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NEW INTEGRATION OF MCDM METHODS AND QFD IN THE SELECTION OF GREEN SUPPLIERS

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Abstract. Currently, topics of operations management and supply chain systems have been gaining more interest of researchers. Efficiency in supply chain activities and operations management firstly benefit organisations. One of the main operations in supply chain systems is the collaboration with selected suppliers. Various models have been proposed in terms of supplier evaluation and selection studies. The invention of a new integrated frame for the building of an effective supplier evaluation system is a multi-attribute task that consists of several factors as external and internal variables. This paper delivers a creative integrated model of supplier selection problem using SWARA, QFD and a new MCDM tool called WASPAS. This work considers customer attitudes in the process of supplier evaluation. To give more weight to customer requirements, a new SWARA method has been designed; additionally, QFD and the house of quality matrix have been used to transform customer requirements into the supplier evaluation index. Finally, WASPAS has been used to rate the performance of suppliers and present supplier ranking scores. Application of initiative ways to propose a systematic supplier selection problem has always been encouraged by supply chain managers. This topic has been addressed in this paper as well.

Keywords: green supplier selection, supply chain management (SCM), multiple criteria decision making (MCDM), SWARA, QFD, WASPAS.

JEL Classification: A12, C44, C80, D81.

Introduction

Selection of suppliers for a typical supply chain system is an important task and one of the leading decision problems. In every manufacturing system that has a lot of properties, variables and tactics, many difficult and complex decision problems, such as supplier selection, must be solved. In addition, numerous factors, indexes and characteristics that have to be analysed by supply chain experts, depend on the whole system as well as external and internal variables. Supply chain designers have to draw on their knowledge and skills to define concepts, algorithms and models in order to optimise the performance of a system as well the system of supplier evaluation considering economic, social, governmental and environmental aspects. In the process of choosing an optimal supplier, many factors, including price, quality, delivery, production plan, facilities and some other specific sub-factors need to be taken into account, which sounds like a multiple criteria decision making (MCDM) problem (Hashemkhani Zolfani *et al.* 2016a, 2016b) Therefore, an efficient and systematic programme to facilitate the process of supplier selection is definitely a key issue in the supply chain management (SCM) structure.

In every MCDM problem, criteria can greatly affect the output of the evaluation system and specifically – supplier evaluation and selection. Traditional studies on supplier selection have concentrated broadly on aspects of supplier selection in terms of some internal and inter-organisational factors, without considering the opinion of their customers or customer requirements (CRs) (CRs are considered as a kind of external variables). Any stable supplier assessment system must consider the external environment of the whole supply chain and pay attention to the establishment of a clear understanding of customer needs, specifically – their subjective performance requirements. Hence, an improvement action is complementary to transit from the traditional approach (economic and general assessment of cost, efficiency, quality, lead time, etc.) to some new era of the supplier selection problem, which for instance highlights buyer satisfaction and the benefit of the stakeholders. In this case, a need for an instrument to connect customer and stakeholder attitudes to relevant supplier criteria is compulsory. This instrument is called the quality function deployment and utilises the house of quality matrix in order to make this fundamental connection (Bevilacqua *et al.* 2006; Büyüközkan *et al.* 2007; Bhattacharya *et al.* 2010; Dursun, Karsak 2013). Thus, the fundamental contribution of this paper from the technical viewpoint can be stated as the way to integrate QFD and a new weighting tool called SWARA, which has some preference of other weighting methods. One of the essential tasks in MCDM modelling is to explore new and logical ways to weight decision factors (attributes). Hence, it is understood that SWARA is preferred to usual weighting methods. To the best of our knowledge, this integration of QFD with SWARA is also new to the literature and no research project in this area has proposed it yet.

