

Article

Sustainable Evaluation of E-Commerce Companies in Vietnam: A Multi-Criteria Decision-Making Framework Based on MCDM

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Abstract: This study aims to effectively support decision-makers in evaluating leading e-commerce companies in Vietnam from a sustainability perspective. In addition, this study evaluates and analyzes criteria that affect the performance of e-commerce companies in Vietnam to find the best practices for e-commerce implementation of managers. In this way, companies can save costs and increase marketing and promotion efficiency, helping to reach more customers. In doing so, an integrated framework based on MCDM is proposed for the first time in e-commerce industry assessment. In the first stage, the fuzzy decision making trial and evaluation Laboratory method is applied to determine the weights of 9 criteria based on collected data. This study lists prominent quantitative evaluation criteria, taking into account the sustainability aspect. In the second phase, ranking the top 12 e-commerce companies in Vietnam according to their performance based on these nine criteria was done by applying the neutrosophic fuzzy axiomatic design method. According to an analysis of the data, the external financial assistance coefficient (12.7%) is the most crucial factor determining how competitive international e-commerce businesses are. The results of this study can help underperforming companies make strategic decisions to improve their performance. Integrating these two techniques provides a new method for evaluating global trading companies that have hitherto remained unaddressed in the trading industry and, therefore, leave a gap that needs to be investigated.

Keywords: e-commerce; sustainable evaluation; decision-making; MCDM; fuzzy

MSC: 90B50



Citation: Le, M.-T. Sustainable Evaluation of E-Commerce Companies in Vietnam: A Multi-Criteria Decision-Making Framework Based on MCDM. *Mathematics* **2024**, *12*, 1681. <https://doi.org/10.3390/math12111681>

Academic Editors: Sankar Kumar Roy, José Luis Verdegay, Armin Fügenschuh and Gerhard-Wilhelm Weber

Received: 2 May 2024
Revised: 19 May 2024
Accepted: 23 May 2024
Published: 28 May 2024



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1. Introduction

With modern advancements and the rise of the Internet, e-commerce has emerged as a critical component of this digital evolution, reshaping the landscape of buying and selling goods and services [1]. According to various data in 2019, Brazil showed e-commerce growth of 16%, Russia 18.7%, India 31.9%, China 27.3%, and South Africa 25% [2]. In 2018, US retail e-commerce sales reached more than 519 billion USD, up 13.2% year over year and more than 200% since 2010 [3]. Over the past decade, the e-commerce industry has seen significant growth with a focus on convenience and accessibility, leading to an increase in online shopping with more and more consumers choosing it. It has played a crucial role in changing the way businesses and consumers shop [4]. E-commerce makes it possible for both customers and businesses to buy or sell goods, and it provides a wide range of online services as well as high-quality, accessible goods and services that not only save time but also maximize profits for both consumers and businesses [5]. In addition, this industry also contributes to the growth of the global economy, bringing many benefits to all stakeholders, such as consumers, businesses, and governments [6]. E-commerce in Vietnam is emerging as an important market in Southeast Asia [7]. The growing e-commerce scene in Vietnam has made notable strides in recent years. This business model has contributed significantly to economic growth in the context of the world, entering the 4.0 revolution

with an average annual growth rate of about 18% [8]. In 2022, revenue from e-commerce in Vietnam grew significantly, reaching approximately 16.4 billion USD, accounting for about 7.5% of the country's total retail sales of goods and services. E-commerce can be considered a favorable environment for the adoption of new business models and the long-term development of the national innovation system from a strategic perspective [9]. Although Vietnam is an effective market for e-commerce to grow, it is still in the early stages and can encounter many different challenges and barriers for e-commerce companies. Most companies struggle to identify the most effective marketing and engagement strategies that align with consumer expectations and knowledge levels [10].

An organization can create a strategic action plan to achieve excellence using benchmarking. This continuous quality improvement allows the company to evaluate strengths and weaknesses in detail and compare the advantages of competitors. By analyzing the development of e-commerce over the years and interacting with consumer marketing strategies, this article proposes a framework to evaluate the overall performance of e-commerce companies. In this benchmark setting, key performance indicators are identified based on sustainable practices (technological, organizational, economic, and environmental), and the most efficient top suppliers are identified according to identified indicators. To achieve this goal, this study presents a multi-criteria decision-making framework based on two MCDM methods: fuzzy decision making trial and evaluation laboratory (FDEMATEL) and neutrosophic fuzzy axiomatic design (NFAD). Recognizing the limitations inherent in many multi-criteria models, such as the degree of inconsistency and misjudgment of alternatives, raises the need to explore new tools to support reasonable and reliable decision-making. T. Saravanakumar and Tae H. Lee developed a hybrid activation-based elastic controller for a class of Takagi–Sugeno (T-S) fuzzy systems. It withstands unknown cyber attacks, probabilistic time delays, controller gain variations, and Two numerical examples show the effectiveness and benefits of the constructed method [11]. In this context, the developed fuzzy DEMATEL method demonstrates outstanding flexibility and proficiency in solving multi-criteria models with more criteria. Compared with other methods, DEMATEL stands out with its ability to evaluate cause-and-effect relationships between factors.

In this paper, to illustrate the proposed framework, the top 12 e-commerce companies in Vietnam are ranked based on actual data collection. This study aims to develop a new MCDM approach to the problem of evaluating e-commerce companies by considering appropriate criteria. The integration of two methods, DEMATEL and NFAD, has been proposed to evaluate and select the most suitable e-commerce companies. To determine the evaluation criteria, a group of experts will be assembled at the first stage. The criteria were then refined based on literature review and expert opinions from various perspectives. The criteria weights are calculated using the DEMATEL method, then the ranking of the e-commerce company with the best potential is performed using NFAD. The integrated application of the DEMATEL and NFAD methods has contributed to improved theoretical understanding and practical implementation for decision support in complex and uncertain environments. The applied methods are used to leverage the DEMATEL-NFAD method to build a framework for evaluating sustainable e-commerce companies with objectively weighted assessments using quantitative data. Although there have been many other studies that have applied the MCDM method in the e-commerce industry, there have been no studies that have applied DEMATEL-NFAD to evaluate e-commerce companies in Vietnam in previous studies. This is also the motivation that led the authors to present this research. In addition, the study can provide valuable insights into the appropriate criteria for evaluating the e-commerce industry towards sustainability. Thus, e-commerce companies can apply them to build development strategies for their companies to retain customers as well as reduce unnecessary costs. Regarding managerial implications, this article provides valuable insights for practitioners, decision-makers, or policymakers to review their latest performance in the context of lasting developments. In addition, evaluating competitors' performance can help businesses orient and focus on enhancing strategies as soon as possible to strengthen their competitiveness.

The structure of this study is organized as follows. In Section 2, a review of the literature is provided. The methods and literature are described in Section 3. The results analysis is presented in Section 4. Section 5 concludes with recommendations for additional research.

2. Literature Review

This study presents an objective weight assessment framework for e-commerce companies using a multi-criteria decision-making framework based on two methods: fuzzy DEMATEL and NFAD. The literature review on global e-commerce company performance evaluation and the research gap and contribution of the current study come first in the literature connected to this topic.

