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A Decision Framework for Supplier Selection in Digital Supply Chains of E-Commerce Platforms Using Interval-Valued Intuitionistic Fuzzy VIKOR Methodology

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Abstract: Digital supply chains (DSCs) are value-driven and collaborative digital systems designed to generate business value for firms through various innovative technologies. Today, we are witnessing companies transitioning from traditional supply chain models to DSCs through digital technologies. The effective selection of digital suppliers during these digital transformation processes is a strategic research topic. Additionally, factors such as the proliferation of information and communication technologies, globalization, and the pandemic have contributed to the expansion of e-commerce platforms. In this rapid growth phase, identifying the right supplier is crucial for the success of e-commerce sites. This study aims to develop an innovative, integrated, and comprehensive decision-making methodology to assist e-commerce platforms in selecting appropriate suppliers for their DSCs. To achieve this, an extended fuzzy VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) method is tested, where criteria and alternative evaluations made by decision-makers (DMs) are characterized by interval-valued intuitionistic fuzzy numbers (IVIFNs). The proposed decision mechanism is tested on the DSS problem of an e-commerce platform specializing in household products. Findings of the application, which uses three experts' opinion to evaluate four digital suppliers based on the seven criteria, are discussed to help e-commerce sites conduct the DSS process more effectively.

Keywords: e-commerce; digital supply chain; fuzzy sets; VIKOR; supplier selection

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1. Introduction

In today's world, digitalization is transforming nearly every aspect of life, including the way supply chains operate. The current digitalization process has driven supply chains toward rapid change and innovation, giving rise to the concept of the digital supply chain (DSC) [1]. DSCs have facilitated the development of activities that create value for various stakeholders within the supply chain ecosystem [2]. By making services more accessible and affordable, DSCs support effective interaction between businesses. To gain a competitive advantage, companies are adapting their supply chains to align with this process, and the investments made in technology highlight the significance of DSCs. In today's competitive environment, where digital transformation is essential, digital supplier selection (DSS) has become a strategically important research topic for firms [3].

Especially after the pandemic, there have been changes in consumers' purchasing behaviour, with many turning to online platforms. Instead of making physical purchases, consumers now prefer to buy products and services online at any time and from any place. Additionally, factors such as widespread internet usage and economic globalization have contributed to the rapid growth of the e-commerce sector [4]. Even users with low levels of technological adaptation have embraced online purchasing due to reasons such as speed, convenience, innovative trade models, the rapid response of e-commerce platforms to innovations, and instalment options. This shift has created new opportunities, particularly for SMEs [5]. However, increasing customer interest has heightened the importance of digital transformation and DSS for e-commerce platforms.

Supplier selection (SS) directly impacts the supply chain performance of companies, and effective execution of the SS process provides a competitive advantage to businesses. Therefore, supplier evaluation is one of the critical decision-making activities faced by companies [2]. Proper SS has a direct effect on the competitive advantage and customer satisfaction of e-commerce sites [6]. Supplier evaluation is considered a significant challenge for e-commerce firms and is a priority research topic [4].

The main objective of the current study is to propose an integrated methodology with a quantitative approach for e-commerce platforms to effectively carry out the DSS process and to test the proposed approach in a real-world case. The additional objectives of the research are as follows: (i) to propose a systematic approach to the problem of SS in DSCs and solve an industrial problem by improving firms' SS processes; (ii) to systematically analyze the literature on DSS and SS for e-commerce sites, including the evaluation criteria tested in these studies and to present an evaluation framework; (iii) to propose an integrated and comprehensive decision-making model that offers a practical and effective solution for real-life problems characterized by uncertain and imprecise data; and (iv) to test a process based on real-life data focused on supplier evaluation and ranking that meets the requirements of e-commerce sites.

In the present study, the extended VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) method, characterized by interval-valued intuitionistic fuzzy numbers (IVIFNs), is used. VIKOR is a valuable method developed for solving complex problems, employing a compromise solution approach that allows for decision-making among conflicting criteria [7]. However, this technique may be inadequate for addressing the complex and uncertain nature of real-life problems. To address these challenges, fuzzy set (FS) theory is frequently utilized, with various extensions of FS theory applied in different decision models [8]. One such extension is intuitionistic fuzzy sets (IFSs), which provide a richer tool compared to traditional FSs. IVIFNs, a variant of intuitionistic fuzzy sets, extend membership and non-membership functions with interval values, offering a broader range for describing fuzzy information. This study tests an integrated fuzzy VIKOR method, where alternative performances and criteria importance levels are expressed using IVIFNs, on a real-world problem.

The proposed approach was tested in the DSS process of an e-commerce platform operating in the household products sector. Seven criteria were identified from the literature review: total cost, digital collaboration, digital competence, technology and functional fit, on-time delivery, organizational design, and quality. An expert group was formed to evaluate these criteria and supplier performance, and four suppliers were assessed. The results indicated that the criteria with the highest degree of importance were Digital Competence (0.158), Total Cost (0.156), and Digital Collaboration (0.155).

The practical and theoretical contributions of the study can be listed as follows:

- A novel DSS model based on VIKOR and IVIFSs was firstly proposed.

- DSS for an e-commerce company in the household appliances industry was analyzed for the first time in the literature.
- Effective factors for DSS in practice were determined, which could be a guide for practitioners in this industry to improve their DSS processes.

2. Literature Review

In the literature review section of this study, the increasing importance of e-commerce platforms in the modern era was discussed, highlighting their growing role in the global market. Following this, studies focusing on SS within e-commerce platforms were examined to understand existing approaches and methodologies. Subsequently, the concept of DSCs was introduced, emphasizing the digital transformation within supply chains. Finally, research efforts aimed at digital supplier evaluation in DSCs were analyzed.

