JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Application of multiple-attribute decision-making model to select suppliers: In the context of service-oriented manufacturing Paradigm

Rahul Kumar[1]
(Research Scholar)
Department of Mathematics
Veer Kunwar Singh University,Ara (Bihar)

Dr. Brajesh Kumar[2]
Professor Department of Mathematics
Veer Kunwar Singh University,Ara (Bihar)

Abstract

In light of service-oriented manufacturing, this study suggests a multiattribute decision-making model that may be utilised to efficiently assess each potential provider. The interval evaluation matrix is created, and the supplier selection index system under service-oriented manufacturing is proposed. We create a method that transforms the value of the mixed attribute into an interval number in light of the mixed attribute of the evaluation index. We utilise a combination model based on the deviation function model and the interval relative entropy ranking approach to assess each prospective supplier, avoiding the subjectivity of the weight and enhancing the discrimination of the alternatives. A final application case is provided to demonstrate the accuracy and viability of the suggested decision-making paradigm.

Keywords: Multiple-attribute model, Service-Oriented Manufacturing, Interval Evaluation Matrix.

1. Introduction

Service-oriented manufacturing is a new advanced manufacturing mode under the background of continuous integration, penetration, and enhancement of manufacturing and service; the advantages and importance of the SOM strategy are gradually recognized by more and more enterprises [1]. Service-oriented manufacturing is both manufacturing oriented by service and manufacturing-based service. Through the integration of products and services, full participation of customers, and mutual provision of productive services and service production by enterprises, the integration of decentralized manufacturing resources and high synergy of their core competitiveness can be achieved [2]. In the service-oriented manufacturing mode, in order to provide product service system to customers and meet personalized customer needs, enterprises in the value chain begin to focus more on their core capabilities and outsource their noncore business to other enterprises [3]. By integrating superior resources between enterprises and acquiring capabilities that cannot be provided by the enterprise itself, the overall value creation can be maximized through mutual cooperation, and the perceived value of customers can be maximized at the same time [4]. In this context, multiple enterprises with different core capabilities will form a community of interests or dynamic alliance, in which the supplier is an important node. As important components of the supply chain, suppliers usually play important roles in the manufacturing process [5].

Therefore, it becomes more crucial to understand how to pick the ideal supplier and create a collaborative, mutually beneficial network connection with it.

Scholars both at home and abroad have currently conducted fruitful study on selecting suppliers, concentrating mostly on the criteria used to evaluate suppliers as well as the methodologies and models used to select suppliers. Some studies on evaluation criteria and procedures have been done in the supplier selection literature. Dickson was the first to make a systematic study on supplier evaluation criteria [6], to summarize the supplier evaluation criteria covering 23 indicators such as quality, cost, and delivery time. On this basis, Weber et al. studied the importance of evaluation criteria in supplier selection [7]. With the change of economic environment and the application of various advanced manufacturing modes, the supplier evaluation criteria are developing and improving continuously [8]. For example, complementary ability, synergy ability, and flexibility of suppliers begin to attract attention. Zhao et al. [9] hold that resource complementarity, cultural synergy, and prealliance linkage are the most important indicators for strategic alliance partner selection. Chen et al. [10] pointed out that the synergy of complementary resources and innovative resources is an important factor to create enterprise value. Guo et al. [11] pointed out that the service-oriented manufacturing makes fundamental changes in the relationship between enterprises and the way of value increment, and the supplier evaluation criteria should also be changed accordingly. Feng et al. [12] divided the service manufacturing network partner collaboration into two dimensions: complementary collaboration and interactive collaboration. Wang et al. [13]. suggested that when choosing suppliers, service-oriented manufacturing companies should give more consideration to the suppliers' environmental performance, service capacity and quality, and cost flexibility. The majority of the index values are true numbers, but the current evaluation methods still have significant flaws, which are reflected in how comprehensive the indicators are and need to be addressed. The emphasis is on research based on traditional supply and demand relationships as opposed to strategic partnerships, and the new supplier requirements under the service-oriented manufacturing mode are not particularly focused.

