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A Hybrid Model for Evaluating the Investment Attractiveness of Companies Using Fuzzy Multi-Criteria Methods

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Abstract. This study develops a novel algorithm to assess the investment attractiveness of companies using multi-criteria decision-making methods (MCDM) such as the Fuzzy Analytic Hierarchy Process (FAHP) and the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS). This approach integrates both quantitative and qualitative aspects, addressing the main limitations of traditional models that often focus solely on internal factors and overlook crucial external variables and qualitative metrics necessary for a comprehensive evaluation. Furthermore, existing models often fail to incorporate adequate risk assessments and typically disregard individual investors' preferences. The algorithm employs fuzzy sets to integrate diverse data, thereby enhancing assessment accuracy in the presence of uncertainty and incomplete information. The model incorporates a range of traditional financial metrics, other quantitative criteria, non-statistical data and subjective investor preferences in order to provide a comprehensive and multifaceted assessment of investment attractiveness. In this article, the FAHP method is employed to determine the weights of the criteria, while the FTOPSIS method is applied to identify the most investment-attractive company. The study tested the model on Russian food retail companies, with Lenta emerging as the most attractive investment option. The results demonstrate the efficacy and applicability of the method for enhancing decision-making precision and objectivity across a spectrum of economic sectors.

Keywords: investment, investment attractiveness, financial analysis, comprehensive assessment, fuzzy sets, MCDM, FAHP, FTOPSIS.

Research area: Social Structure, Social Institutions and Processes; Economics.

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Гибридная модель оценки инвестиционной привлекательности компаний с использованием нечетких многокритериальных методов

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Аннотация. Представлен алгоритм оценки инвестиционной привлекательности компаний, разработанный на основе комплексного подхода, включающего многокритериальные методы принятия решений (MCDM). Анализ существующих моделей выявляет их ключевые недостатки: модели часто фокусируются на внутренних факторах, игнорируя внешние переменные и качественные показатели. Кроме того, многие из них не включают оценку рисков и не учитывают уникальные предпочтения инвесторов. Применение методов, основанных на нечетких множествах, таких как FAHP (Fuzzy Analytic Hierarchy Process) и FTOPSIS (Fuzzy Technique for Order Preference by Similarity to Ideal Solution), позволяет провести всесторонний анализ и оценку факторов, определяющих инвестиционную привлекательность, с учетом специфики отрасли и внешней среды. Разработанная модель позволяет оценить количественные и качественные аспекты, обеспечивая возможность комплексного учета не только традиционных финансовых показателей, но и субъективных предпочтений инвесторов, и дает возможность оценить факторы, для которых нет статистических данных. Модель апробирована на примере оценки инвестиционной привлекательности компаний продуктового ритейла.

Ключевые слова: инвестиции, инвестиционная привлекательность, финансовый анализ, комплексная оценка, нечеткие множества, MCDM, FAHP, FTOPSIS.

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Introduction

This study examines the potential application of multi-criteria decision-making (MCDM) methods for the assessment of investment attractiveness (IA) of companies. The identification of the most attractive companies for investment can be classified as a multi-criteria decision-making task, involving numerous factors that influence the final assessment from various aspects of a company's operations and have industry-specific characteristics. In conducting the assessment, it is essential to consider both internal and external factors. Internal factors can be evaluated through financial, production, and other criteria. External factors, however, are those that the company cannot directly influence, such as changes in consumer behavior. Additionally, it is crucial to recognize that in a dynamic and complex world, there is always uncertainty, which can be observed, for example, in the changing impact of certain factors over time. Therefore, this study decided to use methods based on fuzzy set theory, which, unlike statistical and expert evaluation methods, allow for accounting for the level of uncertainty through the use of membership functions ($\mu(x) \in [0;1]$) of a subset to a given set. It is important to note that a reliable assessment of investment attractiveness is essential not only for investors but also for the company's management.

Thus, IA assessments should provide a comprehensive evaluation, be dynamic, and account for uncertainty and the preferences of decision-makers (DMs) or groups of decision-makers (GDMs). For this purpose, this study proposes the use of a hybrid assessment model consisting of two methods employed in MCDM: FAHP and FTOPSIS.

