Efficient and Sustainable Supplier Selection Strategy forSMEsusing MARCOS: Insights from A Case Study

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Abstract

Supplier selection (SS) is an important aspect of supply chain management (SCM) and appropriate supplier evaluation opens up a lot of opportunities for every organization. Simply looking for suppliers with the cheapest price is no longer considered "efficient supplier selection". Selection of a good set of suppliers is a multiple-criteria-decision-making (MCDM) process. Despite the fact that earlier research has presented several methods and tools for effective supplier selection, only a few approaches have attempted to address issues of SMEs in supplier selection decisions. We proposed an integrated two-stage MCDM approach that consists of Analytical Hierarchy Process (AHP) and Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS) for supplier selection problems of small and medium-sized enterprises (SMEs). And the results are validated with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). AHP & TOPSIS are widely researched and used for a long time but MARCOS is relatively new compared to them. This approach can be easily implemented using a spreadsheet program. This spreadsheet is useful in practical situations and does not require the user to have any prior knowledge of optimization. A real-life case is examined to demonstrate the applicability of the proposed approach. The novelty of this study is that it presents a realistic, easy-to-implement, and proven supplier selection technique for SMEs to achieve sustainability.

Keywords
Supplier selection (SS), Multi-Criteria decision making (MCDM), Analytical Hierarchy Process (AHP), Technique for Order of Preference , and Measurement of Alternatives and Ranking .

1. Introduction
Business characteristics such as the global competitive environment, technological advancements, shorter product life cycles, and stringent service and quality requirements are the most important driving forces for companies to form medium to long-term strategic partnerships with innovative and sustainable suppliers to improve business performance and gain a strategic and competitive edge over their competitors (Rajhans & Barshikar, 2013). In addition, managing suppliers play an important role in SCM because the cost of raw materials and components is the principal cost of a product. The majority of manufacturing companies spend 60 to 80 percent of their revenue on procuring raw materials and components (P. Kumar et al., 2014). As a result, this study emphasizes on investigating the problem of sustainable supplier selection (SSS) using various Multi-Criteria Decision making (MCDM) approaches and developing a practical approach for SS problem of small and medium-sized enterprises (SMEs). Selection of competent suppliers not only lowers purchasing costs but also contributes to product innovation and efficient manufacturing processes. Therefore, supplier selection is seen as an important issue in SCM in order to maintain a competitive edge. Supplier selection (SS) is the process of identifying, evaluating, and contracting with suppliers (Taherdoost & Brard, 2019). The SS process starts with recognizing the need for a good

supplier; determining and formulating decision criteria, initial screening of potential suppliers, final supplier selection, and continuous evaluation and assessment.

Supplier efficiency is one of the most crucial attributes of modern supply chains, therefore, selecting the right suppliers is a critical strategic factor for the company's overall success (Liao & Kao, 2011). The primary goal of the SS process is to lower purchasing risk, increase total value for the buyer, and promote long-term relationships between buyers and suppliers (Das, 2020). In today's intense competition, it is difficult to generate low-cost, high-quality components without sustainable suppliers. Literature reveals that most studies have addressed the issues of large enterprises but there is a dearth of studies that considers the constraints of SMEs. In this regard, this research is aimed to develop a sustainable supplier selection (SSS) approach, especially for SMEs.

The proposed approach consists of modified AHP, MARKOS, and the results are validated with TOPSIS. AHP has been modified so that parameters and sub-parameters are compared pair-wise and the weights of each parameter and sub-parameter are also calculated. Then after, the weights of each sub-parameter were multiplied by the weights of the parameters. In the next step, MARKOS is used to rank the suppliers based on their rating. In the last step, TOPSIScame into action to validate the results. A new approach called MARCOS has been used in this research, and it consists of seven easy steps.This strategy is focused on weighing alternatives and rating them in comparison to a compromisesolution. The compromise solution entails determining utility functions based on the distance betweenanti-idealandidealsolutions,aswellastheaggregations. A case study was conducted on valve manufacturing SMEs in Pune to examine the applicability of the proposed approach.Insights derived from a case study proved that the proposed integrated SS approach is capable of shortlisting suppliers for SMEs and this approach can be easily implemented in SMEs.Therefore,we present an in-depth analysis of MCDM approachesfor supplier evaluation and selection. The following research questions (RQ) are examined in this case study.
RQ 1. Why most SMEs failed to sustain themselves in the competitive market? Why do SMEs not follow any specific SS approach? What are the constraints of SMEs?
RQ2.How can the proposed method help SMEs to select capable and sustainable suppliers?