There are other strategies used to choose suppliers, but they can be loosely categorised as cost method, choice of open tender method, negotiation method, and other qualitative ways (purchasing cost comparison method and ABC cost method, etc.), the fuzzy theory (fuzzy clustering, intuitionistic fuzzy sets and fuzzy SMART, etc.), gray theory (gray relational analysis, etc.), multiple attribute decision-making (AHP and ANP, MAUT, outranking method, TOPSIS, etc.), multiple objective decision-making and mathematical programming (LP, GP, MIP, DEA, etc.), method of probability and statistics, artificial intelligence (evidence reasoning method, neural network, expert system, etc.), other methods (QFD, rough set theory, information entropy, VIKOR method, etc.), and integration method of these methods [14–16]. Zeng et al. [17] constructed a method based on the single-valued neutrosophic hybrid weighted similarity (SVNHWS) and entropy measures for handling SVN MADM problems. Wang et al. [18] studied some logarithmic distance measures and studied their usefulness in multiple attribute group decision-making (MAGDM) problems within single-valued neutrosophic linguistic (SVNL) environments. However, each method has its own advantages and disadvantages and needs to be improved [19]. For example, fuzzy theory has certain advantages in expressing expert opinions, but it usually needs to establish membership function or determine membership degree based on expert experience and judgment [20]. Multiobjective programming model can solve the conflicting objective problems in the process of supplier selection [21]. However, applying analytical approaches to solve particular problems is challenging due to their complexity. With increasing complexity in the practical multiple attribute decision-making environment, decision-makers no longer are satisfied with using real numbers to represent their cognition for alternatives [22].

In light of this, this article refers to the findings of previous studies and proposes a service-oriented manufacturing mode that is established under a supplier selection evaluation index system, builds a decision model, and is based on the bias function model and the method of interval relative entropy sort, in order for service-oriented manufacturing enterprises to successfully solve the vending.

2. Establishment of Supplier Selection Evaluation Criteria in a Service-Oriented Manufacturing Mode

The evaluation criteria for supplier selection in service-oriented manufacturing mode are developed using the guidance of scientific, comprehensive, and operational principles, in combination with the characteristics of service-oriented manufacturing, and drawing on the research findings of pertinent academics. The factor layer is divided into seven sections, each of which is further subdivided by a number of indicators: quality and technology, price, service level, synergy, flexibility, environmental performance, and comprehensive factors.

Table 1

Supplier evaluation criteria under service-oriented manufacturing mode.

Target	Element	Indicators
Supplier evaluation in service manufacturing mode	Quality and technical factors	The quality of the product
		Quality assurance system
		The technical level
	Price factors	The price
		Cost saving capability
	Service-level factors	Service capability
		Order completion rate
		On-time delivery rate
		Delivery completion rate
	Synergy factors	Complementary resources
		Collaborative innovation
		Interface management
		Cultural background
		The enterprise trust
	The flexible factors	Quantity flexibility
		Variety flexibility
		Time flexibility
		Cost flexibility
	Environmental performance factors	The effectiveness of environmental technologies
		Ecological efficiency
		The environmental costs
	Comprehensive factors	Corporate reputation
		The management level
		Development potential

2.1. Quality and Technical Factors

(1) Product quality B1: refers to the qualifying rate of product delivery quality

(2) Quality assurance system B2: refers to the thoroughness and effectiveness of the enterprise's quality assurance system, typically assessed by experts and expressed in the form of comments

(3) Technical level B3: relates to the supplier's capacity for developing new products, which is often determined by the new product development rate.

2.2. Price Factors

(1) Price B4: This is the cost the seller has quoted for the good or service. The pricing typically takes the shape of an interval number to be more competitive.

(2) Cost-saving ability B5: This term refers to the ability of logistics to reduce costs on the presumption that function and quality standards are met. It is typically represented as a percentage of the average logistical cost saved for each delivery.

2.3. Service-Level Factors

(1) Service capacity B6: This is the elastic scale of production and service quantity that the supplier has attained and which may be evaluated by the output within a specific time frame. Typically, this index represents an interval value.

