Cluster-based supplier segmentation: a sustainable data-driven approach

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Received 7 May 2023
Revised 12 August 2023
Accepted 19 September 2023

Abstract

Purpose – Supplier segmentation provides companies with suitable policies to control each segment, thereby saving time and resources. Sustainability has become a mandatory requirement in competitive business environments. This study aims to develop a clustering-based approach to sustainable supplier segmentation.
Design/methodology/approach – The characteristics of the suppliers and the aspects of the purchased items were considered simultaneously. The weights of the sub-criteria were determined using the best-worst method. Then, the K-means clustering algorithm was applied to all company suppliers based on four criteria. The proposed model is applied to a real case study to test the performance of the proposed approach.
Findings – The results prove that supplier segmentation is more efficient when using clustering algorithms, and the best criteria are selected for sustainable supplier segmentation and managing supplier relationships.
Originality/value – This study integrates sustainability considerations into the supplier segmentation problem using a hybrid approach. The proposed sustainable supplier segmentation is a practical tool that eliminates complexity and presents the possibility of convenient execution. The proposed method helps business owners to elevate their sustainable insights.

Keywords Supplier management, Clustering, Sustainability, Purchasing portfolio matrix, Supplier potential matrix
Paper type Research paper

1. Introduction

These days, due to environmental and social concerns and regulations, stakeholders trend toward sustainable development (Gholizadeh *et al.*, 2020). To achieve sustainable business practices, companies need to address economic, social and environmental aspects. In the economic pillar, the materialization of relationships with stakeholders is considered in the markets. All relationships with suppliers, customers and the community ought to be based on trust and the satisfaction of social objectives. For companies, this transition towards sustainability begins with effective procurement management and supplier relationship management, key components of a sustainable supply chain (Joyce and Paquin, 2016). The first step in sustainable management is purchase/procurement management. A sustainable supply chain needs to consider its relationship with the suppliers (Silva *et al.*, 2022). Companies prefer to work with suppliers, who ensure the sustainability of their processes sustainability to outperform the competitors (Xia, 2011). An important element in supply chain management is

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Modern Supply Chain Research and Applications
Vol. 5 No. 3, 2023
pp. 209-228
Emerald Publishing Limited
2631-3871
DOI 10.1108/MSCRA-05-2023-0017

supplier relationship management (Park *et al.*, 2010). It focuses on developing and maintaining the relationships with suppliers (Lambert and Schwieterman, 2012). Selecting suppliers who prioritize sustainability and align with the company's values has become a significant strategy for gaining a competitive edge.

Strategic decisions in supplier segmentation are focused on evaluating suppliers, identifying different approaches, determining the most suitable criteria for segmentation and appropriate methods to segment the suppliers. Segmentation includes three categories: (1) consumer segmentation, (2) industrial customer segmentation and (3) supplier segmentation (Rezaei and Ortt, 2013). Evaluation of suppliers is making different groups from the selected suppliers create different supplier management strategies for segments involved (Rezaei *et al.*, 2015).

Supplier segmentation depends on a wide range of quantitative and qualitative criteria (Rezaei *et al.*, 2015). Multi-criteria decision-making (MCDM) methods should be applied to determine the proper set of decisions (Razmi *et al.*, 2009). K-means algorithm uses numerical data measurements such as Euclidean distance to determine the similarity of data points (Jain *et al.*, 1999). Segmenting suppliers is to more efficiently manage suppliers by designating strategies for subsets of suppliers rather than selecting separate strategies for each supplier (Bai *et al.*, 2017).

This study introduces a groundbreaking method for supplier segmentation that incorporates sustainability considerations into supply chain management. This novel approach simultaneously accounts for supplier characteristics and purchased item attributes, enhancing the accuracy of segmentation. The hybrid methodology, combining the best-worst method and K-means clustering algorithm, aims for precision and practicality. While the model's strengths include sustainability integration and holistic segmentation, it also poses challenges due to complexity, data requirements and algorithm sensitivity. Nevertheless, the paper's contributions align with modern business demands for responsible practices and data-driven decision-making, exemplifying the ongoing pursuit of innovation in supply chain management. Next, the appropriate policy for each group of suppliers is explained. Finally, the validation through a real case study enhances the practicality of the proposed approach and demonstrates its viability in actual supply chain scenarios.

In this study, our research aims to address the following key objectives:

(1) To develop a clustering-based approach that integrates sustainability considerations into supplier segmentation within supply chain management.

(2) To simultaneously assess supplier characteristics and purchased item attributes in order to enhance the accuracy and relevance of segmentation.

(3) To determine the appropriate criteria and sub-criteria for sustainable supplier segmentation by combining the best-worst method and the K-means clustering algorithm.

(4) To validate the proposed approach through a real case study, demonstrating its practicality and effectiveness in actual supply chain scenarios.

By clarifying these research objectives, we aim to contribute to the field of supplier segmentation by offering a comprehensive and innovative methodology that encompasses sustainability dimensions and provides actionable insights for sustainable supplier management.

The rest of the paper is structured as follows. In Section 2, through analyzing the literature of supplier segmentation, with a focus on sustainable sub-criteria, the research gap is analyzed. Section 3 presents the methodology of this study. A real-world case study is analyzed, and the results are illustrated in Section 4. Section 5 presents conclusion and future researches suggestions.

2. Literature review

Segmentation is an effective approach in supplier management. To comply with limited resources and create a sustainable company image, corporates are investing heavily in environmental and social responsibility issues (Bai and Satir, 2020). In this section, the existing literature on supplier segmentation is reviewed. Existing studies are investigated from two different perspectives: 2.1. Supplier segmentation, the Purchasing Portfolio Matrix (PPM) and the Supplier Potential Matrix (SPM), and 2.2. Sustainable supplier segmentation. Table 1 presents some important key differences on related studies.

2.1 Supplier segmentation, the purchasing portfolio matrix and the supplier potential matrix

Large scale organizations deal with a wide variety of products and thus different ranges of suppliers. Buyer-supplier relationships ought to be managed concerning their differentiation (Arabzad *et al.*, 2011). Companies segment their selected suppliers to evaluate different strategies to manage each segment. The PPM was proposed to determine the appropriate purchasing strategies (Kraljic, 1983). The objective was to minimize supply risk and increase purchase power. This approach considers two components, supply risk and profit impact, and classifies the purchased materials of a company into four groups: bottleneck (supply risk: high; profit impact: low); non-critical (supply risk: low; profit impact: low); leverage (profit impact: high; supply risk: low); and strategic (supply risk: high; profit impact: high) (Kraljic, 1983). Recently Nguyen *et al.* (2021) studied organic supply chain performance and their findings indicate several positive determinants impacting the supply chain performance.

