Decision Science Letters 8 (2019) 295–308

Contents lists available at GrowingScience

Decision Science Letters

homepage: www.GrowingScience.com/dsl

Development of decision support system for e-supplier selection in Indian mechanical manufacturing industry using distance based approximation

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C H R O N I C L E

Article history:
Received October 19, 2018
Received in revised format:
October 28, 2018
Accepted December 6, 2018
Available online
December 6, 2018

Keywords:
e-supplier
Supplier selection
e-supply chain
Distance based approximation (DBA)
Manufacturing sector
Indian industries

A B S T R A C T

This paper proposes a framework to develop a deterministic model for the valuation, selection and grading (ranking) of e-suppliers by using Modified Distance Based Approach (MDBA), which has not been used earlier in e-supplier selection. The e-supplier selection system performs a major part for the successful running of any supply chain. Thus, for effective running of any supply chain, it is necessary to build a system for the selection of e-supplier. Building such a decision support system software is important for the development of any decision support system efficiently with reduced cost, time and effort. The current research is based on 8 criteria and 52 sub-criteria by giving equal weightage to all of them. In this study, the major criteria are disintegrated into small sub-criteria. To validate the results obtained through the proposed distance based approximation method, the results are compared with other methodologies. Finally, with the illustration of the example problem, the applicability of the developed model is described.

1. Introduction

The development in the utilization of the internet in the manufacturing sector and an increase in production demand has been a major cause of introducing the e-supply chain. e-supplier selection is a new emerging approach which can lead to improvements in delivery lead time, transportation time, effort and cost of any supply chain. Presently, most of the firms recommend e-procurement by introducing automation in managing the business operations (Vaidyanathan & Devaraj, 2008). In e-procurement various business operations like material handling, quality validation and other value added services are controlled through the internet (Johnson & Whang, 2002). Quality improvement is the major objective of e-procurement (Kerney, 2005). e-Supplier selection process is a blend of qualitative and quantitative factors which leads to a multi-criteria problem. It requires proper synchronization between these tangible and intangible factors for the selection of the best e-supplier

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doi: 10.5267/j.dsl.2018.12.001

(Ghodsypour & Brien, 1998). The main issue involved in e-supplier selection, is the selection of criteria according to the field for the development of a system.

For the improvement in production cycle and supply chain, e-supplier selection has become a necessary variable/factor for the production companies. Various criteria like quality, cost, service, etc. are broadly available for e-supplier selection. These can be further disintegrated into sub-criteria for the ease of decision making and avoiding the ambiguity and vagueness in the decision taken. These criteria and sub-criteria may vary with the difference in the nature of the supply chain. This process of e-supplier selection is very useful for the development of production systems if the criteria finalization and system development successfully take place. During the past few years, production firms faced an era of improvement in terms of advancement in production technology, supply chain system, market globalization and customer demands. World class and domestic competitors are growing day by day, hence, it is necessary for firms to rapidly improve their internal and external processes for staying competitive. In this competitive environment, it is the capability of the firms to strengthen them with minimum cost at a rapid pace than their competitors.

There are varieties supplier selection criteria available in the literature. However, it becomes a challenging process to find out the most suitable and potential criteria among all, which will be more suited to the given problem. The number of criteria for supplier selection also increases day by day with the integration of supply chain in various fields like green supply chain, e-supply chain, etc. This research selects the criteria which are found more suitable for supplier selection and also deals with e-supply chain on the basis of quality, cost, service, delivery, etc.

In this study modified distance based approach is used for the selection and grading (ranking) of e-supplier for automobile manufacturing firms based on 8 main criteria and 52 sub-criteria. This paper is arranged in 7 sections. Sections 2 introduces about the literature review related to e-supplier ranking criteria and selection methods. Section 3, describes about the existing methodology used for selection. The e-supplier ranking & selection procedure is described in Section 4. Section 5 presents the model with the help of examples and ranking of e-suppliers. Section 6 refers to the validation of the results with other techniques. Section 7 finally focuses over the result and a conclusion part.