Over the past decade, many studies have been successful in applying the MCDM method in the e-commerce industry. Table 1 provides an overview of MCDM methods used in previous studies related to the development of the e-commerce industry. Many authors have used MCDM and related techniques to address e-commerce challenges, using methods such as the best holistically adaptable attribute ranking technique (BHARAT) [12–14]; combined compromise solution (COCOSO) [14]; Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR) [15,16]; weighted aggregated sum product assessment (WASPAS) [17,18]; evaluation based on distance from average solution (EDAS) [14,19]; analytic hierarchy process (AHP) [20,21]; technique for order preference by similarity to an ideal solution (FTOPSIS) [18,20–24]; and other MCDM [13,14,18,21,23,24]. Researchers have developed and applied a combination of different MCDM methods. In the study by Daekook Kang et al., the authors applied the fuzzy hierarchical TOPSIS method based on E-SERVQUAL (E-S-QUAL) to measure e-service quality in the e-commerce environment [25]. Aleksandra Bączkiewicz [14,15] used four MCDM methods: TOPSIS, VIKOR, PROMETHEE II (preference ranking organization method for enrichment of evaluations), and COMET (characteristic objects method) to determine the headset option that best fits the established criteria. The results show that MCDM has great potential in the field of online commerce and services. To support consumer decisions to choose the most suitable products from various options, Bączkiewicz et al. [14] combined 5 MCDM methods (TOPSIS-COMET, COCOSO, EDAS, MAIRCA, and MABAC). The study demonstrated that the proposed method has a high potential for websites and e-commerce sites, allowing users to compare products. By integrating the DEMATEL and EDAS methods, Yi-Hsiang Lu et al. [19] discovered important factors that influence consumers' intention to use cross-border e-commerce platforms. The ranking results of the study can determine the best preference among the alternatives for cross-border e-commerce platforms. This body of research highlights the diverse and adaptable nature of MCDM approaches, demonstrating their applicability in addressing various challenges in the e-commerce sector. This study contributes to the continued development of these methods by presenting an innovative decision framework. Specifically, it proposes an integrated approach that combines the strengths of the two methods, FDEMATEL and NFAD. This integrated framework is designed to comprehensively evaluate 12 e-commerce companies in the specific context of Vietnam. In doing so, it endeavors to push the boundaries of current methods and enhance the accuracy and applicability of company assessment methods in Vietnam's dynamic e-commerce landscape.

Table 1. MCDM methods used in previous studies.

No.	Source	Year	Methods							
			BHARAT	COCOSO	VIKOR	FTOPSIS	WASPAS	EDAS	AHP	Other MCDM
1	[26]	2017				X				
2	[27]	2019				X			X	
3	[24]	2019				X				X
4	[21]	2020				X			X	X
5	[15]	2021			X	X				X
6	[14]	2021		X				X		X
7	[14]	2021					X		X	
8	[28]	2022				X				
9	[19]	2022						X		X
10	[16]	2022			X					
11	[29]	2023								X
12	[30]	2023								X
13	[18]	2023					X			X
14	[12]	2024	X							
15	[13]	2024	X							X

To survive and compete globally, leading e-commerce companies are under significant pressure to increase productivity and profits, so many e-commerce managers are looking to technology to maintain and improve their competitive advantage. One of the best measures is to use effective analytics to identify their strengths and weaknesses and improve their performance. Rahayu, R. et al. [31] researched factors affecting small and medium enterprises in developing countries in adopting e-commerce. The findings indicate that the key determinants impacting organizations are perceived benefits, owner inventiveness, owner IT competencies, and owner IT experience. Research by Ramanathan, R [32] pointed out that e-commerce websites must also perform well on various performance criteria to win and retain customers. The study results show that customer satisfaction with claims is considered the most important criterion based on the above discussion and careful review of previous studies. In this study, the decisive criteria for analyzing the performance of e-commerce companies are synthesized, including economics, organizational factors, technology, and environmental aspects, as shown in Table 2.

Table 2. Summary of criteria for evaluating effectiveness in e-commerce.

Main Criteria	Sub-Criteria	Source	Symbol
Technology factors	Technology readiness	[24,31]	CR-01
	Experience in information technology	[31,33,34]	CR-02
	Investment costs for technology	[34]	CR-03
Organizational factors	Customer satisfaction	[32,35]	CR-04
	Employee knowledge	[36]	CR-05
	Perception of business managers	[31,37–39]	CR-06
Economic factors	External financial support	[31]	CR-07
	Company operating expenses	[35]	CR-08
Environmental factors	Efficient sustainable energy use	[40,41]	CR-09

3. Methodology

3.1. Research Framework

MCDM is considered a complex tool for balancing the goals, risks, and limitations of a problem. This article proposes a research framework for the sustainability assessment of large e-commerce companies by considering nine criteria and 12 alternatives. This research framework is shown in Figure 1. In the first stage, the weight coefficient for each criterion is calculated using the fuzzy DEMATEL method. Then, the NFAD method is applied to rank the alternatives.

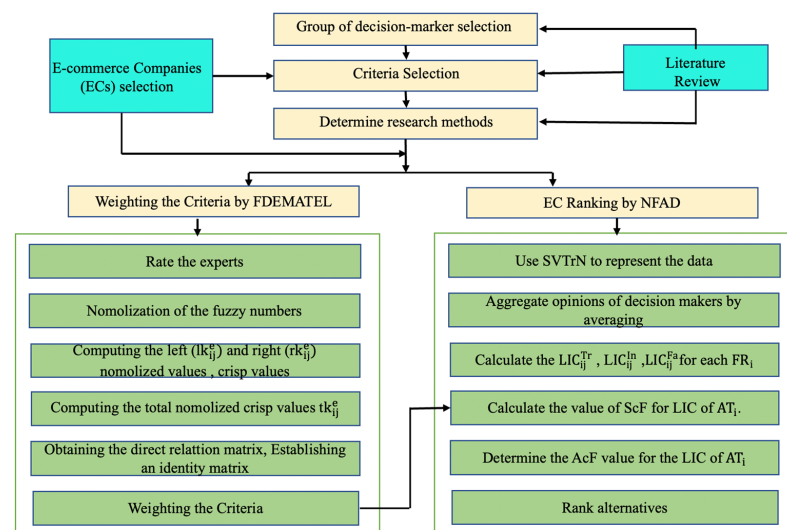


Figure 1. Research framework for decision-making methods used to evaluate ECs.

3.2. Fuzzy DEMATEL Weighting Method

In order to examine the DEMATEL defuzzification literature, Fontela and Gabus developed the DEMATEL approach in 1974; many defuzzification methods have been used to analyze factor correlations. The defuzzification of fuzzy numbers is very important for DEMATEL methods combined with fuzzy logic. The CFCS method is the most commonly accepted defuzzification algorithm in fuzzy logic and DEMATEL modeling [42]. Evaluation of the fuzzy influence $\tilde{k}_e = (k_{ij1}, k_{ij2}, k_{ij3})$ is given by $ij, ij1, ij2, ij3$ expert G_e . The fuzzy DEMATEL technique [43] is summed up in the subsequent steps:

Step 1: Identify criteria and decision-makers

First, issues related to the e-commerce industry are analyzed by a group of decision-makers ($e = 1 \dots E$). Then, based on references and opinions of decision-makers, the criteria ($j = 1 \dots J$) are determined.

Step 2: Rate the experts

Rank the importance of decision makers based on experience and expertise. The weighting coefficient of the e th decision maker (σ_e) is defined as Equation (1). Fuzzy $\tilde{K}_{j1} = (k_{ij1}^e, k_{ij2}^e, k_{ij3}^e)$ represents the expertise of the k th decision-maker [44].

$$\sigma_e = \frac{1 - \sqrt{((1 - k_{ij1}^e) + k_{ij2}^e + k_{ij3}^e)/3}}{\sum_e (1 - \sqrt{((1 - k_{ij1}^e) + k_{ij2}^e + k_{ij3}^e)/3})} \quad (1)$$

where $\sum_{e=1}^E \sigma_e = 1$ and $0 \leq k_{ij1}^e + k_{ij2}^e + k_{ij3}^e \leq 1$.