It is imperative to thoroughly contemplate the attributes intrinsic to suppliers and their interconnections in the pursuit of effective supplier relationship management. An innovative perspective on supplier segmentation emerged with the inception of Supplier Portfolio Management (SPM), devised by Rezaei and Ortt (2012). SPM places a distinct emphasis on the cultivation of robust relationships, underpinned by the evaluation of two pivotal dimensions: "supplier capabilities" and "supplier willingness." Notably, Rezaei and Fallah Lajimi (2019) amalgamated two distinct supplier segmentation methodologies, namely Portfolio Purchasing Model (PPM) and SPM, yielding a hybrid segmentation framework that adeptly harnesses the advantages inherent in both matrices. In a parallel vein, Rius-Sorolla *et al.* (2020) introduced an original paradigm for supplier development, hinged upon a supplier segmentation mechanism that prioritizes risk management as a pivotal precondition for fostering sustainable supply chain growth. The advent of these methodologies, namely

Table 1. Comparing major studies with the present study

Paper	Sustainable segmentation Economic	Environmental	Social	Clustering algorithm	Segmentation approach	MCDM method
Rezaei *et al.* (2015)	×			–	PPM	BWM
Rezaei *et al.* (2017)		×		–	SPM	ELECTRE
Bai *et al.* (2017)		×		Fuzzy, C-means	SPM	VIKOR
Rezaei and Fallah Lajimi (2019)	×			–	SPM-PPM	BWM
Rius-Sorolla *et al.* (2020)	×	×	×	–	PPM	–
This study	×	×	×	*K*-means	SPM-PPM	BWM

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PPM and SPM, has ushered in a novel avenue for researchers to elucidate unique insights into the realm of supplier segmentation. Concomitantly, the SPM and PPM methodologies have laid the foundation for numerous explorations within the research landscape.

2.2 Sustainable supplier segmentation

Cost is the most important component in purchasing; almost every attribute could be interpreted in terms of money when addressing purchasing (Heydari *et al.*, 2020). Therefore, purchasing department considers cost as an essential measure in evaluating suppliers (Abdollahi *et al.*, 2015). Sustainable supplier segmentation criteria are neglected in the related literature (Sabbaghnia *et al.*, 2023). Cousins *et al.* (2008) extended Kraljic's model, considering the third component of environmental costs to integrate environmental issues into supplier segmentation. However, they did not determine which criteria should be used to measure this new component. Pagell *et al.* (2010) developed Kraljic's model by extending the "profit impact" dimension to "risk to profits, the environment and/or society". They resulted existing portfolio models should be changed to face the increased attention to sustainable supply chain management. Rezaei and Ortt (2012) considered environmental factors for segmentation criteria in the SPM model. Supplier capabilities include environmental aspects such as health, safety and availability of clean technologies in addition to traditional criteria. However, sustainability was not their focal attention in that study. Bai *et al.* (2017) extended supplier segmentation based on SPM for green issues. Their willingness criteria for green supplier segmentation contain sub-criteria such as commitment to greening, and willingness to invest in a specific technology. On green supplier selection, Fazlollahtabar and Kazemitash (2022) investigated sustainable resilient supplier selection problem by proposing a novel ranking and selection technique including 114 criteria. Because of the new business rule in terms of sustainability, Puška and Stojanović (2022) developed a fuzzy multi-criteria model on assessing the greenness level in supplier selection problem in Agri-Food industries. Güneri and Deveci (2023) investigated the supplier selection criteria for defense industry developing a fuzzy based decision-making model.

In another study, Rezaei *et al.* (2017) proposed a green supplier segmentation concerning capabilities and willingness. These criteria could lead buyers to reduce their carbon footprint. Rius-Sorolla *et al.* (2020) presented an approach to supplier development. That approach was based on a supplier segmentation method that prioritized risk management as a requisite for developing a supply chain sustainably. Demir *et al.* (2018) proposed a sorting methodology that classified suppliers into three environmental classes (best, moderate, worst) and identified differences in the environmental performance of both classes and individual suppliers. Based on the literature, although purchasing as one part of supply chain components needs to merge with a sustainable approach, sustainable supplier segmentation has received less attention. Most studies lean toward green criteria.

2.3 Gap analysis

To our knowledge, supplier segmentation is an important part of supplier relationship management among both practitioners and academics, and different approaches are developed for it (Rezaei and Fallah Lajimi, 2019; Segura and Maroto, 2017; Bai *et al.*, 2017; Duc *et al.*, 2021). Hybrid models, owing to their comprehensive array of criteria, have demonstrated enhanced efficiency in the realm of supplier segmentation. Curiously, despite their proven efficacy, these models have not garnered substantial attention within this domain. Furthermore, the integration of supply and supplier aspects in sustainable supplier segmentation remains largely unexplored within the context of combined methodologies. Suppliers can be categorized based on the commodities they provide or their inherent attributes. The amalgamation of these attributes alongside a sustainable perspective holds the potential to yield a profoundly effective sustainable supplier segmentation strategy.

In this study, a pioneering hybrid model has been formulated to meticulously segment suppliers. The novel model takes into account not only the nature of the supplies but also the sustainable characteristics exhibited by suppliers. This necessitates the delineation of sub-criteria tailored specifically to sustainable dimensions. These sub-criteria distinctly diverge from the conventional cost-efficiency or responsiveness considerations. Remarkably, conventional practices often designate a score exceeding half as indicative of high performance; however, leveraging clustering algorithms for segmentation could substantially enhance the precision of the process. By employing a clustering algorithm to segment suppliers based on their aggregated final scores, a more pragmatic and operationally viable approach is realized for buyers. Consequently, this study endeavors to synthesize the strengths of Portfolio Purchasing Model (PPM) and Supplier Portfolio Management (SPM) methodologies, culminating in a cluster-based framework. The resulting segmentation tool aptly encompasses sustainable facets, thereby facilitating a holistic and refined approach to supplier segmentation.

3. Methodology

This study deals with the sustainable segmentation of suppliers using a hybrid approach. Segmentation criteria need to be redefined concerning sustainability dimensions to achieve this goal. The main criteria utilized in this study are extracted from PPM and SPM developed by Rezaei and Fallah Lajimi (2019). Then, using review-driven sustainable aspects, the sub-criteria of each criterion is redefined. After computing the normalized scores of suppliers for each criterion, suppliers are segmented by adapting the K-means clustering. K-means leads to segment all suppliers into sixteen groups based on the PPM-SPM approach. In the next section, appropriate policies for each group are suggested. Different strategies are adopted in corresponding with each policy.

3.1 A sustainable approach

In this study, supplier segmentation problem outlines are clarified through PPM and SPM. Sixteen groups are formed based on material types and the supplier relationship-driven from PPM-SPM. The segmentation outline is depicted in Figure 1. Initially, suppliers undergo segmentation through the application of the Portfolio Purchasing Model (PPM) approach. Within this framework, the focus lies on the commodities supplied. This results in the establishment of four distinct groups, categorized according to supply risk and profit impact. As such, each supplier is allocated to one of the following segments: leverage items, strategic items, non-critical items and bottleneck items. Leverage items exhibit a high-profit impact coupled with a low supply risk. Bottleneck items, conversely, demonstrate a high supply risk and a low-profit impact. For non-critical items, both profit impact and supply risk are low, while strategic items encompass high levels of both profit impact and supply risk. Subsequently, the Supplier Portfolio Management (SPM) approach is employed to further segment suppliers. Within this approach, the characteristics unique to each supplier, encompassing factors such as supply risk and profit impact, are meticulously examined. The analysis revolves around two pivotal aspects: supplier capabilities and supplier willingness. This twofold examination is intrinsic to the SPM approach and contributes significantly to the subsequent segmentation process.