2.1. E-Commerce Platforms and Supplier Selection Process

The concept of e-commerce involves organizations that utilize electronic media, such as computer networks and information and communication technologies, and it is characterized by the electronic delivery of products to customers [4]. E-commerce is defined as buying or selling goods and services through platforms like websites, online stores, and social media [6]. The pandemic, in particular, has significantly altered consumers' purchasing behaviour and accelerated the global adoption of e-commerce [9]. Today, rather than making physical purchases, consumers prefer to buy products online at various times and locations. Increased internet usage and economic globalization have led to the proliferation of e-commerce platforms. Additionally, innovative developments such as instalment options, local coordination, and digital notifications have further contributed to the sector's growth [10]. Even consumers with low levels of technological adaptation have turned to online purchasing due to benefits like a wide range of products, speed, and convenience [4]. Moreover, e-commerce has created new business opportunities for small investors by reducing the need for physical stores and allowing for online business activities [11].

The evaluation of suppliers is a complex issue for e-commerce sites, involving various alternatives and selection criteria. For an e-commerce company, the level of service provided by suppliers directly impacts the company's success. The supplier evaluation process is intricate and must be conducted carefully and rigorously, and it is recognized as a significant challenge for companies. In this section of the research, studies employing different quantitative methodologies for SS in e-commerce sites are presented (Table 1).

Bottani and Rizzi [12] proposed an approach using the AHP for SS in the e-procurement environment. Benyoucef and Canbolat [13] developed a supplier selection mechanism based on the AHP method for e-procurement. Fazlollahtabar et al. [14] developed a hybrid methodology that combines AHP, TOPSIS, and nonlinear programming to determine which supplier to select and how much product to purchase from the selected supplier in the electronic market. Rajiv and Salunkhe [15] analyzed a case study in which AHP and TOPSIS were employed to select a courier service provider for e-commerce websites.

Garg [16] aimed to explore SS criteria and the relationships between these criteria using structural equation modelling (SEM). Naseem, Yang, and Xiang [6] tested a methodology combining GRA and TOPSIS techniques to address logistics service provider selection problems for e-commerce sites. Thresia and Cakravastia [17] employed Delphi and AHP techniques for SS in e-commerce-based fashion firms. Kaushik et al. [18] applied BWM and VIKOR techniques to prioritize criteria among suppliers and identify the most suitable supplier for the online fashion retail industry. Pınar [19] proposed an integrated methodology that combines text mining, sentiment analysis, and ELECTRE/VIKOR decision-making techniques to support SS in e-commerce platforms. Pratap et al. [4] evaluated suppliers based on performance parameters using data envelopment analysis to assist e-commerce firms in their supplier evaluation and selection processes. Cao [20] proposed an approach using SEM for SS in e-commerce sites exporting abroad.

Table 1. Summary of research in the field of SS for e-commerce platforms.

References	Criteria
[12]	Electronic catalogue management, catalogue characteristics, information availability, details' availability, visibility, order management, electronic acceptance, order tracking, e-skills
[13]	Quality, delivery, price, service
[14]	Cost, quality, service and support, delivery, innovation, performance
[15]	Price, quality, reliability, service
[16]	Cost, facility, quality, services, infrastructure, finance, management, delivery
[6]	Area, cost, time, payment, service, quality, flexibility, IT
[17]	Economy, quality and service, social, environment, technology, communication
[18]	Operational competency, product attributes, logistics and warehousing, ethics, status, business competencies, versatility
[19]	Quality, comfort, ergonomics, price
[4]	Transportation cost, shipping time, order, quality, delivery
[20]	Characteristic, compatibility, reputation, stability

2.2. Digital Supply Chain and Supplier Selection Process

Digital technologies have radically transformed the way individuals communicate and interact, impacting every sector, including supply chains. Digitalization is reshaping business dynamics, influencing competitive conditions, and redesigning business models [21]. In the context of supply chains, digitalization refers to the use of digital technologies in all activities and the continuous integration of innovative changes in management practises [22]. Today, businesses must interact with other actors in the process through DSC for the production and delivery of their goods and services. The concept of DSC has introduced rapid changes to the sector. Investments made by companies in technology underscore the significance of DSCs and the anticipated benefits for businesses [1].

DSC is a value-oriented process that creates new ways of working, adds value to businesses, and enhances innovative approaches. DSC involves the integration of supply chain process management with innovative technologies [1]. Today, decision-makers (DMs) in supply chain management are increasingly interested in DSC, which employs new solutions to generate additional business value. The existing organizational structures of traditional supply chains are often inadequate for ensuring effective coordination between suppliers and customers [23]. Therefore, transforming traditional supply chain models through digital technology is an area of significant research interest for firms [3].

DSCs create new business opportunities, enhance flexibility, increase revenues, and facilitate process improvement [24]. Digital processes support connectivity between supply chain members and enable more transparent information flow [22]. DSCs enhance the added value of services, making them more accessible and affordable, and they also support and synchronize interactions between businesses [25]. Given the advantages of

DSCs for firms, it is clear that the DSC is a critical research topic for both industries and academia. Companies, in particular, need to select a DSC partner carefully during their digital transformation process. Considering the multi-criteria nature of the SS process, it is apparent that there are limited studies on this subject in the literature, and the number of studies should be increased. In this section of the study, research using quantitative methods for supplier selection in DSCs is reviewed. These studies and the criteria used for supplier selection are presented in Table 2.

Table 2. Summary of research in the field of DSS.

