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Sustainable Supplier Selection Model in Supply Chains During the COVID-19 Pandemic

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Abstract: As global supply chains become more developed and complicated, supplier quality has become increasingly influential on the competitiveness of businesses during the Covid-19 pandemic. Consequently, supplier selection is an increasingly important process for any business around the globe. Choosing a supplier is a complex decision that can result in lower procurement costs and increased profits without increasing the cost or lowering the quality of the product. However, these decision-making problems can be complicated in cases with multiple potential suppliers. Vietnam's textile and garment industry, for example, has made rapid progress in recent years but is still facing great difficulties as the supply of raw materials and machinery depends heavily on foreign countries. Therefore, it is extremely important for textile and garment manufacturing companies in Vietnam to implement an effective supplier evaluation and selection process. While multicriteria decision-making models are frequently employed to assist with supplier evaluation and selection problems, few of these models consider the problem under the condition of a fuzzy decision-making environment. The aim of this paper is to create a hybrid MCDM model using the Fuzzy Analytical Hierarchy Process (FAHP) model and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to assist the supplier selection process in the garment industry in a fuzzy decision-making environment. In this study, the FAHP method is used to evaluate the performance and the weight of each criterion. TOPSIS is then used to rank all potential suppliers. The proposed model is then applied to a real-world case study to demonstrate both the process of calculation as well as its real-world applicability. The results from the case study provide empirical evidence that the model is feasible. The proposed approach can also be used in combination with other MCDM models to better support decision makers and can be modified to be applied in similar supplier selection processes for different industries.

Keywords: MCDM model; FAHP; fuzzy theory; TOPSIS; garment industry; covid-19

1 Introduction

The textile and garment industry of Vietnam sets an annual export target of 33.5 billion USD. To focus on investment in restructuring the internal branch, application of advanced technologies to gradually balance stages, improve productivity and product quality; accommodate production shift in regions; strengthen cooperation, joint venture and linkage between domestic textile and garment enterprises, domestic enterprises and foreign investment; and exploit traditional markets in parallel to the exploration of new markets. The dependence on imported raw materials and machinery for the textile and dyeing stages is a challenge to the sustainable development of Vietnam's textile and garment industry, especially as it interfaces with the global textile value chain. In recent years, businesses have considered implementation of supply chain management (SCM) to be an important issue affecting a company's productivity and efficiency. SCM has become a competitive strategy to connect companies with suppliers and distributors within an interagency system [1]. The supply chain is a system of organizations, people, activities, information and resources related to the transfer of products or services from a manufacturer to its customer [2]. Managing a supply chain puts a focus on continuous improvement to meet customer demand, reduce costs and increase profitability for the business. Since the onset of the Covid-19 pandemic, however, global supply chains have been greatly disturbed, with prolonged periods of demand uncertainty and supply shortage. Thus, supply evaluation and selection processes have become increasingly important during the pandemic, especially for an import-dependent industry such as garment and textile manufacturing in Vietnam.

The selection of one or more suppliers is one of the pressing issues along the supply chain because supplier quality directly affects the performance of the organization at cheaper prices in the corresponding quantities for a limited time. One of the most essential functions to reduce raw material costs is selecting suppliers [1]. Supplier selection is a complex decision-making process which involves multiple criteria. Multicriteria decision-making methods, such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Fuzzy Analytic Network Process (FANP), Data Envelopment Analysis (DEA), among others, are frequently applied to support the decision-making processes [3].

Since Saaty introduced the Analytical Hierarchy Process (AHP) in 1977, the method has become a commonly used quantitative approach to supplier selection [3–11] and supplier performance evaluation [12,13]. The Analytic Network Process (ANP) can also be applied to the same type of multicriteria decision making problems as AHP [14–16]. This approach is more practical because the internal and external relationships between the criteria are simultaneously considered in order to establish the relationships between the clusters [17].

In this study, we present the use of the FAHP and TOPSIS methods to solve supply chain management decision-making problems. Priorities between the criteria, recorded as weightings, are obtained from the FAHP model, after which the TOPSIS model is used to rank all potential suppliers. The proposed model is then applied to a real-world case study to demonstrate its accurate calculation process and real-world applicability.