Some sub-criteria need to be defined for each dimension in both approaches to score suppliers concerning the triple bottom line of sustainability. For the sustainable supplier segmentation, the buying firm should first establish a set of sustainable sub-criteria for each

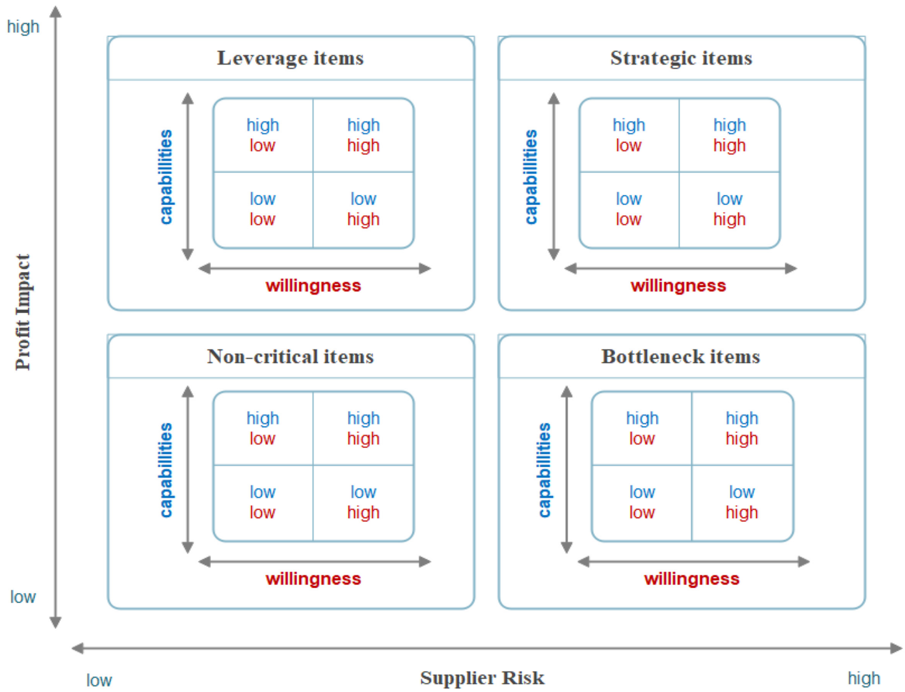

Figure 1.
Combined the PPM-SPM

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segmentation aspect. This requirement is usually accomplished in meeting sessions with the company's key decision-makers. To that end, the sub-criteria are introduced based on the literature (Tables 2 and Table 3). Also, some new sub-criteria are added based on sustainability considerations. Redefining effective sustainable-based sub-criteria assess suppliers and pursue the buyer sustainability goals.

3.2 Score calculation

MCDM approach is utilized to aggregate different criteria. MCDM is designed for problems with a finite or infinite number of choices. In supplier segmentation, each supplier's segment depends on qualitative and quantitative criteria. Therefore, to calculate the final scores of supply risk, profit impact, willingness and capability for each supplier, an MCDM approach is employed. In the relevant literature, different MCDM methods such as VIKOR (Bai *et al.*, 2017) and ELECTRE (Rezaei *et al.*, 2017) are applied to this problem. This study applies BWM (Rezaei, 2016), an efficient method that needs less data and its results are more reliable (Rezaei, 2015). BWM is widely applied in studies; assessing the social sustainability of supply chains (Ahmadi *et al.*, 2017), green supplier selection (Wu *et al.*, 2019), assessing organizations performance (Gupta, 2018). BWM is an MCDM method that serves multiple phases of solving an MCDM problem. It can evaluate alternatives considering criteria, especially when objective metrics are unavailable. BWM can also determine the importance (weight) of criteria to achieve the main problem goals. The method involves a close interaction between decision-makers (DMs) and analysts. BWM has been successfully employed to address real-world MCDM challenges in various domains including business, economics, health, IT and

Supply risk		Recourses/description
Sr1	Accessibility	Amin and Razmi (2009)
Sr2	Delivery time	Fenson *et al.* (2008)
Sr3	Substitution possibilities	Kraljic (1983)
Sr4	Number of available suppliers	Ferreira *et al.* (2015)
Sr5	Carbon disclosure	Rezaei *et al.* (2017)
Sr6	Environmental legal requirements	Demir *et al.* (2018)
Sr7	Environment-friendly materials	Demir *et al.* (2018)
Profit impact		**Recourses/description**
Pi1	Resource consumption	Govindan *et al.* (2015)
Pi2	Item price	Padhi *et al.* (2012)
Pi3	Price variation	Parkouhi *et al.* (2019)
Pi4	Total purchased amount	Large and Thomsen (2011)
Pi5	Environmental costs	Deterioration of natural resources as a result of economic activity
Pi6	Product importance in the project sequence	Ferreira *et al.* (2015)

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Table 2.
Sub criteria related to PPM in this research

Capability		Recourses/description
C1	Green transportation and packaging	Laari *et al.* (2016)
C2	Environmental management	Awasthi *et al.* (2010)
C3	After-sales services	Razmi *et al.* (2009)
C4	Amount of past business	Rezaei and Ortt (2012)
C5	Protecting Employees' health	Macdonald (2005)
C6	Safety and security	To protect an employee from work-related injury and secure the working environment from intruders
C7	Energy efficiency	Rezaei *et al.* (2017)
C8	External recognition	Rezaei *et al.* (2017)
Willingness		**Recourses/description**
W1	Effort in eliminating waste	Kusi-Sarpong *et al.* (2016)
W2	Willing to technological progress	Ghanbarizadeh *et al.* (2019)
W3	Honest and frequent communication	Oghazi *et al.* (2016)
W4	Open to information sharing	Smeltzer (1997)
W5	Gender equality	Equal rights, responsibilities and opportunities to all genders
W6	Racial equity	Equal rights, responsibilities and opportunities to all races
W7	Recycling program	Demir *et al.* (2018)
W8	Social responsibility projects	Demir *et al.* (2018)
W9	Training programs on environmental issues	Demir *et al.* (2018)

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Table 3.
Sub criteria related to SPM in this research

engineering. In essence, BWM is utilized to evaluate alternatives based on their best and worst attributes. It involves constructing a preference matrix, which plays a central role in the BWM's application. The preference matrix is built by considering the relative importance of both criteria and alternatives. This matrix facilitates the determination of rankings, specifically the best and worst rankings, thus aiding in the decision-making process. By emphasizing this methodology, we enhance our ability to address complex decision-making scenarios, where both the best and worst attributes of alternatives are taken into account for ranking purposes. This methodology aligns well with our research objectives and contributes to the robustness of our supplier segmentation approach. For each criterion, an aggregated score is calculated per supplier. According to (Rezaei, 2016) the weights of each sub-criteria is determined as follows:

A set of criteria $\{c_1, c_2, \ldots, c_j, \ldots, c_n\}$ needs to be defined in the first step. Next, the best and the worst criteria should be determined. Then the preferences of the overall best and worst criteria, $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$ and $A_W = (a_{1W}, a_{2W}, \ldots, a_{nW})^T$ are defined. The resulting vectors would be:

The optimal weights $\{w_1^*, w_2^*, \ldots, w_n^*\}$ and z^* is found thorough the following Problem (1):

$$
\begin{aligned}
&Min\, z \\
&s.t. \\
&|w_B - a_{Bj}.w_j| \leq z \quad \forall j \\
&|w_j - a_{jW}.w_W| \leq z \quad \forall j \\
&\sum_j w_j = 1 \\
&w_j \geq 0\ \forall j
\end{aligned}
\tag{1}
$$

For this method, z^* could be used to assess the consistency of the comparisons directly. Consistency is demonstrated by z^* values close to zero.