The k th decision maker conducts linguistic assessments of the potential impact of criterion j on criterion i , where $j, i = 1 \dots J, e = 1 \dots E$. Table 3 shows fuzzy values converted from linguistic evaluation of alternatives between criteria from experts.

Table 3. Impact terms and fuzzy numbers relationship in fuzzy DEMETAL.

Degree of Influence	Impact Term	Corresponding TFNs
Negligible impact	NIM	(0.0, 0.1, 0.3)
Low impact	LIM	(0.1, 0.3, 0.5)
Impact	IM	(0.3, 0.5, 0.7)
Quite high impact	QHIM	(0.5, 0.7, 0.9)
Extremely high impact	EHIM	(0.7, 0.9, 1.0)

Step 3: Nomolize the fuzzy numbers

$$\bar{k}_{ij1}^e = \frac{k_{ij1}^e - \min k_{ij1}^e}{\max k_{ij3}^e - \min k_{ij1}^e} \quad (2)$$

$$\bar{k}_{ij2}^e = \frac{k_{ij2}^e - \min k_{ij1}^e}{\max k_{ij3}^e - \min k_{ij1}^e} \quad (3)$$

$$\bar{k}_{ij3}^e = \frac{k_{ij3}^e - \min k_{ij1}^e}{\max k_{ij3}^e - \min k_{ij1}^e} \quad (4)$$

Step 4: Compute the left (lk_{ij}^e) and right (rk_{ij}^e) nomolized values

$$lk_{ij}^e = \frac{\bar{k}_{ij2}^e}{1 + \bar{k}_{ij2}^e - \bar{k}_{ij1}^e} \quad (5)$$

$$rk_{ij}^e = \frac{\bar{k}_{ij3}^e}{1 + \bar{k}_{ij3}^e - \bar{k}_{ij2}^e} \quad (6)$$

Step 5: Compute crisp values

$$k_{ij}^e = \frac{lk_{ij}^e(1 - lk_{ij}^e) + rk_{ij}^e rk_{ij}^e}{1 - lk_{ij}^e + rk_{ij}^e} \quad (7)$$

Step 6: Compute the total nomolized crisp values tk_{ij}^e

$$tk_{ij}^e = \min k_{ij1}^e + z_{ij}^e (\max k_{ij3}^e - \min k_{ij1}^e) \quad (8)$$

Step 7: Obtain the direct relation matrix though aggregating the normalized crisp value from experts

$$M = \frac{1}{l} \sum_{e=1}^l tk_{ij}^e \quad (9)$$

Step 8: Gather the nomalized direct matrix C

$$C = \frac{M}{\max_{1 \leq i \leq n} \sum_{j=1}^n k_{ij}} ; i, j = 1, 2, \dots, n \quad (10)$$

Step 9: Establish an identity matrix (L).

$$L = \begin{bmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & 1 \end{bmatrix} \quad (11)$$

After that, employ identity matrix (L) minus the nomalized direct matrix (C).

Multiplying the $(L-C)^{-1}$ matrix and (C) matrix obtains the total relation matrix (t).

Step 10. Calculating the sum of rows (ro_i) and columns (co_i) of the total-influence matrix

$$ro_i = [\sum_{j=1}^n t_{ij}]_{n \times 1} = [t_i]_{n \times 1} \quad (12)$$

$$co_i = [\sum_{j=1}^n t_{ij}]_{n \times 1} = [t_i]_{n \times 1} \quad (13)$$

Then computing $(ro_i + co_i)$ and $(ro_i - co_i)$ for mapping the cause and affect diagram.

The word “Prominence” refers to the degree of importance assigned to the criterion by the “ $ro_i + co_i$ ” calculus. The “Relation” formula, which separated these criteria into two groups as illustrated, is used to calculate “ $ro_i - co_i$ ”. It is crucial to define values within the cause and effect group in order to rank the criteria and evaluate the severity of the impacts.

$$ro_i + co_i > 0 : \text{it belongs to the group “cause”}.$$

$$ro_i - co_i < 0 : \text{it belongs to the group “effect”}.$$

The weight (α_j) of the j th criteria is shown in Equation (14):

$$\alpha_j = \frac{ro_j + co_j}{\sum_{j=1}^n (ro_j + co_j)} \quad (14)$$

3.3. NFAD Ranking Method

Fuzzy Set Theory

Linguistic variables are considered more effective than numbers for resolving ambiguities in human judgment. Fuzzy theories have been introduced, developed and widely used in the field of decision making to quantify linguistic terms. Decision makers can not only express their freedom but can also make more prioritized decisions. In this study, the Neutrosophic set was capable of handling uncertain, indeterminate, and inconsistent information. Centralized methods are suitable for modeling inconsistent, uncertain, and indeterminate problems, where human knowledge and human judgment are needed. Neutrosophic set (NS) [45]. Let ξ be the universe, and NS is D in ξ presented by a Tr function Tr_D , I function In_D and a Fa function Fa_D where Tr_D , In_D and Fa_D are the true standard factors of $[0,1]$. It is represented as follows:

$$D = \{ \langle x, (Tr_D(x), In_D(x), Fa_D(x)) \rangle : x \in E, Tr_D, In_D, Fa_D \in]0^-, 1^+ [\}.$$

There is no cap on the amount of $Tr_D(x)$, $In_D(x)$, and $Fa_D(x)$. So,

$$\leq Tr_D(x) + In_D(x) + Fa_D(x) \geq 1 + . \quad (15)$$

Score function (ScF) and accuracy function (AcF) are suitable functions for comparing SVN. Assume $\tilde{D}_1 = (Tr_1, In_1, Fa_1)$ be a SVN, then, the $ScF(\tilde{D}_1)$, $AcF(\tilde{D}_1)$ of a SVN are represented as follows:

$$ScF(\tilde{D}_1) = (2 + Tr_1 - In_1 - Fa_1)/3 \quad (16)$$

$$AcF(\tilde{D}_1) = Tr_1 - Fa_1. \quad (17)$$

(SVTrN-number) $(\tilde{D} = \langle (u_1, v_1, w); Tr_D, In_D, Fa_D \rangle)$ is a particular NS on the real number set R , whose Tr , In , Fa memberships are described in Figure 2, and shown as follows:

$$Tr_D(x) = \begin{cases} (x - u_1)Tr_D / (v_1 - u_1), & (u_1 \leq x \leq v_1) \\ Tr_D, & (x = v_1) \\ (w_1 - x)Tr_D / (c_1 - v_1), & (v_1 \leq x \leq w_1) \\ 0, & \text{otherwise} \end{cases} \quad (18)$$

$$In_D(x) = \begin{cases} (v_1 - x - In_D/(x - u_1))/(v_1 - u_1), & (u_1 \leq x \leq v_1) \\ Tr_D, & (x = v_1) \\ (x - v_1 + In_D(w_1 - x))/(w_1 - v_1), & (v_1 \leq x \leq w_1) \\ 1, & \text{otherwise} \end{cases} \quad (19)$$

$$Fa_D(x) = \begin{cases} (v_1 - x + Fa_D/(x - u_1))/(v_1 - u_1), & (u_1 \leq x \leq v_1) \\ Fa_D, & (x = v_1) \\ (x - w_1 + Fa_D(w_1 - x))/(w_1 - v_1), & (v_1 \leq x \leq w_1) \\ 1, & \text{otherwise} \end{cases} \quad (20)$$

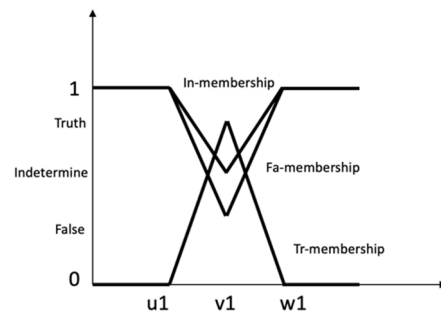


Figure 2. A triangular neutrophil count with standard single value.

