Araştırma Makalesi

A NOVEL MODEL FOR SUPPLIER SELECTION PROBLEM WITH GREEN APPROACH: AN APPLICATION IN THE RETAIL INDUSTRY

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ABSTRACT

Today, good relations between companies and suppliers provide companies with a competitive advantage. Determining the supplier selection criteria and rewarding the suppliers by evaluating them at certain times is of great importance in establishing successful relations with the suppliers. In the study, it is aimed to reduce the supplier preference decisions in the product production process of the size of the firm operating in the textile industry in Istanbul. In this process, the current evaluation criteria were examined with 3 experts from the company and the final criteria were obtained by adding new ones to the sustainability criteria while conducting the literature. The proposed model was evaluated by 3 experts with 34 different sub-criteria under the main criteria of cost, quality, delivery, efficiency, environmental management, technology and social with 9 supplier alternatives. After the evaluation, the Best-Worst Method was preferred to determine the criteria weights and importance limits. Weighted Total Product Evaluation method was applied in the evaluation of alternatives, the performances of 9 suppliers were listed and sensitivity analyzes were made. As a result of the study, suggestions were presented to company executives regarding supplier selection.

Keywords: Multi-Criteria Decision Making, Best-Worst Method, Weighted Aggregated Sum Product Assessment Method, Green Supply Chain

ÖZET

Günümüzde firmalar ile tedarikçiler arasındaki iyi ilişkiler firmalara rekabet avantajı sağlamaktadır. Tedarikçi seçim kriterlerinin belirlenmesi ve tedarikçilerin belirli zamanlarda değerlendirilerek ödüllendirilmesi, tedarikçilerle başarılı ilişkiler kurulmasında büyük önem taşımaktadır. Çalışmada, İstanbul ilinde tekstil sektöründe faaliyet gösteren firmanın büyüklüğünün ürün üretim sürecindeki tedarikçi tercih kararlarının azaltılması amaçlanmaktadır. Bu süreçte firmadan 3 uzman ile mevcut değerlendirme kriterleri incelenmiş ve literatür taraması yapılırken sürdürülebilirlik kriterlerine yenileri eklenerek nihai kriterler elde edilmiştir. Önerilen model 9 tedarikçi alternatifi ile maliyet, kalite, teslimat, verimlilik, çevre yönetimi, teknoloji ve sosyal ana kriterleri altında 34 farklı alt kriter ile 3 uzman tarafından değerlendirilmiştir. Değerlendirme sonrasında kriter ağırlıklarının ve önem limitlerinin belirlenmesinde En İyi-En Kötü Yöntemi tercih edilmiştir. Alternatiflerin değerlendirilmesinde Ağırlıklı Toplam Ürün Değerlendirme yöntemi uygulanmış, 9 tedarikçinin performansları listelenmiş ve duyarlılık analizleri yapılmıştır. Çalışma sonucunda tedarikçi seçimine ilişkin firma yöneticilerine öneriler sunulmuştur.

Anahtar Kelimeler: Çok Kriterli Karar Verme, En İyi-En Kötü Yöntem, Ağırlıklı Toplam Toplam Ürün Değerlendirme Yöntemi, Yeşil Tedarik Zincir

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1. INTRODUCTION

The supply chain is an integrated management that includes many studies such as raw material supply, intermediate material supply, production process, stock management, distribution, sales process and customer relations in the formation process of the final product (Tez et al., 2012).

Supply chain is generally classified as green supply chain, agile supply chain, lean supply chain, humane supply chain and sustainable supply chain in terms of strategic issues and current approaches. The concept of sustainable supply chain has emerged with the increase of social awareness about the consumption of natural resources. Sustainability has three dimensions. These; economic, environmental, and social dimensions. Sustainable supply chain: Material flow can be defined as the successful realization of information and money flow between companies and the successful management of environmental objectives. Companies that implement a sustainable supply chain will have a huge competitive advantage. In this way, they will significantly increase the income of their companies. (RZ et al. 2013)

The main purpose of supplier selection is to determine the most suitable product and/or service provider within the framework of the criteria determined to meet the needs of a business. Selection of the appropriate supplier will greatly increase the success of the business. However, mistakes to be made in the supplier selection process will directly affect product quality, delivery times and thus production, causing additional costs. This situation will adversely affect the long-term performance of the enterprise (Özdemir, 2010)

The presented BWM-WASPAS hybrid model was used in the supplier selection process of a textile retail company operating in Istanbul, in the evaluation of general and sustainable criteria together and in the ranking of suppliers. After the introductory part of the study, in the second part, the studies in the literature on supplier selection and the gaps in the literature are emphasized. The methods used and the application steps of the methods are explained. In the fourth chapter, the process of determining the criteria, definitions of criteria, the application of the methods and the results obtained are explained. In the fifth chapter, the results were interpreted on the basis of the literature. In the last chapter, the results obtained were evaluated, the contribution of the study was mentioned, and suggestions were given.

2. LITERATURE REVIEW

When the literature review was carried out, it was seen that multi-criteria decision-making methods can be used in different sectors, by different authors and together. We listed some studies related to supplier selection as follows.

Guo et al. (2006) proposed a new gray-based approach for the supplier selection problem. Goodarzi et al. (2022), used Fuzzy-Delphi method to obtain the weights of the supplier evaluation criteria, and employed Gray Correlation method and TOPSIS (GC-TOPSIS) to rank suppliers. Rakesh et al. (2022), presented AHP-TOPSIS approach for a sustainable supplier selection problem in the electronic safe company. Tavana et al (2021) suggested fuzzy group best-worst method (FG-BWM) to determine the weights of the criteria for supplier selection in reverse supply chains. Then, F-CoCoSo is deployed to select the most suitable supplier.