(2) Order completion rate B7: This indicator of supplier performance can be stated as the proportion of actual completed orders to anticipated completed orders.

(3) On-time delivery rate B8: This is the proportion of the total quantity of logistics provided within a given time period by the supplier to the number of waybills delivered within that time period on time and in accordance with customer criteria.

(4) Delivery completion rate B9: This metric measures the percentage of the total quantity of items that are delivered in good condition within a specific amount of time.

2.4. Synergy Factors

(1) complimentary resources B10: This term refers to the characteristics that suppliers and service manufacturing companies have that are complimentary in terms of their human resource structures, core technologies, knowledge management, capital, and other resources.

(2) Collaborative innovation B11: This index measures the breadth and depth of innovation in the process of cooperation in order to better meet consumer needs.

(3) Interface management B12: This term describes how suppliers, service-oriented manufacturing companies, and various enterprise departments handle interface docking and management using a variety of technical tools and information-sharing platforms.

(4) culture background B13: This index evaluates how both sides feel about and are prepared to work together to achieve the shared vision, goal, and culture management.

(5) Enterprise trust B14: This term refers to the trust that exists between businesses and can be explicitly evaluated in light of the extent, duration, and effectiveness of such cooperation.

The above indicators can be assessed in the form of comments.

2.5. The Flexible Factors

(1) Quantity flexibility B15: refers to the supplier's ability to alter the quantity of products within its production capacity

(2) Variety flexibility B16: refers to the supplier's capacity to enhance current products and develop new ones in order to adapt to market environment changes as well as the capacity to modify varieties in the supply process

(3) Time flexibility B17: refers to the supplier's capacity to reduce the delivery time in order to meet customer demands.

(4) Cost adaptability B18: It speaks to the company's understanding of the cost structure over the whole product life cycle, reflecting the ongoing competitive advantage of cost

The above indicators can be assessed in the form of grades and scores.

2.6. Environmental Performance Factors

(1) Effectiveness of environmental protection technology B19: This term relates to how well suppliers apply environmental protection technology as determined by expert evaluation and feedback.

(2) Eco-efficiency B20: This is the measure of how valuable the goods and services produced or supplied by the supplier are in relation to the resources and energy they utilise and the environmental burden they impose.

(3) Environmental protection cost B21: This is the price of the supplier's environmental protection input over a specific time period.

2.7. Comprehensive Factors

(1) Corporate reputation B22: this refers to the supplier's standing in the industry

(2) Management level B23: this refers to the supplier's performance in internal system, organisation, and management construction.

(3)Development potential B24 refers to the driving forces behind and long-term strategies for supplier sustainable development.

The above indicators can be assessed in the form of grades and scores.

3. Decision Model Construction of Supplier Selection in Service-Oriented Manufacturing Mode

Supplier selection in service-oriented manufacturing mode is a typical multilevel, uncertain, and multiattribute decision-making problem, which is usually transformed into a comparison and ranking problem of interval numbers [23].

In this study, we identify a group of providers to be assessed as

$P = \{p_1, p_2, \ldots, p_s, \ \ldots, p_m\}(s = 1, 2, \ldots, m),$

As well as the indicator as $B = \{b_1, b_2, \ldots, b_t, \ldots, b_n\}(t = 1, 2, \ldots, n).$

The indexes can be broadly classified into two categories: efficiency and cost. Efficiency indexes are often better when the evaluation value is higher. Let's say that the size of the index weight vector $\omega = \{\omega_1, \omega_2, \ldots \omega_n\},$ **and the size** ω **represents the relative weight of each attribute index.**

ω_t is unknown, and $\sum_{t=1}^{n} \omega_t = 1.$

3.1. Construction of Interval Evaluation Matrix

Let c_{st} stand for the attribute value of the supplier, p_s under the evaluation index, b_t which can take on numerous forms, including exact, interval, or fuzzy numbers. The first evaluation matrix $C = (c_{st})_{m*n}$ is made up of these values.

