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Supplier Selection in Family Small and Medium Enterprises:

Modelling the Priority Attributes With an Integrated Entropy-MARCOS (E-MARCOS) Method

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ABSTRACT

Current literature on family businesses and small and medium enterprises (SMEs) offers some disintegrated insights in view of managing supply chains, particularly the supplier selection agenda. The presence of distinct characteristics inherent to both enterprises calls for a new line of inquiry regarding supplier selection for family SMEs. This work advances the literature by (1) identifying a set of supplier selection attributes best encapsulating the interests of family SMEs, and (2) evaluating these attributes to guide relevant decision-making. With a case study in the food industry and previous lists of supplier selection attributes, ten attributes were considered relevant to family SMEs. Applying the hybrid entropy-MARCOS method yields the priority attributes in decreasing order: on-time delivery, total service quality, product quality, productivity, attitude, response to customer requests, problem-solving capacity, payment terms, price, and flexibility. An analysis with other comparable methods suggests high consistency of these findings. Theoretical insights were discussed.

KEYWORDS

Entropy Method, Family Businesses, MARCOS Method, Small and Medium Enterprises, Supplier Selection

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INTRODUCTION

In the least-developed economies, small and medium enterprises (SMEs) are considered major drivers of employment growth and poverty alleviation (Maksimov et al., 2017; El Hakioui & Louitri, 2017). In a recent report by Tambunan (2019), SMEs, including micro-enterprises, dominate almost all existing firms in Indonesia, contributing to at least 58% of the country's gross domestic product (GDP). Recent analysis positively relates SMEs with the overall wealth of society and demand for more diversified products (Frąckiewicz, 2018). They also induce market competition and are linked to absorbing shocks following a recession (Frąckiewicz, 2018). Empirical insights of Maksimov et al. (2017) in some underdeveloped economies in Africa, Asia, and the Middle East yield that those SMEs securing government contracts, exporting goods to foreign markets, or are female owned, have greater socio-economic contributions, especially in attaining business efficiency and providing higher compensation to their employees. Despite their role in the economy, however, SMEs are exposed to external pressing factors in the global environment including intensified market competition, global financial crises, the advent of information and communication technologies (ICTs), the rise of multi-national companies and transnational corporations, changes in consumer behaviors, trade dumping, terrorism, religious conflicts, and trade wars (Naradda Gamage et al., 2020).

Compared to their counterparts in large firms, SMEs have greater constraints in achieving economies of scale and lower bargaining power and competition (Tong et al., 2022), making them more susceptible to higher transaction costs (Kull et al., 2018). Most reports show SMEs to have limited access to capital, raw materials, information technologies, and marketing of products and services. They also have limited access to guidance from the government while having high interest rates imposed upon them (Eravia & Handayani, 2015). Larger businesses have greater access to information and technological resources. Those determinants of firm size, export orientation, government support, and labor productivity are crucial to profitability (Pilar et al., 2018), aside from motivation in entrepreneurship, education, technologies, and human resource, which have been identified as influencing factors of success (Kurniawati & Yuliando, 2015; Eravia & Handayani, 2015). Frąckiewicz (2018) offered a comprehensive characterization of SMEs, while Yamagishi et al. (2021) outlined their characteristics.

Due to their nontrivial contributions to economic development, SMEs have drawn sustained interest from scholars over the last few decades. The current trends of SME research are identified in five directions; however, the vastness of the field warrants a separate overarching review and bibliometric analysis. First, the capacity of SMEs for innovation is critical to gaining competitive advantage during turbulent times, and initial insights suggest public funding and external support are important contributors (De Martino & Magnotti, 2018; Adam & Alarifi, 2021).

Second, an emerging stream of research focuses on the social responsibility of SMEs (De Zoysa & Takaoka, 2020; Guillén et al., 2022), and a consensus suggests that the performance of SMEs is low but growing.

Third, following the ubiquity of ICTs, the digitalization of SMEs is an important topic in scholarly literature (e.g., Singh et al., 2019; Tóth et al., 2020; Putra & Santoso, 2020). In a case from India, Singh et al. (2019) found that government initiatives and policies, public-private partnerships, and encouragement for ICT service providers are key factors in leapfrogging the digitalization of SMEs.

Fourth, in relation to previous insights regarding the potential differences in the response of firms in view of their sizes (Ocampo, 2017; Ocampo, 2018), recent research themes of SMEs highlight the aspects of sustainability and circular economy (Kot, 2018; Broccardo & Zicari, 2020; Dey et al., 2020). Insights of Broccardo and Zicari (2020) emphasized that sustainability-conscious SMEs pursue initiatives to retain customer loyalty, not reduce costs. Meanwhile, Kot (2018) found that SMEs have a better understanding of the sustainability agenda.

Lastly, considering the challenges inherent in SMEs, the intricacies of the supply chain have forged interests in better understanding the supply chain management of SMEs (Kull et al., 2018;

Asamoah et al., 2020; Tóth et al., 2020). In addition to the challenges for SMEs, the current consensus in the synergistic domain and managing supply chains suggests that SMEs have more diverse goals than large firms. Those may be financial, human, and social capital. When taken together it forms unique resources and liabilities (Kull et al., 2018). Also, the governance structure of most SMEs results in a design that alienates managers from greater market scrutiny and therefore induces greater discretion to respond promptly to idiosyncrasies in strategy formulation, operations planning, and control establishment (Kull et al., 2018).

With the ubiquity of family businesses in SMEs (Jayaram et al., 2014), interest in family business research has been increasing over the last 30 years (Rovelli et al., 2022). Family businesses, whether SMEs or large enterprises, dominate worldwide with a global GDP contribution of 70-80% (Maloni et al., 2017). Two-thirds of India's GDP comes from family businesses, while 85% of private firms in China are owned by families (Family Firm Institute, 2015). European Family Businesses (2016) defines a family business as a firm where "the majority of decision-making rights are in the possession of the natural person(s) who established the firm, or in the possession of the natural person(s) who has/have acquired the share capital of the firm, or in the possession of their spouses, parents, child or children's direct heirs."

Maloni et al. (2017) outlined some characteristics of family businesses including (1) having long-term orientation, being conservative when making fiscal decisions, and risk averseness, (2) eliciting a strong intention to preserve financial and non-financial benefits for family members, (3) translating similar ties with external stakeholders to develop longstanding relationships among generations, (4) embodying organizational isomorphism, (5) having the capacity to make quicker decisions towards business opportunities than their non-family firm counterparts, and (6) retaining greater control of cash for reinvestment. Concerning why family businesses possess these characteristics and perform differently from non-family firms becomes a prominent issue in the domain literature, as Benavides-Velasco et al. (2013) posited. The consensus entails that family firms differ significantly from their non-family counterparts due to their diversity of goals, particularly with the presence of idiosyncratic non-economic goals (Maloni et al., 2017; Darby et al., 2022). Non-financial goals include family legacy, long-term sustainability, and socio-economic wealth, as outlined by Maloni et al. (2017). Insights of previous reports suggest that goals such as family firm image and family involvement impact the innovation potential of family businesses (Arzubiaga et al., 2019; Dangelico et al., 2019) because family firms differ in motivations, most relevant pressures, and innovation view than the non-family counterparts (Dangelico et al., 2019). Empirical reports show non-financial goals may stimulate a better performance of family businesses (Broccardo & Zicari, 2020). However, some setbacks are recognized because the motivation for change gradually dissipates with each generation. Viewing creativity and innovation becomes of lower importance and increases the risk of management ineffectiveness and lack of professionalism due to nepotism (Maloni et al., 2017).