Akdeniz et al. (2007) utilized AHP method for the supplier performance evaluation and selection system of a national retail chain. Kilic (2013) employed fuzzy TOPSIS method to select the best supplier in the air filter sector. Scott et al. (2015) proposed an integrated method to deal with such problems using a combined Analytical Hierarchy Process-Quality Function Distribution (AHP-QFD) and a chance constrained optimization algorithm approach that selects suitable suppliers and distributes orders among them in the most appropriate way. The effectiveness of the proposed decision support system has been demonstrated through practice and validation in the bioenergy industry. Bruno et al. (2013) applied the hybrid AHP-FST model in the rail systems industry in their study. Azizi et al. (2015) applied fuzzy TOPSIS methods in supplier selection in the automotive industry. Polat et al. (2015) proposed an integrated approach that integrates AHP and evidential reasoning (ER) to help construction companies choose the most suitable supplier for their projects. Sasi et al. (2015) used TOPSIS and AHP method together in supplier selection between India and China in the textile industry. Toklu et al (2018) worked on the selection of the machine part supplier used in the production line of a heavy metal factory in Sakarya province. The SWARA method was used to determine the criterion weights, and the WASPAS method was used to evaluate and rank the alternatives. Sureeyatanapas et al. (2018), TOPSIS and ROC methods were used together in egg supplier selection. Supciller et al. (2018) used AHP, TOPSIS, VIKOR, SAW, GIA, MOORA, ELECTRE II and M-TOPSIS methods to select the best supplier for a textile company in Denizli. Kumara et al. (2019) used AHP and TOPSIS to find the most reliable supplier in an Indian heavy locomotive company. Komsiyah et al. (2019) introduced fuzzy ELECTRE method in the selection of cement vendors in a construction company in Indonesia.

A summary of the literature can be seen in the Table 2.3

Tablo 2.3. Various applications of supplier selection

Author	Method Used	Application
Goodarzi, et al. 2022	Fuzzy-Delphi method /Gray Correlation method -TOPSIS	Green supplier assessment under uncertainty in the automation industry
Rakesh et al. 2022	Combined AHP-TOPSIS Method	Electronic safe industry
Tavana, et al. 2021	FG-BWM/ fuzzy CoCoSo	Wood and paper industry
Guo, et al. 2006	Gray-based decision making	Supplier selection application for the manufacturing industry
Scott, et al.2015	AHP-QFD	Bioenergy industry
Toklu, et al. 2018	SWARA-WASPAS	Heavy metal industry
Akdeniz, et al. 2007	AHS	Retail industry
Sureeyatanapas, et al. 2018	TOPSIS-ROC	Egg supplier selection
Kumara, et al. 2019	AHP-TOPSIS	Heavy locomotive industry
Kilic ,2013	Fuzzy TOPSIS	Air filter industry
Polat, et al. 2015	AHP-ER	rail industry
Sasi, et al. 2015	TOPSIS-AHP	Textile industry
Supciller, et al. 2018	AHP/TOPSIS/VIKOR/MOORA/ELECTRE II/M-TOPSIS /Band count method /Copeland method	Textile industry
Komsiyah, et al. 2019	Fuzzy ELECTRE	Cement industry
Bruno, et al. 2013	AHP-FST	Hybrid supplier selection methodology application for aircraft selection in airlines
Azizi, et al. 2015	Fuzzy -TOPSIS	Automotive industry

When the studies were evaluated within the scope of the review, it was determined that apart from the criteria used by all sectors, specific criteria for the scope of the work were required in the evaluation. In the study, it presents a unique content of the sustainability and general criteria specific to the textile sector and the company. In addition, it has been observed in the literature that SWARA method and WASPAS method are preferred more in the literature for criterion weight determination and supplier ranking, while AHP and TOPSIS methods are preferred for supplier ranking. In the literature, it has been determined that there are sector-specific criteria gaps, and sustainable and general criteria are used separately. A unique study will be brought to the literature in which sector- and company-specific, sustainable, and general criteria are evaluated together and BWM and WASPAS methods are used together in calculations. In the literature research, studies were encountered in which green and sustainable-based supplier selection criteria were applied. However, there are no supplier selection studies in which both general and green-sustainable criteria are evaluated together. The literature gap will be filled with this study.

3. METHODOLOGY

The WASPAS method was preferred because it can control the consistency in alternative rankings by performing sensitivity analysis within its own operation, after calculating the criterion weights. (Chakraborty et al.2014)

3.1. Best-Worst Method

The application steps of the method are as follows (Koca., et al 2021)

Step 1: A set of decision criteria needs to be determined. In this step, the decision maker determines the n criteria $\boxed{\{C_1, C_2, \ldots\ldots, C_n\}}$ used to make the decision.

Step 2: The best (most desirable, most important) and worst (least desirable, least important) criteria are determined.

Step 3: It is the stage of determining the best criterion by using a number between 1 and 9 and determining the preference ratio according to all other criteria. It is the stage where the choice of the best criterion is determined by using a number between 1 and 9. All other criteria (1: equally important, 3: moderately more important, 5: very important, 7: much more important, 9: very important).