References	Criteria
[1]	Technology infrastructure, customer centricity, supplier alignment, organizational design, digital competence
[26]	Competency, alignment, cost, price
[27]	Production, ICT, intelligent logistic, maintenance, management
[28]	Economic, social, environmental
[29]	Enablers, time, financial, capabilities, ease of process, support, reputation, functional fit, control linkages, information sharing, business analytics, quality
[2]	Visibility, adopting advanced analytics, capability, collaboration, alignment, agility and flexibility, technology, planning, sharing, knowledge, collaboration, integration
[30]	Technological, socio-political, economic–operational
[3]	Professional support, financial stability, quality, costs, innovation, collaboration, compatibility, capability

Büyüközkan and Göçer [1] developed a group decision-making methodology under uncertainty using fuzzy logic, AHP, and ARAS approaches for DSS. Büyüközkan and Göçer [26] extended this work by developing a hybrid framework that integrates Pythagorean fuzzy sets (FSs), AHP, and complex proportional evaluation. Özbek and Yildiz [27] proposed a method for selecting the most successful digital supplier for an apparel industry enterprise using the fuzzy TOPSIS technique. Stević et al. [28] applied the MARCOS technique to address a sustainable supplier selection problem in the healthcare industry.

Deepu and Ravi [29] aimed to evaluate enterprise information systems based on critical success factors in the supply chain using AHP and TOPSIS techniques. Tavana et al. [2] proposed a methodology for DSS and tested its applicability in a manufacturing company. Krstić et al. [30] explored the applicability of Industry 4.0 technologies in the reverse logistics sector. Gao et al. [3] developed a systematic decision framework for DSS, utilizing BWM, entropy, and COPRAS techniques, particularly in scenarios where information is scarce.

As a result of the literature review conducted within the scope of the research, it was seen that a very limited number of studies aim to contribute to the DSS processes of enterprises through quantitative techniques. It was also seen that these studies focused on some very common MCDM techniques in the literature like AHP [7,9,11] and TOPSIS [14,23] techniques. Different from the literature, an extended version of the VIKOR method with IVIFNs was proposed in this study to support DSS processes for the first time in the literature. Moreover, it is the first study that takes the DSS of e-commerce sites in the literature.

3. Methodology

In complex decision problems, DMs often face the challenge of choosing between multiple conflicting criteria. Adopting a compromise solution approach can help in identifying the most suitable alternative. In this context, the VIKOR technique is a method designed for optimizing multi-criteria decision-making (MCDM) problems [7]. VIKOR, a consensus ranking approach, was developed to rank and select among alternatives with conflicting criteria and varying units of measurement [31]. This technique aims to determine a compromise solution that maximizes group benefit and minimizes individual regret.

In today's complex and uncertain decision-making landscape, FS theory is frequently utilized. This has led to the development and application of various extensions of FS theory in different decision models [8]. One such extension is IFSs. Unlike traditional FS approaches, where membership is treated as binary, IFS theory allows for a more nuanced representation of membership. IVIFNs, an extension of IFSs, provide a broader range for describing fuzzy information by extending functions with interval values [20,32].

The proposed study presents an extension of the VIKOR technique with IVIFNs. Although VIKOR is a technique used in solving complex decision problems using a compromise solution approach, it cannot fully evaluate the uncertain structure of real-life problems. In order to overcome this disadvantage of the method, IVIFNs, which offer a wide range in defining fuzzy information, were integrated into the VIKOR method. Additionally, alternative evaluations provided by DMs are characterized by IVIFNs and a compromise solution that maximizes group benefit and minimizes individual regret was found while taking uncertainty in real life into account.

Step 1. The criteria and alternatives are evaluated with linguistic variables and then the linguistic terms are converted into IVIFN using Table 3 [33]. Thus, decision matrices (DEMs) are created for the criteria and alternatives.

Table 3. Linguistic variables used for criteria and alternative evaluation [33].

Criteria Evaluation		Alternative Evaluation	
Linguistic Terms	**IVIFN ($[\mu^L, \mu^U], [v^L, v^U]$)**	**Linguistic Terms**	**IVIFN ($[\mu^L, \mu^U], [v^L, v^U]$)**
Extremely important	([0.95, 1], [0, 0])	Completely successful	([0.99, 1], [0, 0])
Very important	([0.8, 0.85], [0.05, 0.1])	Extremely successful	([0.9, 0.95], [0.01, 0.04])
Important	([0.6, 0.65], [0.1, 0.15])	Very successful	([0.8, 0.85], [0.05, 0.1])
Less important	([0.3, 0.35], [0.25, 0.3])	Successful	([0.7, 0.75], [0.15, 0.2])
Very unimportant	([0.2, 0.25], [0.3, 0.35])	Somewhat successful	([0.6, 0.65], [0.25, 0.3])
Completely unimportant	([0, 0.05], [0.45, 0.5])	Normal	([0.5, 0.55], [0.35, 0.4])
		Somewhat unsuccessful	([0.4, 0.45], [0.45, 0.5])
		Unsuccessful	([0.3, 0.35], [0.55, 0.6])
		Very unsuccessful	([0.2, 0.25], [0.65, 0.7])
		Extremely unsuccessful	([0.1, 0.15], [0.75, 0.8])
		Completely unsuccessful	([0, 0], [0.99, 1])

Step 2. The importance levels of the criteria are obtained through Equations (1) and (2). The expression λ^k in Equation (1) indicates the DM weight. Moreover. μ^L, μ^U, v^L, and v^U values represent the linguistic variables for criteria evaluation in IVIFN format, while $\breve{w}_j$ shows criteria weights before normalization. The n value in Equation (2) denotes the number of criteria and w_j is the final criteria weight.

$$\breve{w}_j = 1 - \frac{\sum_{k=1}^{K} \frac{\lambda^k(\mu_{ij}^L + \mu_{ij}^U)}{2}}{\sqrt{\sum_{k=1}^{K} \frac{\lambda^k\left((\mu_{ij}^L)^2 + (\mu_{ij}^U)^2 + (v_{ij}^L)^2 + (v_{ij}^U)^2\right)}{2}}} \quad (1)$$

$$w_j = \frac{1 - \check{w}_j}{n - \sum_{j=1}^{n} \check{w}_j} \tag{2}$$

Step 3. The DEM for alternatives is transformed into a combined DEM for alternatives using Equation (3).