2 Literature Review

Many studies in the past decade have focused on supplier evaluation and problems in selection. While supplier selection processes are becoming an increasingly important topic in SMC, their role in modern supply chain practices is only partially explored in the literature.

In this body of research, the supplier selection decision-making problem is commonly solved using quantitative methods and mathematical modelling [18]. In Dickson's study, for example, several different MCDM models are employed to support a supplier selection process [19]. Decision support models for supplier selection processes are also built around a set of criteria (Pi and Low) [20]. Timmerman proposed a single objective weighted linear model in which suppliers are rated on several criteria and in which these ratings are combined into a single score [21]. Pearson and Ellram identified the common supplier selection criteria used by procurement managers in electronics firms [22]. Asemi and Asemi developed a MCDM model using Fuzzy AHP and Fuzzy TOPSIS. This proposed model was then used to support a steel company with its supplier evaluation and selection processes [23]. Wang et al. [24] introduced a MCDM method using Fuzzy ANP and VIKOR methods for supplier selection in the plastics industry. Their proposed model used criteria from the Supply Chain Operation Reference model, which is widely used by organizations to evaluate the operational performance of their supply chains. Chakraborty et al. [25] introduced a decision support tool using AHP, Fuzzy Logic and Artificial Neural Network (ANN) for supplier selection problems. Badi et al. [26] proposed a supplier selection model for the steel manufacturing industry using the combination of Grey-MARCOS methods.

Ghorbani et al. [27] introduced a novel decision-making method using the Kano model and a fuzzy MCDM model, which is built using the FAHP and FTOPSIS methods. Stević et al. [28] proposed an MCDM model based on the MARCOS method. This particular model was developed to support sustainable supplier evaluation and selection processes within the private health care sector. Wang et al. [29] introduced a fuzzy MCDM model by employing Triple Bottom Line Approaches, Fuzzy AHP, and TOPSIS. This model provides a robust and effective method to the sustainable supplier selection problem for companies operating within the garment industry. Wu et al. [30] introduced a Fuzzy MCDM model to solve the fishmeal supplier selection problem in aquacultural production under the specific condition of maintaining sustainability criteria. This model was developed using the entropy method in combination with the VIKOR method. Govidan et al. [31] developed a hybrid MCDM model for socially responsible supplier selection. The model was created using fuzzy Delphi, DEMATEL-ANP and PROMETHEE methods. Ghorabaee et al. [32] introduced a novel MCDM model based on the extended WAPAS method with interval type-2 fuzzy sets. Chen et al. [33] proposed a fuzzy approach to the supplier selection problem in supply chain management using TOPSIS in combination with fuzzy set theory. Yucesan et al. [34] suggested a method to solve the green supplier selection problem by employing the Best-Worst method and Interval Type-2 Fuzzy TOPSIS method. Liao et al. [35] introduced a MCDM model for solving the supplier selection problem, which is based on AHP, goal programming, and Taguchi loss function. Dweiri et al. [36] developed a decision support system for the automotive industry using the AHP method.

As supply chains have increased in complexity, many mathematical models have been employed to support supplier evaluation and selection processes. Talluri et al. [37], Ng et al. [38], Guneri et al. [39] proposed a solution to this problem by using linear programming; integer linear programming was proposed in studies by Chaundry et al. [40] and Rosenthal et al. [41]; integer non-linear programming [42]; multi-objective programming [43–45]; goal programming [46,47]; and data envelopment analysis [48]. Hamdan et al. [49] developed a supplier selection and order allocation (SS/OA) decision support system with environmental performance criteria by employing AHP, Fuzzy TOPSIS and goal programming. Jia et al. [50] introduced an approach for the sustainable SS/OA problem; their suggested method is based on goal programming. Moghaddam [51] introduced a method to solve the SS/OA problem using a hybrid Monte Carlo simulation in