2.Literature review

The articles reviewed in this section are categorized into three groups: (i) SCM issues and constraints of SMEs, (ii) criteria for supplier selection, and (iii) MCDM techniques.

2.1 SCM risks and constraints of SMEs.

Many supply chain risks stem from the SS problem.As perresearch by the Business Continuity Institute in 2013, 75% of organizations face at least one major supply chain disruption every year, and most of the disruptions were caused by supply chain issues(Yoon et al., 2018). SMEs have been the most important part of supply chains but due to numerous constraints, they operate under tremendous pressure. SMEs face a number of challenges, including insufficient capital, difficulty in sourcing raw materials, intense competition, a lack of SCM strategies, and a workforce with a poor educational background (Narkhede and Rajhans, 2019).

Despite the fact that earlier research has presented different methods and tools for effective supplier selection, only a few approaches have attempted to address the issues and constraints of SMEs for SS decision-making.(Ho et al., 2015) has addressed a range of supply chain risk management (SCRM) challenges, including supplier selection and risk reduction strategies.He categorized supply chain risks into seven categories, with supply risk being the most studied, followed by demand risk, manufacturing risk, transportation risk, financial risk, macro risk, and information risk. Table 1 shows a summary of SS approaches with risk considerations.

Table 1. Risk factors in supplier selection

Researchers	**Risk factors**	**Sector**
(Talluri & Narasimhan, 2003)	Poor quality and late delivery	Pharmaceutical
(M. Kumar et al., 2006)	Capacity constraint	Automobile
(Chan & Kumar, 2007)	Dispersed geographical location	Hypothetical example
(Kull, 2008)	Supply disruption or failure	Automobile
(Wu et al., 2010)	Poor service and supply disruption	Hypothetical example

(Govindan et al., 2013)	Supply disruption and inability to respond	Hypothetical example
(Dotoli et al., 2014)	Supply uncertainty	Healthcare
(Scott et al., 2015)	Lack of supplier engagement and supply failure	Energy
(Rao et al., 2017)	Technology risk, management risk, economic risk, information risk, societal risk, environmental risk, and ethical risk	Utility
(Alikhani et al., 2018)	Poor quality, lack of mutual trust, Late delivery, Bankruptcy, Supply constraints, and Supplier profile	Hypothetical example

As supply chain structures became more complex, enterprises become increasingly dependent on their suppliers. As a result of this, enterprises are vulnerable to above-unexpected risk events.In order to reduce supply uncertainty, it is necessary to develop an efficient supplier evaluation and selection method for SMEs

2.2 Criteria for SS

SS is the most crucial strategic decision that a buyer needs to make. (Dickson, 1966), who looked at the importance of supplier assessment criteria, was the first to recognize the multifaceted nature of the problem. Many businesses are currently undergoing rapid changes as a result of technological advancements and changing customer needs. These businesses realized that purchasing quality products at the right price, in the right quantity, and at the right time from the right source is important to their sustainability. Depending on the size of the buying organization, the decision criteria used for vendor selection may differ (Rajhans & Barshikar, 2013). Table 2 shows a list of 23 criteria for evaluating and selecting the best suppliers and their importance.