Operations of SVTrN-number: If $\tilde{D}_1 \leq (a_1, a_2, a_3); Tr_1, In_1, Fa_1$ and $\tilde{D}_2 \leq (b_1, b_2, b_3); Tr_2, In_2, Fa_2$ is two SVTrN-number, then:

$$\tilde{D}_1 \oplus \tilde{D}_2 = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \min(Tr_1, Tr_2), \max(In_1, In_2), \max(Fa_1, Fa_2) \rangle \quad (21)$$

$$\tilde{D}_1 \otimes \tilde{D}_2 = \langle (a_1 b_1, a_2 b_2, a_3 b_3); \min(Tr_1, Tr_2), \max(In_1, In_2), \max(Fa_1, Fa_2) \rangle \quad (22)$$

$$\lambda \tilde{D}_1 = \langle (\lambda a_1, \lambda a_2, \lambda a_3); \min(Tr_1, Tr_2), \max(In_1, In_2), \max(Fa_1, Fa_2) \rangle \quad (23)$$

SC and AcF of SVTrN-number. The ScF $s(\tilde{D}_1)$ and AcF $a(\tilde{D}_1)$ can be defined as follows:

$$ScF s(\tilde{D}_1) = \left(\frac{1}{12}\right)[(a_1 + 2a_2 + a_3)x[2 + Tr_1 - In_1 - Fa_1]] \quad (24)$$

$$AcF s(\tilde{D}_1) = \left(\frac{1}{12}\right)[(a_1 + 2a_2 + a_3)x[2 + Tr_1 - In_1 + Fa_1]] \quad (25)$$

Ranking of SVTrN-number:

$$\text{If } ScF(\tilde{D}_1) < ScF(\tilde{D}_2), \text{ then } \tilde{D}_1 < \tilde{D}_2 \quad (26)$$

$$\text{If } ScF(\tilde{D}_1) = ScF(\tilde{D}_2), \text{ and if.} \quad (27)$$

$$AcF(\tilde{D}_1) < AcF(\tilde{D}_2), \text{ then } \tilde{D}_1 < \tilde{D}_2$$

$$AcF(\tilde{D}_1) > AcF(\tilde{D}_2), \text{ then } \tilde{D}_1 > \tilde{D}_2$$

$$AcF(\tilde{D}_1) = AcF(\tilde{D}_2), \text{ then } \tilde{D}_1 = \tilde{D}_2$$

The information axiom is determined by the lowest information content (LIC), which is related to the ability to maintain planned objectives. The LIC_i is given by:

$$LIC_i = \log_2\left(\frac{1}{\text{probability}_i}\right) \quad (28)$$

The probability of completion is determined by DR and SR. The intersection region of DR and SR is the general region where a satisfactory solution exists, as shown in Figure 3. Probability_i, which represents the uniform probability distribution function, can be stated as follows:

$$\text{Probability}_i = (\text{Common range} / \text{System range}) \quad (29)$$

$$\text{LIC}_i = \text{Log}_2(\text{Common range} / \text{System range}) \quad (30)$$

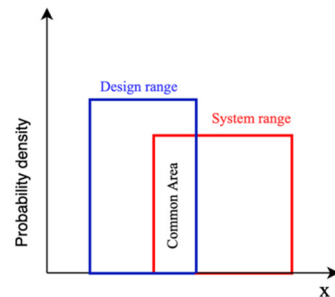


Figure 3. The common area of SR and DR.

The (LIC^{Tr}), (LIC^{In}), and (LIC^{Fa}) symbols, can be shown as follows:

$$\text{LIC}^{\text{Tr}} = \log_2 \frac{\text{Truth} - \text{membership system desgin}}{\text{Truth} - \text{membership Common area}} \quad (31)$$

$$\text{LIC}^{\text{In}} = \log_2 \frac{\text{Indeterminacy} - \text{membership system desgin}}{\text{Indeterminacy} - \text{membership Common area}} \quad (32)$$

$$\text{LIC}^{\text{Fa}} = \log_2 \frac{\text{Falsity} - \text{membership system desgin}}{\text{Falsity} - \text{membership Common area}} \quad (33)$$

3.4. Neutrosophic Fuzzy Axiomatic Design (NFAD)

The following procedures are used in this study's NAD approach for ranking the alternatives:

Step 1: Use SVTrN, which has the form of <Low value (L), Mean value (M), Upper value (U)), and confirmation degree (CD)>, to represent the data. The data representation method is shown in Table 4.

Step 2: Aggregate opinions of decision makers by averaging using Equation (21).

Step 3: Calculate the LIC^{Tr}, LIC^{In}, LIC^{Fa} for each FR_i base on the Formulas (34), (35) and (36), respectively:

$$\text{LIC}_{ij}^{\text{Tr}} = \begin{cases} 0 & \text{if } \hat{p}_{ij1} > \hat{g}_{j3} \text{ or } \hat{p}_{ij3} > \hat{g}_{j1} \\ \log_2 \frac{\text{Truth} - \text{membership system desgin}}{\text{Truth} - \text{membership Common area}} & \text{if } \hat{p}_{ij1} \leq \hat{g}_{j3} \text{ or } \hat{p}_{ij3} \leq \hat{g}_{j1} \end{cases} \quad (34)$$

$$\text{LIC}_{ij}^{\text{In}} = \begin{cases} 0 & \text{if } \hat{p}_{ij1} > \hat{g}_{j3} \text{ or } \hat{p}_{ij3} > \hat{g}_{j1} \\ \log_2 \frac{\text{Indeterminacy} - \text{membership system desgin}}{\text{Indeterminacy} - \text{membership Common area}} & \text{if } \hat{p}_{ij1} \leq \hat{g}_{j3} \text{ or } \hat{p}_{ij3} \leq \hat{g}_{j1} \end{cases} \quad (35)$$

$$\text{LIC}_{ij}^{\text{Fa}} = \begin{cases} 0 & \text{if } \hat{p}_{ij1} > \hat{g}_{j3} \text{ or } \hat{p}_{ij3} > \hat{g}_{j1} \\ \log_2 \frac{\text{Falsity} - \text{membership system desgin}}{\text{Falsity} - \text{membership Common area}} & \text{if } \hat{p}_{ij1} \leq \hat{g}_{j3} \text{ or } \hat{p}_{ij3} \leq \hat{g}_{j1} \end{cases} \quad (36)$$

where $\hat{p}_{ij1}$ and $\hat{p}_{ij3}$ are the L and U values of AT_i by C_i and where $\hat{g}_{j1}$ and $\hat{g}_{j3}$ are L and U values of FR_j.

Table 4. Language variables and SVTrN standards.