Research on family businesses has been widespread to include initiatives associated with internationalization (Rexhepi et al., 2017), marketing (Ghouri et al., 2020), technology adoption (Hendayani & Febrianta, 2020), strategic adaptation to the external environment (Duarte Alonso et al., 2018), among other things. Following the extent that family firms contribute to the economy (Bergamaschi & Randerson, 2016; Chahal & Sharma, 2020) and the complexity of supply chains, several reports highlighted critical insights (Jayaram et al., 2014; Maloni et al., 2017; Hendayani & Febrianta, 2020; Darby et al., 2022). Hendayani and Febrianta (2020) empirically found the significant role of technology in the effectiveness of the supply chain of family businesses. Maloni et al. (2017) offered an array of testable propositions regarding the behavior of family firms in supply chain management including financial performance, outsourcing decisions, supplier integration and partnerships, supplier relationships, and the moderating roles of firm size and firm age. An extension of this line of inquiry rests between the intersection of SMEs and family businesses, which can bring forth a host of differences in their views of managing supply chains. Such a characteristic may combine the inherent behavior of SMEs and the perspectives of family businesses. Attempts at exploring this intersection were reported in the literature (e.g., Jayaram et al., 2014; Ghouri et al., 2020; Darby et al., 2022).

Following a multiple-case study approach, Jayaram et al. (2014) proposed a structural model that integrates the constructs related to family businesses (i.e., attitude toward growth, risk appetite, and professional management) and constructs associated with supply chain management (i.e., information system and supply chain capability). The proposed model highlights six overarching theoretical relationships that capture the integration of SMEs and family businesses in managing supply chains. In the case of the farm echelon, where small-medium farms owned by families are prevalent, Darby et al. (2022) found that resource constraints and diversity of objectives compel farmers to use intuition and experience in decision-making. Their findings also suggest that resource constraints magnify the role of non-financial objectives, leading farmers to prioritize non-economic aspects of the institutional environment.

The latest findings of Darby et al. (2022) have linked previously fractured insights of SMEs and family businesses research especially in supplier selection agenda with supply chains. For instance, the insights of Tóth et al. (2020) suggest that SMEs, specifically smaller ones, only require less elaborate marketing (e.g., company logos) along with word-of-mouth recommendations to evoke attractiveness in partner selection. This finding may be linked to the resource constraint limitations suggested by Darby et al. (2022). On the other hand, Maloni et al. (2017), building on previous findings, described that family businesses choose suppliers sharing similar long-term relational and family orientations, emphasizing the diversity of non-financial objectives of family firms. The empirical insights of Darby et al. (2022) opened a new line of inquiry into the supplier selection problem of family SMEs. This implies that criteria previously identified for SMEs such as product quality, supplier responsiveness, and strategic consideration (Su & Gargeya, 2016) or cost, credit and corporate irregularities (Tong et al., 2022) must be updated to reflect the integration of the characteristics of both SMEs and family businesses. This present work attempts to fill in such a gap in the literature.

The supplier selection problem is widely studied in the literature, including the set of tools guiding decision-makers in addressing the problem. Recent reviews (e.g., Zimmer et al., 2016; Ocampo et al., 2018; Schramm et al., 2020) agree, underscoring the popularity of multi-attribute decision-making (MADM) methods in handling supplier selection problems under various domains. The main motivation lies in the strength of MADM tools in capturing a complex decision-making process in the presence of multiple attributes and alternatives. The problem resembles a hierarchy where a predefined number of alternatives are evaluated under multiple, even conflicting, attributes. The process involves a two-step approach: (1) assigning attribute weights using a given weight-generating MADM tool (e.g., analytic hierarchy process [AHP], best-worst method [BWM], weighted averaging method [WAM]) and (2) evaluating the alternatives by utilizing the same or a different MADM tool (e.g., Technique for Order of Preference by Similarity to Ideal Solution [TOPSIS]), as in the case of hybrid methods. The second part of the process is highly case-specific (i.e., selects the best supplier for a given problem). In most models a fuzzy environment is incorporated into the MADM problem for handling data imprecision and uncertainty; although concerns were raised about incorporating fuzzy sets, particularly in the AHP (Saaty & Tran, 2007; Zhü, 2014).

Several recent works were reported on the use of MADM tools in supplier selection problems. Gupta et al. (2018) conducted a supplier selection problem in the context of innovativeness. They adopted the BWM for the first step subproblem, while fuzzy TOPSIS was utilized for the second step. They identified priority criteria or attributes such as technological resources, employee training, and an effective reward system. Following the operations on fuzzy numbers for weighting the criteria, Yadav et al. (2018) used fuzzy TOPSIS for ranking the suppliers in a manufacturing SME. They incorporated quality, service, delivery, price, and environmental responsibility as criteria or attributes. A similar approach to fuzzy TOPSIS was utilized by Rahpeyma and Zarei (2018) to evaluate the suppliers of a detergent manufacturing industry. Chang (2019) proposed an intuitionistic fuzzy WAM for a supplier selection problem with missing or nonexistent data. Khan and Faisal (2015) illustrate a grey theory-based approach in an enterprise-resource-planning vendor-selection problem. Fei et al. (2019) introduced the integration of the entropy method for assigning the weights of the attributes and the ÉLimination Et Choix Traduisant la REalité (ELECTRE) method for evaluating the suppliers, where data are expressed under Dempster Shafer theory. De Araújo et al. (2015) considered a supplier selection problem under a group environment while utilizing the Preference Ranking for Organization Method for Enrichment Evaluation (PROMETHEE), or PROMETHEE-group decision support system (GDSS), for identifying priority suppliers. Under an interval 2-tuple linguistic environment, Wan et al. (2017) utilized the computational framework of the analytic network process (ANP) for prioritizing the supplier selection attributes, while ELECTRE II was adopted for evaluating the suppliers. More recently, Mahmoudi et al. (2022) proposed the adoption of a fuzzy ordinal priority approach (OPA) for a green and resilient supplier selection problem. Tong et al. (2022), while incorporating the dimensions of product and service capability, cooperation degree and risk factors, adopted an extended PROMETHEE II for sustainable supplier selection problem for SMEs. The preceding list of MADM applications for supplier selection is not comprehensive.