We consider a set of suppliers $i \in \{1, 2, \ldots, m\}$. For each sub-criterion, l_{ij} is the score assigned to each supplier. Then, the final aggregate scores of each criterion for supplier i is determined using Expression (2).

$$
TS_i = \sum_j^n l_{ij}.w_j \quad \forall j \tag{2}
$$

After calculating the total score for each dimension TS_i, the suppliers' normalized scores are determined through Normalization (3).

$$
\widehat{TS}_a = \frac{TS_a - \min\{TS_i\}}{\max\{TS_i\} - \min\{TS_i\}} \quad \forall j \tag{3}
$$

3.3 Clustering

Different clustering algorithms are developed to form clusters from different points of view. One of the widely applied of them is the K-means algorithm (Nazeer and Sebastian, 2009). K-Means attempts to model a dataset into clusters. All clusters have comparable features, yet are different from each other. The reasons for the recognition of K-means are ease and simplicity of implementation, scalability, the speed of convergence and adaptableness to sparse data (Duan *et al.*, 2019). The similarity distance in the K-means algorithm is usually determined using the Euclidean distance (Likas *et al.*, 2003). The process of this clustering is shown in Figure 2. K-means aims to segment suppliers into sixteen clusters in this study. Input data are normalized suppliers' scores (refer to Figure 1 for more details).

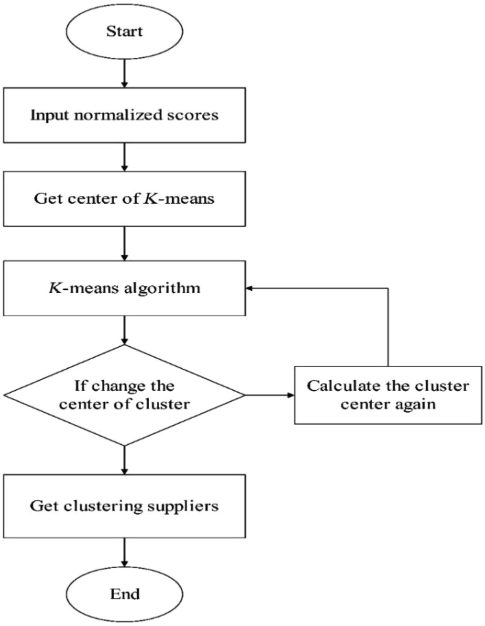

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Figure 2. K-means algorithm process

4. Case study

4.1 The sustainable segmentation

In this section, we delve into a tangible case study, undertaken to empirically evaluate the efficacy of the advanced model proposed. The selected case revolves around a prominent kitchen appliance company situated in the Isfahan province of Iran. The company has garnered a substantial network of 68 suppliers, forming the bedrock of its supply chain. The focal point of this case study is the company's explicit intention to bolster its sustainability performance in tandem with its suppliers collaboratively. This strategic aspiration impels the company to delineate a judicious set of criteria that can effectively categorize and assess its extensive roster of suppliers. By adroitly considering these criteria, the company endeavors to cultivate an environmental ethos, reinforcing its commitment to ecological responsibility. Simultaneously, integrating social dimensions into the supplier classification process can fortify the firm's brand perception and resonance among stakeholders. An astute application of such strategies stands to augment the company's competitive positioning, capitalizing on its burgeoning reputation as a conscientious purveyor of sustainable practices. Furthermore, the strategic deployment of ecologically sound methods not only crystallizes immediate benefits but also engenders a fertile ground for future endeavors such as recycling, material recovery and remanufacturing. To scrutinize the veracity of the conceptual framework posited, an integral facet of this study entails conducting in-depth interviews with the company's Supplier Relationship Management department. Through these dialogues, suppliers are meticulously evaluated, each being critically appraised against the identified sub-criteria pair-wisely. The ensuing segmentation of suppliers, facilitated by the K-means clustering algorithm, begets the definitive classification, which is subsequently subjected to comprehensive analysis and contemplation. This rigorous examination serves as a platform for the exploration of potent supplier development strategies and the elucidation of avenues to foster sustainable synergies.

The criteria used in the segmentation process are presented in Table 2 and 3. Pairwise comparisons were conducted between the best/worst criterion and the others. The proposed MCDM is employed to identify the manufacturer's sustainable supplier segmentation. Finally, the dataset is normalized by solving the Problem (1). Figure 3 depicts the decision processing flow from developing a sustainable supplier segmentation model to extracting managerial insights.

As it is explained in the previous section, Table 4 shows the best sub-criteria to others for the supply risk, which are "profit impact", "capabilities" and "willingness" dimensions. The pairwise comparisons between other sub-criteria to the worst sub-criterion are presented in Table 5. As it can be seen in Tables 4, "accessibility", "item price", "after-sales services" and "open to information sharing" are the most important sub-criteria. According to Table 5, "Number of past businesses", "the importance of the product in the project sequence", "external recognition" and "training programs on environmental issues" are considered to be the least important sub-criteria for each dimension. The optimal weights that are resulted from BWM are shown in Table 6 for each sub-criterion.

An aggregated score for each criterion and each supplier is calculated by multiplying their scores by their weights and adding them up for each dimension, using Equation (2). Then by employing Equation (3), the aggregated score for each supplier and dimension is normalized. The results are shown in Table 7.

IBM SPSS MODELER uses normalized data to implement the clustering. IBM SPSS Modeler uses normalized data to implement clustering in a structured process within the stream network. This process involves two rounds of data clustering to determine clusters for supplier segmentation. The first clustering operation focuses on determining PPM (Profitable Procurement Model) clusters of suppliers, while the second clustering operation aims to determine SPM (Supplier Performance Management) clusters of suppliers. In the PPM clustering step, suppliers are segmented based on the PPM approach, which considers the items supplied by each supplier. This approach results in the formation of four distinct groups, each representing a specific cluster. These clusters are created based on the supply risk and profit impact associated with the supplied items. Data clustering is executed two times. The first one is for determining PPM clusters of the suppliers and the second for

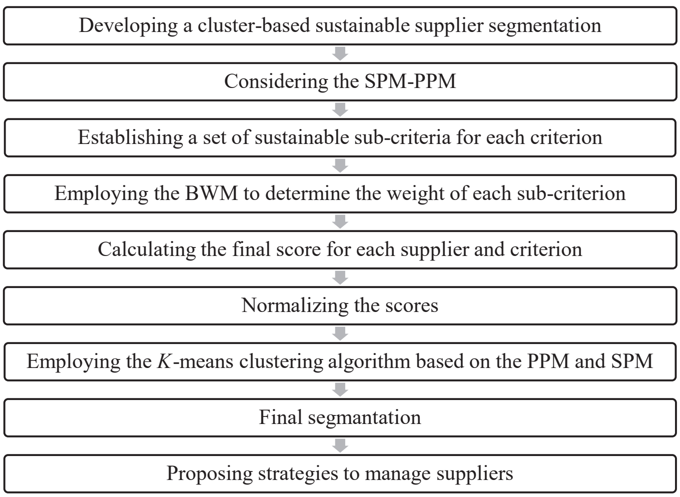

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Figure 3.
The framework of this study

determining SPM clusters of the suppliers. Clustering results are shown in Table 8. The mean score of each dimension for each cluster is shown. Suppliers are segmented Table 9. Finally, suppliers are segmented into 16 groups based on their SPM and PPM clusters.