Table 2. A set of supplier selection criteria (Dickson, 1966)

Importance of criterion	**Criteria**
Very High	Quality; Delivery; performance; warranty and claims.
High	Price; Production facility and capacity; Technical capability; Financial stability; Procedural Compliance; Reputation; Communication System; Management; Operating Controls
Medium	Service; Attitude; Impression; Packaging; Labour relations; Geographical location; Past business; Training aids
Low	Reciprocal arrangements

After being defined as an MCDM problem, SS process has piqued the interest of academics, who haveexamined it from various perspectives. SS problem contains both qualitative and quantitative criteria, and it is required to make a trade-off between them (Mendoza & Ventura, 2012). In SS process, a pool of suppliers is selected based on a set of predetermined criteria such as pricing, quality, delivery, and technical competence (Büyüközkan & Çifçi, 2011; Nourmohamadi Shalke et al., 2018; Zhu et al., 2012).

2.3 MCDM techniques

In recent decades, extensive MCDM techniques have been proposed for SS, such as the analytic hierarchy process (AHP), technique for order performance by similarity to ideal solution (TOPSIS), analytic network process (ANP), data envelopment analysis (DEA), fuzzy set theory, genetic algorithm (GA), case-based reasoning (CBR), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids. (Govindan et al., 2015) conducted a review of literature published between 1997 and 2011 on green purchasing and green supplier selection and in the end, they came to the conclusion that the Analytic Hierarchy Process (AHP) is the most commonly used MCDM method for evaluating green suppliers. (Aouadni et al., 2019) conducted a review of 270 research papers on SS and order allocation published between 2000 and 2017. AHP, TOPSIS, and ANP approaches were considered in roughly 17%, 9%, and 7% of the reviewed papers, respectively.In this area, they highlighted fuzzy multiple-objective programming as a prominent strategy.(Stević et al., 2020) developedthemeasurementalternativesandrankingaccordingtothecompromisesolution(MARCOS) method based on the TOPSIS's principle. Furthermore, the MARCOS approach can beused to contribute to Prospective Multiple

Attribute Decision Making(PMADM), because it shares so many similarities with the aforementioned approach's basic principle.In the evaluation phase, the PMADM model includes future limiters. In the process of reaching ajudgmentregardingapossiblefuturescenario,eachlimiterthatcouldoccurinthefutureandwithinthetimeframeisbeinginvestigatedcanbeconsidered in the starting itself.Isitpossibletoratesustainablesuppliersusing an approach based on the recently created MARCOS method? By addressing this question, thispaper discusses the ability tofind and choose the most appropriate sustainablesupplier in mostindustries.

3. Research Methodology

A case study was carried out on a medium-sized valve manufacturing firm in Pune,Maharashtra. It was frequently observed that purchase managers were frequently purchasing materials in small quantities, as and when needed, from nearby suppliers. As a result, it was necessary to develop an efficient SS approach for SMEs. This article discusses a three-stage integrated approach that consists of the selection of parameters using modified AHP, ranking of suppliers using newly developed MARKOS, and validation of the proposed method with TOPSIS. In the first stage, AHP is modified to calculate the weights of 19 parameters that are highly relevant to SMEs. Table 3 shows the list of criteria and sub-parameters.

Table 3. List of parameters & sub-parameters

Parameters	Sub Parameters
Cost	Net Price
	Transportation Cost
	Quantity Discount
Quality	Production Technology
	Warranty
	Product Durability
	Rejection
	ISO Standards
Delivery	Inventory Management
	Supplier Location
	Mode of Transportation
	Delivery Lead Time
	Safety & Security
Financial	Financial Stability
	Profit/Sales
	Interest Terms
Management	Responsiveness
	Technical Problem Solving
	Product Range

By using AHP we compared the main parameters with the help of professionals working in SMEs. Later each group of sub-parameters was compared with each other and weights were calculated using a spreadsheet program. Weights of sub-parameters were multiplied by the weights of the criteria and finally,the first 5 parameters were selected for further analysis because these parameters were contributing more than 80% of the weights of the total parameters. A newly developed MARKOS is applied next to evaluate alternatives and rank the suppliers; at last, results are validated with TOPSIS.