2. Literature Review

e- Supplier selection process is the most challenging and necessary task for any supply chain. The study of research provides information about various supplier selection criteria and methodology adopted, are summarized in this section. This section of study is split in two portions (1) e-supplier selection criteria and (2) selection techniques.

2.1. e- supplier selection criteria

Supplier selection is a complex procedure in which we work on multi-criteria activities for the selection of a supplier. According to Chang et al. (2007) suppliers are differentiated on the basis of their characteristics like organizational culture, manufacturing procedure, technology capabilities and geographical location for the selection of the best supplier. In the recent study, most of the work in the literature has been found on supply chain management and supplier selection process.

According to Jain et al. (2004) supplier selection process is used in traditional SCM by first setting up the standards for selection criteria and then periodic evaluation is followed to ensure attainment of these standards. Both qualitative and qualitative techniques are used by the researchers discussed in earlier studies for supplier selection (Ramanathan, 2007). Most of the literature found are based on criteria like price, quality, financial status, service, location, delivery, time, and performance (Deng & Chan, 2011; Aksoy & Ozturk, 2011; Kara, 2011). These factors, which are explained earlier are very useful for evaluation of supplier (Chang & Hung, 2010). So, in this literature two types of criteria for e-supplier selection are considered. Some criteria belong to traditional supply chain and others are extracted from an e-supply chain as shown in Table 1.