SWARA method acts differently than other weighting tools, such as AHP, Entropy, ANP and Delphi (Yang, Tzeng 2011; Kwong, Bai 2002). According to this method, the most significant criterion is given the first rank as the best, and the most trivial criterion is given the last rank. The overall ranks are demonstrated according to the mean value of ranks based on the decision of the group of experts. SWARA is beneficial for experts in the assessment of criteria and weights. The benefit is that each of them can determine the importance of each criterion on their own. Afterwards, experts are able to sort the criteria from the first to the last considering the overall outcome (Vafaeipour *et al.* 2014). SWARA presents an opportunity for policy-makers to take decisions based on different situations and to prioritise criteria based on their desired needs and goals. On the same line, the method incorporates expert comments into the process of such crucial projects (Hashemkhani Zolfani 2015)

1. Literature review

The literature review of this article is presented in three sections: The first section is about general ideas regarding the impact of SCM on the economic importance of the green perspective in managing the environment and the world. The green SCM role in sustainability literature is considered in this section as well. The second section is about green SCM literature and its antecedent developments in other fields of research. Finally, the last section is dedicated to the integrated research, which focused on the combination of MCDM methods with SCM.

The importance of economic development and growth is obvious for each nation and is a key part of each government's activities. Environmental issues are involved the part dedicated to the sustainable growth, which is a fundamental consideration these days. The term "green growth" has been considered as major topic at the recent United Nations Conference on the Sustainable Development called Rio+20 (Fahimnia *et al.* 2015). Generally, organisations that are successful and efficient in the sustainable development are considerably influenced by the level of efficiency in the performance of supply chains, particularly, the green performance of supply chain members that have a significant impact on the overall green performance of organisations (Chithambaranathan *et al.* 2015). A greening supply chain is a new paradigm that has been developing in industries and organisations. It can make a considerable contribution to both the economic and environmental development. This general perspective has been named green or environmentally sustainable supply chain management (Varsei *et al.* 2014). This new trend has developed more line the Green Supply Chain Management (GSCM) concept – an important approach to becoming environmentally sustainable (Shabani *et al.* 2014; Yang *et al.* 2013; HooBae *et al.* 2011). In this new GSCM concept, organisations attempt to work together and accomplish more in designing more innovations, incurring fewer expenditures, undertaking less risk, and achieving higher quality (Azadi *et al.* 2014). Many explanations have been offered in the investigation of the Green supply chain management (GSCM) (Vachon, Klassen 2006; Zhu *et al.* 2006, 2008; Min, Kim 2012) but one of the best-summarised definitions has been presented by Sarkis *et al.* 2011 and reads as follows:

GSCM can be defined as an incorporation of environmental issues and concerns into organisational activities taking place at different levels of the supply chain management system. It configures the application of environmental management principles to levels of a product's lifecycle, encompassing the design and material requirements, procurement and purchasing, manufacturing, packaging, logistics and distribution, end-user issues and final recycling to increase the competitive advantage of the company (Eltayeb 2011). The supply chain system can be considered green provided every member and feature of it work appropriately. Suppliers as strategic members of every supply chain should adopt the requirements of the focal company and customers. Hence, analysing and monitoring suppliers within a decisive frame is essential to improve green performance of suppliers (Lee 2009). In the last decade, green manufacturing or green supply chain concept has been growing dramatically among researchers, managers, environmentalists and others (Gunasekaran, Spalanzani 2012; Brockhaus *et al.* 2013). This is a developing trend among those companies, which make a connection between general green practices and their corporate strategies (Gunasekaran, Gallear 2012; Sarkis *et al.* 2011; Dubey *et al.* 2015).