MARKOS approach works by establishing a link between alternatives and reference values (ideal and anti-ideal alternatives). Based on the established relationships, the utility functions of alternatives are calculated, and a compromise ranking for ideal and anti-ideal solutions is created. Utility functions are used to define decision preferences. The position of an alternative concerning an ideal and anti-ideal solution is represented by utility functions. The optimum option is the one that is the most similar to the ideal while also being the most distant from the anti-ideal reference point. The MARCOS technique is carried out in the following manner:

Step 1: Formation of an initial decision-making matrix

A collection of n criteria and m alternatives are defined in multi-criteria models. When making a collective choice, a group of r specialists should be created to assess alternatives using the criteria. Expert evaluation matrices are aggregated into an initial group decision-making matrix in the event of group decision-making.

Step 2: Formation of an extended initial matrix.

The ideal (AI) and anti-ideal (AAI) solutions are defined in this stage as shown in Table 4, and the starting matrix is extended.

Table 4. Extended Initial Matrix

	C_1	C_2	....	C_n
AAI	x_{aa1}	x_{aa2}	....	x_{aan}
A_1	x_{11}	x_{12}	....	x_{1n}
A_2	x_{21}	x_{22}	....	x_{2n}
....	.....	.....	.....	.....
A_m	x_{m1}	x_{m2}	.....	x_{mn}

The least desired choice is the anti-ideal solution (AAI), whereas the most desirable one is the ideal solution (AI). Depending upon the type of criterion, AAI and AI are specified using equations.

$$AAI = \min x_{ij} \quad if i \in B \quad and \ \max x_{ij} \quad if i \in C \qquad \text{(I)}$$

$$AAI = max\ xijif\ i\ \in Band \qquad min\ xij \quad if\ i \in C \qquad \text{(II)}$$

where B denotes a set of benefit criteria and C denotes a set of cost criteria

Step 3: Normalization of the extended initial matrix (X)

The following equations are used to obtain the elements of the normalized matrix N = [nij]mxn

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \ if\ j\ \in C \qquad \text{(III)}$$

$$n_{ij} = \frac{x_{ij}}{x_{aj}} \ if\ j\ \in B \qquad \text{(IV)}$$

where elements xij and xai represent the elements of matrix X.

Step 4: Determination of the weighted matrix

The weighted matrix $V = [v_{ij}]\ m\ x\ n$ is obtained by multiplying the normalized matrix N with the weight coefficients of the criterion wj

$$v_{ij} = n_{ij} * w_j \qquad \text{(V)}$$

Step5: Calculation oftheutility degreeofalternativesKi

The utility degrees of an alternative in relation to the anti-ideal and perfect solution can be determinedusingtheformulaebelow.

$$V_i^- = \frac{s_i}{s_{aai}} \qquad \text{(VI)}$$

$$V_i^+ = \frac{s_i}{s_{ai}} \qquad \text{(VII)}$$

WhereS$_i$(i=1,2…..m)isthesumof the weighted matrixV's members.

$$S_i = \sum_{i=1}^{n} V_{ij} \text{(VIII)}$$

Step 6: Determinationoftheutilityfunctionofalternativesf(Ki)&Rankingthealternatives

Theutilityfunctionrepresentsthetrade-offbetweentheobservablealternativeandtheidealandanti-idealsolutions.Theutilityfunctionofalternativesisgivenbytheequationbelow.

$$f(K_i) = \frac{k_i^+ + k_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \quad \text{(IX)}$$

The utility function in regard to the anti-ideal solution is represented by $f(K_i)$, while $f(K^+)$ representsthe utility function in relation to the ideal solution. The following equations are used to derive utilityfunctionsinregardtotheidealandanti-idealsolutions.

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad \text{(X)}$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad \text{(XI)}$$

To rank the options, the final values of utility functions are evaluated. Theutilityfunctionvalueof analternativeshouldbeashighaspossible.