Table 1
Source of E- Supplier Selection Criteria & Sub- Criteria

Factor	Indicators	Sources
Quality	Online information Quality	(DeLone & McLean, 2003), (Fairchild et al., 2004), (Valahzaghard et al., 2011).
	Online payment procedure	(Mentzer et al., 2001), (Valahzaghard et al., 2011).
	Product Quality	(Tsai et al., 2010), (Sanayei et al., 2010), (Wu, 2010), (Shemshadi et al., 2011), (Liao & Kao, 2011), (Vinodh et al., 2011), (Chang et al., 2011), (Deng & Chan, 2011), (Aksoy & Öztürk, 2011), (Kara, 2011), (Kilincci & Onal, 2011), (Akarte et al., 2001), (Priya et al., 2012), (Ozkan et al., 2011), (Ghodsypour & O'Brien, 1998), (Kar & Pani, 2014), (Garg et al.), (Pal et al., 2013), (Jain et al., 2013), (Valahzaghard et al., 2011), (Valahzaghard et al.,2011).
	Fulfilled Order Accuracy	(Mentzer et al., 2001), (Garg et al., 2010), (Valahzaghard et al., 2011)
	Quality Control	(Ghodsypour & O'Brien, 1998), (Benyoucef et al., 2003), (Kar & Pani, 2014), (Jain et al., 2013), (Jariyal & Garg 2012).
Cost	Product Cost	(Valahzaghard et al.,2011), (Zhang et al., 2009), (Lee & Amy, 2009), (Wu et al. 2009), (Sanayei et al., 2010), (Wu, 2010), (Shemshadi et al., 2011), (Akarte et al., 2001), (Priya et al., 2012), (Ozkan et al., 2011), (Ghodsypour & O'Brien, 1998), (Benyoucef et al., 2003), (Kar & Pani, 2014), (Garg et al.), (Tang & Jarmillo, 2005), (Pal et al., 2013), (Jain et al., 2013), (Valahzaghard et al., 2011), (Jariyal & Garg, 2012).
	Discount on Product Cost	(Kar & Pani, 2014), (Jain et al., 2013).
Delivery	Online Delivery Schedule	(Humphreys et al., 2001), (Valahzaghard et al., 2011).
	Delivery Lead Time	(çebi & Bayraktar, 2003), (Prahinski & Benton, (2004), (Pi & Low, 2005), (Kreng & Wang, 2005), (Li et al., 2006), (Hsu et al., 2006), (Zhang et al., 2009), (Lee & Amy, 2009), (Shemshadi et al., 2011), (Liao & Kao, 2011), (Vinodh et al., 2011). (Priya et al., 2012), (Kar & Pani, 2014), (Garg et al.), (Tang & Jarmillo, 2005), (Ozkan et al., 2011), (Jain et al., 2013), (Valahzaghard et al., 2011).
	Fulfilled order timely	(Mentzer et al., 2001), (Akarte et al., 2001), (Ozkan et al., 2011), (Ghodsypour & O'Brien, 1998), (Benyoucef et al., 2003), (Kar & Pani, 2014), (Garg et al.), (Tang & Jarmillo, 2005), (Pal et al., 2013), (Jain et al., 2013), (Valahzaghard et al., 2011), (Valahzaghard et al., 2011).
Service	Site Design	(DeLone & McLean, 2003), (Valahzaghard et al., 2011).
	Responsiveness	(Parasuraman et al., 1988), (Ghodsypour & O'Brien, 1998), (Kar & Pani, 2014), (Ozkan et al., 2011), (Valahzaghard et al., 2011),
	Customer Support	(Priya et al., 2012), (Ozkan et al., 2011), (Garg et al.), (Tang & Jarmillo, 2005), (Valahzaghard et al., 2011), (Valahzaghard et al.,2011).
	Accessibility	(Lancaster et al., 2006), (Ozkan et al., 2011), (Ghodsypour & O'Brien, 1998), (Valahzaghard et al., 2011).
Flexibility	Online order Track	(Lancaster et al., 2006), (Valahzaghard et al., 2011).
	Reaction to demand Change	(Young-Ybarra & Wiersema, 1999), (Grewal & Tansuhaj, 2001), (Chircu & Kauffman, 2000), (Narasimhan & Kim, 2001), (Ozkan et al., 2011), (Ghodsypour & O'Brien, 1998), (Garg et al.), (Tang & Jarmillo, 2005), (Jain et al., 2013), (Valahzaghard et al., 2011), (Valahzaghard et al.,2011).