Traditional supplier evaluation tools mainly concentrated on internal measures as economic and conventional factors in the evaluation process to improve organisational performance and maintain profits. Moreover, the used method and models included simple variables and parameters and, in other words, were not stable or robust enough to be globally developed. Many researchers and practitioners have already suggested and acquired MCDM and its integration in crisp, fuzzy, grey and group decision-making (GDM) environments to address supplier selection problems in traditional and green supply chain systems (Chai 2013; Govindan 2013). Among them, linear programming-based approach (Ghodsypour, O'brien 1998), AHP (Kahraman *et al.* 2003; Pi, Low 2006; F. T. Chan, H. K. Chan 2010; Kilincci, Onal 2011), Grey Relational Analysis (GRA) (Yang, Cheng 2006), MOORA method (Karande, Chakraborty 2012; A. Baležentis, T. Baležentis 2011), and TOPSIS (Yazdani, Payam 2015) have been recognised as single approaches while hybrid or integrated models have been successfully applied to optimize supplier evolution process, including the combined analytical network process (ANP) and multi-objective mixed integer linear programming (MOMILP) (Demirtas, Üstün 2008), AHP-QFD combined approach (HooBae *et al.* 2011), "Vlse Kriterijumska Optimizacija Kompromisno Resenje" (VIKOR) (Yazdani, Graeml 2014) and "ELimination and Et Choice Translating Reality" (ELECTRE) (Chatterjee *et al.*2011), integrated VIKOR and ANP (Lixin *et al.* 2008), VIKOR method in fuzzy GDM environment (Sanayei *et al.* 2010), fuzzy QFD model (Amin, Razmi 2009), fuzzy preference ranking organisation method for enrichment evaluation (PROMETHEE) method (Chen *et al.* 2011), ELECTRE I algorithm in a GDM environment (Hatami-Marbini, Tavana 2011), grey-VIKOR (P. Chatterjee, R. Chatterjee 2012), COPRAS-Grey (Hashemkhani Zolfani *et al.* 2012) and fuzzy GDM approach using QFD model (Dursun, Karsak 2013), integrated SWOT analysis, adapted data envelopment analysis (DEA) and TOPSIS (Chen 2011) model, hybrid method using step-wise weight assessment ratio analysis (SWARA) and VIKOR methods (Alimardani *et al.* 2013), rough sets theory (RST) and multi-objective mixed integer programming (MOMIP)-based approach (Xia, Wu 2007), hybrid QFD method (Rajesh, Malliga 2013; Asadabadi 2014), and combined ANP and modified GRA method (Hashemi *et al.* 2015).

2. Research methodology

In this section, the proposed algorithm for rating and evaluation of suppliers is discussed and developed. At first, following the house of quality matrix in QFD process, customer requirements (CRs) and supplier evaluation criteria have been identified. For the purposes of this study, CRs covered the financial stability, environmental management system, waste disposal, management commitment, quality control systems, manufacturing, facility and reverse logistic for supplier criteria quality adoption, price, energy consumption, delivery speed, green design, re-use and recycle rate and production planning, which were the main elements of the QFD model. The crucial task of QFD was to translate customer needs to engineering and technical parameters to be usable and understandable for supplier evaluation. Then, to achieve relative importance of CRs, the SWARA method has been employed. The CRs and related weights (Table 1) have been derived based on expert opinions and approaches. In the next phase, purchasing experts have detected the relationship between CRs. Normalised weights of criteria have then been used as an input for the WASPAS process. In the third phase, WASPAS technique has been used to solve the decision problem and finally deliver the ranking of all suppliers.

2.1. SWARA method

SWARA is a new and interesting weighing discipline. It is a suitable method for the subjects with priorities that had been specified earlier, according to situations. SWARA is able to estimate expert opinions regarding the importance ratio of criteria. The procedure for the determination of weights by SWARA as mathematical stepwise analysis can be expressed as follows:

***Step* 1 –** All criteria should be sorted based on expert ideas (Zavadskas, Vilutienė 2006; Zavadskas *et al.* 2008; 2010).

***Step* 2 –** From the second criterion, the comparative importance of the average value s_j should be determined as follows: the relative importance of the criterion *j* in relation to the previous (*j* – 1) criterion (Stanujkic *et al.* 2015).

***Step* 3 –** Determine the coefficient k_j:

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases}. \tag{1}$$

***Step* 4 –** Determine the recalculated weight w_j:

$$w_j = \begin{cases} 1 & j = 1 \\ \dfrac{x_{j-1}}{k_j} & j > 1 \end{cases}. \tag{2}$$

***Step* 5 –** The final step in the calculation of criteria weights:

$$q_j = \frac{w_j}{\sum_{k=1}^{n} w_j}, \tag{3}$$

where q_j denotes the relative weight of the criterion *j*.