As MARCOS is a relatively new MCDM method, TOPSIS was applied next to ensure the accuracy of the findings.

4. Case study

The case study is conducted on a medium-scale manufacturing company located in Pune, Maharashtra. Frequently, it was observed that purchase managers ordered small quantities from local suppliers which led to higher costs, quality issues, and stock-out situations. Therefore, it was necessary to develop a practical and efficient supplier selection approach for SMEs because professionals working in SMEs are not experts in MCDM techniques. Therefore, our emphasis was on the simplicity and practicality of the approach. In this view, an excel spreadsheet program is developed in such a way that purchase managers working in SMEs can easily use it and can assist supplier selection decision-making. This spreadsheet program is divided into three sections. In the first step, criteria and sub-parameters are compared pair-wise to determine their weights, and then the weights of criteria are multiplied by the weights of sub-parameters. The process is depicted in Tables 5, 6, and 7.

Table 5. Pair-wise comparison of criteria

Criteria	Scale	Criteria	Scale
Cost	9	Quality	9
Cost	7	Delivery	7
Cost	9	Financials	3
Cost	9	Management	3
Quality	9	Delivery	7
Quality	9	Financials	5
Quality	9	Management	3
Delivery	7	Financials	5
Delivery	7	Management	5
Financials	5	Management	5

Table 6. Comparison matrix

Parameter	Cost	Quality	Delivery	Financials	Management
Cost	1.00	1.00	1.00	3.00	3.00
Quality	1.00	1.00	1.29	1.80	3.00
Delivery	1.00	0.78	1.00	1.40	1.40
Financials	0.33	0.56	0.71	1.00	1.00
Management	0.33	0.33	0.71	1.00	1.00
Sum	3.67	3.67	4.71	8.20	9.40

Table 7. Normalized matrix

Parameter	Cost	Quality	Delivery	Financials	Management	Sum	Normalized weight
Cost	0.27	0.27	0.21	0.37	0.32	1.44	0.29
Quality	0.27	0.27	0.27	0.22	0.32	1.36	0.27
Delivery	0.27	0.21	0.21	0.17	0.15	1.02	0.20
Financials	0.09	0.15	0.15	0.12	0.11	0.62	0.12
Management	0.09	0.09	0.15	0.12	0.11	0.56	0.11
Sum	1.00	1.00	1.00	1.00	1.00	5.00	1.00

The same procedure is used to calculate the weights of sub-parameters, and the weights of criteria are finally multiplied by the weights of sub-parameters, as shown in Table 8.

Table 8. Final weights and ranks

Parameters	Sub Parameters	PV of criteria	PV of Sub-Parameters	Weights	Rank
Cost	Net Price	0.29	0.49	0.1402	1
Cost	Transportation Cost	0.29	0.19	0.0559	9
Cost	Quantity Discount	0.29	0.32	0.0924	3
Quality	Production Technology	0.27	0.39	0.1050	2
Quality	Warranty	0.27	0.21	0.0580	7
Quality	Product Durability	0.27	0.17	0.0448	10
Quality	Rejection	0.27	0.14	0.0368	11
Quality	ISO Standards	0.27	0.10	0.0269	16
Delivery	Inventory Management	0.20	0.28	0.0565	8
Delivery	Supplier Location	0.20	0.31	0.0626	5
Delivery	Mode of Transportation	0.20	0.16	0.0326	14
Delivery	Delivery Lead Time	0.20	0.14	0.0288	15
Delivery	Safety & Security	0.20	0.11	0.0228	18
Financical	Finalcial Stability	0.12	0.53	0.0663	4
Financical	Profit/Sales	0.12	0.27	0.0339	13
Financical	Interest Terms	0.12	0.19	0.0242	17

Management	Responsiveness	0.11	0.52	0.0584	6
Management	Technical Problem Solving	0.11	0.32	0.0364	12
Management	Product Range	0.11	0.16	0.0175	19

As shown in Table 9, only the top five parameters were chosen because they account for half of the weight, and the contributions of other sub-parameters were insignificant in comparison.