$$\check{r}_{ij} = \left(\begin{bmatrix} 1 - \prod_{j=1}^{n} \left(1 - \mu^{L}_{\tilde{A}}\right)^{\lambda^k}, \\ 1 - \prod_{j=1}^{n} \left(1 - \mu^{U}_{\tilde{A}}\right)^{\lambda^k} \end{bmatrix} \begin{bmatrix} \prod_{j=1}^{n} \left(v^{L}_{\tilde{A}}\right)^{\lambda^k}, \\ \prod_{j=1}^{n} \left(v^{U}_{\tilde{A}}\right)^{\lambda^k} \end{bmatrix} \right) \tag{3}$$

Step 4. Using Equation (4) for benefit criteria and Equation (5) for cost criteria, the positive ideal solution (PIS) and negative ideal solution (NIS) values are obtained.

$$\tilde{f}^{*}_{j} = \left(\left[\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right), \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right)\right], \left[\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right), \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right)\right]\right)$$

$$\left(\begin{bmatrix} \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = max_i^{\tilde{\mu}^{L}_{\tilde{A}}(\tilde{x}^{*}_{j})}, \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = max_i^{\tilde{\mu}^{U}_{\tilde{A}}(\tilde{x}^{*}_{j})} \\ \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = min_i^{\tilde{v}^{L}_{\tilde{A}}(\tilde{x}^{*}_{j})}, \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = min_i^{\tilde{v}^{U}_{\tilde{A}}(\tilde{x}^{*}_{j})} \end{bmatrix} \right) \tag{4}$$

$$\tilde{f}^{-}_{j} = ([\tilde{\mu}^{L}_{\tilde{A}}(\tilde{x}^{-}_{j}), \tilde{\mu}^{U}_{\tilde{A}}(\tilde{x}^{-}_{j})], [\tilde{\mu}^{L}_{\tilde{A}}(\tilde{x}^{-}_{j}), \tilde{\mu}^{U}_{\tilde{A}}(\tilde{x}^{-}_{j})])))])$$

$$\left(\begin{bmatrix} \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = min_i^{\tilde{\mu}^{L}_{\tilde{A}}(\tilde{x}^{-}_{j})}, \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = min_i^{\tilde{\mu}^{U}_{\tilde{A}}(\tilde{x}^{-}_{j})} \\ \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = max_i^{\tilde{v}^{L}_{\tilde{A}}(\tilde{x}^{-}_{j})}, \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = max_i^{\tilde{v}^{U}_{\tilde{A}}(\tilde{x}^{-}_{j})} \end{bmatrix} \right)$$

$$\tilde{f}^{*}_{j} = \left(\left[\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right), \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right)\right], \left[\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right), \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right)\right]\right)$$

$$\left(\begin{bmatrix} \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = min_i^{\tilde{\mu}^{L}_{\tilde{A}}(\tilde{x}^{*}_{j})}, \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = min_i^{\tilde{\mu}^{U}_{\tilde{A}}(\tilde{x}^{*}_{j})} \\ \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = max_i^{\tilde{v}^{L}_{\tilde{A}}(\tilde{x}^{*}_{j})}, \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{*}_{j}\right) = max_i^{\tilde{v}^{U}_{\tilde{A}}(\tilde{x}^{*}_{j})} \end{bmatrix} \right) \tag{5}$$

$$\tilde{f}^{-}_{j} = \left(\left[\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right), \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right)\right], \left[\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right), \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right)\right]\right)$$

$$\left(\begin{bmatrix} \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = max_i^{\tilde{\mu}^{L}_{\tilde{A}}(\tilde{x}^{-}_{j})}, \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = max_i^{\tilde{\mu}^{U}_{\tilde{A}}(\tilde{x}^{-}_{j})} \\ \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = min_i^{\tilde{v}^{L}_{\tilde{A}}(\tilde{x}^{-}_{j})}, \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}^{-}_{j}\right) = min_i^{\tilde{v}^{U}_{\tilde{A}}(\tilde{x}^{-}_{j})} \end{bmatrix} \right)$$

Step 5. First, $\pi^{L}_{\tilde{A}}$ and $\pi^{U}_{\tilde{A}}$ are calculated by Equation (6). Then, using Equation (7), the distance of the criteria from the PIS ($d(\tilde{f}^{*}_{j}, \tilde{x}_{ij})$) and the distance between the PIS and NIS ($d(\tilde{f}^{*}_{j}, \tilde{f}^{-}_{j})$) are obtained.

$$\pi^{L}_{\tilde{A}} = 1 - \mu^{U}_{\tilde{A}} - v^{U}_{\tilde{A}} \tag{6}$$

$$\pi^{U}_{\tilde{A}} = 1 - \mu^{L}_{\tilde{A}} - v^{L}_{\tilde{A}}$$

$$d\left(\tilde{f}_j^{*}, \tilde{x}_{ij}\right) = \frac{1}{4}\left(\begin{array}{c} \left|\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}_{ij}\right)\right| + \left|\tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}_{ij}\right)\right| \\ + \left|\tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}_{ij}\right)\right| + \left|\tilde{v}^{U}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{v}^{U}_{\tilde{A}}\left(\tilde{x}_{ij}\right)\right| \\ + \left|\tilde{\pi}^{L}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\pi}^{L}_{\tilde{A}}\left(\tilde{x}_{ij}\right)\right| + \left|\tilde{\pi}^{U}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\pi}^{U}_{\tilde{A}}\left(\tilde{x}_{ij}\right)\right| \end{array}\right) \tag{7}$$