	IT infrastructure Flexibility	(Wixom & Watson, 2001), (Dai & Kauffman, 2002), (Kim & Narasimhan, 2002), (Valahzaghard et al., 2011).
	Capacity	(Tang & Jarmillo, 2005).
	Production Flexibility	(Kar & Pani, 2014), (Jain et al., 2013).
Trust	Website Security	(Fairchild et al., 2004), (Harland et al., 2007), (Jun & Cai, 2003), (Phan & Stata, 2002), (Soliman & Janz, 2004), (Tang & Jarmillo, 2005), (Garg et al.), (Valahzaghard et al., 2011).
	Reliability	(Head & Hassanein, 2002), (Becerra & Gupta, 2003), (Ratnasingam & Pavlou, 2003), (Garg et al.), (Jain et al., 2013), (Valahzaghard et al., 2011).
	Assurance	(Schröder & McEachern, 2002), (Manning et al., 2006), (Turner & Davies, 2002), (Parasuraman et al., 1988), (Kar & Pani, 2014), (Pal et al., 2013), (Valahzaghard et al., 2011).
	Integrity, Benevolence, Competence	(Fairchild et al., 2004), (Harland et al., 2007), (Reichheld & Schefter, 2000), (Soliman & Janz, 2004), (Garg et al.), (Valahzaghard et al., 2011).
Past Performance	E-Transaction	(Mentzer et al., 2001), (Ahire & Dreyfus, 2000), (Choi & Eboch, 1998), (Eagly & Chaiken, 1993), (Park, 1999), (Pugliese, 2000), (Tracica, 2002), (Kar & Pani, 2014), (Tang & Jarmillo, 2005), (Valahzaghard et al., 2011).
	e- Commerce Capability	(Barua et al., 2004), (Zhu & Kraemer, 2002), (Coates & McDermott, 2002), (Hausman et al., 2002), (Williams et al., 2002), (Eisenhardt & Martin, 2000), (Valahzaghard et al., 2011).
	Reputation & Past Business Record	(Priya et al., 2012), (Kar & Pani, 2014), (Garg et al.), (Benyoucef et al., 2003), (Ozkan et al., 2011), (Pal et al., 2013), (Valahzaghard et al.,2011).
Finance		(Valahzaghard et al., 2011), (Vinodh et al., 2011), (Chang et al., 2011), (Deng & Chan, 2011), (Tsai et al., 2010), (Kilincci & Onal, 2011), (Chen et al., 2006), (Yang & Chen, 2006), (Bottani & Rizzi, 2006), (Benyoucef et al., 2003), (Kar & Pani, 2014), (Ozkan et al., 2011), (Pal et al., 2013), (Valahzaghard et al.,2011).
Facility	IT Equipment Capabilities	(Benantar, 2001), (Benassi, 1999), (Dinnie, 1999), (Friedman, 2000), (Railsback, 2001), (Kar & Pani, 2014), (Valahzaghard et al., 2011).
	Production Equipment & Technological Capabilities	(Weber et al., 1991), (Petroni & Braglia, 2000), (Muralidharan et al., 2001), (Ha & Krishnan, 2008), (Tsai et al., 2010), (Akarte et al., 2001), (Ozkan et al., 2011), (Benyoucef et al., 2003), (Kar & Pani, 2014), (Tang & Jarmillo, 2005), (Pal et al., 2013), (Valahzaghard et al., 2011), (Valahzaghard et al., 2011).
	R & D Facility	(Tang & Jarmillo, 2005), (Benyoucef et al., 2003), (Kar & Pani, 2014), (Ozkan et al., 2011), (Garg et al.), (Valahzaghard et al. 2011).
Location		(Aksoy & Öztürk, 2011), (Kilincci & Onal, 2011), (Tsai et al., 2010), (Mohammady Garfamy, 2006), (Yang & Chen, 2006), (Ireton, 2007), (Kar & Pani, 2014), (Garg et al.), (Tang & Jarmillo, 2005), (Benyoucef et al., 2003), (Pal et al., 2013), (Valahzaghard et al.,2011).
Organizational Structure	Communication Capabilities	(Priya et al., 2012), (Ozkan et al., 2011), (Kar & Pani, 2014), (Benyoucef et al., 2003), (Valahzaghard et al.,2011).