Table 3.1. BWM comparison scale

Importance level	Oral Expression for Comparison of Criteria
1	Equally important
2	Equally moderately important
3	Moderately more important
4	Moderately much more important
5	Strongly important
6	Very important as strong
7	Important as very strong
8	More important as very strong
9	Quite very important

This step results in a vector called Best-Others (AB) that moves from best to other. This vector is as follows:

$$A_{B=} (a_{B1,} a_{B2\ ,\dots\dots\dots} a_{Bn}) \quad (1)$$

Each a_{Bj} in the vector A_B represents the preference of the best criterion B according to the j criterion.

Also, a_{BB}= 1. This means that the most important criterion is compared with it.

Step 4: It is concerned with determining the preference ratios of all other criteria over the worst preferred criterion using a number between 1 and 9. In this step, the relative importance of the other criteria with respect to the worst criterion was determined by the decision maker. Using a number from 1 to 9, because of this step, the worst of the vector should look like this:

$$A_w = (a_{1w}, a_{2w,} a_{3w,} \dots \dots, a_{nw})^T \quad (2)$$

In this vector, each a_{jw} denotes the preference of criterion j over the worst criterion W. And $a_{ww} = 1$, which means that the worst criterion is compared with it.

Step 5: In the last step, the most appropriate weight should be determined for each criterion.

$$(W^*{}_1, W^*{}_2, W^*{}_3, \dots \dots, W^*{}_n) \quad (3)$$

The goal at this stage is to determine the optimal weights of the criteria to ensure maximum absolute differences.

The optimum weight for the criteria is each pair of $\frac{W_B}{W_j}$ and $\frac{W_j}{W_W}$ for $\frac{W_B}{W_j} = a_{Bj}$ and $\frac{W_j}{W_W} = a_{jW}$, respectively.

J values must be present $\{|W_B - \alpha_{Bj} W_j|, |W_j - \alpha_{jW} W_W|\}$ where maximum absolute differences are minimized. Therefore, the following has been converted to the min - max model:

Under restrictions,

$$minmax_j\{|W_B - \alpha_{Bj} W_j|, |W_j - \alpha_{jW}, W_W|\} \quad (4)$$

$$\textstyle\sum_j W_j = 1 \quad (5)$$

$$W_j \geq 0 \quad (6)$$

$$min\ \xi^L \quad (7)$$

$$\left|\frac{W_B}{W_j} - \alpha_{Bj}\right| \leq \xi, \quad (8)$$

$$\left|\frac{W_j}{W_W} - \alpha_{jW}\right| \leq \xi \quad (9)$$

$$\textstyle\sum_j W_j = 1 \quad (10)$$

$$W_j \geq 0, \quad (11)$$

3.2. Weighted Aggregated Sum Product Assessment Method

The steps of the WASPAS method are summarized below (Zavadskas., et al 2012; Zavadskas. et al 2013; Zavadskas, et al 2015)

In the problem handled in this method, there are m alternatives.

$A_i\ (i = 1, 2, \ldots, m)$ and n criteria are specified as $C_j\ (j = 1,2, \ldots, n)$

Step 1: Creating the decision matrix (X) showing the performance of the alternatives in the problem based on the criteria in the problem.

$$X = [X_{ij}]_{mxn} = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{bmatrix}$$

$$(\mathrm{i} = 1,2, \ldots, \mathrm{m\ and\ j} = 1,2, \ldots, \mathrm{n}) \tag{12}$$

Step 2: Normalizing the decision matrix $(\bar{x}_{ij})$. Two different equations are used depending on whether the evaluation criterion is maximization or minimization.

$$\bar{x}_{ij} = \frac{x_{ij}}{maxi(x_{ij})}$$

$$(\mathrm{i} = 1,2, \ldots, \mathrm{m\ and\ j} = 1,2, \ldots, \mathrm{n}) \tag{13}$$

$$\bar{x}_{ij} = \frac{min(x_{ij})}{x_{ij}}$$

$$(\mathrm{i} = 1,2, \ldots, \mathrm{m\ and\ j} = 1,2, \ldots, \mathrm{n}) \tag{14}$$

Step 3: i. the total relative importance of the alternative, calculated separately according to the Weighted Sum Model (WSM) and the Weighted Product Model (WPM). The total relative importance of an alternative according to WSM $(Qi^{(1)})$ and the total relative importance of an alternative according to WPM $(Qi^{(2)})$ are calculated using Equation (15) and Equation (16), respectively.

$$Q_i^{(1)} = \sum_{j=1}^{n} \bar{x}_{ij}\, w_j \tag{15}$$

$$Q_i^{(2)} = \prod_{j=1}^{n} \bar{x}_{ij}^{\,w_j} \tag{16}$$

Step 4: The overall relative importance of the alternatives can be determined as a general formul

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda) Q_i^{(2)}$$
$$= \lambda \sum_{j=1}^{n} (x_{ij})\, w_j + (1-\lambda) \prod_{j=1}^{n} (x_{ij})^{w_j} \quad \lambda = 0, 0.1, \ldots .1 \tag{17}$$

Qi in the WASPAS method i. shows the total relative importance of the alternative. λ is a parameter used in the WASPAS method and takes a value between 0 and 1. In calculations, the value of λ is left to the decision maker, but (Zavadskas et al. 2012) proposed an equation to find the optimum value for λ. Alternatives are ranked according to their Q values. The best alternative is the one with the highest Q value.

The proposed hybrid method can be seen in figure 3.2.