This work contributes to the supplier selection problem in two ways. First, it identifies a list of supplier selection attributes that represent the intricacies of family SMEs, which have limited insights in the literature. Second, it evaluates the list of attributes for family SMEs to identify priority attributes that could be used as inputs for informed decision-making. The latter is positioned in the first step of the previously described two-step approach to using MADM tools in supplier selection problems. In evaluating the attributes, this work adopts a hybrid approach involving the entropy method and the recently developed Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS). The entropy method is based on the Shannon entropy and hinges on the concept of diversity of attribute data (DAD) in a given evaluation (Chen, 2021). Attributes with higher DAD are assigned higher weights. The entropy method is widely used in the generation of attribute weights within a MADM problem (Azadfallah, 2018). In the supplier selection problem literature, it is used in weighting the attributes to evaluate the suppliers of new agricultural machinery products (Lu et al., 2019), green furniture (Dos Santos et al., 2019), oil and gas (Kaviani et al., 2020), petroleum products (Wood, 2016), and building materials (Chen, 2019a) among hundreds of works in the general MADM application literature.

The advantage of the entropy method lies in its computational convenience and tractability, even in large-scale decision-making, compared with its counterparts AHP and BWM, which require a high cognitive workload in the judgment elicitation process. On the other hand, the MARCOS method was proposed by Stević et al. (2020) to deal with a MADM problem with a high number of decision criteria or attributes. Compared with other methods, the MARCOS method is more flexible, and computationally easier, as the decision problem incorporates more attributes. It integrates two major actions present in most MADM methods: (1) the ratio method and (2) the reference point method. As outlined by Stević et al. (2020), the MARCOS method defines reference points, determines the relationships between the alternatives and the reference points, and evaluates the utility degrees of these relationships. Recent applications of the MARCOS method include the evaluation of sustainability performance (Badi et al., 2022), renewable energy sources (Karaaslan et al., 2022), lithium battery plants (Hashemkhani Zolfani et al., 2022), human resources (Stević & Brković, 2020), and railway projects (Bouraima et al., 2021), among other things. The integration of entropy and MARCOS methods, termed E-MARCOS, in evaluating supplier selection attributes for family SMEs is demonstrated here in an actual case study in the food industry. Identifying these priority attributes help guide family SMEs in their supplier selection problems, which eventually become inputs to resource allocation decision, planning, and performance evaluation.

The remainder of this paper is arranged as follows. The Preliminaries section presents concepts of the entropy and MARCOS methods. The Methods section outlines the case study information, the application of the E-MARCOS to the case study, and a comparative analysis with the results of other comparable MADM methods. Discussion of results and the theoretical implications of the findings will follow. It ends with concluding remarks and a discussion of future works in the concluding section.

PRELIMINARIES

This section presents a brief background of entropy and MARCOS methods. The details are intended to make this article self-containing, leaving out more detailed concepts of the topics. Thus, readers are encouraged to refer to previous discussions on the entropy method as applied in MADM problems (Lotfi & Fallahnejad, 2010) and the introductory work of the MARCOS method (Stević et al., 2020).

The Entropy Method

Commonly known as Shannon entropy or information entropy, entropy in information is used to evaluate the content of the information of a given message (Shannon, 1948). In the context of the MADM, the decision matrix $X = \left(x_{ij}\right)_{m\times n}$, where x_{ij} reflects the evaluation for the alternative i $\left(i = 1,\ldots,m\right)$ with respect to the attribute (or criterion) j $\left(j = 1,\ldots,n\right)$, contains an amount of information; thus, the entropy can be used to evaluate the attribute (Nijkamp, 1977). The entropy method then uses the information entropy to measure the diversity of attribute data (DAD) among a given set of alternatives (Chen, 2019b; Chen, 2019c). The higher the DAD of the attribute becomes, the larger the weight assigned to the attribute (Chen, 2019b; Chen, 2019c). In effect, the weights of the attributes obtained through the entropy method only represent the difference in the DAD of the attributes and should not be generally used to reflect the actual importance of the attributes (Li et al., 2017; Chen, 2021). When the actual importance of the attributes is desired, then the entropy method cannot be directly used (Chen, 2021), and subjective weighting methods such as the AHP (Saaty, 1980), the criteria importance through inter-criteria correlation (CRITIC) (Diakoulaki et al., 1995), the BWM (Rezaei, 2015), full consistency method (Pamučar et al., 2018), among others, are deemed more appropriate. However, if the subjective preference can be ignored, then the entropy method can be used to represent the attribute weights (Lotfi & Fallahnejad, 2010; Chen, 2021). Due to its simplicity, its application within MADM is widespread (e.g., Kaviani et al., 2020; Wu et al., 2021; Yusuf et al., 2022).

The following steps present the computational procedure for obtaining the attribute weights using the entropy method:

Step 1: Given a decision matrix $X = \left(x_{ij}\right)_{m\times n}$, obtain the normalized decision matrix $R = \left(r_{ij}\right)_{m\times n}$, where:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{1}$$

The resulting r_{ij} values become dimensionless and allow for comparisons among attributes.

Step 2: Compute the information entropy h_j of each attribute j using:

$$h_j = -h_0 \sum_{i=1}^{m} r_{ij} \ln r_{ij}\,,\ \forall j = 1,\ldots,n \tag{2}$$

where $h_0 = \dfrac{1}{\ln m}$ is the entropy constant and $r_{ij} \ln r_{ij}$ is defined as 0 whenever $r_{ij} = 0$ for any $i = 1,\ldots,m$ and $j = 1,\ldots,n$.

Step 3: Calculate the degree of diversification of each attribute j.

The degree of diversification is denoted as:

$$d_j = 1 - h_j,\ \forall j = 1,\ldots,n \tag{3}$$

Step 4: Obtain the entropy weight w_j for each j which is represented by:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{4}$$

Here, $0 \le w_j \le 1$ ($\forall j$) and $\sum_{j=1}^{n} w_j = 1$.

The MARCOS Method

Recently developed by Stević et al. (2020), the MARCOS method centers on the idea of ideal and negative ideal solutions from the decision matrix that portrays the evaluation of the alternatives under different attributes. Unlike the popular TOPSIS method (Hwang & Yoon, 1981), which uses Euclidean distance in evaluating each alternative against these solutions, the MARCOS method hinges on the utility functions as bases for defining decision preferences. In its computational framework, the utility functions represent the position of an alternative with respect to the reference values (i.e., ideal and negative ideal solutions). And then the best alternative is closest to the ideal solution and farthest from the negative ideal solution.

The algorithm of the MARCOS method is presented in the following steps:

Step 1: Initialize the decision matrix $X = \left(x_{ij}\right)_{m \times n}$, where x_{ij} denotes the evaluation of the performance of the alternative i under attribute j. The sets of m alternatives and n attributes are defined by the specific MADM domain problem.