2.2.e- supplier selection technique

The selection of the best evaluation method is very important task in a supply chain for fulfilling different objectives. There were several objectives in the traditional supply chain like maximization of profit, minimization of cost, improving quality. Traditional literature ranges from the single objective method for multi- objective linear programming model (Ghodsypour & O'Brien, 1998). The objectives of e- supplier selection is also similar to the traditional supply chain such as improving quality, reducing cost, and increasing profit. The supplier selection method in traditional SCM has been same just like e-supplier selection (Kara, 2011). Multi criteria decision making approach and mathematical programming model are adopted by most of researchers in the literature. Fuzzy TOPSIS and two-stage stochastic programming were developed for supplier selection by Kara (2011). Fuzzy analytical hiararch process (AHP) approach for supplier selection in manufacturing washing machine was preferred by Kilincci and Onal (2011). Fuzzy analytic network process for supplier selection was used by Vinodh et al. (2011) in manufacturing organizations. A Hierarchy MCDM model based on fuzzy set theory and VIKOR method was proposed to deal with the supplier used by Sanayei et al. (2010). There are various techniques used and some of them had been explained earlier. The different techniques used in literature for supplier selection are given in the Table 2.

Table 2
Sources of e-supplier selection methodology

Methodology	References
Delphi	(Valahzaghard et al., 2011), (Kar & Pani, 2014).
Fuzzy MADM	(Valahzaghard et al., 2011).
Fuzzy VIKOR	Valahzaghard et al., 2011), (Shemshadi, 2011).
Fuzzy Delphi	(Valahzaghard et al., 2011).
Fuzzy TOPSIS	(Chen et al., 2006), (Liao & kao, 2011), (Deng & Chan, 2011), (Kilic, 2013), (Junior et al., 2014), (Luthra et al., 2016).
ANOVA	(Kar & Pani, 2014).
ANP	(Lin et al., 2011).
OLAP using SPSS	(Priya et al., 2012).
AHP	(Akarte et al., 2001), (Tang & Jarmillo, 2005), (Benyoucef et al., 2003), (Ozkan et al., 2011), (Ghodsypour & O'Brien, 1998), (Bhutia & O'Brien, 2012), (Muralidharan et al., 2002), (Garg et al., 2014), (Shakey, 2006).
Linear Programming	(Lin et al., 2011), (Ghodsypour & O'Brien, 1998), (Kilic, 2013).
Fuzzy AHP	(Jain et al., 2013), (Chamodrakas & Batis, 2010), (Sevkli & Koh, 2008), (Valahzaghard et al., 2011), (Lee & Amy 2009), (Ho Ha & Krishnan, 2008), (Chan & Kumar, 2007), (chan et al., 2008), (Kahraman et al., 2003).
TOPSIS	(Lin et al., 2011), (Bhutia & Phipon, 2012), (Junior et al., 2014).
SIR. VIKOR	(Valahzaghard et al., 2011).
MCDM-Matrix method	(Jarial & Garg, 2012)(Garg et al., 2010).
Distance Based Approximation	(Kumar & Garg , 2010),(Gupta Amit, 2014),(kumar & Garg., 2013), (Garg et al., 2010).
Multi Choice Goal Programming	(Liao & Kao, 2011).
Data Envelopment Analysis	(Ho Ha & Krishnan, 2008).
Neural Network	(Ho Ha & Krishnan, 2008).
Fuzzy Approach	(Junior et al., 2013), (Chan et al., 2004).
Fuzzy DEMTEL	(Chang et al., 2011).

3. Methodology Adopted

3.1 Modified Distance Based Approach

Specifying the ideally perfect value of attributes in the procedure and defining the optimum state of overall objective are the points of consideration for the growth of Distance Based Approximation approach (DBA). In this study, optimum e-supplier selection is the optimal state of objective. The distance based approximation approach has earlier been used for optimal selection of software reliability growth models (Sharma et al., 2010); grading and selection of robots (Garg et al., 2010) and optimal selection of commercial off-the-shelf, etc. (Garg et al., 2017). The effects of weight can be easily accommodated by distance based approach for ranking the various criteria used to rank different

attributes. The value of the composite distance of alternative e-supplier from optimal value can be determined by modified distance based approach. e-suppliers rankings are performed in ascending/ descending order on the basis of composite distance value from the optimal value i.e. zero. The MDBA is explained below in the following steps. The set of attributes, presenting the performance rating of each alternate e-supplier against each ranking criterion can be represented by the following criteria matrix:

$$[x_{ij}] = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1j} \\ x_{21} & x_{22} & \cdots & x_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} \\ x_{op1} & x_{op2} & \cdots & x_{opj} \end{bmatrix}, \quad (1)$$

Here, i $(i = 1, 2, ...n)$, and j $(j = 1, 2, ...m)$ represent the number of e-suppliers and e-supplier selection criteria, respectively. Here, x_{ij} represents the weight of i^{th} supplier for j^{th} criteria and X_{opj} gives the optimal value for any particular criteria among all available alternatives of e-suppliers.