4.2 Strategy suggestion

In alignment with the literature, different strategies are offered for developing different supplier segments (Rezaei and Fallah Lajimi, 2019). These strategies help the organization to improve their suppliers in each segmentation effectively. Sustainability is a novel aspect of this segmentation and differentiates the present study from the previous ones. These strategies can improve sustainability in some suppliers to increase competitiveness among them and assist companies to have more sustainable supplier selection. The results of supplier segmentation and proposed strategies are as follows:

Group 1 (SPM1 - PPM1): six suppliers

Best to others	*Sr1*	*Sr2*	*Sr3*	*Sr4*	*Sr5*	*Sr6*	*Sr7*		
Sr1	1	2	3	5	7	9	6		
Best to others	*Pi1*	*Pi2*	*Pi3*	*Pi4*	*Pi5*	*Pi6*			
Pi2	3	1	7	9	5	6			
Best to others	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	
C3	2	2	1	3	4	5	6	7	
Best to others	*W1*	*W2*	*W3*	*W4*	*W5*	*W6*	*W7*	*W8*	*W9*
W4	3	3	2	1	4	4	5	5	6

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Table 4. The best to others for each sub-criterion

Others to the worst	W9	Others to the worst	C8	Others to the worst	Pr4	Others to the worst	Sr6
W1	5	C1	2	Pi1	3	Sr1	9
W2	5	C2	2	Pi2	9	Sr2	5
W3	5	C3	7	Pi3	2	Sr3	4
W4	6	C4	3	Pi4	1	Sr4	3
W5	4	C5	4	Pi5	4	Sr5	3
W6	4	C6	5	Pi6	3	Sr6	1
W7	3	C7	6			Sr7	3
W8	2	C8	1				
W9	1						

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Table 5. Others to the worst for each sub-criterion

Supply risk	z^*	Sr1	Sr2	Sr3	Sr4	Sr5	Sr6	Sr7		
Weight	0.049	0.383	0.21	0.144	0.086	0.062	0.037	0.072		
Profit impact	z^*	Pr1	Pr2	Pr3	Pr4	Pr5	Pr6			
Weight	0.072	0.186	0.485	0.080	0.046	0.111	0.093			
Capability	z^*	C1	C2	C3	C4	C5	C6	C7	C8	
Weight	0.1	0.154	0.154	0.292	0.13	0.098	0.078	0.065	0.027	
Willingness	z^*	W1	W2	W3	W4	W5	W6	W7	W8	W9
Weight	0.063	0.112	0.112	0.168	0.272	0.084	0.084	0.067	0.067	0.035

Source(s): Created by authors

Table 6. Obtained weights for each sub-criterion from BWM

Table 7.
Suppliers' normalized scores

Supplier	Supply risk	Profit impact	Capability	Willingness	Supplier	Supply risk	Profit impact	Capability	Willingness
1	0.955	0.116	0.959	0.566	33	0.041	0.954	0.364	0.214
2	0.647	0.132	0.796	0.144	34	0.802	0.458	0.099	0.122
3	0.771	0.428	0.091	0.153	35	0.808	0.197	0.228	0.197
4	0.481	1.000	0.266	0.869	36	0.836	0.169	0.634	0.059
5	0.699	0.343	0.922	0.112	37	0.141	0.368	0.422	0.022
6	0.691	0.752	0.202	0.000	38	0.709	0.853	0.573	0.983
7	0.623	0.595	0.488	0.396	39	0.490	0.676	0.705	0.990
8	0.636	0.424	0.137	0.861	40	0.347	0.273	0.736	0.755
9	0.219	0.658	0.236	0.286	41	0.691	0.098	0.277	0.429
10	0.769	0.863	0.452	0.077	42	0.711	0.144	0.437	0.034
11	0.439	0.125	0.955	0.940	43	0.631	0.818	0.465	0.381
12	0.674	0.315	0.114	0.934	44	0.105	0.060	0.507	0.375
13	0.946	0.000	0.920	0.800	45	0.389	0.054	0.104	0.636
14	0.477	0.683	0.492	0.991	46	0.702	0.494	0.754	0.462
15	0.134	0.720	0.927	0.161	47	0.949	0.402	0.244	0.549
16	0.158	0.938	0.821	0.008	48	0.006	0.938	0.335	0.871
17	0.184	0.947	0.742	0.394	49	0.278	0.728	0.175	0.929
18	0.597	0.616	0.679	0.814	50	0.323	0.211	0.242	0.477
19	0.294	0.509	0.788	0.638	51	0.961	0.198	0.245	0.108
20	0.879	0.067	0.150	0.537	52	0.412	0.305	0.044	0.756
21	0.360	0.871	0.986	0.011	53	0.876	0.109	0.111	0.260
22	0.000	0.875	0.593	0.023	54	0.325	0.912	0.164	0.278
23	0.866	0.182	0.000	0.420	55	0.944	0.894	0.059	0.145
24	0.379	0.562	0.266	0.928	56	0.408	0.136	0.660	0.841
25	0.370	0.526	0.037	0.070	57	0.122	0.634	0.351	0.115
26	0.479	0.289	0.694	0.616	58	0.021	0.330	0.088	0.895
27	1.000	0.702	0.902	0.488	59	0.223	0.387	0.557	0.223
28	0.582	0.674	1.000	0.773	60	0.284	0.619	0.380	0.446
29	0.981	0.981	0.400	0.069	61	0.029	0.002	0.598	0.337
30	0.389	0.397	0.670	0.862	62	0.568	0.275	0.179	0.018
31	0.878	0.239	0.790	0.798	63	0.746	0.614	0.427	0.976
32	0.096	0.436	0.943	0.342	64	0.671	0.180	0.640	1.000

Source(s): Created by authors

Leverage items have a high impact on profit. The suppliers of this category are probably experts or famous in producing the items. They also may have many customers. Despite their high capability, they have not shown much willingness to supply for these reasons. As items produced are leverage, improving the relationship (Rezaei *et al.*, 2015) and long-term

Cluster	*PPM1*	*PPM2*	*PPM3*	*PPM4*
Supply risk (level/mean)	Low/0.25	High/0.75	Low/0.26	High/0.79
Profit impact (level/mean)	High/0.75	High/0.74	Low/0.26	Low/0.22
Size of cluster	19	12	17	20
Cluster	*SPM1*	*SPM2*	*SPM3*	*SPM4*
Willingness (level/mean)	Low/0.25	High/0.83	Low/0.19	High/0.8
Capability (level/mean)	High/0.73	High/0.74	Low/0.24	Low/0.2
Size of cluster	17	16	22	13