2.2. QFD method

QFD is an engineered tool, which transforms the requirements of end-users and customers into specific and understandable characteristics of the product design and production process. QFD transformations are handled by a matrix displaying the relationships between the voice of the customers and the quality characteristics. It is known as the *House of Quality* (HoQ) matrix, which expresses the relationship between the CRs (WHATs) and the supplier attributes (HOWs) (Chen *et al.* 2005). The general QFD model incorporates the following characteristics in the HoQ: (a) WHATs matrix, (b) HOWs matrix, (c) the relationship matrix between WHATs and HOWs, (d) the relative importance or weights of WHATs, (e) the interrelationship between HOWs, and (f) weights of HOWs (Khademi-Zare *et al.* 2010). In this study, QFD has been applied to connect the supplier evaluation criteria to the customer requirements to obtain more reliable and global decision objectives.

The general steps for the implementation of the QFD model are as follow:

***Step* 1** – To identify the WHATs.

***Step* 2** – To define the HOWs.

***Step* 3** – To assign priority weights to the CRs. In this paper, this process is done using the SWARA method.

***Step* 4** – To release the relationship matrix (or the HoQ resulting matrix) using the knowledge of the decision maker to build this relationship matrix using a four point scale: *weak relationship* (1), *moderate relationship* (3), *strong relationship* (6) and *very strong relationship* (9). Users can address their judgement using moderate values as 2, 4, 5, 7 and 8. These relationships indicate how supplier evaluation criteria can quantitatively satisfy the CRs.

***Step* 5** – To compute the overall priorities of supplier attributes. In the study case, these weights are interpreted as the relative weights of the supplier selection criteria. Suppose that n supplier selection criteria are used to satisfy m CRs. Then, the degree of importance (weight) w_j of the j-th supplier selection criterion, with $j = 1, \ldots, n$ is computed as follows:

$$w_j = \sum_{i=1}^{m} R_{ij} C_i \,, \tag{4}$$

where, for $j = 1, \ldots, n$ and $i = 1, \ldots, m$, R_{ij} denotes the relationship between the j-th supplier selection criteria and the i-th CR and C_i represents the weight of i-th CR computed using the SWARA method. The normalised weight of each supplier $\tilde{w}_j$ is computed by the following equation:

$$\tilde{w}_j = \frac{w_j}{\sum_{j=1}^{n} w_j} \,. \tag{5}$$

2.3. Weighted Aggregated Sum Product Assessment (WASPAS)

Weighted Aggregated Sum Product Assessment (WASPAS) is one of the most recently developed MCDM tools. It is the mixture of two MCDM approaches, i.e. the Weighted Sum Model (WSM) and the Weighted Product Model (WPM). The following formulas report the ranking of decision alternatives:

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}, \tag{6}$$

where n is the number of evaluation criteria and $j = 1, \ldots, n$, x_{ij} is the performance rating of the I alternative upon the j-th decision criterion. This decision matrix is normalised using the following equations, where the normalised generic element of the decision matrix is denoted by $\tilde{x}_{ij}$:

For benefit attributes:

$$\tilde{x}_{ij} = \frac{x_{ij}}{\max\limits_{i} x_{ij}}, j = 1, \ldots, n;\ i = 1, \ldots, m. \tag{7}$$

For non-benefit attributes:

$$\tilde{x}_{ij} = \frac{\min\limits_{i} x_{ij}}{x_{ij}}, j = 1, \ldots, n;\ i = 1, \ldots, m. \tag{8}$$

To compute WASPAS weighted normalised decision matrix, the following two actions must be performed. The first one is assigned to the summarization process of WASPAS:

$$\tilde{\tilde{x}}_{ij,sum} = \tilde{x}_{ij} w_j, j = 1, \ldots, n;\ i = 1, \ldots, m \tag{9}$$

and for the multiplication part;

$$\tilde{\tilde{x}}_{ij,mult} = \tilde{x}_{ij}^{w_j}, \text{ where } j = 1, \ldots, n;\ i = 1, \ldots, m. \tag{10}$$