$$[z] = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nm} \\ z_{op1} & z_{op2} & \cdots & z_{opm} \end{bmatrix}, \quad (2)$$

where

$$z_{ij} = \frac{x_{ij} - \overline{x_j}}{S_j}, \quad (3)$$

$$\overline{x_j} = \frac{1}{n}\sum_{i=1}^{n} x_{ij}, \quad (4)$$

$$S_j = \left[\frac{1}{n}\sum_{i=1}^{n}(x_{ij} - \overline{x}_j)\right]^{1/2}, \quad (5)$$

where; n = Number of e-supplier selection criteria; X_{ij} = Indicator value of alternative e-supplier *I* for criteria *j* and S_j = Standard deviation of criteria of *j*. In the next step, we find the distance or difference from each criterion to the reference point, which is achieved by subtracting the optimal value from the corresponding element. Next step is to introduce the performance rating difference of each e-supplier selection criteria by representing the aggregated preference weight and the final weighted distance matrix given by

$$[W] = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1j} \\ w_{21} & w_{22} & \cdots & w_{2j} \\ \cdots & \cdots & \cdots & \cdots \\ w_{i1} & w_{i2} & \cdots & w_{ij} \end{bmatrix}, \quad (6)$$

where

$$W_{ij} = (z_{opj} - z_{ij})\, w_j, \quad (7)$$

and w_j represents the weight of the j^{th} criterion. Finally Euclidean composite distance value between each e- supplier is derived from:

$$CD\,i = \left[\sum_{j=1}^{m}\{(z_{opj} - z_{ij})w_j\}^2\right]^{1/2}.$$

The composite distances generally define the gap or difference between the each of two available alternatives of the e-supplier. It is also termed as a mathematical expression of several dimensions in which each alternative e-supplier can be compared.

4. Ranking and Selection Procedure

4.1.Identification of E-supplier

Supply chain management has become a crucial task now days and for better handling e-supply chain is mostly used in business. This research work is mainly concentrated over finding and ranking the available e-suppliers. This paper actually includes a case study of a firm which mainly manufactures the exhaust system for both 2-wheelers and 4-wheelers. This is a Japan Indian private limited firm established in India in 2003 in Bawal, Rewari. It is an ISO 14001, OSHAS and TS certified company. It is the key and sole supplier for global brands like Suzuki, Honda, Yamaha, and Daikin. This firm received the supply from the four different e-suppliers for the same component. So, this paper actually will give the ranking to these four available e-suppliers.

4.2. E-supplier Selection Criteria: Identification and selection

There are many criteria and sub-criteria available in the open literature which tabulated earlier in the literature survey. The researcher during the selection of the criteria or sub-criteria mainly focused on characteristics like quality, cost, service etc. which are closely related to the mechanical manufacturing sector. Each of the criteria is important in a specific manner and related to e-supplier selection and useful for fulfilling the objective of this research work.

