2007.10.046>.
44. Meng, Q.; Liu, X.; Song, Y.; Wang, W. An Extended Generalized TODIM Method for Risk Assessment of Supply Chain in Social Commerce under Interval Type-2 Fuzzy Environment. *J. Intell. Fuzzy Syst.* **2019**, *37*, 8551–8565. <https://doi.org/10.3233/JIFS-190061>.
45. Tang, J.; Liu, X.; Wang, W. A Hybrid Risk Prioritization Method Based on Generalized TODIM and BWM for Fine-Kinney under Interval Type-2 Fuzzy Environment. *Hum. Ecol. Risk Assess. Int. J.* **2021**, *27*, 954–979. <https://doi.org/10.1080/10807039.2020.1789840>.
46. Celik, E.; Yucesan, M.; Gul, M. Green Supplier Selection for Textile Industry: A Case Study Using BWM-TODIM Integration under Interval Type-2 Fuzzy Sets. *Environ. Sci. Pollut. Res.* **2021**, *28*, 64793–64817. <https://doi.org/10.1007/s11356-021-13832-7>.
47. Gong, X.; Zhang, J.; Zhao, X. A BWM-TODIM Based Integrated Decision Framework for Financial Technology Selection with Interval Type-2 Fuzzy Sets. *IAENG Int. J. Appl. Math.* **2022**, *52*, 826–837.
48. Bošković, S.; Jovčić, S.; Simić, V.; Švadlenka, L.; Dobrodolac, M.; Bacanin, N. A New Criteria Importance Assessment (CIMAS) Method in Multi-Criteria Group Decision-Making: Criteria Evaluation for Supplier Selection. *Facta Univ. Ser. Mech. Eng.* **2025**, *23*, 335. <https://doi.org/10.22190/FUME230730050B>.
49. Keshavarz Ghorabae, M.; Amiri, M.; Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J. A New Multi-Criteria Model Based on Interval Type-2 Fuzzy Sets and EDAS Method for Supplier Evaluation and Order Allocation with Environmental Considerations. *Comput. Ind. Eng.* **2017**, *112*, 156–174. <https://doi.org/10.1016/j.cie.2017.08.017>.
50. Petrović, N.; Jovanović, V.; Petrović, M.; Nikolić, B.; Mihajlović, J. Comparative Investigation of Normalization Techniques and Their Influence on MCDM Ranking—A Case Study. *Spec. Mech. Eng. Oper. Res.* **2025**, *2*, 172–190. <https://doi.org/10.31181/smeor21202542>.
51. Chen, S.-M.; Lee, L.-W. Fuzzy Multiple Attributes Group Decision-Making Based on the Interval Type-2 TOPSIS Method. *Expert Syst. Appl.* **2010**, *37*, 2790–2798. <https://doi.org/10.1016/j.eswa.2009.09.012>.
52. Qin, J.; Liu, X.; Pedrycz, W. An Extended TODIM Multi-Criteria Group Decision Making Method for Green Supplier Selection in Interval Type-2 Fuzzy Environment. *Eur. J. Oper. Res.* **2017**, *258*, 626–638. <https://doi.org/10.1016/j.ejor.2016.09.059>.
53. Chen, S.-M.; Yang, M.-W.; Lee, L.-W.; Yang, S.-W. Fuzzy Multiple Attributes Group Decision-Making Based on Ranking Interval Type-2 Fuzzy Sets. *Expert Syst. Appl.* **2012**, *39*, 5295–5308. <https://doi.org/10.1016/j.eswa.2011.11.008>.
54. Rodrigues, D.; Rua, O.L. Open Innovation as a Model to Boost the Business Success of SMEs in the Automotive Sector: A Multiple Case Study. *J. Open Innov. Technol. Mark. Complex.* **2025**, *11*, 100577. <https://doi.org/10.1016/j.joitmc.2025.100577>.
55. Kizielewicz, B.; Sałabun, W. Benchmark Study of Re-Identification Methods Based on Stochastic Fuzzy Normalization and Their Application to Decision-Making Problems in Engineering. *FU Mech. Eng.* **2025**, *23*, 511–532. <https://doi.org/10.22190/FUME240916004K>.
56. Wu, D.; Mendel, J.M. A Comparative Study of Ranking Methods, Similarity Measures and Uncertainty Measures for Interval Type-2 Fuzzy Sets. *Inf. Sci.* **2009**, *179*, 1169–1192. <https://doi.org/10.1016/j.ins.2008.12.010>.
57. Özçil, A.; Aytac Adali, E. A Novel MCDM Method: The Integrative Reference Point Approach. *Informatica* **2025**, *36*, 625–655. <https://doi.org/10.15388/25-INFOR594>.

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