A joint generalised criterion of weighted aggregation of additive and multiplicative methods can be then proposed as follows:

$$Q_i = 0.5 \sum_{j=1}^{n} \tilde{\tilde{x}}_{ij,sum} + 0.5 \prod_{j=1}^{n} \tilde{\tilde{x}}_{ij,mult}, j = 1, \ldots, n;\ i = 1, \ldots, m. \tag{11}$$

In order to increase the ranking accuracy and effectiveness of the decision-making process, using the WASPAS method, a more generalised equation for determining the total relative importance of the alternatives can be employed (Zavadskas *et al.* 2012):

$$Q_i^{\lambda} = \lambda \sum_{j=1}^{n} \tilde{\tilde{x}}_{ij,sum} + (1-\lambda) \prod_{j=1}^{n} \tilde{\tilde{x}}_{ij,mult}. \tag{12}$$

Finally, the candidate alternatives can be ranked based on the Q- values, i.e. the best alternative would be the one having the highest Q-value. When the value of λ is 0, the WASPAS method coincides with WPM, while for $\lambda = 1$, WASPAS corresponds to WSM. Recently, researchers have been using WASPAS and trying to increase its applicability.

3. Results and discussion

The proposed model for supplier evaluation has been implemented in the Steel Alborz Company in Iran, which is active in the stainless steel industry. This company is one of the most famous companies in the Middle East with export to more than 40 countries in different continents. In this section, SWARA has been primarily applied for evaluating the relative importance of each customer requirement. Experts have considered eight requirements and delivered weights and relative importance of each requirement following the SWARA process. The results of SWARA weights are exhibited in Table 1. The financial stability has been the most important requirement in this study in terms of the expert attitude.

Table 1. SWARA outcomes as assigned weights for CRs

Customer requirements	Comparative importance of the average value S_j	Coefficient $K_j = 1 + S_j$	Recalculated weight w_j	Final weight q_j
Financial stability (FS)	–	1	1	**0.212**
Environmental management system (EMS)	0.2	1.2	0.833	**0.176**
Waste disposal program (WDP)	0.15	1.15	0.725	**0.153**
Management commitment (MC)	0.2	1.2	0.604	**0.128**
Quality control systems (QCS)	0.18	1.18	0.512	**0.108**
Manufacturing (M)	0.25	1.25	0.409	**0.087**
Facility (F)	0.15	1.15	0.356	**0.075**
Reverse logistic (RL)	0.24	1.24	0.287	**0.061**

The next section is to reach the main weights of supplier criteria. This task has been handled using the QFD model and the house of quality matrix. In fact, experts should have determined how a typical supplier criterion could satisfy customer requirement. This operation is shown in Table 2. As demonstrated at the end of the QFD process, the weights and normalised weights of the decision criteria have been produced using Equations 4 and 5.

Table 2. HoQ matric and QFD procedure for the weight of a supplier criterion

HOWs (Requirements)	WHATs (Criteria)							Weight of requirements by SWARA
	Quality adoption	Price	Energy consumption	Delivery speed	Green design	Re-use, re-cycle rates	Production planning	
Financial stability (FS)	7	5	6	6	4	2	5	0.212
Environmental management system (EMS)	6	3	3	4	5	4	3	0.176
Waste disposal program (WDP)	4	8	7	4	1	2	6	0.153
Management commitment (MC)	5	3	4	2	4	5	5	0.128
Quality control systems (QCS)	6	2	2	3	4	4	7	0.108
Manufacturing (M)	5	3	4	5	2	1	6	0.087
Facility (F)	8	5	6	6	3	2	7	0.075
Reverse logistic (RL)	3	6	5	4	6	4	5	0.061
Weight of criteria	5.66	4.41	4.70	4.30	3.59	2.99	5.25	30.903
Normalized weight of criteria	0.183	0.143	0.152	0.139	0.116	0.097	0.170	

At this level, weights of all criteria and performance rating of candidate alternatives had to be obtained. Weights have been calculated by the SWARA-QFD integrated approach. So, for the performance of suppliers, Table 3 has been provided by experts based on qualitative scales. Then, to translate the qualitative variable, Table 4 as a reference datasheet has been used and also the initial decision matrix for applying WASPAS (Table 5).