Linguistic Terms	L, M, U	Confirmation Level (T, I, F)
Extremely low (EL)	<(0, 0, 1)>	Extremely not sure (ENoS) <(0, 1, 1)>
Very low (VL)	<(0, 1, 2)>	Not sure (NoS) <(0.2, 0.8, 0.8)>
Fairly Low (FL)	<(1, 2, 3)>	Fairly sure (FS) <(0.3, 0.7, 0.7)>
Low (L)	<(2, 3, 4)>	Quite sure (QS) <(0.5, 0.5, 0.5)>
Quite high (QH)	<(3, 4, 5)>	Sure(S) <(0.7, 0.4, 0.4)>
High (H)	<(4, 5, 6)>	Very sure (VS) <(0.8, 0.2, 0.2)>
Very high (VH)	<(5, 6, 7)>	Strongly sure (SS) <(0.9, 0.1, 0.1)>
Extremely high (EH)	<(7, 8, 9)>	Extremely sure (ES) <(1, 0, 0)>

Step 4: Calculate the value of ScF for LIC of AT_i

After calculating the LIC_{ij}^{Tr} , LIC_{ij}^{In} , and LIC_{ij}^{Fa} we obtain the form of SVN. Thus, ScF is calculated according to Equation (37).

$$ScF_i = \sum_{j=1}^n ScF_{ij} \cdot W_j = \sum_{j=1}^n [2 + Tr_{ij} - In_{ij} - Fa_{ij}] / 3 \cdot W_j \quad (37)$$

Step 5: Determine the AcF value for the LIC of AT_i

After computing the LIC_{ij}^{Tr} , LIC_{ij}^{In} , and LIC_{ij}^{Fa} , we obtain the form of SVN. Therefore, AcF is determined using Equation (38).

$$AcF_i = \sum_{j=1}^n AcF_{ij} \cdot W_j = \sum_{j=1}^n [Tr_{ij} - Fa_{ij}] \cdot W_j \quad (38)$$

Step 6: Rank alternatives.

Select the best alternative based on the ranking of the SVTrN using Equations (39) and (40). Then rank them based on AT_i if ScF_i of the alternatives are equal. This section is shown as follows:

$$\text{If } ScF_i < ScF_j, \text{ then } AT_i < AT_j \text{ (i.e. } AT_i \text{ is worse than } AT_j) \quad (39)$$

$$\text{If } ScF_i = ScF_j \text{ and if,} \quad (40)$$

$$\text{If } AcF_i < AcF_j, \text{ then } AT_i < AT_j \text{ (i.e. } AT_i \text{ is worse than } AT_j)$$

$$\text{If } AcF_i > AcF_j, \text{ then } AT_i > AT_j \text{ (i.e. } AT_i \text{ is better than } AT_j)$$

$$\text{If } AcF_i = AcF_j, \text{ then } AT_i = AT_j \text{ (i.e. } AT_i \text{ is equal to } AT_j)$$

4. Discussion

4.1. A Case Study

To evaluate the performance of leading e-commerce companies in Vietnam based on specific influential and conflicting criteria, this study aims to provide a fuzzy MCDM framework as well as collect expert assessments. In this study, a group of 10 experts who have worked in the e-commerce industry with more than ten years of experience were consulted, and they evaluated the impact of the criteria in assessing 12 e-commerce companies bringing high efficiency to the e-commerce field. More specifically, Figure 4 is a cause-and-effect diagram to show the direct and indirect relationships between criteria and sub-criteria in this paper. Twelve leading e-commerce companies in Vietnam are used to test the effectiveness of the proposed model, which are the Gioi Di Dong (EC-01), LAMECO (EC-02), TIKI (EC-03), Shopee Vietnam (EC-04), VNPay (EC-05), Lazada (EC-06), Sendo (EC-07), VCCORP (EC-08), VNP Group (EC-09), FPT (EC-10), UPBASE (EC-11), and META ECOM (EC-12).

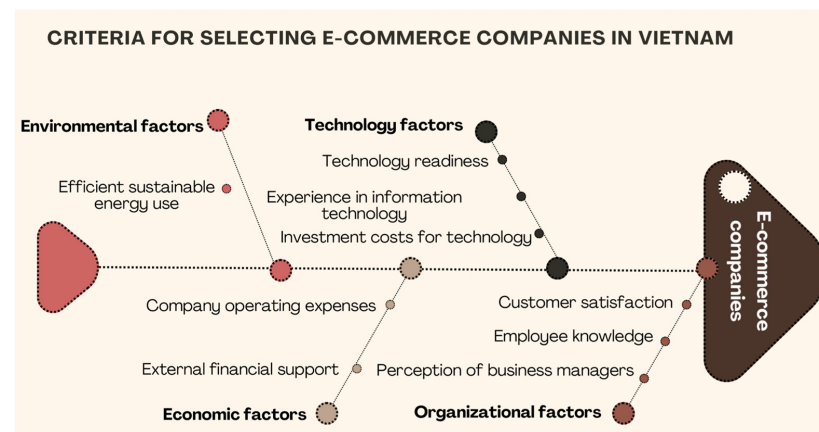


Figure 4. Criteria for selecting e-commerce companies in Vietnam.

4.2. Calculation of Criteria Weights with FDEMATEL

Initially, ten experts were formed to study the impact of evaluation criteria on the performance of 12 e-commerce companies. At this stage, meaningful weights are determined using the FDEMATEL weighting method. As a result, the weights of all nine criteria for each aspect, including economic, business organization, technology, and environmental aspects, are shown in Table 5. The importance of the nine criteria is shown in Figure 5. As can be seen, external financial support (CR-07), perception of business managers (CR-06), and company operating expenses (CR-08) have the greatest impact on the e-commerce industry at 12.7%, 12.0%, and 11.9%, respectively. These figures show that business organization and economic factors are of great importance in evaluating the performance of e-commerce companies.

Table 5. Weighting results of all criteria.

Criteria	ro_i	co_i	Prominence	Relation	Weight
CR-01	4.70	4.76	9.45	−0.06	0.09
CR-02	6.27	5.09	11.36	1.18	0.11
CR-03	5.05	5.32	10.37	−0.27	0.10
CR-04	5.40	5.94	11.34	−0.54	0.11
CR-05	4.27	5.78	10.04	−1.51	0.10
CR-06	6.82	5.24	12.06	1.57	0.12
CR-07	6.67	6.06	12.73	0.61	0.13
CR-08	5.62	6.36	11.97	−0.74	0.12
CR-09	5.42	5.65	11.07	−0.23	0.11

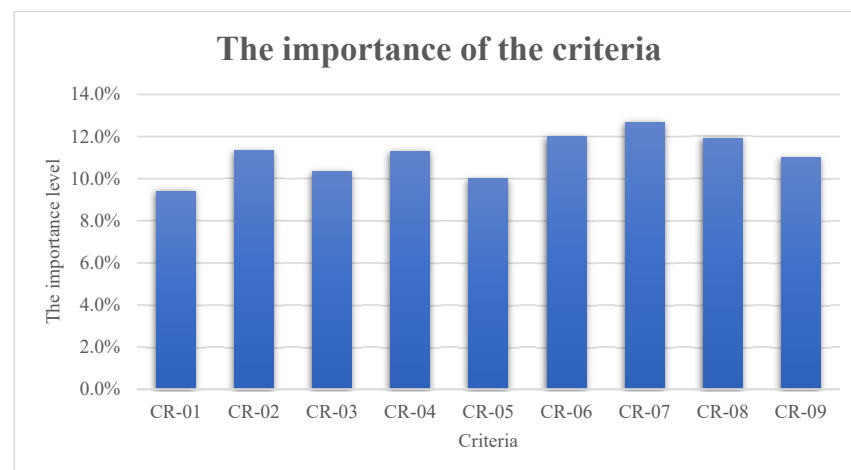


Figure 5. The importance of the criteria.

4.3. Ranking Alternatives with NFAD

After calculating the weights of those decision-makers, summarize the opinions of decision-makers, as in Table 6. This section synthesizes the average method according to Formula (21).

Table 6. The aggregated direct influence matrix.