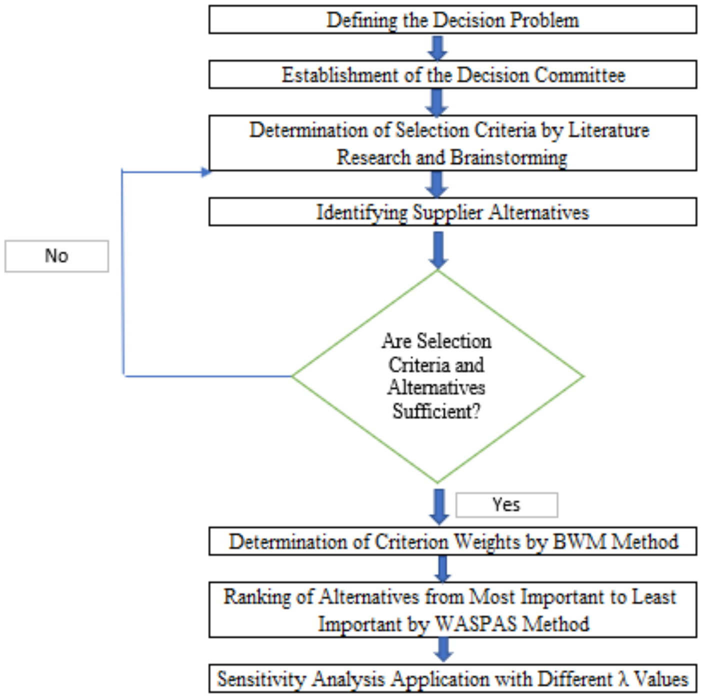

Figure 3.2. Application steps

4. APPLICATION

In this study, it is presented a hybrid BWM and WASPAS method in order to select green-based supplier for a retail company operating in Istanbul. BMW method has been employed to determine weight of the criteria and WASPAS method has been used ranking the alternatives. Three decision makers have been evaluated selected main and sub criteria. Evaluation criteria are obtained via literature and expert opinions. Seven main criteria and thirty four sub-criteria are shown in table 4.2

Table 4.2. Evaluation criteria

Criteria Name	Main Criteria	Sub-Criteria Name	Sub-Criteria
K1	Cost	K11	Price Advantage
		K12	Transportation - Logistics Cost
		K13	Discount for Bulk Order
		K14	After Sales Service
K2	Quality	K21	Quality Control Pass Rate
		K22	Average Number of Quality Control Passes
		K23	Customer Return Rate
		K24	Past Performance
		K25	Fit Performance
		K26	PPS Performance
		K27	Product Quality
K3	Delivery	K31	Rate of Compliance with the Given Term
		K32	Delivery Time- Production Time
		K33	Reaction time
		K34	Goods Shipment Type
		K35	Technical Capacity
K4	Flexibility	K41	Collection Preparation Capacity
		K42	Adaptation to Change in Demand
		K43	Inventory Availability
		K44	Personalization

		K45	Information Sharing
K5	Environmental Management	K51	Chemical Substance Management
		K52	Waste Management-Pollution Control
		K53	Reverse Logistics Application Case
		K54	Recycling Material Usage Status
K6	Technology	K61	Technological Compatibility
		K62	Existing Production Facilities Capabilities
		K63	Innovation Capacity
		K64	Importance Given to R&D Studies
K7	Social	K71	Social Compliance Score
		K72	Corporate Social Responsibility
		K73	Immigrant Employee Status
		K74	Social Gender Equality
		K75	Volunteering Studies in the Institution

The describtion of the criteria are given below.

Cost: It is the price of the product produced by the supplier. (Demiralay et al 2022; Rakesh et al 2022; Masoomi et al 2022; Azadniaa et al 2012)

Price Advantage: The cost of the products supplied from the supplier is low. (Expert)

Transportation-Logistics Cost: It is the cost that occurs depending on the variables such as product weight and distance to be transported, which occurs from the entrance of the product to the supplier's warehouse and until it is delivered to the customer. (Tavana et al 2021; Supciller et al 2018)

Discount for Bulk Order: It is the amount of discount applied by the supplier on the cost based on order quantity while producing the products. (Kheng et al 2010)

After-Sales Service: Services provided by the manufacturer to the company after receiving the products from the supplier. (Deste et al 2021; Ozturk et al 2011)

Quality: The product requested from the supplier is at an acceptable quality level. (Demiralay et al 2022; Ozturk et al 2011; Supciller et al 2018)

Quality Control Pass Rate: It is the rate at which the supplier's products pass the quality control. (Expert)

Average Number of Quality Control Passes: It is the average of the number of all visits to the number of models while the quality control process of the company's products produced at the supplier is carried out. (Expert)

Customer Return Rate: After sales, the average return rate of the company's products for that season is processed. (Expert)

Past Performance: It is the evaluation of the suppliers that have worked before by looking at their previous reports, and the evaluation of the suppliers that will be worked for the first time by examining the products they produce. (Toklu et al 2018)

Fit Performance: It is the performance of the fit samples sent by the supplier before production. It is calculated by scoring out of 5. (Expert)

PPS Performance: It is the supplier's PPS (the first sample out of the band after production starts) performance. It is calculated by scoring out of 5. (Expert)

Product Quality: It is the level of meeting customer demands and expectations of a product. (Supciller et al 2018; Sureeyatanapas et al 2018)