Table 3. Supplier performance rating using qualitative scales

Alternatives	Quality adoption	Price	Energy consumption	Delivery speed	Green design	Re-use, re-cycle rates	Production planning
S_1	First	Second	High	So fast	Harmful	70%	Excellent
S_2	Fourth	Fifth	Reasonable	Fast	Harmful	75%	Suitable
S_3	Sixth	Sixth	High	Middle	Harmful	65%	Suitable
S_4	First	Most expensive	High	So fast	Compatible	85%	Excellent
S_5	Fifth	Fourth	Reasonable	Middle	Harmful	75%	Suitable
S_6	First	Third	High	Fast	Compatible	85%	Excellent

Table 4. References for translating qualitatie data to quantitative values

Quality		Price		Energy consumption		Delivery speed		Green design		Prod. planning	
Qualitative variable	Assigned value	Qualitative variable	Assigned value	Qualitative variable	Assigned value	Qualitative variable	Assigned value	Qualitative variable	Assigned value	Qualitative variable	Assigned value
First	10	Most exp. (First)	10	High	8	So fast	10	Compat-ible	8	Excel-lent	8
Second	8	Second	8	Reason-able	6	Fast	8	Low harmful	6	Suit-able	6
Third	6	Third	6	Low	4	Middle	6	Average harmful	4	Weak	4
Forth	4	Forth	4	Very low	2	Low	4	Harmful	2	Zero plan	2
Fifth	2	Fifth	2			Very low	2				
Sixth	1	Sixth	1								

Table 5. Converted qualitative data of suppliers for the evaluation of the process (the initial decision matrix)

Alternative	Quality adoption	Price	Energy consumption	Delivery speed	Green design	Re-use, re-cycle rates	Production planning
S_1	10	8	8	10	2	0.7	8
S_2	4	2	6	8	2	0.75	6
S_3	1	1	8	6	2	0.65	6
S_4	10	10	8	10	8	0.85	8
S_5	2	4	6	6	2	0.75	6
S_6	10	6	8	8	8	0.85	8

The next step to solve the supplier evaluation problem is to follow the WASPAS algorithm. The structure and step-wise procedure of WASPAS have been introduced in Section 2.3. First of all, a normalised decision matrix is required. To obtain a normalised decision matrix, Equations 7 and 8 have to be used for the benefit and non-benefit criteria. For this work, all of the criteria except the price and resource consumption have been included in the category of the benefit criteria. Table 6 exhibits the normalised decision matrix.

Thereafter, weighted normalised supplier matrix must be achieved. As stated earlier, in the algorithm of WASPAS, the weighted normalised decision matrix has been composed of two concepts of MCDM – the weighted summation method and the weighted multiplication method. Those formulas are introduced as Equations 7 and 8. The weighted normalised supplier matrix is pictured in Table 7.

Table 6. Normalised matrix for supplier evaluation

Alternatives	Quality adoption	Price	Energy consumption	Delivery speed	Green design	Re-use, re-cycle rates	Production planning
Supplier 1	1	0.125	0.75	1	0.25	0.82	1
Supplier 2	0.4	0.5	1	0.8	0.25	0.88	0.75
Supplier 3	0.1	1	0.75	0.6	0.25	0.76	0.75
Supplier 4	1	0.1	0.75	1	1	1.00	1
Supplier 5	0.2	0.25	1	0.6	0.25	0.88	0.75
Supplier 6	1	0.17	0.75	0.8	1	1.00	1