The applicability of MCDM methods in Russian and international research is a topic worthy of further research.

Literature review

In Russian research, the application of MCDM methods is not as widespread as in international studies. Specifically, MCDM methods have been applied, for example, to assess the welfare of Russian regions using the TOPSIS method (Malafeevskii, 2022). In another study, the TOPSIS method was employed to evaluate entrepreneurial activity in the Far Eastern Federal District (Dukanich, Kuvshinova, 2020). Additionally, an article discusses the analysis of cause-and-effect relationships using the DEMATEL method within the framework of analyzing the role of a balanced scorecard system in the strategic management of an organization (Nazarov, Begicheva, 2023). In general, Russian studies that apply MCDM methods are most frequently observed in technical sciences, which suggests that this topic has not yet been sufficiently developed in the economic field.

Regarding international authors, some studies are presented in Table 1. These studies focus on the general evaluation of company performance, investments, and related topics.

Table 1 demonstrates the extensive applicability of MCDM methods.

An analysis of existing methods for assessing the investment attractiveness (IA) of companies reveals several shortcomings. Many current models focus exclusively on internal factors, neglecting external variables that can significantly impact analysis results. Additionally, many models are unable to adequately integrate qualitative criteria into the analysis. The use of qualitative data may be limited due to a lack of access to necessary information, such as commercial secrecy or the absence of reliable statistical data on certain aspects. Many existing approaches do not include risk assessments, which is a significant drawback. Moreover, analysis methods often ignore the unique preferences and goals of individual investors, leading to inappropriate recommendations. The application of fuzzy sets in methods such as FAHP (Fuzzy Analytic Hierarchy Process) and FTOPSIS (Fuzzy Technique for Order Preference by Similarity to Ideal Solution) offers several advantages that significantly enhance the quality and efficiency of the analytical process. Fuzzy sets allow for effective handling of uncertain information, making the analysis more adaptable to real-world conditions where obtaining precise data is not always possible. Moreover, the utilization of fuzzy sets permits the integration of qualitative data, including expert assessments, subjective opinions, imprecise score evaluations, and other assessment methodologies, thereby expanding the scope of applicability for these methods.

Results

In order to assess a company's IA, it is necessary to consider a wide range of criteria and other aspects, as previously described in this article. In this context, we propose an assessment algorithm based on a hybrid comprehensive model. This model combines two MCDM methods, which can be calculated by a single decision-maker (DM) or a group of decision-makers (GDM). In this section, we consider the calculation algorithm of each method.

Table 1. Overview of MCDM methods' applications

Authors	MCDM methods	Application areas
Aghaei M., 2021	TOPSIS	Evaluation of brand value in the mobile phone industry.
Sarmas E., Marinakis V., Doukas H., 2022	TOPSIS	Financing investments in energy efficiency improvements and determining optimal grant funding plans.
Tafur Y., Lilford E., Aguilera R. F., 2022	AHP, TOPSIS	Assessment of foreign investment risks in the oil sector of South America
Abdel-Basset M., Ding W., Mohamed R. 2020	AHP, VIKOR, TOPSIS	Assessments of financial efficiency in manufacturing industries
Vijayakumar S.R., Suresh P., Sasikumar K., et al., 2022	FAHP, FTOPSIS	Selection of the most investment-attractive project
Rajaa K., Yuan J., et al., 2021	TOPSIS	Assessment of risks of foreign investment projects in the power grid sector
Kou G., Yuksel S., Dinçer H., et al 2023	q-ROF DEMATEL, q-ROF TOPSIS	Identification of the most significant environmental factors for ensuring sustainable development and solving investment tasks in European economies
Oussama Z., Ahmed H., Nabil C., 2024	TOPSIS	Formation of a macroeconomic efficiency index for 16 countries in the MENA region
Gavalas D., Syriopoulos T., Tsatsaronis M., 2022	FDEMATEL, FANP, MOORA	Assessment of efficiency and competitiveness of shipbuilding industry companies
Yusuf Tansel C., Beril K., et al., 2022	AHP, VIKOR	Assessment of financial criteria of wholesale and retail trade companies
Turegunv N., 2022	TOPSIS, VIKOR	Assessment of financial criteria of tourism sector companies
Marjanovich I., Popovic Z., 2020	CRITIC, TOPSIS	Assessment of financial performance of Serbian banks