The mixed initial matrix C can be defined as

$$C = \begin{cases} c_{st} & \text{attribute value is the exact value,} \\ \left[c_{st}^{l}, c_{st}^{u}\right], & \text{attribute value is interval number,} \\ \left(c_{st}^{l}, c_{st}^{u}, c_{st}^{r}\right), & \text{attribute value is fuzzy number.} \end{cases} \quad (1)$$

In real life, the decision-makers prefer to utilize linguistic terms rather than employing the exact numbers owing to the complication of the socioeconomic environment and fuzziness of human beings thinking [24].

To make the experts' evaluation more accurate, a set of fuzzy linguistic values is set up and noted as {Extremely Bad, Very Bad, Bad, Medium Bad, Medium, Medium Good, Good, Very Good, Extremely Good} ({EB, VB, B, MB, M, MG, G, VG, EG} for short). The evaluation data of qualitative criteria are given by experts in the form of fuzzy linguistic values that correspond to fuzzy numbers [25]. Mapping rules of linguistic variables and triangular fuzzy number are shown in Table 2.

Table 2

Mapping rules of linguistic variables and triangular fuzzy numbers.

No.	Linguistic evaluation value	Triangular fuzzy number
1	Extremely bad (EB)	(0.0, 0.1, 0.2)
2	Very bad (VB)	(0.1, 0.2, 0.3)
3	Bad (B)	(0.2, 0.3, 0.4)
4	Medium bad (MB)	(0.3, 0.4, 0.5)
5	Medium (M)	(0.4, 0.5, 0.6)
6	Medium good (MG)	(0.5, 0.6, 0.7)
7	Good (G)	(0.6, 0.7, 0.8)
8	Very good (VG)	(0.7, 0.8, 0.9)
9	Extremely good (EG)	(0.8, 0.9, 1.0)

Many indicators' information during the supplier selection process is not quantifiable. The interval number is introduced to ascertain the attribute value of each index in order for analysis and evaluation. We convert the mixed attribute index into an interval number index based on the generalisation and applicability of analysis and decision-making, and then we build the interval evaluation matrix E.

$$E = \left|\left[e_{st}^{l}, e_{st}^{r}\right]\right|_{m\times n}. \quad (2)$$

The initial evaluation matrix, or E, was developed as depicted in

$$\left[e_{st}^{l}, e_{st}^{r}\right] = \begin{cases} \left[e_{st}, e_{st}\right], & \text{attribute value is the exact value,} \\ \left[e_{st}^{l}, e_{st}^{u}\right], & \text{attribute value is interval number,} \\ \left[\dfrac{\left(e_{st}^{l} + e_{st}^{u}\right)}{2}, \dfrac{\left(e_{st}^{u} + e_{st}^{r}\right)}{2}\right], & \text{attribute value is riangular fuzzy number.} \end{cases} \quad (3)$$

3.2. Normalization of the Interval Number Matrix

In order to avoid the effect of adopting different units and to reduce the variability, the attribute values of the original indicators need to be normalized [26]. The normalized interval matrix U can be determined by using (4). For a criterion if the larger value is better, it can be normalized by using (5), whereas for a criterion if the smaller value is better, it can be normalized by using (6).

$$U = \left\| \left[u_{st}^{l}, u_{st}^{r} \right] \right\|_{m\times n}, \qquad (4)$$

$$\begin{cases} u_{st}^{l} = \dfrac{e_{st}^{l}}{\sqrt{\sum_{s=1}^{m} \left(e_{st}^{r}\right)^{2}}}, \\ u_{st}^{r} = \dfrac{e_{st}^{r}}{\sqrt{\sum_{s=1}^{m} \left(e_{st}^{l}\right)^{2}}}, \end{cases} \qquad (5)$$

$$\begin{cases} u_{st}^{l} = \dfrac{\left(1/e_{st}^{r}\right)}{\sum_{s=1}^{m} \left(1/e_{st}^{l}\right)^{2}}, \\ u_{st}^{r} = \dfrac{\left(1/e_{st}^{l}\right)}{\sum_{s=1}^{m} \left(1/e_{st}^{r}\right)^{2}}. \end{cases} \qquad (6)$$

3.3 Obtaining the Closeness Coefficient and Ranking the Order of Alternatives

The closeness coefficient between the candidate supplier and the ideal solution is calculated based on (28).