Source(s): Created by authors

Table 8.
Results of the clustering

Supplier	PPM	SPM	Group	Supplier	PPM	SPM	Group
1	PPM 4	SPM 2	8	35	PPM 4	SPM 3	12
2	PPM 4	SPM 1	4	36	PPM 4	SPM 1	4
3	PPM 4	SPM 3	12	37	PPM 3	SPM 3	11
4	PPM 1	SPM 4	13	38	PPM 2	SPM 2	6
5	PPM 4	SPM 1	4	39	PPM 1	SPM 2	5
6	PPM 2	SPM 3	10	40	PPM 3	SPM 2	7
7	PPM 2	SPM 1	2	41	PPM 4	SPM 3	12
8	PPM 4	SPM 4	16	42	PPM 4	SPM 3	12
9	PPM 1	SPM 3	9	43	PPM 2	SPM 1	2
10	PPM 2	SPM 3	10	44	PPM 3	SPM 1	3
11	PPM 3	SPM 2	7	45	PPM 3	SPM 4	15
12	PPM 4	SPM 4	12	46	PPM 2	SPM 1	2
13	PPM 4	SPM 2	8	47	PPM 4	SPM 4	16
14	PPM 1	SPM 2	5	48	PPM 1	SPM 4	13
15	PPM 1	SPM 1	1	49	PPM 1	SPM 4	13
16	PPM 1	SPM 1	1	50	PPM 3	SPM 3	11
17	PPM 1	SPM 1	1	51	PPM 4	SPM 3	12
18	PPM 2	SPM 2	6	52	PPM 3	SPM 4	15
19	PPM 1	SPM 2	5	53	PPM 4	SPM 3	12
20	PPM 4	SPM 4	16	54	PPM 1	SPM 3	9
21	PPM 1	SPM 1	1	55	PPM 2	SPM 3	10
22	PPM 1	SPM 1	1	56	PPM 3	SPM 2	7
23	PPM 4	SPM 3	12	57	PPM 1	SPM 3	9
24	PPM 1	SPM 4	13	58	PPM 3	SPM 4	15
25	PPM 1	SPM 3	9	59	PPM 3	SPM 1	3
26	PPM 3	SPM 2	7	60	PPM 1	SPM 3	9
27	PPM 2	SPM 1	2	61	PPM 3	SPM 1	1
28	PPM 2	SPM 2	6	62	PPM 4	SPM 3	12
29	PPM 2	SPM 3	10	63	PPM 2	SPM 4	14
30	PPM 3	SPM 2	7	64	PPM 4	SPM 2	8
31	PPM 4	SPM 2	8	65	PPM 3	SPM 1	3
32	PPM 3	SPM 1	3	66	PPM 1	SPM 2	5
33	PPM 1	SPM 3	9	67	PPM 3	SPM 4	15
34	PPM 4	SPM 3	12	68	PPM 3	SPM 3	11

Source(s): Created by authors

Table 9.
Final segmentation

commitment can be the recommended strategy with this group. Their low willingness could be only in improving sustainable aspects. In that case, the company can also share sustainable values through some meetings.

Group 2 (SPM1 - PPM2): four suppliers

Suppliers who supply these strategic items are highly capable with low willingness. As strategic items can be supplied from very few suppliers, it is recommended to improve their relationship through collaborations (Modi and Mabert, 2007) and long-term commitment.

Group 3 (SPM1 - PPM3): four suppliers

This segment belongs to those suppliers who can offer the lowest price for non-critical items while the quality of their products is acceptable. A high market share is a reason for having low willingness. Therefore, purchasing large batches and having a permanent relationship can be the best strategy with these suppliers.

Group 4 (SPM1 - PPM4): three suppliers

Since suppliers of this group have a high capability and bottleneck items are challenging to purchase, keeping the suppliers and developing them could be the most suitable strategy. Incentive policies and providing awareness of the effects of supplier activities on the environment and society could improve their sustainable willingness.

Group 5 (SPM2 - PPM1): three suppliers

This segment has the best supplier for leverage items. Then long-term contracts and sharing knowledge and experiences can be the recommended strategy.

Group 6 (SPM2 - PPM2): three suppliers

Relationships with these suppliers should be developed due to the importance of the strategic items and high willingness and capability. As strategic items are the crucial products for the buyer and very few suppliers have enough knowledge to supply them, if it is possible to purchase supplier shares and be partners in their ownership and management, it is suggested that this investment be occurred by considering the other necessary points. The other strategy is long-term commitment since they are the most important suppliers for strategic items.

Group 7 (SPM2 - PPM3): three suppliers

This segment has the best suppliers for non-critical items. Extending the relationship to encompass other items (Rezaei and Fallah Lajimi, 2019) can make them a suitable alternative for suppliers with low capability or willingness. Developing relationships is the most reasonable strategy with this group.

Group 8 (SPM2 - PPM4): four suppliers

Enhancing the relationship (Rezaei and Fallah Lajimi, 2019) and Long-term contracts could be the most appropriate strategy with these suppliers. Due to high capability and willingness, relationships should be developed with them. These are the most important suppliers for bottleneck items.

Group 9 (SPM3 - PPM1): six suppliers

Leverage items supplied from suppliers have low capability and willingness in this segment. These items could easily be purchased from another supplier. Then the best strategy is the replacement.

Group 10 (SPM3 - PPM2): four suppliers

Since strategic items play a crucial role in making a profit in products, these suppliers need to be replaced by the other options. If there is no other supplier to replace, financial and physical investment (Rezaei *et al.*, 2015) could be the right strategy.

Group 11 (SPM3 - PPM3): three suppliers

As the supply risk of non-critical items is low and many other suppliers are able to supply them, the best strategy is "replacement".

Group 12 (SPM3 - PPM4): ten suppliers

A few suppliers may supply bottleneck items. If it is possible, replacement is the best strategy due to the low capability of this group. Otherwise, the buyer can persuade the supplier to work on some sub-criteria like using more environmentally friendly materials or improving delivery time.

Group 13 (SPM4 - PPM1): four suppliers

Due to the nature of leverage items in easy purchase from other suppliers, it is better to replace this group with other suppliers.

Group 14 (SPM4 - PPM2): one supplier

Because of the high willingness of suppliers in this segment, the company can raise suppliers' capability through transferring knowledge or investment. However, replacement is recommended strategy if another supplier can supply this strategic item.

Group 15 (SPM4 - PPM3): four suppliers

Assuming that it is easy to supply non-critical items, the best strategy with low-capability suppliers is "replacement".

Group 16 (SPM4 - PPM4): three suppliers

This group of suppliers cannot be replaced because the items that they supply are bottleneck items. Therefore, encouraging suppliers to improve knowledge and skills, sharing information and Supplier Empowerment Programs are the best strategies.

4.3 Managerial insights

This study integrates sustainability considerations to supplier segmentation problem in a hybrid approach. Moreover, the *K*-means clustering method is employed to segment the suppliers. These characteristics of this study differ from published literature in this field. Some studies considered sustainable dimensions in the supplier management area, but most (Bai *et al.*, 2017; Rezaei *et al.*, 2017) focused only on the green dimension. In this study, the triple bottom line of sustainability is taken into account.

The proposed approach boosts the feasibility of managing supplier relationships concerning sustainable development. Suppliers are evaluated and segmented based on four dimensions presented in this study. Implementing a sustainable approach in supplier relationships management was a real challenge for our case. Sustainability as an integrated point of view requires all departments' participation. The presented sustainable supplier segmentation is a practical tool which eliminating complexity and presenting the possibility of convenient execution. Practitioners can add (or eliminate) sub-criteria to employ the customized version of the proposed model on their firms easily based on their situation. Diverse strategies are developed for different supplier segments; each supplier's suitable program is planned based on the cluster belongings. The proposed strategies based on the presented supplier segmentation can be employed with the current approach for every case. The company achieves sustainable goals through its relationships with the suppliers. The case study aimed to improve their brand image and attract the consumers' attention. The proposed method helps business owners to elevate their sustainable insight.

4.4 Research limitations

While this study seeks to contribute valuable insights into sustainable supplier segmentation, it is essential to acknowledge certain limitations that could impact the interpretation and generalizability of the findings. These limitations underscore the complexities inherent in research endeavors and provide avenues for future investigations to refine and expand upon the current framework.