$$d\left(\tilde{f}_j^{*}, \tilde{f}_j^{-}\right) = \frac{1}{4}\left(\begin{array}{c} \left|\tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\mu}^{L}_{\tilde{A}}\left(\tilde{x}_j^{-}\right)\right| + \left|\tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\mu}^{U}_{\tilde{A}}\left(\tilde{x}_j^{-}\right)\right| \\ + \left|\tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{v}^{L}_{\tilde{A}}\left(\tilde{x}_j^{-}\right)\right| + \left|\tilde{v}^{U}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{v}^{U}_{\tilde{A}}\left(\tilde{x}_j^{-}\right)\right| \\ + \left|\tilde{\pi}^{L}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\pi}^{L}_{\tilde{A}}\left(\tilde{x}_j^{-}\right)\right| + \left|\tilde{\pi}^{U}_{\tilde{A}}\left(\tilde{x}_j^{*}\right) - \tilde{\pi}^{U}_{\tilde{A}}\left(\tilde{x}_j^{-}\right)\right| \end{array}\right)$$

Step 6. Equation (8) is used to obtain the group utility value ($S_{(i)}$) and individual regret value ($R_{(i)}$) of the decision alternatives. Then, using Equation (9), the $Q_{(i)}$ of the alternatives are obtained. It is assumed that the most successful decision alternative has the lowest $Q_{(i)}$ value.

$$S_{(i)} = \sum\nolimits_{j=1}^{n} \left[w_j \frac{d\left(\tilde{f}_j^{*}, \tilde{x}_{ij}\right)}{d\left(\tilde{f}_j^{*}, \tilde{f}_j^{-}\right)}\right] \tag{8}$$

$$R_{(i)} = \max_j \left[w_j \frac{d\left(\tilde{f}_j^{*}, \tilde{x}_{ij}\right)}{d\left(\tilde{f}_j^{*}, \tilde{f}_j^{-}\right)}\right]$$

$$S^{*} = \min_i S_{(i)},\ S^{-} = \max_i S_{(i)} \tag{9}$$

$$R^{*} = \min_i R_{(i)},\ R^{-} = \max_i R_{(i)}$$

$$Q_{(i)} = v\left(\frac{S_{(i)} - S^{*}}{S^{-} - S^{*}}\right) + (1\text{-}v)\left(\frac{R_{(j)} - R^{*}}{R^{-} - R^{*}}\right)$$

Step 7. Compliance with acceptable availability (Condition 1) and acceptable stability (Condition 2) is checked. According to Condition 1, Equation (10) must be satisfied. The DQ value here is 0.25 if the number of alternatives is 4 or less. Condition 2 requires that the first ranked alternative has the lowest value of at least one of $S_{(i)}$ and $R_{(i)}$.

$$Q^{[2]} - Q^{[23]} \geq DQ \tag{10}$$

4. Application

In this part, the proposed evaluation framework is tested in solving the DSS problem of an e-commerce site serving in the household products category. Firstly, the studies in the literature on DSS and SS for e-commerce sites were systematically reviewed. As a result of the literature review, seven criteria were identified to be evaluated within the scope of the study. These criteria are Total Cost (C_1), Digital Collaboration (C_2), Digital Competence (C_3), Technology and Functional Fit (C_4), On-Time Delivery (C_5), Organizational Design (C_6) and Quality (C_7). Definitions of these criteria are provided in Table 4. An expert group was formed, consisting of three decision-makers (DMs)—DM_1, DM_2, and DM_3—who are specialists in the purchasing department of the e-commerce site and play a key role in the supplier selection process. The group evaluated four supplier companies (A_1, A_2, A_3, and A_4). The importance levels of the criteria were assessed using a six-point linguistic scale, while the degree to which each alternative met the criteria was evaluated using an eleven-point linguistic scale (Table 3). The steps followed in the implementation process are detailed below.

Table 4. Criteria and definitions used in the application.

Criterion	Definition	References
Total Cost (C_1)	Total cost of ownership, which includes the unit price of the material/product as well as other costs such as transportation, service, tracking, inventory holding, insurance, and servicing	[5,9,12,13,18,26,28,30]
Digital Collaboration (C_2)	Collaboration of digital capabilities among stakeholders in the supply chain, effectively communicating information, improving coordination, and establishing appropriate connections	[10,11,14,31]
Digital Competence (C_3)	The supplier creates a digitally enabled business model and gains a competitive advantage through the use of ICT	[7,9,11,14,19,31,32]
Technology and Functional Fit (C_4)	Suppliers' technological tools and business processes, such as ERP, inventory software, and data integration, are compatible with the technological infrastructure, business requirements, and operational processes of the buyer company	[9,11,14,31]
On-Time Delivery (C_5)	It represents the supplier's total time required for order delivery, ability to meet delivery schedules, and delivery capability	[5,11,12,19,27]
Organizational Design (C_6)	Aligning the supplier's nature, values, standards, processes, and capabilities with the firm's core business strategy	[7,13,14,23]
Quality (C_7)	The supplier's ability to meet requirements/standards that may affect the overall quality of the finished product and the supplier's level to consistently fulfil quality specifications	[5,11–14,26,28]

Step 1. DMs' assessments of the importance of the criteria and the extent to which the alternatives fulfil the criteria are given in Tables 5 and 6.

Table 5. Criteria evaluations of DMs.

	DM_1	DM_2	DM_3
C_1	([0.8, 0.85], [0.05, 0.1])	([0.6, 0.65], [0.1, 0.15])	([0.95, 1], [0, 0])
C_2	([0.8, 0.85], [0.05, 0.1])	([0.6, 0.65], [0.1, 0.15])	([0.6, 0.65], [0.1, 0.15])
C_3	([0.95, 1], [0, 0])	([0.95, 1], [0, 0])	([0.8, 0.85], [0.05, 0.1])
C_4	([0.3, 0.35], [0.25, 0.3])	([0.8, 0.85], [0.05, 0.1])	([0.3, 0.35], [0.25, 0.3])
C_5	([0.3, 0.35], [0.25, 0.3])	([0.6, 0.65], [0.1, 0.15])	([0.3, 0.35], [0.25, 0.3])
C_6	([0.3, 0.35], [0.25, 0.3])	([0.3, 0.35], [0.25, 0.3])	([0.3, 0.35], [0.25, 0.3])
C_7	([0.6, 0.65], [0.1, 0.15])	([0.8, 0.85], [0.05, 0.1])	([0.3, 0.35], [0.25, 0.3])

Table 6. DMs' evaluation of alternatives.