Company	CR-01	CR-02	CR-03
EC-01	$\langle(3.4, 4.4, 5.4), (0.3, 0.7, 0.7)\rangle$	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$	$\langle(4, 5, 6), (0.3, 0.7, 0.7)\rangle$
EC-02	$\langle(3.7, 4.7, 5.7), (0.5, 0.5, 0.5)\rangle$	$\langle(4.3, 5.3, 6.3), (0.3, 0.7, 0.7)\rangle$	$\langle(4.2, 5.2, 6.2), (0.5, 0.5, 0.5)\rangle$
EC-03	$\langle(2.1, 3.1, 4.1), (0.3, 0.7, 0.7)\rangle$	$\langle(3.8, 4.8, 5.8), (0.3, 0.7, 0.7)\rangle$	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$
EC-04	$\langle(2.7, 3.7, 4.7), (0.3, 0.7, 0.7)\rangle$	$\langle(3.7, 4.7, 5.7), (0.3, 0.7, 0.7)\rangle$	$\langle(3.8, 4.8, 5.8), (0.5, 0.5, 0.5)\rangle$
EC-05	$\langle(4.8, 5.8, 6.8), (0.3, 0.7, 0.7)\rangle$	$\langle(4.4, 5.4, 6.4), (0.3, 0.7, 0.7)\rangle$	$\langle(3, 4, 5), (0.5, 0.5, 0.5)\rangle$
EC-06	$\langle(2.2, 3.2, 4.2), (0.5, 0.5, 0.5)\rangle$	$\langle(4.5, 5.5, 6.5), (0.3, 0.7, 0.7)\rangle$	$\langle(4.5, 5.5, 6.5), (0.3, 0.7, 0.7)\rangle$
EC-07	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$	$\langle(3.1, 4.1, 5.1), (0.3, 0.7, 0.7)\rangle$	$\langle(2.4, 3.4, 4.4), (0.3, 0.7, 0.7)\rangle$
EC-08	$\langle(4.6, 5.6, 6.6), (0.3, 0.7, 0.7)\rangle$	$\langle(4.2, 5.2, 6.2), (0.3, 0.7, 0.7)\rangle$	$\langle(3.1, 4.1, 5.1), (0.5, 0.5, 0.5)\rangle$
EC-09	$\langle(4.6, 5.6, 6.6), (0.3, 0.7, 0.7)\rangle$	$\langle(3.2, 4.2, 5.2), (0.3, 0.7, 0.7)\rangle$	$\langle(4.6, 5.6, 6.6), (0.3, 0.7, 0.7)\rangle$
EC-10	$\langle(5.5, 6.5, 7.5), (0.3, 0.7, 0.7)\rangle$	$\langle(4.3, 5.3, 6.3), (0.3, 0.7, 0.7)\rangle$	$\langle(3.9, 4.9, 5.9), (0.3, 0.7, 0.7)\rangle$
EC-11	$\langle(3.9, 4.9, 5.9), (0.5, 0.5, 0.5)\rangle$	$\langle(3.1, 4.1, 5.1), (0.7, 0.4, 0.4)\rangle$	$\langle(3, 4, 5), (0.5, 0.5, 0.5)\rangle$
EC-12	$\langle(5, 6, 7), (0.3, 0.7, 0.7)\rangle$	$\langle(3.1, 4.1, 5.1), (0.3, 0.7, 0.7)\rangle$	$\langle(4.1, 5.1, 6.1), (0.3, 0.7, 0.7)\rangle$
FR	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$	$\langle(3, 4, 5), (0.3, 0.7, 0.7)\rangle$	$\langle(4.9, 5.9, 6.9), (0.3, 0.7, 0.7)\rangle$
Company	CR-04	CR-05	CR-06
EC-01	$\langle(4, 5, 6), (0.5, 0.5, 0.5)\rangle$	$\langle(4, 5, 6), (0.3, 0.7, 0.7)\rangle$	$\langle(3.6, 4.6, 5.6), (0.3, 0.7, 0.7)\rangle$
EC-02	$\langle(2.9, 3.9, 4.9), (0.3, 0.7, 0.7)\rangle$	$\langle(4, 5, 6), (0.7, 0.4, 0.4)\rangle$	$\langle(3.7, 4.7, 5.7), (0.5, 0.5, 0.5)\rangle$
EC-03	$\langle(2.8, 3.8, 4.8), (0.3, 0.7, 0.7)\rangle$	$\langle(3.8, 4.8, 5.8), (0.5, 0.5, 0.5)\rangle$	$\langle(2.4, 3.4, 4.4), (0.3, 0.7, 0.7)\rangle$
EC-04	$\langle(4.1, 5.1, 6.1), (0.3, 0.7, 0.7)\rangle$	$\langle(3.2, 4.2, 5.2), (0.3, 0.7, 0.7)\rangle$	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$
EC-05	$\langle(3.2, 4.2, 5.2), (0.3, 0.7, 0.7)\rangle$	$\langle(3.6, 4.6, 5.6), (0.3, 0.7, 0.7)\rangle$	$\langle(4.6, 5.6, 6.6), (0.3, 0.7, 0.7)\rangle$
EC-06	$\langle(3.1, 4.1, 5.1), (0.3, 0.7, 0.7)\rangle$	$\langle(2.9, 3.9, 4.9), (0.3, 0.7, 0.7)\rangle$	$\langle(2.9, 3.9, 4.9), (0.3, 0.7, 0.7)\rangle$
EC-07	$\langle(4, 5, 6), (0.3, 0.7, 0.7)\rangle$	$\langle(3.2, 4.2, 5.2), (0.3, 0.7, 0.7)\rangle$	$\langle(2.6, 3.6, 4.6), (0.5, 0.5, 0.5)\rangle$
EC-08	$\langle(4.2, 5.2, 6.2), (0.3, 0.7, 0.7)\rangle$	$\langle(4.6, 5.6, 6.6), (0.3, 0.7, 0.7)\rangle$	$\langle(3.6, 4.6, 5.6), (0.3, 0.7, 0.7)\rangle$
EC-09	$\langle(3.4, 4.4, 5.4), (0.3, 0.7, 0.7)\rangle$	$\langle(3.7, 4.7, 5.7), (0.3, 0.7, 0.7)\rangle$	$\langle(3.3, 4.3, 5.3), (0.3, 0.7, 0.7)\rangle$
EC-10	$\langle(4.3, 5.3, 6.3), (0.5, 0.5, 0.5)\rangle$	$\langle(4.2, 5.2, 6.2), (0.3, 0.7, 0.7)\rangle$	$\langle(2.9, 3.9, 4.9), (0.3, 0.7, 0.7)\rangle$
EC-11	$\langle(4.3, 5.3, 6.3), (0.3, 0.7, 0.7)\rangle$	$\langle(4.6, 5.6, 6.6), (0.3, 0.7, 0.7)\rangle$	$\langle(3.7, 4.7, 5.7), (0.3, 0.7, 0.7)\rangle$
EC-12	$\langle(4.2, 5.2, 6.2), (0.3, 0.7, 0.7)\rangle$	$\langle(3.2, 4.2, 5.2), (0.3, 0.7, 0.7)\rangle$	$\langle(3.7, 4.7, 5.7), (0.3, 0.7, 0.7)\rangle$
FR	$\langle(4.4, 5.4, 6.4), (0.3, 0.7, 0.7)\rangle$	$\langle(4, 5, 6), (0.3, 0.7, 0.7)\rangle$	$\langle(3.9, 4.9, 5.9), (0.3, 0.7, 0.7)\rangle$
Company	CR-07	CR-08	CR-09
EC-01	$\langle(3.5, 4.5, 5.5), (0.5, 0.5, 0.5)\rangle$	$\langle(4.5, 5.5, 6.5), (0.3, 0.7, 0.7)\rangle$	$\langle(3.1, 4.1, 5.1), (0.3, 0.7, 0.7)\rangle$
EC-02	$\langle(2.8, 3.8, 4.8), (0.3, 0.7, 0.7)\rangle$	$\langle(2.6, 3.6, 4.6), (0.7, 0.4, 0.4)\rangle$	$\langle(4.3, 5.3, 6.3), (0.3, 0.7, 0.7)\rangle$
EC-03	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$	$\langle(4.2, 5.2, 6.2), (0.3, 0.7, 0.7)\rangle$	$\langle(4.5, 5.5, 6.5), (0.3, 0.7, 0.7)\rangle$
EC-04	$\langle(3, 4, 5), (0.3, 0.7, 0.7)\rangle$	$\langle(4.1, 5.1, 6.1), (0.3, 0.7, 0.7)\rangle$	$\langle(3.1, 4.1, 5.1), (0.3, 0.7, 0.7)\rangle$
EC-05	$\langle(3.2, 4.2, 5.2), (0.3, 0.7, 0.7)\rangle$	$\langle(3.3, 4.3, 5.3), (0.3, 0.7, 0.7)\rangle$	$\langle(3.7, 4.7, 5.7), (0.3, 0.7, 0.7)\rangle$
EC-06	$\langle(3.8, 4.8, 5.8), (0.3, 0.7, 0.7)\rangle$	$\langle(2.8, 3.8, 4.8), (0.3, 0.7, 0.7)\rangle$	$\langle(3.8, 4.8, 5.8), (0.3, 0.7, 0.7)\rangle$
EC-07	$\langle(3.2, 4.2, 5.2), (0.3, 0.7, 0.7)\rangle$	$\langle(2.8, 3.8, 4.8), (0.3, 0.7, 0.7)\rangle$	$\langle(3.1, 4.1, 5.1), (0.3, 0.7, 0.7)\rangle$
EC-08	$\langle(3.9, 4.9, 5.9), (0.3, 0.7, 0.7)\rangle$	$\langle(3.3, 4.3, 5.3), (0.3, 0.7, 0.7)\rangle$	$\langle(4, 5, 6), (0.3, 0.7, 0.7)\rangle$
EC-09	$\langle(4.1, 5.1, 6.1), (0.3, 0.7, 0.7)\rangle$	$\langle(3.8, 4.8, 5.8), (0.3, 0.7, 0.7)\rangle$	$\langle(4.1, 5.1, 6.1), (0.3, 0.7, 0.7)\rangle$
EC-10	$\langle(3.4, 4.4, 5.4), (0.5, 0.5, 0.5)\rangle$	$\langle(3.7, 4.7, 5.7), (0.3, 0.7, 0.7)\rangle$	$\langle(3.6, 4.6, 5.6), (0.3, 0.7, 0.7)\rangle$
EC-11	$\langle(3.8, 4.8, 5.8), (0.3, 0.7, 0.7)\rangle$	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$	$\langle(5.2, 6.2, 7.2), (0.3, 0.7, 0.7)\rangle$
EC-12	$\langle(3, 4, 5), (0.3, 0.7, 0.7)\rangle$	$\langle(4.5, 5.5, 6.5), (0.5, 0.5, 0.5)\rangle$	$\langle(4.2, 5.2, 6.2), (0.5, 0.5, 0.5)\rangle$
FR	$\langle(3.9, 4.9, 5.9), (0.3, 0.7, 0.7)\rangle$	$\langle(3.7, 4.7, 5.7), (0.3, 0.7, 0.7)\rangle$	$\langle(3.5, 4.5, 5.5), (0.3, 0.7, 0.7)\rangle$