Step 2: Form an extended decision matrix by defining the ideal solution A^+ and the negative ideal solution A^-. Equation (5) shows the extended decision matrix:

$$\tilde{X} = \begin{matrix} A^- \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ A^+ \end{matrix} \begin{pmatrix} x_1^- & x_2^- & \cdots & x_n^- \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \\ x_1^+ & x_2^+ & \cdots & x_n^+ \end{pmatrix} \tag{5}$$

The reference values A^+ and A^- are defined in Equation (6) and Equation (7), respectively:

$$A^{-}=\left\{x_{j}^{-}:j=1,\ldots,n\right\}=\left\{\left(\min_{i} x_{ij}:j\in C_{B}\right),\left(\max_{i} x_{ij}:j\in C_{C}\right):x_{ij}\in X\right\} \tag{6}$$

$$A^{+}=\left\{x_{j}^{+}:j=1,\ldots,n\right\}=\left\{\left(\max_{i} x_{ij}:j\in C_{B}\right),\left(\min_{i} x_{ij}:j\in C_{C}\right):x_{ij}\in X\right\} \tag{7}$$

where C_B is the set of maximizing attributes and C_C is the set of minimizing attributes.

Step 3: Normalize the extended decision matrix $\tilde{X}$. The elements of the normalized decision matrix $n_{ij} \in N$, are obtained by means of the following equations:

$$N=\begin{matrix} A^{-} \\ A_{1} \\ A_{2} \\ \cdots \\ A_{m} \\ A^{+} \end{matrix}\begin{pmatrix} n_{1}^{-} & n_{2}^{-} & \cdots & n_{n}^{-} \\ n_{11} & n_{12} & \cdots & n_{1n} \\ n_{21} & n_{22} & \cdots & n_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ n_{m1} & n_{m2} & \cdots & n_{mn} \\ n_{1}^{+} & n_{2}^{+} & \cdots & n_{n}^{+} \end{pmatrix} \tag{8}$$

$$n_{ij}=\frac{x_{j}^{+}}{x_{ij}} \ \forall j\in C_{c} \tag{9}$$

$$n_{ij}=\frac{x_{ij}}{x_{j}^{+}} \ \forall j\in C_{B} \tag{10}$$

where $x_{ij} \in X$.

Step 4: Obtain the weighted decision matrix $V=\left(v_{ij}\right)_{m'\times n}$, where $m'=m+2$. It is carried out by multiplying each element of N by its corresponding criterion weight w_j. Specifically:

$$V=\begin{matrix} A^{-} \\ A_{1} \\ A_{2} \\ \cdots \\ A_{m} \\ A^{+} \end{matrix}\begin{pmatrix} v_{1}^{-} & v_{2}^{-} & \cdots & v_{n}^{-} \\ v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \\ v_{1}^{+} & v_{2}^{+} & \cdots & v_{n}^{+} \end{pmatrix}$$

$$v_{ij} = n_{ij} * w_j \ \forall i, j \tag{11}$$

Step 5: Compute the utility degree of the alternatives, denoted as $K_i = \left(K_i^-, K_i^+\right)$ for $i = 1, \ldots, m$.

Let S_i be the row sum of the elements in V such that:

$$S_i = \sum_{j=1}^{n} v_{ij} \ \forall i \tag{12}$$

and S^- and S^+ as:

$$S^- = \sum_{j=1}^{n} v_j^- \tag{13}$$

$$S^+ = \sum_{j=1}^{n} v_j^+ \tag{14}$$

then the utility degrees of an alternative i are given below:

$$K_i^- = \frac{S_i}{S^-} \ \forall i \tag{15}$$

$$K_i^+ = \frac{S_i}{S^+} \ \forall i \tag{16}$$

Step 6: Determine the utility function $f\left(K_i\right)$ of the alternatives. It is the compromise of the alternative under consideration with respect to the ideal and negative ideal solutions. Equation (17) defines $f\left(K_i\right)$:

$$f\left(K_i\right) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1 - f\left(K_i^-\right)}{f\left(K_i^-\right)}} \ \forall i \tag{17}$$

where $f\left(K_i^+\right)$ is the utility function of the alternative i with respect to the ideal solution, while $f\left(K_i^-\right)$ is the utility function of the alternative i with respect to the negative ideal solution. These utility functions are obtained by:

$$f\left(K_i^+\right) = \frac{K_i^-}{K_i^+ + K_i^-} \ \forall i \tag{18}$$

$$f\left(K_i^-\right) = \frac{K_i^+}{K_i^+ + K_i^-} \ \forall i \tag{19}$$

Step 7: Rank the alternatives. The ranking of the alternatives is based on the utility functions $f\left(K_i\right)$, $i = 1, \ldots, m$. The best alternative has the largest value of $f\left(K_i\right)$.

METHODS

Case Study Information

Due to the vital role of suppliers to effectively managing supply chains, supplier selection attributes or criteria were widely studied in the domain literature. For brevity, an extensive literature review that would generate an overarching list of these attributes is skipped here. Instead, a reference to earlier works that comprehensively identify these attributes is adopted. Three highly cited articles become the bases of our comprehensive list including the popular works of Ha and Krishnan (2008), Liao and Kao (2011), and Abdolshah (2013). In summary, their works independently performed a comprehensive literature review of supplier selection criteria or attributes in supply chain management. Overlaps on their lists exist, and the summary, along with their assigned codes for easier recall, is shown in the Appendix. The list yields 48 supplier selection attributes.

The list of attributes is mapped to the characteristics of family businesses belonging to SMEs within the context of supply chain management. An important finding of the work of Jayaram et al. (2014) in extracting constructs relevant to family SMEs in supply chains suggests three crucial characteristics that could be used to differentiate family SMEs in view of how they manage supply chains. These include concepts such as attitude towards growth, risk appetite, and professional management. Attitude towards growth is associated with the perception of the owner towards the growth potential of the business. This perception drives the owner to pursue initiatives such as improving business processes, entering new markets, and achieving profitability, which lend to business growth. With a highly centralized decision-making structure, the entrepreneurial motivation of the owner or its attitude towards growth is crucial to the growth of food family SMEs in general. Risk appetite is the risk-taking or risk-aversion behavior of the owner of the family SMEs. Jayaram et al. (2014) found that if the attitude of the owner towards growth is pessimistic, it tends to be risk averse. Owners who are optimistic about their business growth take more risks, such as expanding business operations and investing in information system capabilities, which are crucial for managing supply chains effectively. Jayaram et al. (2014) placed emphasis on professional management following Stewart and Hitt (2012), who argued that family businesses should have a degree of professionalism just like non-family firms. Succeeding empirical findings in the literature suggest that the professionalization of family businesses including increased non-family involvement, investing in human resource information systems, and decentralization of structure (Dekker et al., 2015) and standardization (Tan, 2021) has a positive effect on firm performance (Dekker et al., 2015; Costa et al., 2022; Polat & Benligiray, 2022).