One primary limitation pertains to the scope of the case study. The research is centered around a single kitchen appliance company located in Isfahan province, Iran, which may limit the generalizability of the results to a broader context. While the insights gained are valuable for the specific company under investigation, the applicability of the proposed clustering-based approach to sustainable supplier segmentation should be further explored across diverse industries and geographic regions.

Furthermore, the availability and accuracy of data play a crucial role in the precision of the proposed model. In this study, the analysis heavily relies on supplier characteristics, purchased item attributes and sustainability-related sub-criteria. Any discrepancies or inaccuracies in the data used for analysis could potentially introduce bias or limitations to the results. Future research should consider employing robust data validation processes and exploring alternative data sources to enhance the accuracy of the model.

The application of the *K*-means clustering algorithm, while effective in segmenting suppliers based on selected criteria, might not capture all nuances within the data. The algorithm's reliance on distance metrics for clustering could potentially overlook intricate patterns or relationships that could be better captured by more advanced clustering techniques. Therefore, future studies could explore the utilization of alternative clustering algorithms to validate and enhance the segmentation outcomes.

Another limitation to consider is the evolving nature of sustainability considerations and supplier relationships. The sub-criteria identified for sustainable supplier segmentation in this study are based on the current state of the literature and industry practices. However, as sustainability evolves and companies adopt new practices, the relevance and significance of these sub-criteria may change. Continuous monitoring and updating of the segmentation criteria are essential to ensure their alignment with contemporary sustainability trends.

In conclusion, while this study contributes a novel approach to sustainable supplier segmentation, it is imperative to recognize the limitations inherent in any research endeavor. The specific context of the case study, potential data biases, algorithmic constraints and the dynamic nature of sustainability considerations all contribute to the boundaries within which the findings should be interpreted. These limitations present opportunities for future research to refine and expand upon the proposed model, ensuring its applicability and relevance across various scenarios.

5. Conclusion

After analyzing the literature on supplier segmentation, no study was found for segmenting suppliers sustainably using clustering methods and hybrid approaches. In this research, appropriate sub-criteria for sustainable supplier segmentation are provided. Some of the criteria are sub-selected from the related literature, and the rest of them are defined as a new sustainable segmentation sub-criterion for the first time. A group including the supply management team and the company managers was formed to score the sub-criteria for each supplier. BWM is employed to change the importance of each qualitative sub-criterion to the quantitative weights. Then by using the *K*-means algorithm, suppliers were clustered based on PPM and SPM. Segmenting through preset boundary scores may cause an imprecise segmentation that leads to the subsequent implementation of wrong policies for suppliers. Clustering determines appropriate boundary scores to all scores. Because of considering all aspects of sustainability and defining sub-criteria concerning sustainable development, the results of sustainable segmentation are different from economic segmentation. In the end, the best strategies for each group are suggested. Considering sustainable development may place more suppliers in low parts than economic segmentation. Cluster-based segmentation considers all the features simultaneously and compares data much better than other approaches. Segmenting suppliers through clustering considers each supplier's characteristics and compares scores of all suppliers with each other. Therefore, using clustering algorithms for segmentation is more efficient.

In the supplier segmentation subject, many studies are using diverse methods. While each of those methods could be used for different segmentation approaches. For future studies, defining new approaches for supplier segmentation or combining recently presented approaches could be considered. In many cases, a supplier concerning various characteristics and products cannot be allocated to a single segment. Therefore, different clustering approaches such as fuzzy clustering methods can be used. Other MCDM methods could be implemented to calculate aggregate scores. As is mentioned in the Introduction, there are three kinds of segmentation. Clustering techniques could be used in other segmentations as well. It is also essential to investigate and examine how each strategy can be implemented successfully. It is beneficial to analyze the consequences of using inappropriate strategies for the segments for future studies.

References

Abdollahi, M., Arvan, M. and Razmi, J. (2015), "An integrated approach for supplier portfolio selection: lean or agile?", *Expert Systems with Applications*, Vol. 42, pp. 679-690.

Ahmadi, H.B., Kusi-Sarpong, S. and Rezaei, J. (2017), "Assessing the social sustainability of supply chains using Best Worst Method", *Resources, Conservation and Recycling*, Vol. 126, pp. 99-106.

Amin, S.H. and Razmi, J. (2009), "An integrated fuzzy model for supplier management: a case study of ISP selection and evaluation", *Expert Systems with Applications*, Vol. 36, pp. 8639-8648.

Arabzad, S.M., Razmi, J. and Ghorbani, M. (2011), "Classify purchasing items based on risk and profitability attributes; using MCDM and FMEA techniques", *Research Journal of International Studies*, Vol. 1, pp. 80-85.

Awasthi, A., Chauhan, S.S. and Goyal, S.K. (2010), "A fuzzy multicriteria approach for evaluating environmental performance of suppliers", *International Journal of Production Economics*, Vol. 126, pp. 370-378.

Bai, C. and Satir, A. (2020), "Evaluating green supplier satisfaction", *Modern Supply Chain Research and Applications*, Vol. 2, pp. 63-81.

Bai, C., Rezaei, J. and Sarkis, J. (2017), "Multicriteria green supplier segmentation", *IEEE Transactions on Engineering Management*, Vol. 64, pp. 515-528.

Cousins, P., Lamming, R. and Squire, B. (2008), *Strategic Supply Management: Principles, Theories and Practice*, Pearson Education, ISBN-13: 9781408250235.

Demir, L., Akpınar, M.E., Araz, C. and Ilgın, M.A. (2018), "A green supplier evaluation system based on a new multi-criteria sorting method: VIKORSORT", *Expert Systems with Applications*, Vol. 114, pp. 479-487.

Duan, C.-Y., Chen, X.-Q., Shi, H. and Liu, H.-C. (2019), "A new model for failure mode and effects analysis based on k-means clustering within hesitant linguistic environment", *IEEE Transactions on Engineering Management*, Vol. 69, pp. 1837-1847.

Duc, D.A., Van, L.H., Yu, V.F., Chou, S.-Y., Hien, N.V., Chi, N.T., Toan, D.V. and Dat, L.Q. (2021), "A dynamic generalized fuzzy multi-criteria croup decision making approach for green supplier segmentation", *Plos One*, Vol. 16, e0245187.

Fazlollahtabar, H. and Kazemitash, N. (2022), "Design of Fazl-Tash novel method for sustainable resilient comprehensive supplier selection problem", *Kybernetes*, Vol. 51, pp. 275-301.

Fenson, C., Edin, P. and Holmer, E. (2008), "How purchasing practitioners use the Kraljic matrix", Stockholm School of Economics Masters Thesis.

Ferreira, L.M.D., Arantes, A. and Kharlamov, A.A. (2015), "Development of a purchasing portfolio model for the construction industry: an empirical study", *Production Planning and Control*, Vol. 26, pp. 377-392.

Ghanbarizadeh, A., Heydari, J., Razmi, J. and Bozorgi-Amiri, A. (2019), "A purchasing portfolio model for the commercial construction industry: a case study in a mega mall", *Production Planning and Control*, Vol. 30, pp. 1283-1304.

Gholizadeh, H., Fazlollahtabar, H. and Khalilzadeh, M. (2020), "A robust fuzzy stochastic programming for sustainable procurement and logistics under hybrid uncertainty using big data", *Journal of Cleaner Production*, Vol. 258, 120640.