Source: compiled by the authors

Table 2. Ranking scale

Importance	Fuzzy numbers (Chang, 1993)	Saaty's scale (Saaty, 1993)
Equal	(1, 1, 1)	1
Moderate	(1, 3/2,2)	3
Strong	(3/2, 2, 5/2)	5
Very strong	(2, 5/2, 3)	7
Extreme	(5/2, 3, 7/2)	9

Source: compiled by the authors

Let us examine the general calculation algorithm for the FAHP (Fuzzy Analytic Hierarchy Process).

1. The relative importance of each criterion is determined through a process of pairwise comparison, using the following linguistic variables (Table 2) to quantify the degree of importance:

2. Next, the value of the fuzzy synthetic degree (extent) S_i with respect to the i-th criterion is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (1)$$

In order to obtain of $\sum_{j=1}^{m} M_{gi}^{j}$ it is necessary to perform a fuzzy addition operation of *m* values of the degree of analysis (extent) for a particular matrix:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_i, \sum_{j=1}^{m} m_1, \sum_{j=1}^{m} u_i\right) \quad (2)$$

In order to find $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{i}\right]^{-1}$, the operation of fuzzy addition M_{gi}^{j} $(j = 1, 2, \dots, m)$ is performed in such a way that:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{n} l_i, \sum_{j=1}^{n} m_1, \sum_{j=1}^{n} u_i\right) \quad (3)$$

Subsequently, the inverse value of the vector is calculated in accordance with the equation:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad (4)$$

2. The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$$V(M_2 \geq M_1) = sup[\min(\mu_{M1}(x), \mu_{M2}(\gamma))] \quad (5)$$

and can be expressed as follows:

$$(V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M2}(d) = \begin{cases} 1, \text{если } m_2 \geq m_1, \\ 0, \text{если } l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases} \quad (6)$$

where *d* – the ordinate of the highest intersection point *D* between μ_{M1} and μ_{M2} (Fig. 1).

To compare M_1 and M_2, it is necessary to determine both values $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

3. The degree of the possibility that a convex fuzzy number may be greater than *k* convex fuzzy numbers $M_i(i = 1,2,\dots, k)$ can be calculated as:

$$V(M \geq M_1, M_2, \dots, M_k) = \\ = V[M \geq M_1), (M \geq M_2), \dots, (M \geq M_k)] = \\ = \min V(M \geq M_i), i = 1, 2, \dots, k \quad (7)$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \quad (8)$$

for $k = 1,2,\dots, n$; $k \neq i$, then the weight vector is determined as follows:

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T, \quad (9)$$

where $A_i(i = 1,2,\dots, n)$ is a vector of evaluated parameters consisting of *n* elements.

Via normalization, the normalized weight vectors have the following form:

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \quad (10)$$

where *W* is non-fuzzy number.

Next, consider the FTOPSIS method, which allows obtaining the final ranking of alternatives.

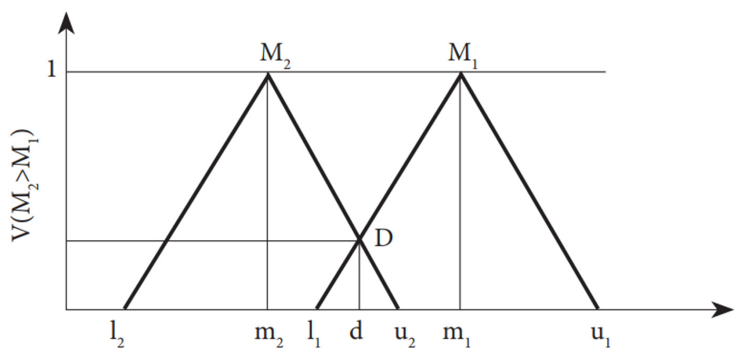

Fig. 1. Intersection between M_1 and M_2

Source: compiled by the authors

1. The FTOPSIS method can be represented by the matrix D:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1j} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2j} \\ \dots & \dots & \dots & \dots \\ \tilde{x}_{i1} & \tilde{x}_{i2} & \dots & \tilde{x}_{ij} \end{bmatrix} \end{array}$$