In this study, two sets of research participants were considered. The first set is composed of 50 participants who are involved with family-owned businesses categorized as SMEs (e.g., management consultants, management practitioners, business owners, and those involved in teaching management, particularly in supply chain management). These participants were asked to highlight supplier selection attributes that they believe are important in family businesses. They are expected to provide ample information in narrowing down 48 different established in the literature and suggest additional attributes they believe to be relevant. The second set of participants is composed of 10 family SME owners who are carefully chosen based on their length of ownership or experience and role in the business. The length of ownership or experience should qualify for at least five years. The work conducted in the business is based on the scope of responsibilities, preferably supply chain activities. To illustrate the case the participants were selected from the food industry.

A two-stage data-gathering approach was implemented in this work. The first stage requires the first set of participants to evaluate the relevance of the 48 supplier selection attributes in family SMEs using a 5-point Likert scale, with 1, 2, 3, 4, and 5 representing *strongly disagree, disagree, no opinion, agree, and strongly agree*, respectively. With a response of 70%, the corresponding questionnaire for the first stage received 35 responses out of the 50 that were sent. Out of 35 responses, 80% were family SME owners, and 20% were affiliated with family businesses. This number of respondents falls well within the arguments Kull et al. (2018) set forth regarding SME research in supply chain management. With minimal resources, family SMEs tend to position their agenda with highly relevant attributes, which may be input to strategic planning and decision-making. Thus, in this work, the output of the first stage is to identify those attributes that are highly relevant to family SMEs. The top 10 attributes with the highest scores across the 35 responses were only considered and processed for the second stage of the study. These attributes are presented in Table 1. In the second stage, the second set of participants (i.e., 10 family-owned SMEs in the food industry) was asked to evaluate the importance of the supplier selection attributes to the characteristics of successful family SMEs in view of managing supply chains. These characteristics include attitude towards growth, risk appetite, and professional management. The output of the second stage is to determine the priority attributes using the proposed E-MARCOS method.

The Application of the Proposed E-MARCOS Approach for Evaluating Supplier Selection Attributes in Family Food SMEs

The details of the application of the proposed E-MARCOS method are as follows:

Step 1: Decision-makers elicit their evaluations in a decision matrix. Let m be the number of highly relevant supplier selection attributes and n be the number of characteristics of successful family

Table 1. Highly relevant supplier selection attributes

Codes	Highly relevant supplier selection attributes
PQU	Product quality
TSQ	Total service quality
OTD	On-time delivery
ATT	Attitude
RTC	Response to customer request
PSC	Problem-solving capacity
PTE	Payment terms
PRI	Price
FLE	Flexibility
PRO	Productivity

SMEs associated with managing supply chains. And then each decision-maker k elicits judgments x_{ij}^k, representing the importance of an attribute i $\left(i = 1,\ldots,m\right)$ with respect to a characteristic j $\left(j = 1,\ldots,n\right)$. In this case, $x_{ij}^k \in \left\{1,2,3,4,5\right\}$, where 1 represents the least importance while 5 denotes the highest importance. These judgments are stored in a decision matrix of the form:

$$X^k = \left(x_{ij}^k\right)_{m\times n} \ \forall k = 1,\ldots,p \tag{20}$$

In effect, p decision matrices are obtained. For brevity, these matrices are not presented here.

Step 2: Aggregate the decision matrices. This process requires a single aggregate decision matrix that must be generated from the set of decision matrices in Step 1. Various aggregation approaches are available; however, the simple averaging method is considered the most popular (Ocampo et al., 2021). The aggregate decision matrix X is obtained using the following expression:

$$X = \left(x_{ij}\right)_{m\times n} \tag{21}$$

where:

$$x_{ij} = p^{-1}\sum_{k=1}^{p} x_{ij}^k \ \forall i,j \tag{22}$$

The aggregate decision matrix is shown in Table 2.

Table 2. The aggregate decision matrix

Supplier selection attributes	Professional management	Attitude towards growth	Risk appetite
PQU	4.6	4.5	4.6
TSQ	4.6	4.7	4.7
OTD	4.6	4.8	4.6
ATT	4.6	4.4	4.4
RTC	4.5	4.2	4.4
PSC	4.1	4.3	4.2
PTE	4.0	4.1	4.1
PRI	4.0	4.1	4.1
FLE	3.7	4.1	4.4
PRO	4.6	4.5	4.6

Step 3: Obtain a normalized decision matrix R. Using Equation (1), the normalized decision matrix $R = \left(r_{ij}\right)_{m \times n}$ is obtained and presented in Table 3.

Step 4: Compute the information entropy h_j for each characteristic j. The information entropy values h_j $\left(\forall j\right)$ are computed using Equation (2). Following the necessary calculations, the information entropy vector becomes $\left(h_1, h_2, h_3\right) = \left(0.99875, 0.99934, 0.99952\right)$.

Step 5: Generate the degree of diversification of each characteristic j. Following Equation (3), the degree of diversification values d_j $\left(\forall j\right)$ result in $\left(d_1, d_2, d_3\right) = \left(0.00125, 0.00066, 0.00048\right)$.

Step 6: Obtain the entropy weight w_j of all characteristics. The entropy weights w_j $\left(\forall j\right)$, which can approximate the priority weights of the characteristics, are found to be $\left(w_1, w_2, w_3\right) = \left(0.52385, 0.27472, 0.20143\right)$ with the application of Equation (4).

Step 7: From the aggregate decision matrix in Step 2, form an extended decision matrix. The extended decision matrix $\tilde{X}$ is generated with the calculations provided in Equation (5) to Equation (7). Table 4 illustrates $\tilde{X}$, with A^- and A^+ obtained from Equation (6) and Equation (7), respectively.

Step 8: Compute for the normalized extended decision matrix. As provided in Equation (8) to Equation (10), the normalized extended decision matrix N is shown in Table 5.

Step 9: Generate weighted decision matrix V. In this proposed E-MARCOS approach, the weighted decision matrix V incorporates the entropy weights of the characteristics found in Step 6 in conjunction with Equation (11). The matrix V is shown in Table 6.

Step 10: Compute the utility degree of the supplier selection attributes. The utility degree K_i for each attribute i is obtained through a series of calculations involving Equation (12) up to Equation (16).

Step 11: Create the utility function $f\left(K_i\right)$ for each attribute. From Step 10, the function $f\left(K_i\right)$ involves the application of Equation (17) to Equation (19).

Step 12: Evaluate the ranking of the attributes. The utility functions $f\left(K_i\right)$ $\left(\forall i\right)$ found in Step 11 serve as the bases for ranking the supplier selection attributes. The values K_i, $f\left(K_i\right)$, and the ranks of the attributes are summarized in Table 7.