Delivery: It is the delivery of the produced products to the stores or warehouses by the supplier. (Supciller et al 2018; Rakesh et al 2022; Kapar 2013; Kumar et al 2018)

Rate of Compliance with the Given Deadline: It is the scoring of how much it complies with the deadline agreed with the supplier. The average number of days late for all orders during the season has been calculated. +1 point is added for each day. (Expert)

Delivery Time- Production Time: The time given by the company for the production delivery at the order stage. The time elapsed between the zero day and the given deadline is considered. (Firm; Tavana et al 2021; Supciller et al 2018; Komsiyaha et al 2019)

Response Time: It is the supplier's ability to respond to the company as soon as possible in the face of emergencies. Toklu et al 2018)

Shipment of the Goods: It is the delivery of the goods in the most appropriate form, packaging, and conditions according to the characteristics of the products requested from the supplier. (Toklu et al 2018)

Technical Capacity: It refers to the product variety that the supplier can produce with the machines it has. The technical capacity of the supplier is scored out of 5 and considered. If a completely basic product is working, 1 point is awarded, up to 5 points depending on the product detail. (Ozturk et al 2011)

Flexibility: It is the tolerance given by the supplier to the changing demands of the firm. (Goodarzi et al 2022; Rakesh et al 2022)

Collection Preparation Capacity: It is the supplier's ability to prepare collections. It is calculated by scoring out of 5. If he does not prepare a collection, 0 points, he has a showroom + 2 points, the rate of preparing a collection is +1,2,3,4,5 points. (Expert)

Adaptation to Change in Demand: The product to be supplied is in line with the demand. (Ozturk et al 2011)

Inventory Availability: It is the ability of the supplier to use the fabric and accessories it has in its own body while producing the products (Chan et al 2010)

Personalization: It is the ability to integrate the design requests and demands of the company into the products by the supplier (Gules et al 2014)

Information Sharing: It is the supplier's good communication with the company throughout the product production process. (Chan et al 2010; Gules et al 2014)

Environmental Management: It is the management structure carried out by the suppliers to ensure that the environment is not harmed in the production processes or that the damage remains within the applicable legal limits. (Rakesh et al 2022)

Chemical Substance Management: Management of harmful and harmless chemicals that occur in the product production process (Expert)

Waste Management-Pollution Control: It is a form of management that includes reducing the wastes generated in the production processes of the suppliers, separating them according to their characteristics and pollution levels, collecting, storing, recycling, and controlling the processes before and after their disposal. (Rakesh et al 2022; Masoomi et al 2022; Tavana et al 2021; Deste et al 2021)

Case of Reverse Logistics Application: Renewing, reproducing, recycling, maintaining, and repairing materials in the form of fibers, fabrics, and products, and gaining value again. (Deste et al 2021)

Recycled Material Usage Status: The supplier's ability to use recycled fibers and fabrics in the product production process. (Deste et al 2021)

Technology: It is the application of the machines and devices created and used by the suppliers to produce the product, in the structures and processes of the methods. (Goodarzi et al 2022; Ecemis 2018)

Technological Compatibility: It is the harmony between the production and management processes of suppliers. (Ecemis 2018)

Existing Production Facilities Capabilities: Suppliers' production facilities are suitable and production capabilities are open to development. (Ecemis 2018)

Innovation Capacity: It is the supplier's use of existing technologies in their processes and transforming them into new products that will benefit internal and external stakeholders. (Chan et al 2010)

Importance Given to R&D Studies: It is the suppliers' investments based on R&D studies. (Kapar 2013)

Social: Volunteering, social responsibilities of the supplier (Deste et al 2021)

Social Compliance Score: Supplier's social compliance score is considered. If the company is producing directly, its own audit score, if there are sub-producers, the score of the supplier with the lowest score among all active sub-producers is reflected in the calculation. (Expert)

Corporate Social Responsibility: Suppliers act ethically and responsibly towards society and produce various projects in this context. (Rakesh et al 2021; Deste et al 2021)

Migrant Employee Status: It is the number of migrant employees in the suppliers. (Expert)

Gender Equality: It is the equal participation of women and men working in the work area of the suppliers. (Expert)

Volunteering Studies in the Institution: Developing volunteering projects with its employees. (Expert)

Stage 1: Determining the weight of the criteria by the Best-Worst Method

Step 1: 7 main criteria and 34 sub-criteria were determined by the decision makers as given in figure 4.2.