combination with goal programming. Erdem et al. [52] proposed a decision support system for the SS/OA problem. The system, developed based on AHP and goal programming, was tested in a real-life environment and has since received positive feedback. Aktar Demirtas et al. [53] introduced an approach to the order allocation problem in a multi-period inventory sizing environment. The suggested approach is based on the ANP method and Archimedean Goal Programming (AGP). Wey et al. [54] developed a novel approach to the transportation infrastructure project selection based on the Fuzzy Delphi method, ANP and Zero-One Goal Programming. Nazari-Shirkouhi et al. [55] developed a two-phase fuzzy multi-objective linear programming (FMOLP) approach to the SS/OA problem. Govindan et al. [56] proposed an MCDM and MOLP method to support the green SS/OA process in their study of the paper manufacturing industry. Vahidi et al. [57] attempted to address the sustainable SS/OA problem with operational and disruption risks by introducing a mathematical programming model. The model is built on a hybrid SWOT-QFD framework and a programming model with a mixed sustainability and resilience function. Amin et al. [58] suggested an approach based on both a fuzzy SWOT analysis and fuzzy linear programming to address the SS/OA problem. Khoshfetrat et al. [59] attempted to approach the SS/OA problem under the condition of an uncertain decision-making environment in the automotive industry by developing a fuzzy multi-objective mathematical model. Hosseini et al. [60] developed an approach to the resilient SS/OA problem using mixed integer mathematical programming with disruptive events. Li et al. [61] introduced environmental and supply risks elements into a novel mathematical model to approach the SS/OA problem. You et al. [62] combined a fuzzy MCDM model and MOLP model to develop a decision support tool for the sustainable SS/OA problem. Mari et al. [63] developed an approach to the SS/OA problem with resilient criteria and under the condition of a fuzzy environment. The proposed approach is a fuzzy possibilistic MOLP model.

With the emergence of the Covid-19 pandemic, however, supply chains been globally disrupted, especially considering the increased uncertainty of supply that the pandemic has brought to bear on most industries [64,65]. In the present study, we develop a mathematical approach to support the supplier evaluation and selection process of the garment and textile manufacturing industry. The proposed approached is based on the FAHP and TOPSIS methods. The proposed model is then applied to a real-world case study to demonstrate its calculation process and real-world applicability.

3 Methodology

3.1 Research Development

The research process is carried out according to the main steps as shown in Fig. 1.

3.2 Methodology

3.2.1 Fuzzy Analytic Hierarchy Process

Fuzzy set theory was developed by Zadeh (1965) [66] to represent the uncertain and vagueness of human language. The theory allows mathematical operators to be performed in the fuzzy domain. A fuzzy set is defined as a class of objects with continuous grades of membership and characterized by its membership function. The membership function assigns each object in the set with a membership degree, which ranges between one and zero.
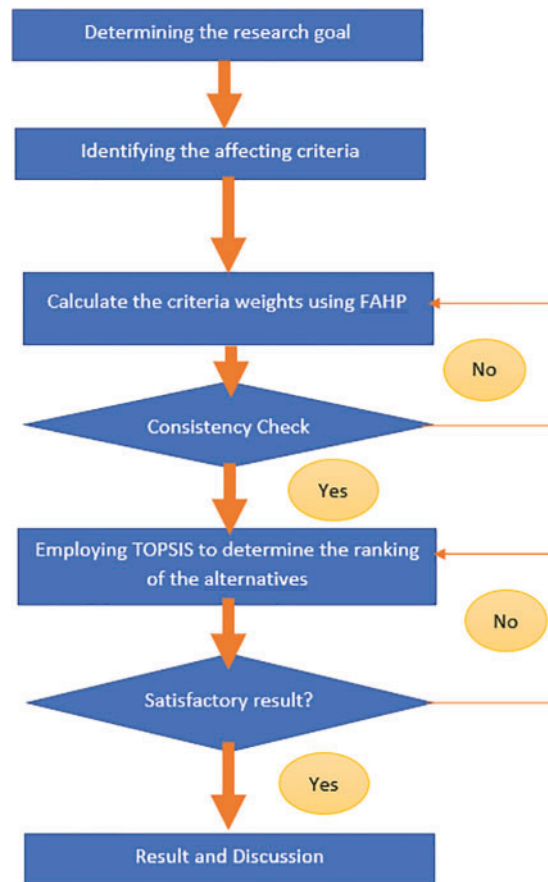
Figure 1: Research process