Table 3. The normalized decision matrix

Supplier selection attributes	Professional management	Attitude towards growth	Risk appetite
PQU	0.10624	0.10297	0.10431
TSQ	0.10624	0.10755	0.10658
OTD	0.10624	0.10984	0.10431
ATT	0.10624	0.10069	0.09977
RTC	0.10393	0.09611	0.09977
PSC	0.09469	0.09840	0.09524
PTE	0.09238	0.09382	0.09297
PRI	0.09238	0.09382	0.09297
FLE	0.08545	0.09382	0.09977
PRO	0.10624	0.10297	0.10431

Table 4. The extended decision matrix

Supplier selection attributes	Professional management	Attitude towards growth	Risk appetite
A^-	3.7	4.1	4.1
PQU	4.6	4.5	4.6
TSQ	4.6	4.7	4.7
OTD	4.6	4.8	4.6
ATT	4.6	4.4	4.4
RTC	4.5	4.2	4.4
PSC	4.1	4.3	4.2
PTE	4.0	4.1	4.1
PRI	4.0	4.1	4.1
FLE	3.7	4.1	4.4
PRO	4.6	4.5	4.6
A^+	4.6	4.8	4.7

Table 5. The normalized extended decision matrix

Supplier selection attributes	Professional management	Attitude towards growth	Risk appetite
A^-	0.80435	0.85417	0.87234
PQU	1.00000	0.93750	0.97872
TSQ	1.00000	0.97917	1.00000
OTD	1.00000	1.00000	0.97872
ATT	1.00000	0.91667	0.93617
RTC	0.97826	0.87500	0.93617
PSC	0.89130	0.89583	0.89362
PTE	0.86957	0.85417	0.87234
PRI	0.86957	0.85417	0.87234
FLE	0.80435	0.85417	0.93617
PRO	1.00000	0.93750	0.97872
A^+	1.00000	1.00000	1.00000

Table 6. The weighted decision matrix

Supplier selection attributes	Professional management	Attitude towards growth	Risk appetite
A^-	0.42136	0.23465	0.17572
PQU	0.52385	0.25755	0.19714
TSQ	0.52385	0.26899	0.20143
OTD	0.52385	0.27472	0.19714
ATT	0.52385	0.25182	0.18857
RTC	0.51246	0.24038	0.18857
PSC	0.46691	0.24610	0.18000
PTE	0.45552	0.23465	0.17572
PRI	0.45552	0.23465	0.17572
FLE	0.42136	0.23465	0.18857
PRO	0.52385	0.25755	0.19714
A^+	0.52385	0.27472	0.20143

Table 7. The priority ranking of supplier selection attributes

Supplier selection attributes	S_i	K_i^-	K_i^+	$f\left(K_i^-\right)$	$f\left(K_i^+\right)$	$f\left(K_i\right)$	Rank
A^-	0.83173	1.00000	0.83173	0.45407	0.54593	0.60373	
PQU	0.97854	1.17652	0.97854	0.45407	0.54593	0.71029	3
TSQ	0.99428	1.19543	0.99428	0.45407	0.54593	0.72171	2
OTD	0.99571	1.19716	0.99571	0.45407	0.54593	0.72276	1
ATT	0.96425	1.15933	0.96425	0.45407	0.54593	0.69992	5
RTC	0.94142	1.13188	0.94142	0.45407	0.54593	0.68334	6
PSC	0.89301	1.07368	0.89301	0.45407	0.54593	0.64821	7
PTE	0.86589	1.04108	0.86589	0.45407	0.54593	0.62852	8
PRI	0.86589	1.04108	0.86589	0.45407	0.54593	0.62852	8
FLE	0.84459	1.01546	0.84459	0.45407	0.54593	0.61306	10
PRO	0.97854	1.17652	0.97854	0.45407	0.54593	0.71029	3
A^+	1.00000	1.20231	1.00000	0.45407	0.54593	0.72587	

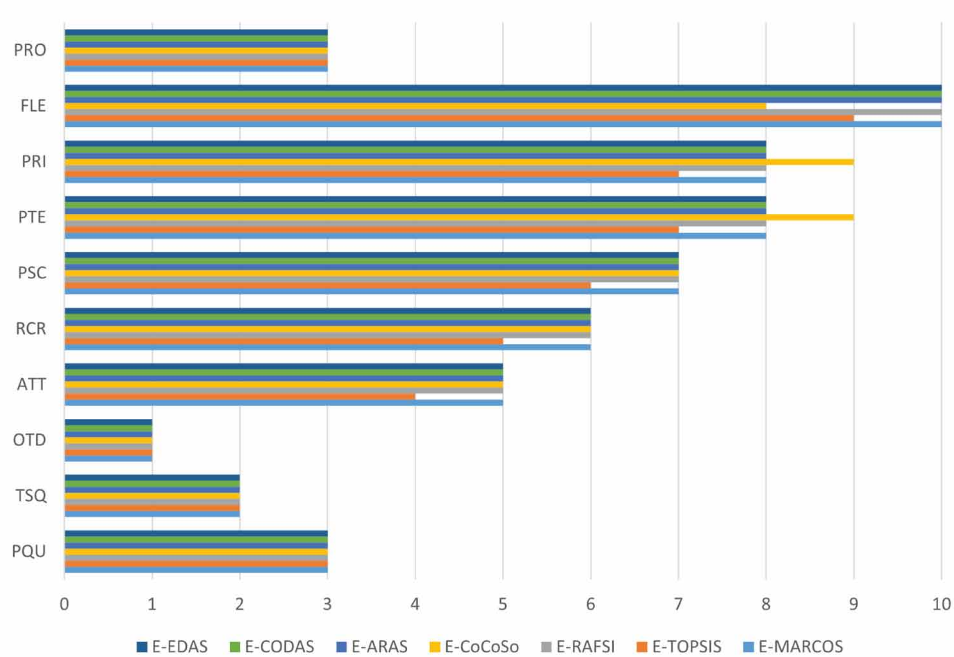
Based on Table 7, the priorities of the attributes have the following ranks: OTD $\succ$ TSQ $\succ$ PQU $\asymp$ PRO $\succ$ ATT $\succ$ RTC $\succ$ PSC $\succ$ PTE $\asymp$ PRI $\succ$ FLE.

Comparative Analysis

With the same attribute weights reported in Step 6 of the last subsection and the aggregate decision matrix in Table 2, compared are the efficacy of the MARCOS method with other comparable MADM methods. Note that Stević et al. (2020) demonstrated a comparative analysis of the MARCOS method with other known MADM tools and found consistency in the priority rankings. In this section, expanded upon are the analysis to emerging techniques and evaluation of the consistency of results. In choosing a subset among an array of MADM methods for the analysis, put forward are two main qualifications: (1) the method is based on a decision matrix that portrays the evaluation of alternatives on the rows and attributes or criteria on the columns, and (2) the model has limited parameters, unlike some popular methods such as the PROMETHEE and ELECTRE. These qualifications are set as controls to appropriately compare the performance of MARCOS with other closely available MADM methods. Following these qualifications, six other methods were chosen including the TOPSIS (Hwang & Yoon, 1981), the Ranking of Alternatives through Functional mapping of criterion sub-intervals into a Single Interval (RAFSI) (Žižović et al., 2020), the Combined Compromise Solution (CoCoSo) (Yazdani et al., 2019), the Additive Ratio ASsessment (ARAS) (Zavadskas & Turskis, 2010), the COmbinative Distance-based ASsessment (CODAS) (Ghorabaee et al., 2016), and Evaluation based on Distance from Average Solution (EDAS) (Ghorabaee et al., 2015). For brevity, the algorithms of these methodologies are not presented here. A comprehensive discussion of those methods can be found in those references.