DM_i	C_j	A_1	A_2	A_3	A_4
DM_1	C_1	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]
	C_2	[0.5, 0.55], [0.35, 0.4]	[0.6, 0.65], [0.25, 0.3]	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]
	C_3	[0.6, 0.65], [0.25, 0.3]	[0.7, 0.75], [0.15, 0.2]	[0.6, 0.65], [0.25, 0.3]	[0.5, 0.55], [0.35, 0.4]
	C_4	[0.7, 0.75], [0.15, 0.2]	[0.4, 0.45], [0.45, 0.5]	[0.4, 0.45], [0.45, 0.5]	[0.4, 0.45], [0.45, 0.5]
	C_5	[0.5, 0.55], [0.35, 0.4]	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.4, 0.45], [0.45, 0.5]
	C_6	[0.4, 0.45], [0.45, 0.5]	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]	[0.6, 0.65], [0.25, 0.3]
	C_7	[0.6, 0.65], [0.25, 0.3]	[0.7, 0.75], [0.15, 0.2]	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]
DM_2	C_1	[0.6, 0.65], [0.25, 0.3]	[0.7, 0.75], [0.15, 0.2]	[0.6, 0.65], [0.25, 0.3]	[0.5, 0.55], [0.35, 0.4]
	C_2	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]	[0.4, 0.45], [0.45, 0.5]	[0.3, 0.5], [0.2, 0.5]
	C_3	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]
	C_4	[0.7, 0.75], [0.15, 0.2]	[0.4, 0.45], [0.45, 0.5]	[0.4, 0.45], [0.45, 0.5]	[0.5, 0.55], [0.35, 0.4]
	C_5	[0.5, 0.55], [0.35, 0.4]	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.4, 0.45], [0.45, 0.5]
	C_6	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]	[0.4, 0.45], [0.45, 0.5]	[0.6, 0.65], [0.25, 0.3]
	C_7	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]
DM_3	C_1	[0.6, 0.65], [0.25, 0.3]	[0.6, 0.65], [0.25, 0.3]	[0.5, 0.55], [0.35, 0.4]	[0.5, 0.55], [0.35, 0.4]
	C_2	[0.6, 0.65], [0.25, 0.3]	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]	[0.4, 0.45], [0.45, 0.5]
	C_3	[0.7, 0.75], [0.15, 0.2]	[0.7, 0.75], [0.15, 0.2]	[0.5, 0.55], [0.35, 0.4]	[0.5, 0.55], [0.35, 0.4]
	C_4	[0.6, 0.65], [0.25, 0.3]	[0.5, 0.55], [0.35, 0.4]	[0.5, 0.55], [0.35, 0.4]	[0.5, 0.55], [0.35, 0.4]
	C_5	[0.4, 0.45], [0.45, 0.5]	[0.5, 0.55], [0.35, 0.4]	[0.7, 0.75], [0.15, 0.2]	[0.4, 0.45], [0.45, 0.5]
	C_6	[0.4, 0.45], [0.45, 0.5]	[0.5, 0.55], [0.35, 0.4]	[0.4, 0.45], [0.45, 0.5]	[0.5, 0.55], [0.35, 0.4]
	C_7	[0.5, 0.55], [0.35, 0.4]	[0.7, 0.75], [0.15, 0.2]	[0.4, 0.45], [0.45, 0.5]	[0.5, 0.55], [0.35, 0.4]

Step 2. The importance levels of the criteria are obtained using Equations (1) and (2). In this application, the coefficients of the DMs are equal. Calculation results showed that the criterion with the highest degree of importance is C_3 (0.158). The criteria weights are C_3 (0.158), C_1 (0.156), C_2 (0.155), C_7 (0.144), C_5 (0.133), C_4 (0.132), and C_6 (0.121), respectively.

Step 3. The DEM for the alternatives is transformed into a combined DEM using Equation (3). The DEM is given in Table 7.

Table 7. Combined DEM for alternatives.

C_j	A_1	A_2	A_3	A_4
C_1	[0.6, 0.8], [0, 0.2]	[0.636, 0.841], [0, 0.168]	[0.569, 0.771], [0.034, 0.235]	[0.535, 0.738], [0.068, 0.268]
C_2	[0.535, 0.738], [0, 0.262]	[0.506, 0.711], [0.104, 0.305]	[0.435, 0.636], [0.168, 0.368]	[0.368, 0.569], [0.2, 0.435]
C_3	[0.636, 0.841], [0, 0.159]	[0.669, 0.874], [0, 0.135]	[0.569, 0.771], [0.034, 0.235]	[0.535, 0.738], [0.068, 0.268]
C_4	[0.669, 0.874], [0, 0.126]	[0.435, 0.636], [0.168, 0.368]	[0.435, 0.636], [0.168, 0.368]	[0.468, 0.669], [0.135, 0.335]
C_5	[0.468, 0.669], [0.126, 0.331]	[0.569, 0.771], [0.034, 0.235]	[0.636, 0.841], [0, 0.168]	[0.4, 0.6], [0.2, 0.4]
C_6	[0.435, 0.636], [0.159, 0.364]	[0.468, 0.669], [0.135, 0.335]	[0.4, 0.6], [0.2, 0.4]	[0.569, 0.771], [0.034, 0.235]
C_7	[0.569, 0.771], [0, 0.229]	[0.669, 0.874], [0, 0.135]	[0.468, 0.669], [0.135, 0.335]	[0.435, 0.636], [0.168, 0.368]

Step 4. In the current implementation, all of the evaluation criteria considered are utility-based criteria. Therefore, PIS and NIS values are calculated using Equation (4) for all criteria (Table 8).