While there are many forms of fuzzy numbers, triangular fuzzy numbers are employed in this research due to their efficiency and ease of use [67–71]. It is defined in Fig. 2.

$$\mu(x) = \begin{cases} \dfrac{x-a}{b-a}, & a \leq x \leq b \\[2mm] \dfrac{c-x}{c-b}, & b \leq x \leq c \\[2mm] 0, & \textit{otherwise} \end{cases} \tag{1}$$

If $a = b = c$, the fuzzy number $\tilde{A}$ becomes a real number. Therefore, real numbers are considered as special fuzzy numbers [72].

The implementation of the Fuzzy AHP model consists of four stages as follows according to Buckley [73]:

Stage 1: Building the Fuzzy AHP model

The decision maker compares the criteria and alternative based on Fig. 3:
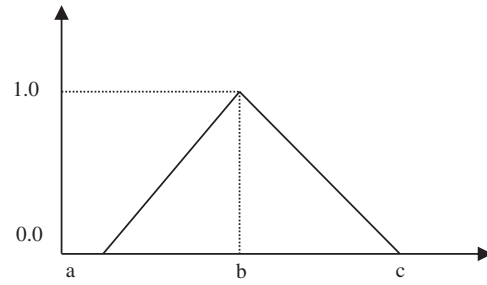
Stage 2: Creating the pairwise comparison matrix