Figure 1 shows the results of the comparative analysis. It shows that the E-MARCOS method yields completely consistent results with other MADM methods in the top three attributes (i.e.,

Figure 1. Comparison of rankings among entropy-based MADM methods



Note. Comparing the results of the E-MARCOS approach with other MADM methods.

OTD, TSQ, PQU, PRO). It also results in similar rankings for attributes ATT, RCR, and PSC, except with the E-TOPSIS method having underestimated rankings for the same attributes. Finally, only E-CoCoSo and E-TOPSIS yield different but closely related rankings with the E-MARCOS method for attributes PTE, PRI, and FLE.

To gain deeper insight into their similarities and differences, a matrix of pairwise Spearman's rank correlation coefficients is presented in Table 8. It implies that the E-MARCOS approach yields perfectly consistent results with E-RAFSI, E-ARAS, E-CODAS, and E-EDAS, with E-TOPSIS and E-CoCoSo resulting in slightly different but highly consistent rankings (i.e., $\rho \geq 0.96$). It also appears that both E-TOPSIS and E-CoCoSo report imperfectly consistent rankings with other MADM methods under consideration. The consistency is still considered remarkably high with $\rho \geq 0.92$ for all comparisons. These insights confirm the comparative analysis Stević et al. (2020) reported, depicting the MARCOS method's consistency with other methods.

While they offer comparable rankings, the MARCOS method possesses significant advantages, as Stević et al. (2020) outlined. They include (1) the flexibility of MARCOS in solving MADM problems with more attributes or criteria, (2) the simplicity of the algorithm even with increasing the number of decision components (i.e., attributes, alternatives), (3) robustness of the results regardless of changes in the measurements scales of attributes, (4) stability in processing large datasets, and (5) stability and reliability in dynamic environments including the rank reversal problem.

RESULTS AND DISCUSSION

From the characteristics identified by Jayaram et al. (2014), the entropy method assigns more priority to professional management followed by attitude towards growth and risk appetite. This finding of putting more emphasis on professional management about how family SMEs view managing supply chains is consistent with those in the literature (Dekker et al., 2015; Costa et al., 2022; Polat & Benligiray, 2022) particularly in the case of the food industry, which is governed by a set of rigorous standards. The nepotism prevalent in family SMEs triggers a lack of professionalism, as family members engage in key positions of the business, followed by a highly centralized organizational structure. Certain family members may lack the necessary knowledge and experience in the positions they hold, and such a scenario may be detrimental to the business, especially in the food industry, where key positions require technical knowledge of food science and technology. In addition, a highly centralized structure exacerbates the dilemma where critical decisions may come from non-fully informed or non-expert family members. Thus, emphasizing initiatives that highlight professionalism likely increases the supply chain performance of family SMEs.

From the previous literature review of supplier selection attributes, 48 attributes were considered for the first stage evaluation, which aims to obtain a narrow list of attributes relevant

Table 8. Spearman's rank (ρ) correlation coefficients

	E-MARCOS	E-TOPSIS	E-RAFSI	E-CoCoSo	E-ARAS	E-CODAS	E-EDAS
E-MARCOS	1	0.96364	1	0.96364	1	1	1
E-TOPSIS		1	0.96364	0.92727	0.96364	0.96364	0.96364
E-RAFSI			1	0.96364	1	1	1
E-CoCoSo				1	0.96364	0.96364	0.96364
E-ARAS					1	1	1
E-CODAS						1	1
E-EDAS							1

to the characteristics of family SMEs. The evaluation of experts in the food industry yields the ten most relevant attributes: product quality, total service quality, on-time delivery, attitude, response to customer requests, problem-solving capacity, payment terms, price, flexibility, and productivity. The application of the hybrid E-MARCOS method results in the priority ranking of the supplier selection attributes of on-time delivery, total service quality, product quality, productivity, attitude, response to customer requests, problem-solving capacity, payment terms, price, and flexibility. Discussed here is the relevance of on-time delivery, total service quality, product quality, and productivity as priority attributes of family SMEs in supplier selection decisions.

These findings are consistent with Braglia and Petroni (2000), which suggests the importance of on-time delivery. On-time delivery is measured by the ability of the suppliers to deliver the goods on time based on the agreed arrangement. In the food industry, where managing inventories is a premium due to the nature of the products (e.g., ingredients are voluminous at fixed quantities and presence of expiration dates), the reliability of the suppliers in terms of on-time delivery is critical in the entire supply chain. Disruptions become inevitable in the absence of required inventories especially when the availability of substitutes is minimal. These disruptions entail numerous repercussions including production slowdown or stoppage, of which both adversely affect the downstream supply chain. In most cases they incur costs related to holding inventories, penalties, and opportunity losses. On-time delivery promotes a degree of professionalism among family SMEs and achieves non-financial goals prevalent in family firms (Maloni et al., 2017; Darby et al., 2022), such as firm image and family legacy. As Maloni et al. (2017) proposed, family businesses tend to adopt more supplier integration and partnerships than their non-family counterparts. On-time delivery resides at the core of integration and partnerships with suppliers.

Total service quality and product quality follow on-time delivery on the priority list, which agrees with the finding of Su and Gargeya (2016) in the SME literature. Total service quality is measured by how close the goods are to the manufacturer’s specifications (Magdalena, 2012), and product quality is associated with the product’s overall durability, reliability, accuracy, and ease of operation. In a highly differentiated food business, the quality of the food product (e.g., roasted chicken) and the associated service lend to the legacy of the family business. To some extent, such a family legacy (e.g., offering the best roasted chicken in the community) is uncompromising, and family businesses strive to achieve consistency in the quality and delivery of their food products including food safety (Tiu et al., 2021). This requires quality raw materials (i.e., ingredients) from their suppliers. Suppliers who have built long relationships with the family businesses tend to do so because of the more personal, emotional, and social nature of the family (Maloni et al. (2017). On the other side, family SMEs put priority on suppliers capable of delivering quality inventories and then build valued relationships with them. As they tend to stay longer in the supplier relationship, family SMEs prefer suppliers with higher productivity before the engagement commences. Higher productivity implies less likely interruption in the delivery of supplies, which positively affects the family legacy to their customers and the downstream supply chain. Placing price at the bottom of the priority list of supplier selection attributes strengthens the theoretical underpinning in the literature, which suggests that family SMEs tend to emphasize non-financial goals (Darby et al., 2022). In this case, family SMEs engaging in food products emphasize non-financial goals, such as family legacy, which may be demonstrated by paying more attention to product quality than seeking suppliers offering minimum costs. Thus, instead of looking for another supplier offering low-cost dressed chicken as a raw material for a roasted chicken, family SMEs maintain their relationships with the supplier who continues to deliver the dressed chicken that fits desired quality for their roasted chicken. Such a direction ensures a long-term presence in the industry as it maintains the legacy of the family business. Following the comparative analysis, these findings of the entropy-MARCOS method are in high agreement with the results of other comparable MADM methods. In summary, the priority supplier selection attributes identified in this study support the theoretical propositions (Maloni et al., 2017) and expand some empirical findings (Darby et al., 2022) in the literature, which suggests the presence of the diversity of goals among family SMEs, and to some extent, non-financial goals are preferred over financial ones.