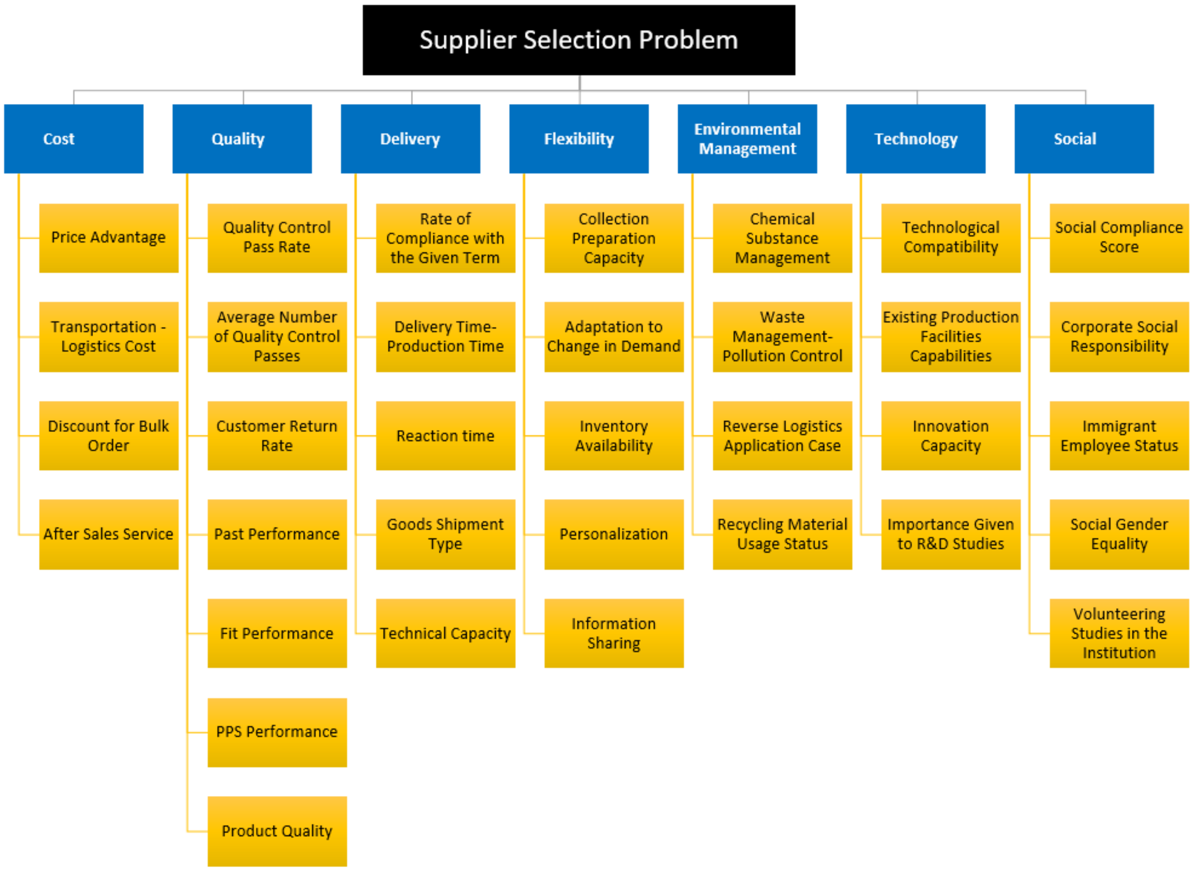

Figure 4.2. Main and sub-criteria for presented model

Step 2: The best and worst criteria are determined as shown in table 4.3.

Table 4.3. The best criteria and worst criteria

Criteria	The Best Criteria	The Worst Criteria
Price Advantage	X	
Transportation - Logistics Cost		X
Quality	X	
Delivery		X
Rate of Compliance with the Given Term	X	
Reaction time		X
Collection Preparation Capacity	X	
Inventory Availability		X
Chemical Substance Management	X	
Reverse Logistics Application Case		X
Technological Compatibility		X
Existing Production Facilities Capabilities	X	
Social Compliance Score	X	
Volunteering Studies in the Institution		X

Step 3: For the criteria, the BWM comparison scale was used to determine the best criteria and to determine the preference rates according to other criteria. Preference rates of the best criteria over other criteria are shown in table 4.4.

Table 4.4. Preference rates of the best criteria over other criteria

Main Criteria	KV1	KV2	KV3	Sub Criteria	KV1	KV2	KV3
Cost	9	2	3				
				Price Advantage	1	1	1
				Transportation - Logistics Cost	3	4	9
				Discount for Bulk Order	4	3	5
				After Sales Service	5	3	7
Quality	1	1	1				
				Quality Control Pass Rate	9	9	3
				Average Number of Quality Control Passes	8	6	9
				Customer Return Rate	9	4	2
				Past Performance	6	6	5
				Fit Performance	9	7	7
				PPS Performance	9	6	8
				Product Quality	1	1	1
Delivery	9	3	8				
				Rate of Compliance with the Given Term	1	1	1
				Delivery Time- Production Time	3	5	2
				Reaction time	4	4	8
				Goods Shipment Type	4	3	7
				Technical Capacity	5	5	6
Flexibility	6	4	5				
				Collection Preparation Capacity	1	1	1
				Adaptation to Change in Demand	4	5	3

				Inventory Availability	4	4	9
				Personalization	3	4	4
				Information Sharing	3	3	7
Environmental Management	7	4	3				
				Chemical Substance Management	1	1	1
				Waste Management-Pollution Control	2	3	2
				Reverse Logistics Application Case	3	4	8
				Recycling Material Usage Status	3	3	7
Technology	8	7	7				
				Technological Compatibility	5	3	6
				Existing Production Facilities Capabilities	1	1	1
				Innovation Capacity	4	3	3
				Importance Given to R&D Studies	4	3	5
Social	7	4	6				
				Social Compliance Score	1	1	1
				Corporate Social Responsibility	5	4	2
				Immigrant Employee Status	6	4	5
				Social Gender Equality	7	5	4
				Volunteering Studies in the Institution	6	4	8

Step 4: For the criteria, using the BWM comparison scale, the process of determining the preference rates of all other criteria according to the worst preferred criterion was carried out. Preference rates of all other criteria according to the worst preferred criterion are shown in table 4.5.