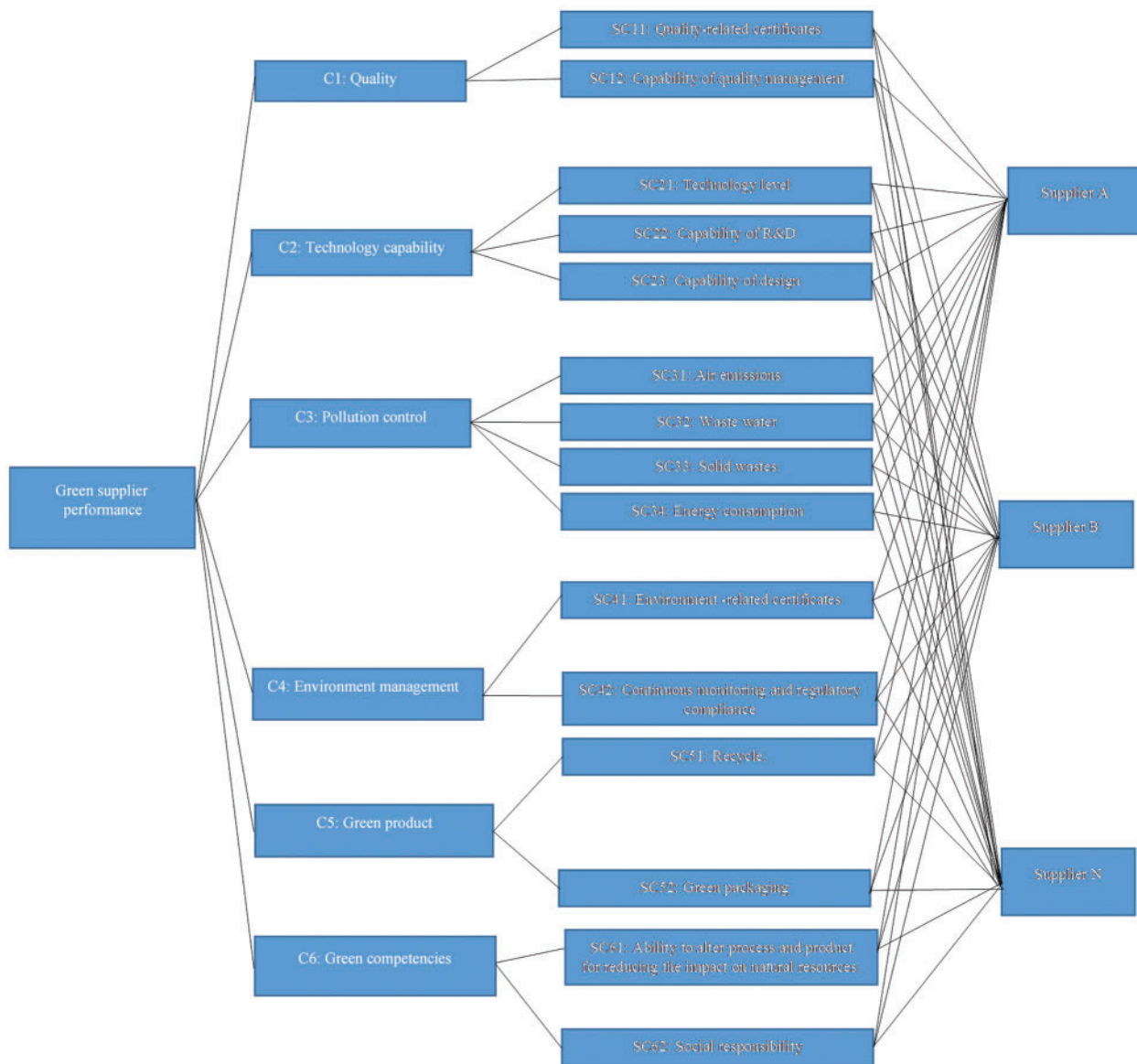**Figure 2:** Triangular fuzzy number

Figure 3: Fuzzy AHP model

A pairwise comparison matrix is created using fuzzy numbers. The matrix is represented as follows:

$$\widetilde{A^k} = \begin{bmatrix} \widetilde{a_{11}^k} & \widetilde{a_{12}^k} & \cdots & \widetilde{a_{1n}^k} \\ \widetilde{a_{21}^k} & \widetilde{a_{22}^k} & \cdots & \widetilde{a_{2n}^k} \\ \cdots & \cdots & \cdots & \cdots \\ \widetilde{a_{n1}^k} & \widetilde{a_{n2}^k} & \cdots & \widetilde{a_{nn}^k} \end{bmatrix} \tag{2}$$

where $\widetilde{A^k}$ is the pairwise comparison matrix of the fuzzy elements and $\widetilde{a_{nn}^k}$ is the triangular fuzzy mean value.

Should there be more than one decision maker, the preferences of each expert $(\widetilde{a_{nn}^k})$ are averaged and $(\tilde{a}_{ij})$ is determined as in Eq. (3):

$$\tilde{a}_{ij} = \frac{\sum_{k=1}^{K} \widetilde{a_{nn}^k}}{K} \tag{3}$$

Stage 3: Based on the average preferences, the pair-wise contribution matrix will then be updated as displayed in Eq. (4).

$$\tilde{A} = \begin{bmatrix} \widetilde{a_{11}} & \cdots & \widetilde{a_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{a_{n1}} & \cdots & \widetilde{a_{nn}} \end{bmatrix}$$

Stage 4: Based on the study by Buckley [71], the geometric mean of the comparison values that have been fuzzified for each criterion is determined using Eq. (5). The values of $\widetilde{g}_i$ are triangular values.

$$\widetilde{g}_i = \left(\prod_{j=1}^{n} \tilde{a}_{ij} \right)^{1/n}, \quad i = 1, 2, \ldots, n \tag{4}$$

Stage 5: The fuzzified weights for each criterion can be determined in Eq. (5) by combining the following three minor stages:

Stage 5a: Determine the vector summation of each $\widetilde{g}_i$.

Stage 5b: Determine the inverse power of summation vector. Replace the fuzzified triangular and sort into ascending order.

Stage 5c: Determine the fuzzified weight by multiplying each with its inverse vector.

$$\tilde{w}_i = \tilde{g}_i \otimes (\widetilde{g}_1 \otimes \widetilde{g}_2 \otimes \ldots \otimes \widetilde{g}_n)^{-1} = (lw_i, mw_i, uw_i) \tag{5}$$

Stage 6: Because $\tilde{w}_i$ are triangular numbers that are still fuzzified, the defuzzification process must be used with the Centre of Area method as used in the study by Chou et al. [74]; its method is shown in Eq. (6):

$$Y_i = \frac{lw_i + mw_i + uw_i}{3} \tag{6}$$

Stage 7: Even when Y_i is a normal number, normalizing it is still required using Eq. (7):

$$Z_i = \frac{Y_i}{\sum_{i=1}^{n} Y_i} \tag{7}$$

These seven stages are used to determine the normalized weights for both criteria and alternatives. From these results, the highest scoring alternative is presented to the decision maker as the best alternative to choose.