CONCLUSION AND FUTURE WORK

Recent literature on SMEs and family businesses offers insight in view of managing supply chains especially in the supplier selection agenda. When taken together, the characteristics of SMEs and the diversity of goals of family businesses demand a new line of inquiry in the supplier selection problem, which the current literature shares fragmented findings. This work contributes to the emerging literature by (1) identifying supplier selection attributes appropriate for family SMEs and (2) evaluating the priorities of these attributes as inputs to planning, resource allocation decision, and performance evaluation. What has been addressed are these considerations using a case study of family SMEs in the food industry with a two-stage approach. In the first stage, 48 supplier selection attributes were obtained from reviews reported in the literature and 35 expert decision-makers involved in family SMEs identified the 10 most relevant attributes. In the second stage, priority evaluation of these attributes follows the popular approach in the literature – the use of MADM methods. Due to the computational convenience and tractability of the approach, a hybrid entropy-MARCOS method was introduced. The entropy method assigns the priorities of the characteristics of family SMEs, while the newly developed MARCOS method evaluates the 10 supplier selection attributes.

Findings in the first stage yield product quality, total service quality, on-time delivery, attitude, response to customer requests, problem-solving capacity, payment terms, price, flexibility, and productivity as the supplier selection attributes most appropriate to family SMEs. The application of the entropy-MARCOS approach in the second stage suggests the priority ranking of these attributes: (1) on-time delivery, (2) total service quality, (3) product quality, (3) productivity, (5) attitude, (6) response to customer requests, (7) problem-solving capacity, (8) payment terms, (8) price, and (10) flexibility. These findings offer theoretical insights. First, they support previous insights regarding the presence of non-financial goals of family SMEs such as family legacy, family image, and long-term sustainability, among others. And these goals often dominate financial ones. The presence of on-time delivery, total service quality, product quality, and productivity at the top of the priority list ensures an uninterrupted downstream supply chain with consistent delivery of sustained product quality, promoting family image and legacy. The presence of price or payment terms at the bottom of the priority list further emphasizes this insight. This implies that family SMEs in the case of the food industry, tend to engage with suppliers that help them achieve consistent quality and ensure family legacy by delivering quality food products. Second, as the current literature recently suggests, family SMEs tend to engage more in supplier integration and partnerships and promote long-term supplier relationships. The top priority attributes are critical prerequisites for supplier partnerships and relationships. This implies that family SMEs put greater emphasis on these prerequisites in supplier selection before engaging further in supplier relationships. The comparative analysis with known MADM methods such as the EDAS, CODAS, ARAS, CoCoSo, RAFSI, and TOPSIS yields high consistency of these results. Although idiosyncrasies exist, these findings would serve as starting points of discussion in supplier selection of family SMEs.

Nevertheless, this work is not free from limitations. First, the findings may be bounded by the case-specific conditions of the food industry, and they reflect the interests of family SMEs in the industry. Thus, findings must be adopted with caution when directly applied to other industries. Future work may extend such analysis to other industries (e.g., manufacturing, healthcare, hospitality) and compare the findings of this study with those future insights. Second, the list of initial supplier selection attributes may be extended by performing a separate systematic literature review. Increased digitalization in the supply chain during the last few years may involve more relevant attributes. Third, an actual supplier selection problem in family SMEs while incorporating the priority attributes identified in this study may be performed in future work. Finally, integrating the notion of imprecision and uncertainty in the judgment elicitation process may be a relevant future agenda. It may include investigation on the use of fuzzy sets, intuitionistic fuzzy sets, neutrosophic sets, Pythagorean fuzzy sets, Fermatean fuzzy sets, hesitant fuzzy sets, and q-rung orthopair fuzzy sets, among others, in the computational framework of the E-MARCOS method.

CONFLICT OF INTEREST

All authors of this article declare there are no competing interest.

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APPENDIX

Table 9. Summary of Supplier Selection Attributes

Codes	Supplier selection attributes	References
SSA1	Price (cost)	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA2	Product quality	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA3	Delivery	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA4	Warranties and claims	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA5	After-sales services	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA6	Technical support	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA7	Training aids	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA8	Attitude	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA9	Total service quality	Liao and Kao (2011)
SSA10	Performance history	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA11	Financial position	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA12	Geographical location	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA13	Management and organization	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA14	Labor relations	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA15	Relationship closeness	Liao and Kao (2011)
SSA16	Conflict/problem-solving capability	Liao and Kao (2011)
SSA17	Communication system	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA18	Response to customer request	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA19	E-commerce capability	Ha and Krishnan (2008); Abdolshah (2013)
SSA20	JIT capability	Ha and Krishnan (2008); Abdolshah (2013)
SSA21	Technical capability	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA22	Production capability	Liao and Kao (2011)
SSA23	Production facilities and capacity	Ha and Krishnan (2008); Abdolshah (2013)

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Table 9. Continued

Codes	Supplier selection attributes	References
SSA24	Packaging ability	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA25	Operational controls	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA26	Ease-of-use	Ha and Krishnan (2008); Abdolshah (2013)
SSA27	Maintainability	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA28	Amount of past business	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA29	Reputation and position in the industry	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA30	Reciprocal arrangements	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA31	Impression	Ha and Krishnan (2008); Liao and Kao (2011); Abdolshah (2013)
SSA32	Business attempt	Liao and Kao (2011)
SSA33	Size	Liao and Kao (2011)
SSA34	Environmentally-friendly products	Ha and Krishnan (2008); Abdolshah (2013)
SSA35	Product appearance	Ha and Krishnan (2008); Abdolshah (2013)
SSA36	Catalog technology	Ha and Krishnan (2008); Abdolshah (2013)
SSA37	Dependability	Abdolshah (2013)
SSA38	Flexibility	Abdolshah (2013)
SSA39	Payment terms	Abdolshah (2013)
SSA40	Productivity	Abdolshah (2013)
SSA41	Applicable to conceptual manufacturing	Abdolshah (2013)
SSA42	Manufacturing challenges	Abdolshah (2013)
SSA43	Driving power	Abdolshah (2013)
SSA44	To match the lead times	Abdolshah (2013)
SSA45	Personal capability	Abdolshah (2013)
SSA46	To be solution-oriented	Abdolshah (2013)
SSA47	Global factors	Abdolshah (2013)
SSA48	Environmental risk	Abdolshah (2013)

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