Table 7 shows the results of truth membership, indeterminacy membership, and false membership for each function requirement. Compute the LIC^{Tr} , LIC^{In} , and LIC^{Fa} according to the Formulas (34), (35), and (36), respectively.

The results of computing the ScF value are shown in Table 8. ScF is calculated using Equation (37).

Table 7. The results of the LIC^{Tr}, LIC^{In}, and LIC^{Fa}.

LIC ^{Tr}	CR-01	CR-02	CR-03	CR-04	CR-05	CR-06	CR-07	CR-08	CR-09
EC-01	0.15	0.83	1.72	1.06	0.00	0.47	1.06	1.47	0.64
EC-02	0.72	3.03	1.66	4.00	0.00	0.72	2.30	3.04	1.47
EC-03	3.47	1.47	3.47	4.64	0.72	4.00	0.64	0.83	2.00
EC-04	1.47	1.24	2.72	0.47	1.47	0.64	1.72	0.64	0.64
EC-05	3.03	3.47	9.06	2.64	0.64	1.24	1.24	0.64	0.30
EC-06	3.44	4.00	0.64	3.03	2.30	2.00	0.15	1.72	0.47
EC-07	0.00	0.15	0.00	0.64	1.47	3.44	1.24	1.72	0.64
EC-08	2.30	2.64	7.06	0.30	1.03	0.47	0.00	0.64	0.83
EC-09	2.30	0.30	0.47	2.00	0.47	1.03	0.30	0.15	1.03
EC-10	0.00	3.03	2.00	0.56	0.30	2.00	1.25	0.00	0.15
EC-11	1.06	0.88	9.06	0.15	1.03	0.30	0.15	0.30	5.47
EC-12	4.00	0.15	1.47	0.30	1.47	0.30	1.72	1.89	1.66
LIC ^{In}	CR-01	CR-02	CR-03	CR-04	CR-05	CR-06	CR-07	CR-08	CR-09
EC-01	0.15	0.83	1.72	0.42	0.00	0.47	0.42	1.47	0.64
EC-02	0.08	3.03	1.02	4.00	0.00	0.08	2.30	1.96	1.47
EC-03	3.47	1.47	3.47	4.64	0.08	4.00	0.64	0.83	2.00
EC-04	1.47	1.24	2.08	0.47	1.47	0.64	1.72	0.64	0.64
EC-05	3.03	3.47	8.42	2.64	0.64	1.24	1.24	0.64	0.30
EC-06	2.81	4.00	0.64	3.03	2.30	2.00	0.15	1.72	0.47
EC-07	0.00	0.15	0.00	0.64	1.47	2.81	1.24	1.72	0.64
EC-08	2.30	2.64	6.42	0.30	1.03	0.47	0.00	0.64	0.83
EC-09	2.30	0.30	0.47	2.00	0.47	1.03	0.30	0.15	1.03
EC-10	0.00	3.03	2.00	−0.07	0.30	2.00	0.61	0.00	0.15
EC-11	0.42	−0.20	8.42	0.15	1.03	0.30	0.15	0.30	5.47
EC-12	4.00	0.15	1.47	0.30	1.47	0.30	1.72	1.25	1.02
LIC ^{Fa}	CR-01	CR-02	CR-03	CR-04	CR-05	CR-06	CR-07	CR-08	CR-09
EC-01	0.15	0.83	1.72	0.42	0.00	0.47	0.42	1.47	0.64
EC-02	0.08	3.03	1.02	4.00	0.00	0.08	2.30	1.96	1.47
EC-03	3.47	1.47	3.47	4.64	0.08	4.00	0.64	0.83	2.00
EC-04	1.47	1.24	2.08	0.47	1.47	0.64	1.72	0.64	0.64
EC-05	3.03	3.47	8.42	2.64	0.64	1.24	1.24	0.64	0.30
EC-06	2.81	4.00	0.64	3.03	2.30	2.00	0.15	1.72	0.47
EC-07	0.00	0.15	0.00	0.64	1.47	2.81	1.24	1.72	0.64
EC-08	2.30	2.64	6.42	0.30	1.03	0.47	0.00	0.64	0.83
EC-09	2.30	0.30	0.47	2.00	0.47	1.03	0.30	0.15	1.03
EC-10	0.00	3.03	2.00	−0.07	0.30	2.00	0.61	0.00	0.15
EC-11	0.42	−0.20	8.42	0.15	1.03	0.30	0.15	0.30	5.47
EC-12	4.00	0.15	1.47	0.30	1.47	0.30	1.72	1.25	1.02

Table 8. The value of ScF.