3.2.2 The Technique for Order of Preference by Similarity to Ideal Solution Model

TOPSIS is a multi-criteria decision analysis method, that was originally developed by Hwang et al. [75] in 1981 with further developments by Yoon [76] in 1987 and Hwang and subsequently by Lai and Liu in 1993 [77]. The TOPSIS process is carried out as follows:

Step 1: Create an evaluation matrix consisting of m alternatives and n criteria. With the intersection of each alternative and criteria given as x_{ij}, we therefore arrive at the matrix $(x_{ij})_{mxn}$.

Step 2: The matrix $(x_{ij})_{mxn}$ is then normalized to form the matrix:

$R = (r_{ij})_{mxn}$ using the normalization method

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}}, \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n$$

Step 3: Calculate the weighted normalized decision matrix:

$$t_{ij} = r_{ij}.w_j, \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n$$

where $w_j = \dfrac{W_j}{\sum_{k=1}^{n} W_k}$, j = 1, 2,..., n so that $\sum_{i=1}^{n} w_j = 1$, and W_j is the original weight given to the indicator v_j, j = 1, 2,..., n

Step 4: Determine the worst alternative (A_w) and the best alternative (A_b):

$$A_w = \{\langle \max(t_{ij} \mid i = 1, 2, \ldots, m \mid j \in J_-), \langle \min(t_{ij} \mid i = 1, 2, \ldots, m \mid j \in J_+)\} = \{t_{wj} \mid j = 1, 2, \ldots, n\}$$

$$A_b = \{\langle \min(t_{ij} \mid i = 1, 2, \ldots, m \mid j \in J_-), \langle \max(t_{ij} \mid i = 1, 2, \ldots, m \mid j \in J_+)\} = \{t_{wj} \mid j = 1, 2, \ldots, n\}$$

Step 5: Calculate the L^2- distance between the target alternative i and the worst condition A_w:

$$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2}, \quad i = 1, 2, \ldots, m$$

as well as distance between the target alternative i and the worst condition A_b:

$$d_b = \sqrt{\sum_{j=1}^{n}(t_{ij} - t_{bj})^2}, \quad i = 1, 2, \ldots, m$$

Step 6: Calculate the similarity to the worst condition:

$$s_{iw} = \frac{d_{ib}}{(d_{iw} + d_{ib})} \quad i = 1, 2, \ldots, m$$

$s_{iw} = 1$ if and only if the alternative solution has the best condition; and

$s_{iw} = 0$ if and only if the alternative solution has the worst condition.

Step 7: Rank the alternatives according to s_{iw} $(i = 1, 2, \ldots, m)$

4 Case Study

To test the effectiveness of the FAHP-TOPSIS model, the implementation of hybrid model to select a sewing machine supplier was implemented in two phases, first using FAHP to calculate the weight of all criteria and then using the TOPSIS model to rank potential suppliers.

4.1 Fuzzy Analytical Hierarchy Process Model

Summary results from the FAHP model are presented in Tab. 1:

Table 1: Summary results from FAHP Model

Criteria	Fuzzy sum of each row			Fuzzy synthetic extent			Degree of possibility (Mi)	Weight
SC11	9.3778	12.5918	17.4706	0.0280	0.0511	0.0974	0.4912	0.0475
SC12	9.5203	12.9846	17.9640	0.0284	0.0527	0.1002	0.5094	0.0493
SC21	11.9578	16.5140	22.5289	0.0357	0.0670	0.1256	0.6602	0.0639
SC22	11.4964	15.9341	21.8870	0.0343	0.0647	0.1220	0.6389	0.0618
SC23	14.1206	19.5739	26.4900	0.0421	0.0794	0.1477	0.8512	0.0824
SC31	9.6402	13.1384	18.2083	0.0288	0.0533	0.1015	0.5175	0.0501
SC32	10.2069	13.6775	18.7516	0.0304	0.0555	0.1045	0.5389	0.0522
SC33	13.0871	17.8701	23.6305	0.0390	0.0725	0.1317	0.7728	0.0748
SC34	14.4753	19.9700	26.4173	0.0432	0.0810	0.1473	0.8629	0.0835
SC41	12.2529	16.8833	22.9517	0.0366	0.0685	0.1280	0.7353	0.0712
SC42	11.4305	15.6780	21.5605	0.0341	0.0636	0.1202	0.6803	0.0658
SC51	16.8871	23.7643	32.0363	0.0504	0.0964	0.1786	1.0000	0.0968
SC52	11.3327	15.4784	21.2278	0.0338	0.0628	0.1183	0.6690	0.0648
SC61	11.6425	15.9314	21.8203	0.0347	0.0647	0.1217	0.6916	0.0669
SC62	11.9381	16.4251	22.2752	0.0356	0.0667	0.1242	0.7125	0.0690

4.2 The Technique for Order of Preference by Similarity to Ideal Solution Model

After using the FAHP model to evaluate criteria, TOPSIS model will be developed to rank suppliers, a result as the following shown in Tabs. 2–4.

Table 2: Normalized matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9
SC11	0.2525	0.4546	0.3536	0.1515	0.2525	0.3536	0.1515	0.4546	0.4041
SC12	0.1768	0.2946	0.4125	0.1768	0.5303	0.2946	0.4125	0.2946	0.2357
SC21	0.1504	0.2005	0.4511	0.4010	0.4010	0.2506	0.4511	0.3509	0.1504
SC22	0.2817	0.1690	0.4507	0.1127	0.5071	0.2254	0.4507	0.2254	0.3381
SC23	0.2454	0.3436	0.3436	0.3927	0.3927	0.2454	0.4418	0.3436	0.1473
SC31	0.1681	0.3783	0.2942	0.3783	0.3363	0.3363	0.3783	0.3783	0.2942
SC32	0.1796	0.4789	0.5388	0.1796	0.1796	0.2993	0.4789	0.1796	0.1796
SC33	0.2990	0.3417	0.3417	0.3417	0.2990	0.2990	0.3417	0.3845	0.3417
SC34	0.2676	0.4818	0.3747	0.1071	0.4282	0.2141	0.3747	0.2676	0.3212
SC41	0.3264	0.4351	0.1632	0.4895	0.2720	0.3807	0.3807	0.2176	0.1632
SC42	0.2420	0.3871	0.1452	0.4355	0.2420	0.4355	0.4355	0.2420	0.2904
SC51	0.4247	0.4247	0.0944	0.4247	0.1888	0.3304	0.3775	0.3775	0.1416
SC52	0.3185	0.3185	0.3583	0.2787	0.3583	0.3583	0.2787	0.3583	0.3583
SC61	0.3638	0.3638	0.3234	0.3234	0.3638	0.3234	0.2830	0.3234	0.3234
SC62	0.1535	0.1535	0.2558	0.3582	0.4093	0.3582	0.3582	0.4093	0.4093