The concept of relative closeness is presented, and the following calculating procedure is used:

$$L_{s}^{*} = \frac{d_{s}^{-}}{d_{s}^{*} + d_{s}^{-}}, \quad (s = 1, 2, \ldots, m). \qquad (28)$$

The alternative p_i is far from the negative ideal reference point and close to the ideal reference point if index Ls is approaching. Sort the L_s in each possible p_i in decreasing order. The optimal option will be the p_i alternative with the highest L_s value.

4. Conclusions

According to the new characteristics of supplier selection in service-oriented manufacturing, this paper develops a reasonable supplier evaluation index system, which includes quality and technology, price, service level, collaborative ability, flexibility, environmental performance, and comprehensive factors. The index system enhances the evaluation criteria of supplier selection and converts the language evaluation value into the form. The candidate suppliers are assessed using the combined model based on the deviation function model and the interval relative entropy ranking approach. To better prevent the subjectivity issue, the weight of the attribute is determined using the deviation function model. The scheme sorting is improved in discrimination and decision accuracy using the interval relative entropy sorting technique. In order to maximise overall value creation with suppliers, realise the integration of manufacturing resources in the supply chain, raise the overall management standard of the company, and strengthen its core competencies, service-oriented manufacturing enterprises can optimise their supply networks by establishing a scientific and reasonable system for selecting their suppliers. The proposed method, which offers a new way to choose the best supplier for service-oriented manufacturing firms and also offers fresh concepts for other multiattribute decision-making problems, is demonstrated through an application case to demonstrate its effectiveness and viability.