Govindan, K., Rajendran, S., Sarkis, J. and Murugesan, P. (2015), "Multi criteria decision making approaches for green supplier evaluation and selection: a literature review", *Journal of Cleaner Production*, Vol. 98, pp. 66-83.

Güneri, B. and Deveci, M. (2023), "Evaluation of supplier selection in the defense industry using q-rung orthopair fuzzy set based EDAS approach", *Expert Systems with Applications*, Vol. 222, 119846.

Gupta, H. (2018), "Assessing organizations performance on the basis of GHRM practices using BWM and Fuzzy TOPSIS", *Journal of Environmental Management*, Vol. 226, pp. 201-216.

Heydari, J., Heidarpoor, A. and Sabbaghnia, A. (2020), "Coordinated non–monetary sales promotions: buy one get one free contract", *Computers and Industrial Engineering*, Vol. 142, 106381.

Jain, A.K., Murty, M.N. and Flynn, P.J. (1999), "Data clustering: a review", *ACM Computing Surveys (CSUR)*, Vol. 31, pp. 264-323.

Joyce, A. and Paquin, R.L. (2016), "The triple layered business model canvas: a tool to design more sustainable business models", *Journal of Cleaner Production*, Vol. 135, pp. 1474-1486.

Kraljic, P. (1983), "Purchasing must become supply management", *Harvard Business Review*, Vol. 61, pp. 109-117.

Kusi-Sarpong, S., Sarkis, J. and Wang, X. (2016), "Assessing green supply chain practices in the Ghanaian mining industry: a framework and evaluation", *International Journal of Production Economics*, Vol. 181, pp. 325-341.

Laari, S., Töyli, J., Solakivi, T. and Ojala, L. (2016), "Firm performance and customer-driven green supply chain management", *Journal of Cleaner Production*, Vol. 112, pp. 1960-1970.

Lambert, D.M. and Schwieterman, M.A. (2012), "Supplier relationship management as a macro business process", *Supply Chain Management: An International Journal.*

Large, R.O. and Thomsen, C.G. (2011), "Drivers of green supply management performance: evidence from Germany", *Journal of Purchasing and Supply Management*, Vol. 17, pp. 176-184.

Likas, A., Vlassis, N. and Verbeek, J. (2003), "The global k-means clustering algorithm", *Pattern Recognition*, Vol. 36, pp. 451-461.

Macdonald, L.A. (2005), *Wellness at Work: Protecting and Promoting Employee Health and Wellbeing*, CIPD Publishing.

Modi, S.B. and Mabert, V.A. (2007), "Supplier development: improving supplier performance through knowledge transfer", *Journal of Operations Management*, Vol. 25, pp. 42-64.

Nazeer, K.A. and Sebastian, M. (2009), "Improving the accuracy and efficiency of the k-means clustering algorithm", *Proceedings of the world Congress on Engineering*, Citeseer.

Nguyen, H., Pham, V.K. and Phan, T.T. (2021), "Determinants of export organic supply chain performance: empirical study of fruits and vegetables in Vietnam", *Journal of International Logistics and Trade*, Vol. 19, pp. 147-161.

Oghazi, P., Rad, F.F., Zaefarian, G., Beheshti, H.M. and Mortazavi, S. (2016), "Unity is strength: a study of supplier relationship management integration", *Journal of Business Research*, Vol. 69, pp. 4804-4810.

Padhi, S.S., Wagner, S.M. and Aggarwal, V. (2012), "Positioning of commodities using the kraljic portfolio matrix", *Journal of Purchasing and Supply Management*, Vol. 18, pp. 1-8.

Pagell, M., Wu, Z. and Wasserman, M.E. (2010), "Thinking differently about purchasing portfolios: an assessment of sustainable sourcing", *Journal of Supply Chain Management*, Vol. 46, pp. 57-73.

Park, J., Shin, K., Chang, T.W. and Park, J. (2010), "An integrative framework for supplier relationship management", *Industrial Management and Data Systems*.

Parkouhi, S.V., Ghadikolaei, A.S. and Lajimi, H.F. (2019), "Resilient supplier selection and segmentation in grey environment", *Journal of Cleaner Production*, Vol. 207, pp. 1123-1137.

Puška, A. and Stojanović, I. (2022), "Fuzzy multi-criteria analyses on green supplier selection in an agri-food company", *Journal of Intelligent Management Decision*, Vol. 1, pp. 2-16.

Razmi, J., Rafiei, H. and Hashemi, M. (2009), "Designing a decision support system to evaluate and select suppliers using fuzzy analytic network process", *Computers and Industrial Engineering*, Vol. 57, pp. 1282-1290.

Rezaei, J. (2015), "Best-worst multi-criteria decision-making method", *Omega*, Vol. 53, pp. 49-57.

Rezaei, J. (2016), "Best-worst multi-criteria decision-making method: some properties and a linear model", *Omega*, Vol. 64, pp. 126-130.

Rezaei, J. and Fallah Lajimi, H. (2019), "Segmenting supplies and suppliers: bringing together the purchasing portfolio matrix and the supplier potential matrix", *International Journal of Logistics Research and Applications*, Vol. 22, pp. 419-436.

Rezaei, J. and Ortt, R. (2012), "A multi-variable approach to supplier segmentation", *International Journal of Production Research*, Vol. 50, pp. 4593-4611.

Rezaei, J. and Ortt, R. (2013), "Supplier segmentation using fuzzy logic", *Industrial Marketing Management*, Vol. 42, pp. 507-517.

Rezaei, J., Kadziński, M., Vana, C. and Tavasszy, L. (2017), "Embedding carbon impact assessment in multi-criteria supplier segmentation using ELECTRE TRI-rC", *Annals of Operations Research*, Vol. 312, pp. 1-23.

Rezaei, J., Wang, J. and Tavasszy, L. (2015), "Linking supplier development to supplier segmentation using Best Worst Method", *Expert Systems with Applications*, Vol. 42, pp. 9152-9164.

Rius-Sorolla, G., Estelles-Miguel, S. and Rueda-Armengot, C. (2020), "Multivariable supplier segmentation in sustainable supply chain management", *Sustainability*, Vol. 12, p. 4556.

Sabbaghnia, A., Heydari, J. and Razmi, J. (2023), "Participative pricing and donation programs in a socially concerned supply chain", *Corporate Social Responsibility and Environmental Management*, Vol. 30, pp. 146-164.

Segura, M. and Maroto, C. (2017), "A multiple criteria supplier segmentation using outranking and value function methods", *Expert Systems with Applications*, Vol. 69, pp. 87-100.

Silva, M.E., Fritz, M.M.C. and El-Garaihy, W.H. (2022), "Practice theories and supply chain sustainability: a systematic literature review and a research agenda", *Modern Supply Chain Research and Applications*, Vol. 4, pp. 19-38.

Smeltzer, L.R. (1997), "The meaning and origin of trust in buyer-supplier relationships", *International Journal of Purchasing and Materials Management*, Vol. 33, pp. 40-48.

Wu, Q., Zhou, L., Chen, Y. and Chen, H. (2019), "An integrated approach to green supplier selection based on the interval type-2 fuzzy best-worst and extended VIKOR methods", *Information Sciences*, Vol. 502, pp. 394-417.

Xia, Y. (2011), "Competitive strategies and market segmentation for suppliers with substitutable products", *European Journal of Operational Research*, Vol. 210, pp. 194-203.

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