Table 3: Normalized weighted matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9
SC11	0.0120	0.0216	0.0168	0.0072	0.0120	0.0168	0.0072	0.0216	0.0192
SC12	0.0087	0.0145	0.0203	0.0087	0.0261	0.0145	0.0203	0.0145	0.0116
SC21	0.0096	0.0128	0.0288	0.0256	0.0256	0.0160	0.0288	0.0224	0.0096
SC22	0.0174	0.0105	0.0279	0.0070	0.0314	0.0139	0.0279	0.0139	0.0209
SC23	0.0202	0.0283	0.0283	0.0324	0.0324	0.0202	0.0364	0.0283	0.0121
SC31	0.0084	0.0189	0.0147	0.0189	0.0168	0.0168	0.0189	0.0189	0.0147
SC32	0.0094	0.0250	0.0281	0.0094	0.0094	0.0156	0.0250	0.0094	0.0094
SC33	0.0224	0.0256	0.0256	0.0256	0.0224	0.0224	0.0256	0.0288	0.0256
SC34	0.0224	0.0402	0.0313	0.0089	0.0358	0.0179	0.0313	0.0224	0.0268
SC41	0.0232	0.0310	0.0116	0.0348	0.0194	0.0271	0.0271	0.0155	0.0116
SC42	0.0159	0.0255	0.0096	0.0287	0.0159	0.0287	0.0287	0.0159	0.0191
SC51	0.0411	0.0411	0.0091	0.0411	0.0183	0.0320	0.0365	0.0365	0.0137
SC52	0.0206	0.0206	0.0232	0.0180	0.0232	0.0232	0.0180	0.0232	0.0232
SC61	0.0244	0.0244	0.0216	0.0216	0.0244	0.0216	0.0189	0.0216	0.0216
SC62	0.0106	0.0106	0.0176	0.0247	0.0282	0.0247	0.0247	0.0282	0.0282

5 Discussion

In the current global business climate, the uncertainty inherent to both the supply and demand sides of a given supply chain have increased substantially due to the Covid-19 pandemic. For this reason, it is extremely important for companies to develop effective supplier evaluation and selection processes when selecting a supply chain. For garment and textile manufacturers in Vietnam, this prodcess is even more paramount to their survival, as they are heavily dependent on offshore suppliers in China. In this study, we developed a supplier evaluation and selection

model based on the FAHP and TOPSIS models. With a set of 6 criteria and 15 sub-criteria, which were developed based on relevant literature in addition to industry experts' reviews, this model allows decision makers to evaluate potential suppliers comprehensively. The choice of FAHP and TOPSIS methods also allows for increased applicability in the model, as the methods are easy to understand and widely available in decision-making support software.

Table 4: Ranking results

Alternatives	Si+	Si−	Ci	Ranking
A1	0.0516	0.0401	0.4377	8
A2	0.0355	0.0596	0.6271	2
A3	0.0478	0.0477	0.4995	7
A4	0.0502	0.0540	0.5184	5
A5	0.0382	0.0541	0.5862	3
A6	0.0419	0.0428	0.5055	6
A7	**0.0224**	**0.0629**	**0.7371**	**1**
A8	0.0422	0.0469	0.5263	4
A9	0.0569	0.0343	0.3760	9

The model is then applied to a real-world case study to demonstrate its calculation step validity and overall feasibility as a practical solution to the emergent supplier choice problem. In the case study, we considered nine potential suppliers and evaluated their performance based on the proposed 6 criteria and 15 sub-criteria. The model suggests that the optimal supplier is supplier A7 with a performance score of 0.7371, followed by A2 (0.6271) and then A5 (0.5184). Through this study, we successfully created a hybrid MCDM model using Fuzzy AHP and the TOPSIS model to assist the supplier selection process in the garment industry. Results from the case study show that the model is in fact a feasible one. The model can also be used in combination with other MCDM models to better support the decision-maker.

6 Conclusion

Selection of the garment industry's suppliers is crucial to decision-makers managing supply chains. Careful selection of suppliers in the garment industry is a top concern in this field. It is important for garment supply chains to have robust and effective supplier selection processes. However, these processes tend to be based on the decision-makers' experiences, which are often incomplete or inaccurate, and are therefore ineffective. This study aimed to create a robust and effective supplier selection model by using a Fuzzy Analytical Hierarchy Process (FAHP) Model and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to assist the supplier selection process in the garment industry under the condition of a fuzzy decision-making environment. In this study, we used the FAHP method to evaluate the performance and weight of the selected criteria: we determined that FAHP is the appropriate method for evaluating and making multi-criteria decisions in cases where the decision-making process involves a large number of criteria that can be interdependent of one another. Next, we used the TOPSIS method to rank potential suppliers. This research provides businesses in the garment industry an effect tool to support their decision-making processes. Future research can be developed based upon the proposed approach using different MDCD methods, such as FANP or WASPAS. Comparison

studies can also be conducted to evaluate the performance of existing supplier selection and evaluation models during and after the Covid-19 pandemic.

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