$$W = [w_1, w_2, \dots, w_n],$$

where $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$, $i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$ и $\tilde{w}_j, j = 1, 2, \dots, n$. Note that $\tilde{x}_{ij}$ (a triangular fuzzy number) is an assessment of alternative A_i concerning the j-го criterion C_j, w_j denotes the weight of the j-го criterion C_j.

In the classical approach, the evaluation of criteria in the FTOPSIS method is typically conducted with the involvement of experts, which allows for the consideration of multiple perspectives and opinions. However, it should be noted that the FTOPSIS method can be utilized not only by groups of experts, but also individually by one person. This work proposes an alternative approach based on the use of criterion volumes over the past three years as a data source for forming fuzzy numbers, where:

a_{ij} – the minimum volume of the criterion over the considered period is used as the lower bound of the fuzzy number for alternative i concerning criterion j;

b_{ij} – the average volume of the criterion over the three years for alternative i concerning criterion j;

c_{ij} – the maximum volume of the criterion over the three years for alternative i concerning criterion j.

For qualitative criteria, the following scale is used (Table 3).

2. If evaluations from multiple experts were used, the aggregated evaluation of the $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ i-th alternative for the j-th criterion is found as follows:

$$a_{ij} = \min_k \{a_{ij}^k\}, b_{ij} = \frac{1}{K} \sum_{k=1}^{K} b_{ij}^k, c_{ij} = \max_k c_{ij}^k \quad (11)$$

3. Calculate the normalized fuzzy decision matrix. The normalized fuzzy decision matrix $\tilde{R} = [\tilde{r_{ij}}]$, where:

$$\tilde{r_{ij}} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ и } c_j^* = \max_i \{c_{ij}^k\} \quad (12)$$

(for benefit criteria)

or

$$\tilde{r_{ij}} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ и } a_j^- = \min_i \{a_{ij}^k\}$$

(for cost criteria) (13)

4. Calculate the weighted normalized fuzzy decision matrix. The weighted normalized fuzzy decision matrix $\tilde{V} = (\tilde{v}_{ij})$, где $\tilde{v}_{ij} = \tilde{r}_{ij} \times w_j$.

$$\tilde{V} = \begin{bmatrix} \tilde{v}_{11} & \tilde{v}_{12} & \dots & \tilde{v}_{1j} \\ \tilde{v}_{21} & \tilde{v}_{22} & \dots & \tilde{v}_{2j} \\ \dots & \dots & \dots & \dots \\ \tilde{v}_{i1} & \tilde{v}_{i2} & \dots & \tilde{v}_{ij} \end{bmatrix} = \begin{bmatrix} w_1\tilde{r}_{11} & w_2\tilde{r}_{12} & \dots & w_n\tilde{r}_{1j} \\ w_1\tilde{r}_{21} & w_2\tilde{r}_{22} & \dots & w_n\tilde{r}_{2j} \\ \dots & \dots & \dots & \dots \\ w_1\tilde{r}_{i1} & w_2\tilde{r}_{i2} & \dots & w_n\tilde{r}_{ij} \end{bmatrix} \quad (14)$$

5. The next step is to identify the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS).

Table 3. Ranking scale

Linguistic values	Fuzzy triangular numbers
Very low	(1, 1, 3)
Low	(1, 3, 5)
Medium	(3, 5, 7)
High	(5, 7, 9)
Very high	(7, 9, 9)

Source: compiled by the authors

Initially, in the method proposed by Chen (2006), the vectors A^* и A^- are defined as $\tilde{v}_n^* = (1,1,1)$ and $\tilde{v}_n^- = (0,0,0)$, representing the maximum and minimum possible normalized values. However, a more relevant approach, as suggested by Collan and Luukka (2006), employs the observed maximum and minimum values, where:

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*),$$

где (15)

$$\tilde{v}_n^* = \left(\max_i v_{ij1}, \max_i v_{ij2}, \max_i v_{ij3}\right)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-),$$

где (16)

$$\tilde{v}_n^- = \left(\min_i v_{ij1}, \min_i v_{ij2}, \min_i v_{ij3}\right)$$

This approach provides a more comprehensive account of the uncertainty or variability of the criteria, as it contains significantly more information.