Table 4.5. Preference rates of all other criteria according to the worst preferred criterion

Main Criteria	KV1	KV2	KV3	Sub Criteria	KV1	KV2	KV3
Cost	3	9	8				
				Price Advantage	3	4	9
				Transportation - Logistics Cost	1	1	1
				Discount for Bulk Order	5	3	3
				After Sales Service	4	3	4
Quality	8	9	8				
				Quality Control Pass Rate	9	4	8
				Average Number of Quality Control Passes	1	1	1
				Customer Return Rate	9	7	7
				Past Performance	7	5	5
				Fit Performance	9	6	6
				PPS Performance	8	6	3
				Product Quality	8	4	9
Delivery	1	1	1				
				Rate of Compliance with the Given Term	4	4	8
				Delivery Time- Production Time	3	5	7
				Reaction time	1	1	1
				Goods Shipment Type	4	4	4

				Technical Capacity	5	5	5
Flexibility	4	4	2				
				Collection Preparation Capacity	4	4	9
				Adaptation to Change in Demand	4	5	7
				Inventory Availability	1	1	1
				Personalization	3	4	6
				Information Sharing	4	5	4
Environmental Management	4	4	7				
				Chemical Substance Management	3	4	8
				Waste Management-Pollution Control	2	3	6
				Reverse Logistics Application Case	1	1	1
				Recycling Material Usage Status	3	4	3
Technology	5	3	4				
				Technological Compatibility	1	1	1
				Existing Production Facilities Capabilities	5	3	6
				Innovation Capacity	4	3	5
				Importance Given to R&D Studies	4	3	3
Social	6	4	5				
				Social Compliance Score	6	4	8
				Corporate Social Responsibility	7	5	7
				Immigrant Employee Status	6	4	4
				Social Gender Equality	6	4	6
				Volunteering Studies in the Institution	1	1	1

Step 5: In the last step, the most suitable weights of the criteria were determined. The criteria weights are shown in table 4.6.

Table 4.6. Criteria weights table

Main Criteria	Weights	Sub Criteria	Local Weights	Global Weights
Cost	0,158			
		Price Advantage	0,413	0,065
		Transportation - Logistics Cost	0,240	0,038
		Discount for Bulk Order	0,196	0,031
		After Sales Service	0,150	0,024
Quality	0,396			
		Quality Control Pass Rate	0,103	0,041
		Average Number of Quality Control Passes	0,038	0,015
		Customer Return Rate	0,158	0,063
		Past Performance	0,108	0,043
		Fit Performance	0,080	0,032
		PPS Performance	0,082	0,033
		Product Quality	0,431	0,171
Delivery	0,041			
		Rate of Compliance with the Given Term	0,458	0,019
		Delivery Time- Production Time	0,213	0,009
		Reaction time	0,057	0,002

		Goods Shipment Type	0,153	0,006
		Technical Capacity	0,119	0,005
Flexibility	0,109			
		Collection Preparation Capacity	0,456	0,050
		Adaptation to Change in Demand	0,157	0,017
		Inventory Availability	0,059	0,006
		Personalization	0,166	0,018
		Information Sharing	0,162	0,018
Environmental Management	0,126			
		Chemical Substance Management	0,489	0,061
		Waste Management-Pollution Control	0,267	0,034
		Reverse Logistics Application Case	0,083	0,010
		Recycling Material Usage Status	0,162	0,020
Technology	0,073			
		Technological Compatibility	0,089	0,007
		Existing Production Facilities Capabilities	0,533	0,039
		Innovation Capacity	0,204	0,015
		Importance Given to R&D Studies	0,174	0,013
Social	0,098			
		Social Compliance Score	0,486	0,048
		Corporate Social Responsibility	0,198	0,019
		Immigrant Employee Status	0,134	0,013
		Social Gender Equality	0,126	0,012
		Volunteering Studies in the Institution	0,055	0,005

Stage 2: Application of Weighted Aggregated Sum Product Assessment Method for Evaluation and Ranking of Alternatives

Step 1: After determining the importance levels of the criteria in supplier selection, a questionnaire was applied to 9 alternative suppliers and 3 expert decision makers on the basis of 1-9 (extremely weak-extremely good) criteria in order to create the decision matrix. The decision matrix is included in SI-1.

Step 2: The decision matrix was normalized by using equations 13 and 14 in line with the maximization or minimization criterion class of the evaluation criterion. The normalized matrix is included in SI-2.

Step 3: WSM and WPM values were calculated according to equations 15 and 16. WSM values are included in SI-3, WPM values are included in SI-4.

Step 4: The overall relative importance of the alternatives is calculated by equation 17 for $\lambda = 0.5$. Calculations are shown in table 4.7.

Table 4.7. Significance levels of alternatives for λ=0.5

		T1	T2	T3	T4	T5	T6	T7	T8	T9
λ	$Q_i^{(1)}$	0,700	0,582	0,740	0,550	0,503	0,605	0,783	0,822	0,669
	$Q_i^{(2)}$	0,666	0,549	0,708	0,526	0,483	0,582	0,726	0,772	0,616
	0,5	0,683	0,566	0,724	0,538	0,493	0,593	0,754	0,797	0,642
	Arrangement	**4**	**7**	**3**	**8**	**9**	**6**	**2**	**1**	**5**

As a result of the calculations for λ=0.5, the order T8>T7 >T3>T1>T9>T6>T2>T4>T5 has been reached.

4.1. Sensitivity Analysis

The λ parameter takes a value between 0 and 1. λ=0 λ=0.1 λ=0.2 λ=0.3 λ=0.4 λ=0.5 λ=0.6 λ=0.7 λ=0, 8 λ=0.9 λ=1 values were replaced in equation 17 and sensitivity analysis was performed. The results obtained are shown in table 4.8.