ScF	CR-01	CR-02	CR-03	CR-04	CR-05	CR-06	CR-07	CR-08	CR-09
EC-01	0.05	0.04	0.01	0.07	0.06	0.06	0.09	0.02	0.04
EC-02	0.07	−0.04	0.05	−0.07	0.06	0.09	−0.01	0.04	0.02
EC-03	−0.04	0.02	−0.05	−0.09	0.08	−0.07	0.05	0.04	0.00
EC-04	0.01	0.03	0.02	0.05	0.02	0.05	0.01	0.05	0.04
EC-05	−0.03	−0.05	−0.18	−0.02	0.04	0.03	0.03	0.05	0.06
EC-06	0.00	−0.07	0.04	−0.03	−0.01	0.00	0.07	0.01	0.05
EC-07	0.06	0.06	0.06	0.04	0.02	−0.01	0.03	0.01	0.04
EC-08	−0.01	−0.02	−0.12	0.06	0.03	0.06	0.08	0.05	0.04
EC-09	−0.01	0.06	0.05	0.00	0.05	0.04	0.07	0.07	0.03
EC-10	0.06	−0.04	0.00	0.09	0.05	0.00	0.08	0.07	0.06
EC-11	0.06	0.11	−0.18	0.06	0.03	0.06	0.07	0.06	−0.12
EC-12	−0.06	0.06	0.02	0.06	0.02	0.06	0.01	0.05	0.05

Then calculate the AcF value for LIC of each alternative using Equation (38). Finally, the final ranking of the positions is calculated according to Formulas (39) and (40). The best alternative is selected according to ScF_i . If the ScF_i of the alternatives is equal, rank them according to each alternative. From NFAD's final rankings in Figure 6, the Gioi Di Dong (EC-01) is determined to be the company with the most effective operations in the e-commerce industry in Vietnam, with a score of 0.44. For many years, the Gioi Di Dong has been different in customer experience and in implementing business strategies compared to other competitors. In addition, the Gioi Di Dong also puts customers' interests first, grasping customer psychology for better management [46]. FPT (EC-10) is an e-commerce company with the second most promising score of 0.38. Just like the Gioi Di Dong, FPT operates and builds a service style with customers as the top priority. The company's marketing and management strategies are also unified among branches, bringing sustainable development for the company and increased competitiveness [47]. The organization considered to have the next potential e-commerce activity based on criteria and expert assessments is VNP Group (EC-09) with a score of 0.35.

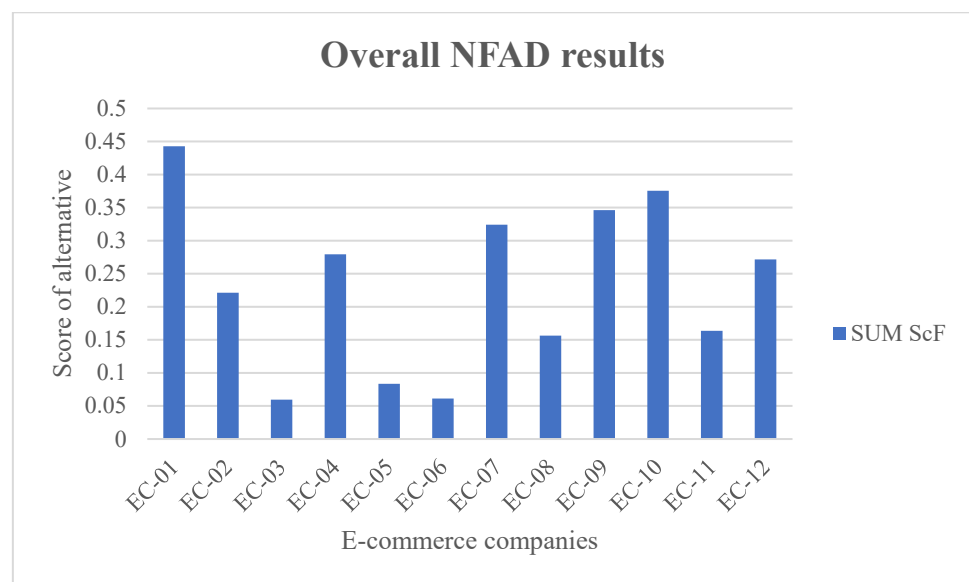


Figure 6. Overall NFAD results.

4.4. Managerial Implications

Managers of e-commerce businesses are facing more and more pressure to prove their worth and boost the efficiency and competitiveness of their companies. Survival is determined by the quality of their goods and services. Its quality and strategic excellence help businesses gain customer loyalty and competitive advantage. An appropriate methodological framework and a comprehensive set of quality assessment criteria based on technological, organizational, economic, and environmental factors will provide managers with the necessary guidance to develop an assessment system. These evaluation systems could provide electronics companies with the feedback they need to become more competitive. In addition, evaluating, ranking, and classifying suppliers for e-commerce businesses is based on real data. The insights will help practitioners develop new strategies for appropriate investments in supplier relationships.

5. Conclusions

E-commerce is one of the fields that makes an important contribution to Vietnam's sustainable economic development. Over the past years, this industry has grown strongly and is a pioneer in the digital economy, creating motivation for economic development and leading digital transformation in businesses. The main goal of this research is to explore the potential of sustainable e-commerce as well as evaluate the performance of

Vietnamese businesses in the field of e-commerce by using FDEMATEL in combination with NFAD. According to expert opinion and literature review, we have initially identified the necessary factors to evaluate EC in the Vietnamese context. We have carefully and extensively evaluated to identify nine criteria to evaluate the twelve companies most effectively in terms of economics, organizational factors, technology, and environmental aspects in the decision-making process. The results show that “external financial support”, “perception of business managers”, and “company operating expenses”, are the three most important criteria in evaluating the performance of leading e-commerce companies in Vietnam. The three top-performing companies have been identified in line with the strong growth of the e-commerce industry. Although there have been a number of studies that have implemented MCDM methods for the general e-commerce field, there have been no studies that have applied the two methods fuzzy decision making trial and evaluation laboratory and neutrosophic fuzzy axiomatic design to evaluate the performance of e-commerce companies in Vietnam. Therefore, introducing a newly proposed decision-making framework based on NFAD is very important and serves as a valuable reference for evaluating companies’ performance in the future. Moreover, this research can promote the sustainable development of Vietnam’s e-commerce industry. Although the research has many important contributions in many aspects to the e-commerce industry in general and e-commerce companies in Vietnam in particular, this research still has certain limitations. First, the initial assessment of the industry and the criteria is mainly based on the opinions of experts. In addition, many other researchers have used various mathematical methods to evaluate the e-commerce industry in general. Furthermore, this research was evaluated on a scale in Vietnam, so it is proposed to expand the scope of research on the e-commerce industry to a global scale to have a more objective view and develop a set of evaluation criteria broader. In future studies, companies in the e-commerce industry can apply this decision-making framework to increase operational efficiency as well as increase competitiveness in the market.

Funding: This research received no external funding.

Data Availability Statement: Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Acknowledgments: The author appreciates the support from the Ho Chi Minh City University of Technology and Education, Vietnam.

Conflicts of Interest: The author declares no conflicts of interest.

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