6. Calculate the distance (d_i^* и d_i^-) from each alternative to FPIS and FNIS:

$$d_i^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_{ij}^*\right), i = 1,2, \dots, m, \quad (17)$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_{ij}^-\right), i = 1,2, \dots, m \quad (18)$$

7. Calculate the closeness coefficient to the ideal solution. At this step, the closeness to the ideal solution is calculated using the formula:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (19)$$

8. The ranking of alternatives is determined by comparing the values of *CCi*.

Consider the application of these methods in assessing the investment attractiveness of grocery retail companies. To illustrate, consider a decision-maker who is analyzing the attractiveness of a company for investment based on a certain set of criteria (Fig. 2).

Suppose that the decision-maker has identified the most important criteria as follows (Table 4).

In accordance with the FAHP method, it is initially necessary to calculate the values of the fuzzy synthetic degree (extent) S_i.

$$S_{c_1-c_4} = (3{,}50,\ 4{,}50,\ 5{,}50) \otimes$$
$$\otimes (0{,}08,\ 0{,}10,\ 0{,}13) = (0{,}29,\ 0{,}46,\ 0{,}70);$$

$$S_{C_5,C_6} = (2{,}50,\ 3{,}17,\ 4{,}00) \otimes$$
$$\otimes (0{,}08,\ 0{,}10,\ 0{,}13) = (0{,}21,\ 0{,}32,\ 0{,}51);$$

$$S_{C_7-C_{10}} = (1{,}90,\ 2{,}17,\ 2{,}67) \otimes$$
$$\otimes (0{,}08,\ 0{,}10,\ 0{,}13) = (0{,}16,\ 0{,}22,\ 0{,}34).$$

The aforementioned fuzzy values are then subjected to comparison via the application of equation (11), thereby yielding the following values:

$$V\left(S_{c_1-c_4} \geq S_{C_5,C_6}\right) = 1, V\left(S_{c_1-c_4} \geq S_{C_7-C_{10}}\right) = 1;$$

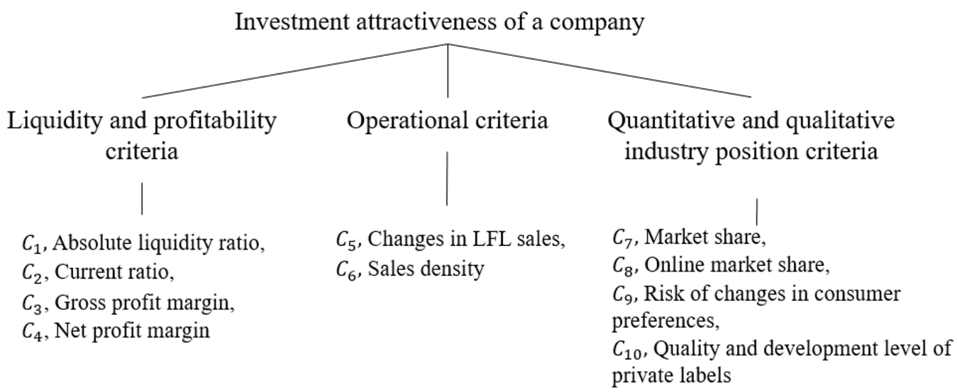

Fig. 2. Criteria of company's investment attractiveness

Source: Compiled by the authors

Table 4. Matrix of pairwise comparison of criteria

	$C_1 - C_4$	C_5, C_6	$C_7 - C_{10}$
$C_1 - C_4$	(1,1,1)	(1, 3/2,2)	(3/2, 2, 5/2)
C_5, C_6	(1/2, 2/3, 1)	**(1,1,1)**	(1, 3/2,2)
$C_7 - C_{10}$	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	**(1,1,1)**