It has been observed that changing the λ value does not change the order of T8>T7>T3>T1>T9>T6>T2>T4>T5.

Table 4.8. Relative and total significance of alternatives

		T1	T2	T3	T4	T5	T6	T7	T8	T9
	$Q_i^{(1)}$	0,700	0,582	0,740	0,550	0,503	0,605	0,783	0,822	0,669
	$Q_i^{(2)}$	0,666	0,549	0,708	0,526	0,483	0,582	0,726	0,772	0,616
λ Values	0	0,666	0,549	0,708	0,526	0,483	0,582	0,726	0,772	0,616
	0,1	0,669	0,552	0,712	0,528	0,485	0,584	0,732	0,777	0,621
	0,2	0,673	0,556	0,715	0,531	0,487	0,586	0,738	0,782	0,626
	0,3	0,676	0,559	0,718	0,533	0,489	0,589	0,743	0,787	0,632
	0,4	0,680	0,562	0,721	0,536	0,491	0,591	0,749	0,792	0,637
	0,5	0,683	0,566	0,724	0,538	0,493	0,593	0,754	0,797	0,642
	0,6	0,686	0,569	0,727	0,540	0,495	0,596	0,760	0,802	0,647
	0,7	0,690	0,572	0,730	0,543	0,497	0,598	0,766	0,807	0,653
	0,8	0,693	0,576	0,734	0,545	0,499	0,600	0,771	0,812	0,658
	0,9	0,697	0,579	0,737	0,548	0,501	0,603	0,777	0,817	0,663
	1	0,700	0,582	0,740	0,550	0,503	0,605	0,783	0,822	0,669
	Arrangement	4	7	3	8	9	6	2	1	5

4.2. DISCUSSION

Supplier selection is a selection process in which companies from every sector must decide in their processes. It is a study in which the criteria specific to the retail company are evaluated together with the sustainable and general supplier selection criteria. When the literature studies are examined, it is seen that AHP SWARA TOPSIS methods are generally applied.

Application of commonly used methods is not preferred in the study. In the selection of methods, whether the criteria are quantitative and qualitative and the number of criteria are taken into consideration. Efficiency is prioritized in obtaining the results of the study. For this reason, BWM method is preferred in calculating criterion weights. The WASPAS method is preferred because it is not used together with the BWM method in literature reviews, considering the sensitivity analysis as a result of the ranking of the suppliers and the sensitivity analysis can be done within their own application steps. When compared to other studies, the criteria used in the study include sustainability-related criteria, general criteria and, for example, technology and quality criteria that affect the results of each other, and the fact that it includes a total of 41 comprehensive criteria reveals its difference from other studies.

It is thought that it will be a guide for those who work on supplier selection. It is thought that the preferred method will be suitable for use in other sectors and will provide efficiency in the solution and will provide preferability.

5. CONCLUSIONS

In the study, the selection criteria of the most suitable suppliers and suppliers were evaluated by evaluating the company criteria and previous studies in the literature, and 7 main criteria and 34 sub-criteria, which are the final criteria for the company, were examined.

As a result of model calculations, it is the quality criterion that has the highest weight among the main criteria. The quality criterion is the most important criterion among the company's employees. It has been concluded that the quality criterion is the most important criterion in the evaluation of suppliers, both in calculations and in the preferences of company employees. The second most important criterion in supplier selection is cost. These criteria are environmental management, flexibility, social, technology and delivery, respectively.

When the order of importance of the main criteria is evaluated, the main criterion for delivery is in the last place with a weight of 0.041, while the quality criterion is decisive with a weight of 0.396. While the quality criterion is the most important criterion, it is not expected that the machinery and equipment used in the quality of the product is important and the technology criterion is not expected to take place as the penultimate criterion. Environmental management criteria for sustainability are in the third place.

When the sub-criteria are compared, it is seen that the product quality is very important compared to the other quality sub-criteria. Likewise, other important sub-criteria are price advantage, chemical substance management, collection preparation capacity, social compliance score, capabilities of existing production facilities, and compliance with the given maturity, respectively.

As a result of the solution of the proposed BWM-WASPAS model, Supplier-8 ranked first with 3,148 values. Then Supplier-7 (2.884), Supplier-3 (2.742), Supplier-1 (2.709), Supplier-9 (2.561), Supplier-6 (2.421), Supplier-2 (2.278), Supplier-4 (2.158) and Supplier-5 (1,794) was determined as the best suppliers. It is suggested that the t-shirts to be produced by the company are primarily produced by Supplier-8. It has been reported that if there is a problem with Supplier-8 (T8) during the production process, other suppliers will be evaluated respectively.

To evaluate the reliability of supplier ranking, λ=0 λ=0.1 λ=0.2 λ=0.3 λ= 0.4 λ=0.5 λ=0.6 λ=0.7 λ= 0.8 λ= 0.9 λ=1. Sensitivity analyzes were made regarding the supplier rankings obtained when all the values were changed. As a result of the analysis, it was seen that the change in λ value did not change the supplier ranking.

As a result, the model developed to determine which supplier to work with in summer t-shirt production is flexible to add new criteria and suppliers. It is thought that this model can also be applied in the evaluation of other suppliers that the company works with and that it will play an active role in the selection of suppliers in the production process of different product groups.

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