Table 9. Top five parameters

Sub-Parameters	**Weight**	**FinalWeight**
NetPrice	0.14484	0.29
ProductionTechnology	0.10602	0.21
Quantity Discount	0.10343	0.21
FinancialStability	0.07358	0.15
SupplierLocation	0.07110	0.14
Sum	0.50	1.00

Following that, MARKOS is used to evaluate the alternatives and select the most competent supplier. Table 10 depicts the MARKOS procedure.

Table 10. Suppliers ranking using MARKOS.

	Si	**K-**	**k+**	**fk-**	**fk-**	**fki**	**Rank**
AAI	0.679						
Supplier A	0.750	1.105	0.750	0.404	0.596	1.428	5
Supplier B	0.793	1.169	0.793	0.404	0.596	1.472	3
Supplier C	0.764	1.126	0.764	0.404	0.596	1.442	4
Supplier D	0.813	1.198	0.813	0.404	0.596	1.491	2
Supplier E	0.925	1.363	0.925	0.404	0.596	1.604	1
AI	1						

In the third step, as shown in Table 11, TOPSIS is used to validate the results.

Table 11. Suppliers ranking using TOPSIS.

Alternatives	Net Price	Production Technology	Quantity Discount	Financial Stability	Supplier Location	Si+	Si-	Closeness Coefiicient	Rank
Supplier A	0.153	0.099	0.092	0.054	0.063	0.004	0.001	0.118	5
Supplier B	0.136	0.128	0.104	0.054	0.055	0.003	0.005	0.635	3
Supplier C	0.153	0.085	0.081	0.063	0.063	0.005	0.005	0.491	4
Supplier D	0.119	0.099	0.092	0.072	0.047	0.002	0.004	0.648	2
Supplier E	0.102	0.085	0.069	0.072	0.070	0.002	0.009	0.834	1
V+	0.10226	0.12783	0.06933	0.07207	0.07041				

V-	0.1533 9	0.08522	0.10400	0.05405	0.04694				

5. Conclusion and future research agenda.

In the modern supply chain, traditional single-criterion method centered on the lowest cost is not sufficient. Although the literature on supplier selection has recommended a variety of tools and techniques for effectively evaluating suppliers, there has been no thorough evaluation of supplier selection models from SME's point of view. Furthermore, there is a dearth of studies in the literature that considered the limitations of SMEs.In view of this research gap, this research addressed the supplier selection issue of SMEs and revealed that SMEs can gain a competitive advantage if they follow the proposed method of supplier selection. A spreadsheet program is developed for professionals working in SMEs that will assist them in SS decision-making. In addition, the developed spreadsheet program is designed to incorporate the changes in criteria or sub-criteria very easily and the same change will be reflected in the entire program. Therefore the results can be generalized to any sector where different criteria or sub-criteria are of prime importance. The results of the case study conducted on a manufacturing company revealed that the proposed method and developed spreadsheet program are capable to alleviate supplier selection issues of SMEs.

References

Alikhani, R., Torabi, S. A., & Altay, N., Strategic supplier selection under sustainability and risk criteria. *International Journal of Production Economics*., 2018. https://doi.org/10.1016/j.ijpe.2018.11.018

Aouadni, S., Aouadni, I., & Rebaï, A. , A systematic review on supplier selection and order allocation problems. *Journal of Industrial Engineering International*, *15*, 267–289, 2019.

Büyüközkan, G., & Çifçi, G., A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information. *Computers in Industry*, *62*(2), 164–174, 2011. https://doi.org/10.1016/j.compind.2010.10.009

Chan, F. T. S., & Kumar, N., Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Omega*, *35*(4), 417–431, 2007. https://doi.org/10.1016/j.omega.2005.08.004

Das, N., *Supplier Selection Criteria and Methods in Supply Chain (A Statistical Approach)*. *7*(10), 2667–2673. , 2020.