Source: calculated by the authors

$$V(S_{C_5,C_6} \geq S_{c_1-c_4}) =$$
$$= 0{,}617, V(S_{C_5,C_6} \geq S_{C_7-C_{10}}) = 1;$$

$$V(S_{C_7-C_{10}} \geq S_{c_1-c_4}) =$$
$$= 0{,}174, V(S_{C_7-C_{10}} \geq S_{C_5,C_6}) = 0{,}565;$$

Then the importance weights are calculated using (12):

$$d'(S_{c_1-c_4}) = \min(1, \quad 1) = 1;$$

$$d'(S_{C_5,C_6}) = \min(0{,}617, \quad 1) = 0{,}617;$$

$$d'(S_{C_7-C_{10}}) = \min(0{,}174, \ 0{,}565) = 0{,}174.$$

After normalization, the following weights were obtained for the criteria:

$$S_{c_1-c_4} = 0{,}5584, S_{C_5,C_6} = 0{,}3446,$$
$$S_{C_7-C_{10}} = 0{,}097$$

Next, suppose that the decision-maker, using data from the financial statements of companies and other resources, evaluated their performance for 2020–2022 as follows. For convenience, we will present the alternatives in columns (Table 5).

The subsequent stage of the algorithm is to calculate the normalized values of the matrix utilising the formulas (17) and (18). This process yields the results presented in Table 6.

The subsequent step is to calculate the weighted normalized matrix (Table 7).

Subsequently, the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) must be determined in accordance with formulas (20) and (21).

Ranking and selection of the best alternative among the possible alternatives (companies).

Thus, the most investment-attractive company is Lenta.

Table 5. Companies' performance criteria for 2020–2022

Criteria	Magnit			Lenta			X5 Retail Group		
	a	b	c	a	b	c	a	b	c
Absolute liquidity ratio	0,19	0,51	0,83	0,51	0,67	0,83	0,15	0,19	0,23
Current ratio	0,84	0,89	0,95	0,86	0,86	0,87	0,50	0,55	0,60
Gross profit margin	0,23	0,23	0,24	0,23	0,23	0,23	0,24	0,25	0,25
Net profit margin	0,01	0,02	0,03	0,01	0,02	0,04	0,01	0,02	0,02
Changes in LFL Sales	0,07	0,10	0,12	0,02	0,04	0,05	0,05	0,08	0,11
Sales density, thousand RUB/sq.m.	204,96	227,00	249,03	295,48	299,41	303,34	262,10	279,25	296,40
Market share, %	3	5	7	1	1	3	5	7	9
Online market share, %	1	1	3	1	3	5	5	7	9
Risk of changes in consumer Preferences	1	3	5	3	5	7	1	3	5
Quality and development level of private labels	3	5	7	5	7	9	5	7	9

Source: annual reports, company analyst guides, Statista.

Table 6. Elements of the normalized decision matrix

Criteria	Magnit			Lenta			X5 Retail Group		
	a	b	c	a	b	c	a	b	c
Absolute liquidity ratio	0,2308	0,6142	0,9976	0,6107	0,8053	1,0000	0,1757	0,2255	0,2752
Current ratio	0,8859	0,9430	1,0000	0,9044	0,9115	0,9186	0,5244	0,5809	0,6374
Gross profit margin	0,8968	0,9107	0,9246	0,8859	0,8952	0,9044	0,9577	0,9788	1,0000
Net profit margin	0,3199	0,5091	0,6983	0,1810	0,5905	1,0000	0,3860	0,4541	0,5221
Changes in LFL Sales	0,5785	0,7893	1,0000	0,1901	0,3182	0,4463	0,4215	0,6570	0,8926
Sales density	0,6757	0,7483	0,8210	0,9741	0,9870	1,0000	0,8640	0,9206	0,9771
Market share	0,3333	0,5556	0,7778	0,1111	0,1111	0,3333	0,5556	0,7778	1,0000
Online market share	0,1111	0,1111	0,3333	0,1111	0,3333	0,5556	0,5556	0,7778	1,0000
Risk of changes in consumer Preferences	0,2000	0,3333	1,0000	0,1429	0,2000	0,3333	0,2000	0,3333	1,0000
Quality and development level of private labels	0,3333	0,5556	0,7778	0,5556	0,7778	1,0000	0,5556	0,7778	1,0000