Table 8. PIS and NIS values of criteria.

C_j	PIS	NIS
C_1	[0.636, 0.841], [0, 0.168]	[0.535, 0.738], [0.068, 0.268]
C_2	[0.535, 0.738], [0, 0.262]	[0.368, 0.569], [0.2, 0.435]
C_3	[0.669, 0.874], [0, 0.135]	[0.535, 0.738], [0.068, 0.268]
C_4	[0.669, 0.874], [0, 0.126]	[0.435, 0.636], [0.168, 0.368]
C_5	[0.636, 0.841], [0, 0.168]	[0.4, 0.6], [0.2, 0.4]
C_6	[0.569, 0.771], [0.034, 0.235]	[0.4, 0.6], [0.2, 0.4]
C_7	[0.669, 0.874], [0, 0.135]	[0.435, 0.636], [0.168, 0.368]

Step 5. The $\pi^L_{\tilde{A}}$ and $\pi^U_{\tilde{A}}$ values of the criteria are obtained using Equation (6). Then $d(\tilde{f}^*_j, \tilde{x}_{ij})$ and $d(\tilde{f}^*_j, \tilde{f}^-_j)$ values are calculated using Equation (7) and are presented in Table 9.

Table 9. The $d(\tilde{f}^*_j, \tilde{x}_{ij})$ and $d(\tilde{f}^*_j, \tilde{f}^-_j)$ values of the criteria.

C_j	$\pi^L_{A_1}(x_j)$	$\pi^U_{A_1}(x_j)$	$\pi^L_{A_2}(x_j)$	$\pi^U_{A_2}(x_j)$	$\pi^L_{A_3}(x_j)$	$\pi^U_{A_3}(x_j)$	$\pi^L_4(x_j)$	$\pi^U_4(x_j)C_1$
C_1	0	0.4	−0.009	0.364	−0.005	0.397	−0.005	0.397
C_2	0	0.465	−0.016	0.39	−0.004	0.397	−0.004	0.432
C_3	0	0.364	−0.008	0.331	−0.005	0.397	−0.005	0.397
C_4	0	0.331	−0.004	0.397	−0.004	0.397	−0.004	0.397
C_5	0	0.405	−0.005	0.397	−0.009	0.364	−0.001	0.4
C_6	0	0.406	−0.004	0.397	−0.001	0.4	−0.005	0.397
C_7	0	0.431	0.008	0.331	−0.004	0.397	−0.004	0.397

Step 6. After the $S_{(i)}$ and $R_{(i)}$ of the alternatives are calculated through Equation (8), the $Q_{(i)}$ values are calculated using Equation (9) (Table 10). At this stage, the value of v is taken as 0.5. According to the implementation results, the most successful alternative is A_1.

Table 10. $S_{(i)}$, $R_{(i)}$, and $Q_{(i)}$ values of alternatives.

-	A_1	A_2	A_3	A_4
$S_{(i)}$	0.31	0.343	0.662	0.793
$R_{(i)}$	0.092	0.123	0.123	0.145
$Q_{(i)}$	0	0.324	0.654	1

Step 7. The difference between the Q_i of the second most appropriate alternative A_2 and the most appropriate alternative A_1 is 0.324 and is higher than the DQ value. Therefore, Condition 1 is satisfied. Condition 2 is also, satisfied since the most suitable alternative A_1 has the lowest values for both $S_{(i)}$ and $R_{(i)}$.

5. Discussion

Today, with the widespread adoption of digital technologies, there has been a significant shift from traditional supply chains to DSCs. Concurrently, as consumers increasingly turn to online purchasing, the use of e-commerce sites has surged. Consequently, DSS for e-commerce platforms has become a critical research topic. This study proposes an MCDM framework specifically designed for evaluating and selecting digital suppliers for e-commerce sites. The goal of this research is to enhance both academic and industrial understanding by analyzing the existing literature on DSS and SS in the e-commerce domain and to develop a decision support mechanism that can effectively aid in the supplier selection process.

In this study, an integrated and comprehensive framework for DSS in e-commerce websites is proposed, utilizing the IVIFN and the extended VIKOR technique. This approach includes a seven-step procedure designed to effectively evaluate digital suppliers. At the first step, decision-makers evaluated criteria and alternatives using linguistic variables, and those evaluated were transformed into IVIFNs using the equivalents presented in Table 3. Then, Equations (1) and (2) were used to calculate criteria weights. Next, the decision matrix constructed using three decision-makers' evaluations transformed to aggregated DEM using Equation (3) in the third step. The fourth step was the calculation of PIS and NIS values for each criterion. Equation (7) was used in Step 5 to calculate the distance of each alternative to the PIS and the distance between PIS and NIS. Group utility and individual regret values of each alternative were obtained using Equation (8) in Step 6. Then, Equation (9) was used to calculate Q_{i} values, which is used to compare alternatives. At the last step, compliance with acceptable availability and acceptable stability conditions were checked.

Compared to traditional approaches and FSs, IVIFN provides greater flexibility in addressing real-life problems. By combining IVIFN with the VIKOR technique, the proposed methodology leverages these advantages to enhance decision-making. The seven criteria used in the research were identified through a systematic and detailed review of the literature on DSS and SS for e-commerce platforms. This literature review established the foundation for the DSS framework developed in this study. In addition, as a result of the literature review, it has been observed that there are not enough studies using quantitative methods on an increasingly important research topic such as DSS and that the studies focus on classical decision-making techniques.