Dickson, G. W. An Analysis Of Vendor Selection Systems And Decisions. *Journal of Purchasing*, *2*(1), 5–17. , 1996.

Dotoli, M., Epicoco, N., Falagario, M., & Sciancalepore, F. , A cross-efficiency fuzzy Data Envelopment Analysis. *COMPUTERS & INDUSTRIAL ENGINEERING*., 2014.

Govindan, K., Khodaverdi, R., & Jafarian, A. , A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production*, *47*, 345–354. , 2013.

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P., Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. *Journal of Cleaner Production*, *98*, 66–83. , 2015.

Ho, W., Zheng, T., Yildiz, H., & Talluri, S., Supply chain risk management: A literature review. *International Journal of Production Research*, *53*(16), 5031–5069, 2015.

Kull, T. J.,. *r Fo Pe er Re vi*, https://doi.org/10.1109/TEM.2008.922627, 2018.

Kumar, M., Vrat, P., & Shankar, R. , *A fuzzy programming approach for vendor selection problem in a supply chain*. *101*, 273–285, 2006.

Kumar, P., Bhattacharya, A., & Ho, W. , Int . J . Production Economics Strategic supplier performance evaluation : A case-based action research of a UK manufacturing organisation. *Intern. Journal of Production Economics*, 1–23, 2014.

Liao, C. N., & Kao, H. P. , An integrated fuzzy TOPSIS and MCGP approach to supplier selection in supply chain management. *Expert Systems with Applications*, *38*(9), 10803–10811. , 2011.

Mendoza, A., & Ventura, J. A., Analytical models for supplier selection and order quantity allocation. *Applied Mathematical Modelling*, *36*(8), 3826–3835, 2012.

Narkhede, G., & Rajhans, N., Insights on Supply chain needs and issues in Indian SMEs. *Industrial Engineering Journal*, *12*(2)., 2019.

Nourmohamadi Shalke, P., Paydar, M. M., & Hajiaghaei-Keshteli, M. , Sustainable supplier selection and order allocation through quantity discounts. *International Journal of Management Science and Engineering Management*, *13*(1), 20–32, 2018.

Rajhans, A. N. R., & Barshikar, B. S. R., Vendor selection using analytical hierarchy process. *Proceedings of International Conference on Computers and Industrial Engineering, CIE*, *2*(April), 1145–1152, 2013.

Rao, C., Xiao, X., Goh, M., Zheng, J., & Wen, J. , Compound mechanism design of supplier selection based on multi-attribute auction and risk management of supply chain. *Computers and Industrial Engineering*, *105*, 63–75, 2017.

Scott, J., Ho, W., Dey, P. K., & Talluri, S., A decision support system for supplier selection and order allocation in stochastic, multi-stakeholder and multi-criteria environments. *International Journal of Production Economics*, *166*, 226–237. , 2015.

Stević, Ž., Pamučar, D., Puška, A., & Chatterjee, P., Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS). *Computers and Industrial Engineering*, *140*, 106231.2020.

Taherdoost, H., & Brard, A. , Analyzing the Process of Supplier Selection Criteria and Methods. *Procedia Manufacturing*, *32*, 1024–1034, 2019.

Talluri, S., & Narasimhan, R. , *Vendor evaluation with performance variability : A max – min approach Vendor evaluation with performance variability : A max – min approach*. *2217*(February). , 2003.

Wu, Z., Choi, T. Y., & Rungtusanatham, M. J. , *Supplier – supplier relationships in buyer – supplier – supplier triads : Implications for supplier performance*. *28*, 115–123, 2003.

Yoon, J., Talluri, S., Yildiz, H., & Ho, W. , Models for supplier selection and risk mitigation: a holistic approach. *International Journal of Production Research*, *56*(10), 3636–3661. , 2018.

Zhu, Q., Sarkis, J., & Lai, K. H. , Examining the effects of green supply chain management practices and their mediations on performance improvements. In *International Journal of Production Research* (Vol. 50, Issue 5). , 2012.

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