References

1. Z. Lu, "An analytical study on service-oriented manufacturing strategies," *International Journal of Production Economics*, vol. 139, no. 1, pp. 220–228, 2012.
2. J. Gao, Y. Yao, V. C. Y. Zhu, L. Sun, and L. Lin, "Service-oriented manufacturing: a new product pattern and manufacturing paradigm," *Journal of Intelligent Manufacturing*, vol. 22, no. 3, pp. 435–446, Jun. 2011.
3. W. Lin, Z. Jiang, and N. Li, "A survey on the research of service-oriented manufacturing," *Industrial Engineering Management*, vol. 14, no. 6, pp. 1–31, 2009.J. Chen, S. Tong, and S. Yao, "Research on value co-creation mechanism in service manufacturing," *Science and Technology Progress and Policy*, vol. 31, no. 1, pp. 435–446, 2014.
4. Q. Zhang, Z. Guo, F. Man, and J. Ma, "Evaluation and selection of manufacturing suppliers in B2B E-commerce environment," *Complexity*, vol. 2020, pp. 1–8, 2020.
5. G. W. Dickson, "AN analysis OF vendor selection systems and decisions," *Journal of Purchasing*, vol. 2, no. 1, pp. 5–17, 1966.
6. C. A. Weber, J. R. Current, and W. C. Benton, "Vendor selection criteria and methods," *European Journal of Operational Research*, vol. 50, no. 1, pp. 2–18, 2007.
7. Y. Yuan, T. Guan, X. Yan, and Y. Li, "Based on hybrid VIKOR method decision making model for supplier selection," *Control and Decision*, vol. 29, no. 3, pp. 551–560, 2014.
8. C. Zhao and Y. Jiang, "Empirical research on Chinese enterprise strategic alliance partners characters matching standard," *Studies in Science of Science*, vol. 28, no. 4, pp. 558–565, 2010.
9. S. Chen, X. Shi, and S. Wu, "Impact of complementary assets and innovation asset synergy on performance-from the Prospect of moderating effect of environmental dynamism," *Systems Engineering*, vol. 33, no. 1, pp. 61–67, 2015.
10. R. Guo and Z. He, "FNN Based vendor selection in service-oriented manufacturing enterprises," *Journal of Xi'an Technological University*, vol. 31, no. 4, pp. 340–344, 2011.
11. B. Feng, W. Suo, and Z. Fan, "Evaluation on collaborative performances of a service-manufacturing network considering the fuzzy correlations of multicriteria," *Chinese Journal of Management Science*, vol. 20, no. 4, pp. 95–103, 2012.
12. L. Wang, L. Sun, and T. Feng, "Study on vendor selection in service-oriented manufacturing enterprises," *Commercial Research*, vol. 23, no. 2, pp. 1–5, 2010.
13. A. Sanayei, S. Farid Mousavi, and A. Yazdankhah, "Group decision making process for supplier selection with VIKOR under fuzzy environment," *Expert Systems with Applications*, vol. 37, no. 1, pp. 24–30, 2010.
14. W. Ho, X. Xu, and P. K. Dey, "Multi-criteria decision making approaches for supplier evaluation and selection: a literature review," *European Journal of Operational Research*, vol. 202, no. 1, pp. 16–24, 2010.
15. J. Chai, J. N. K. Liu, and E. W. T. Ngai, "Application of decision-making techniques in supplier selection: a systematic review of literature," *Expert Systems with Applications*, vol. 40, no. 10, pp. 3872–3885, 2013.
16. S. Zeng, Y. Hu, T. Balezentis, and D. Streimikiene, "A multi-criteria sustainable supplier selection framework based on neutrosophic fuzzy data and entropy weighting," *Sustainable Development*, vol. 28, no. 5, pp. 1431–1440, 2020.
17. J. Wang, S. Zeng, and C. Zhang, "Single-valued neutrosophic linguistic logarithmic weighted distance measures and their application to supplier selection of fresh aquatic products," *Mathematics*, vol. 8, no. 3, p. 14, 2020.
18. B. Zheng and F. Liu, "The determination of weights in supplier selection by using DEA/TOPSIS model," *Industrial Engineering Journal*, vol. 06, pp. 55–59, 2011.
19. L. Y. Zhai, L. P. Khoo, and Z. W. Zhong, "Towards a QFD-based expert system: a novel extension to fuzzy QFD methodology using rough set theory," *Expert Systems with Applications*, vol. 37, no. 12, pp. 8888–8896, 2010.
20. X. Liu, H. Li, C. Wang, and C. Chu, "A survey of supplier selection models and approaches," *Chinese Journal of Management Science*, vol. 12, no. 1, pp. 139–148, 2004.
21. X. Deng, J. Wang, and G. Wei, "Multiple attribute decision making based on power muirhead mean operators under 2-tuple linguistic pythagorean fuzzy environment," *Cognitive Computation*, vol. 2020, 2020.
22. H. Zhao, Y. Bao, and S. Guan, "Study on sorting method of interval numbers in multiple attribute decision making and its application," *Mathematics in Practice and Theory*, vol. 43, no. 19, pp. 43–48, 2013.
23. F. Lei, G. Wei, H. Gao, J. Wu, and C. Wei, "TOPSIS method for developing supplier selection with probabilistic linguistic information," *International Journal of Fuzzy Systems*, vol. 22, no. 3, pp. 749–759, 2020.
24. Y. Feng, Z. Zhang, G. Tian et al., "A novel hybrid fuzzy grey TOPSIS method: supplier evaluation of a collaborative manufacturing enterprise," *Applied Sciences-Basel*, vol. 9, no. 18, p. 25, 2019.
25. P. Pitchipoo, P. Venkumar, and S. Rajakarunakaran, "Grey decision model for supplier evaluation and selection in process industry: a comparative perspective," *International Journal of Advanced Manufacturing Technology*, vol. 76, no. 9–12, pp. 2059–2069, 2015.
26. W. Tang, D. Ding, and S. Liu, "Research on supplier selection based on mix-attribute index," *Journal of Hefei University of Technology*, vol. 34, no. 3, pp. 457–461, 2011.
View.
27. Y. Su, X. Meng, Z. Zhao, and Z. Li, "Cognitive virtual network embedding algorithm based on weighted relative entropy," *Ksii Transactions on Internet and Information Systems*, vol. 13, no. 4, pp. 1845–1865, 2019.