To demonstrate the applicability of the proposed integrated procedure, a real-life case study of an e-commerce website in the household products category was analyzed. In this study, four alternative digital suppliers were evaluated based on seven criteria. The proposed methodology proved to be a viable decision-making tool for digital supplier evaluation. This approach can serve as a strategic evaluation tool for DSS by DMs and researchers alike. The findings of the study offer valuable insights for e-commerce websites, enabling them to conduct the DSS process more effectively.

It has been seen that at the end of the literature review conducted within the scope of this research, a very limited number of studies aim to contribute to the DSS processes of enterprises through quantitative techniques. It was also seen that these studies focused on some very common MCDM techniques in the literature like AHP [7,9,11] and TOPSIS [14,23] techniques. The integrated, novel, and hybrid method provides a new point of view to the field of this research. In the literature, DSS decisions for garment industry [27], healthcare [28], manufacturing [2], and logistics [30] companies were considered so far. There are no studies that focus on DSS of household appliance seller e-commerce companies. Moreover, the evaluation criteria in this study were determined after a comprehensive and detailed literature review for the first time in the literature and differ from the other studies.

5.1. Conclusions

There is a significant gap in the literature regarding supply chain research focused on digitalization. The aim of the current study is to fill this gap in the literature in the field of DSS and to present practical findings that can contribute to decision-makers. DSS is a critical research area that requires a comprehensive examination with real data and specific industry contexts. This study aims to enhance the DSS process for companies and provide valuable insights for both academic and industrial purposes. Determining effective criteria in DSS can serve as a guide for DMs. The findings indicate that the most influential criterion in DSS is Digital Competence (0.158). The criteria are ranked in the following order of importance: Digital Competence (0.158), Total Cost (0.156), Digital Collaboration (0.155), Quality (0.144), On-Time Delivery (0.133), and Technology and Functional Compatibility (0.121).

The application revealed that Digital Competence is the most critical criterion for DSS. Digital competence refers to a supplier's ability to leverage information and communication technologies to create a digitally enabled business model and gain a competitive advantage by offering smart products. In a DSC environment, suppliers must utilize next-generation technological enablers that facilitate autonomous decision-making or self-learning. Key technological enablers include big data, the Internet of Things (IoT), and cloud computing. A supplier demonstrating high digital competence maintains seamless communication with supply chain partners and offers a robust digitally enabled business model. Additionally, features such as a mobile application or website that allows customers to track their orders and delivery status further enhance a supplier's level of digital competence.

Total Cost, a traditional criterion in SS, emerged as the second most significant criterion in the study. Beyond just the price of the material or product, the study also considered transportation, service, tracking, inventory, insurance, and servicing costs. While cost remains a traditional SS criterion, it is crucial for digital procurement selection as well. As companies transform to adapt to the digital age, suppliers must maintain competitive product costs. To achieve this, they should focus on innovation and R&D activities that can help reduce unit product costs.

In the study, Digital Collaboration was identified as the third most important criterion in DSS. Digital collaboration refers to the coordination and integration of digital capabilities between the supplier and the customer. Effective digital collaboration is crucial for enhancing e-commerce performance. Improved collaboration boosts both efficiency and cohesion within the supply chain. To enhance digital collaboration, suppliers should leverage common digital platforms, such as cloud-based software or ERP systems, to facilitate information and data sharing among supply chain stakeholders. Interfaces that enable seamless interaction between different software systems and support efficient data flow are essential. Additionally, embracing transparency and data sharing practises will help in better process management and enable rapid decision-making.

Another main purpose of the study is to present theoretical findings that can contribute to researchers. VIKOR, utilized in this study, is an MCDM method based on a consensus solution approach, providing effective results for complex decision problems. While traditional MCDM techniques like VIKOR use crisp values, real-life problems often involve uncertain and imprecise information. To address these complexities, FS theory and IFSs are commonly employed. IVIFNs, an extension of IFSs, offer a broad scope for describing fuzzy information. This study proposes an innovative approach integrating IVIFNs with the VIKOR technique, applying it for the first time in the DSS domain. A review of the existing literature reveals a limited number of studies on DSS, with most relying on classical MCDM techniques such as AHP and TOPSIS. Additionally, this research is the first to analyze the DSS process specifically for an e-commerce site in the household products sector.

The research findings contribute significantly to the literature on MCDM by expanding the understanding and application of MCDM techniques. The study proposes a fuzzy decision-making approach based on a consensus solution strategy for the effective evaluation of digital suppliers. By incorporating IVIFNs, the approach utilizes linguistic terms in the evaluation of criteria and alternatives, thereby addressing uncertainties in the decision-making process. This proposed methodology is anticipated to pave the way for future research integrating IVIFNs with various MCDM techniques and to offer new scientific insights into decision-making processes.

5.2. Limitations and Further Research Issues

To contribute to the DSS process for e-commerce websites, this study proposes a model based on a systematic literature review and tests it with a real case study. The practical findings are expected to be valuable for both researchers and DMs. However, the study does have limitations, and future research could address these gaps and further develop the model.

First, the model proposed in this study is based on a literature review, which may be considered a limitation. Including a committee of experts with experience in supplier selection and from diverse fields could enhance the criteria determination process through methods such as Delphi analysis. Additionally, the evaluation of criteria and alternatives was conducted by a committee of three individuals. Expanding the DM group could further contribute to the robustness and validity of the research.

In the present research, the case study was conducted during the SS process of an e-commerce website specializing in household products. Companies from various industrial backgrounds may have different expectations and requirements for DSS based on their specific goals. Therefore, applying the proposed methodology to different sectors or developing alternative roadmaps could yield valuable insights for DMs. Furthermore, exploring the integration of IVIFN with other MCDM techniques and testing these approaches in the context of DSS could significantly contribute to the theoretical literature.

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