Source: calculated by the authors

Table 7. Elements of the weighted normalized matrix

Criteria	Magnit			Lenta			X5 Retail Group		
	a	b	c	a	b	c	a	b	c
Absolute liquidity ratio	0,1289	0,3429	0,5570	0,3410	0,4497	0,5584	0,0981	0,1259	0,1537
Current ratio	0,4947	0,5265	0,5584	0,5050	0,5089	0,5129	0,2928	0,3244	0,3559
Gross profit margin	0,5008	0,5085	0,5163	0,4947	0,4998	0,5050	0,5347	0,5466	0,5584
Net profit margin	0,1786	0,2843	0,3899	0,1011	0,3297	0,5584	0,2155	0,2535	0,2915
Changes in LFL Sales	0,1994	0,2720	0,3446	0,0655	0,1097	0,1538	0,1453	0,2264	0,3076
Sales density	0,2329	0,2579	0,2829	0,3357	0,3402	0,3446	0,2978	0,3173	0,3368
Market share	0,0323	0,0539	0,0754	0,0108	0,0108	0,0323	0,0539	0,0754	0,0970
Online market share	0,0108	0,0108	0,0323	0,0108	0,0323	0,0539	0,0539	0,0754	0,0970
Risk of changes in consumer Preferences	0,0194	0,0323	0,0970	0,0139	0,0194	0,0323	0,0194	0,0323	0,0970
Quality and development level of private labels	0,0323	0,0539	0,0754	0,0539	0,0754	0,0970	0,0539	0,0754	0,0970

Source: calculated by the authors

Conclusion

The results of the study demonstrate the significant potential of the developed algorithm for assessing the investment attractiveness of a company. The application of an integrated approach, including the FAHP and FTOPSIS methods, taking into account the theory of fuzzy sets, allows for the overcoming of the limitations of one-dimensional and static models. The achievement of scientific novelty is due to the development of a methodological tool that allows for integrating multiple criteria and accounting for uncertainty in a dynamically changing external environment. For the first time, MCDM methods have been adapted and applied to assess the investment attractiveness of companies. The algorithm has broad prospects for application in assessing investment attractiveness in various sectors of the economy.

Table 8. Identification of the positive and negative ideal solutions

Criteria	FPIS			FNIS		
	a	b	c	a	b	c
Absolute liquidity ratio	0,3410	0,4497	0,5584	0,0981	0,1259	0,1537
Current ratio	0,5050	0,5265	0,5584	0,2928	0,3244	0,3559
Gross profit margin	0,5347	0,5466	0,5584	0,4947	0,4998	0,5050
Net profit margin	0,2155	0,3297	0,5584	0,1011	0,2535	0,2915
Changes in LFL Sales	0,1994	0,2720	0,3446	0,0655	0,1097	0,1538
Sales density	0,3357	0,3402	0,3446	0,2329	0,2579	0,2829
Market share	0,0539	0,0754	0,0970	0,0108	0,0108	0,0323
Online market share	0,0539	0,0754	0,0970	0,0108	0,0108	0,0323
Risk of changes in consumer Preferences	0,0194	0,0323	0,0970	0,0139	0,0194	0,0323
Quality and development level of private labels	0,0539	0,0754	0,0970	0,0323	0,0539	0,0754

Source: calculated by the authors

Table 9. Ranking of companies by the FTOPSIS method

Alternatives	d+	d-	CC	Rank
Magnit	0,4696	0,7901	0,6272	2
Lenta	0,4449	0,7997	0,6425	1
X5 Retail Group	0,7684	0,4698	0,3794	3

Source: calculated by the authors

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