Table 7. Weighted normalised decision matrix for suppliers

Alternatives	Quality adoption	Price	Energy consumption	Delivery speed	Green design	Re-use, re-cycle rates	Production planning
Weighted normalised (Summarization section) matrix of WASPAS							
Supplier 1	0.183	0.018	0.114	0.139	0.029	0.08	0.17
Supplier 2	0.073	0.071	0.152	0.111	0.029	0.085	0.128
Supplier 3	0.018	0.143	0.114	0.083	0.029	0.074	0.128
Supplier 4	0.183	0.014	0.114	0.139	0.116	0.097	0.17
Supplier 5	0.037	0.036	0.152	0.083	0.029	0.085	0.128
Supplier 6	0.183	0.024	0.114	0.111	0.116	0.097	0.17
Weighted normalised (Multiplication section) matrix of WASPAS							
Supplier 1	1	0.743	0.957	1	0.851	0.981	1
Supplier 2	0.846	0.906	1	0.969	0.851	0.988	0.952
Supplier 3	0.656	1	0.957	0.931	0.851	0.974	0.952
Supplier 4	1	0.72	0.957	1	1	1	1
Supplier 5	0.745	0.82	1	0.931	0.851	0.988	0.952
Supplier 6	1	0.774	0.957	0.969	1	1	1

Table 8. Ranking of suppliers by WASPAS and different values of λ

Alternatives	Rank of WASPAS for suppliers								
	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$	$\lambda = 0.5$	$\lambda = 0.6$	$\lambda = 0.7$	$\lambda = 0.8$	$\lambda = 0.9$
Supplier 1	3	3	3	3	3	3	3	3	3
Supplier 2	4	4	4	4	4	4	4	4	4
Supplier 3	5	5	5	5	5	5	5	5	5
Supplier 4	2	2	2	2	2	2	1	1	1
Supplier 5	6	6	6	6	6	6	6	6	6
Supplier 6	1	1	1	1	1	1	2	2	2

To finalise the process of supplier selection through the WASPAS method, Equation 12 has been used. Based on this equation, the values of Q have been computed and the supplier ranking has been generated. Table 8 indicates the ranking of suppliers. Normally the WASPAS optimal ranking score (equation 11) is expressed by $\lambda = 0.5$ According to this table, the supplier order preference is as given below:

Supplier 6 > supplier 4 > supplier 1 > supplier 2 > supplier 3 > supplier 5, supplier 4 is the favourite candidate while supplier 5 is the worst one among all. However, in this work, a different value of λ (Table 8) has slightly changed the ranking of suppliers. In addition, except for a little change in $\lambda = 0.7$,$\lambda = 0.8$ and $\lambda = 0.9$ rankings, the other ranking scores have remained the same, demonstrating the stability of the proposed method and WASPAS.

Conclusions

Supplier selection has been accomplished based on internal and external aspects. During the assessment of suppliers, external variables, such as customer needs and stakeholder attitudes had to be satisfied. On the other hand, suppliers have been analysed considering economic, environmental and other factors of the system. This paper has elaborated on a new structure to appraise suppliers according to a model, which connects supplier evaluation attributes to required customer values using the house of quality matrix and the QFD model. Customer requirements are defined and then experts attempt to connect supplier attributes by a rating system. To be meaningful and to catch the effect of customer importance, weights of customer requirements have been generated using a new weighting method SWARA. At the end of this stage, normalised weights of each decision attribute have been obtained. For prioritisation and getting the ranking of suppliers, WASPAS method has been developed. WASPAS enhances the chance of more reliable and optimal values. In this work, a supplier selection problem has been undertaken within a green supply chain system and so some green measures have been presented to conduct the QFD evaluation process. Planning, organising and evaluating the green supply chain operations are particularly critical issues in today's competitive circumstances. Due to this, the importance of green suppliers as one of the substantial elements of a supply chain and their standard assessment has been gaining more attention of managers. Through this research, the authors of this article have indicated the possibility to integrate the QFD approach, SWARA weighting and WASPAS methods to reward proactive suppliers and eliminate or reform the defective ones. Although the proposed model has the ability to be implemented in the industry or any other sector, some limitations can be named. Provided users and experts indicate their judgements during the decision process using linguistic variables, fuzzy QFD and fuzzy MCDM must be deployed. Interdependency between decision variables and customer factors can possibly be resolved using the ANP or DEMATEL techniques. Moreover, the group decision-making framework can be addressed for future research perspectives.

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