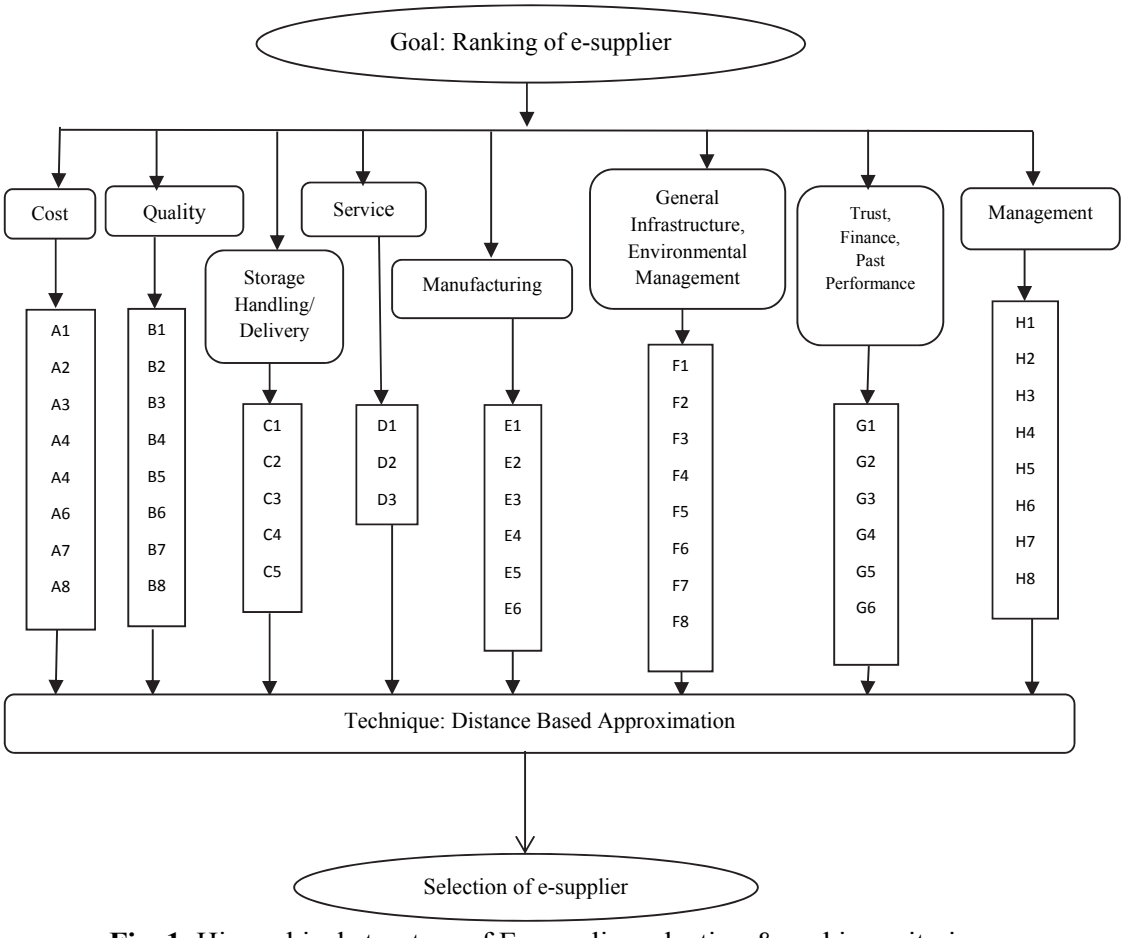

Fig. 1. Hierarchical structure of E- supplier selection & ranking criteria

By collecting the data from the literature and the experts' opinion, 52 sub- criteria have been finalized and grouped into 8 categories, namely (1) cost (2) quality (3) storage Handling/Delivery (4) Service (5) Manufacturing (6) General, infrastructure & Environmental Management (7) Trust, Finance & Past Performance (8) Management. E-supplier selection criteria are arranged in a hierarchical structure in Fig. 1. The e-supplier selection criteria which include in this research seems to be sufficient for achieving the goal, i.e. ranking of e-suppliers.

4.3.Experts Identification & Selection

With the lack of experience and maturity in the area of e-supply chain, it becomes impossible to identify the relevant data available in the open literature that would be favorable for e-supplier selection and their ranking. So, researchers first study the open literature and collect the primary data available seems to be dealing with the e-supplier selection criteria. To find out the relevance of the data the researchers took the assistance of experts from the manufacturing industry and academia that have sufficient experience in supply chain for dealing with e-supplier selection problems. This study includes only those experts who are dealing with the mechanical manufacturing sector. Optimal data collection was done only after considering the expert's opinion. An expert with having the perfect knowledge in their field is alone sufficient for elicitation process. But it is better to have more than one expert in avoiding mistakes due to limited knowledge. The researchers selected their experts on the basis of publications, experience in the area of e- supplier selection while working in any institutions or industry, capability and versatility for handling various issues.

4.4.Questionnaire Design

The researchers fabricated the questionnaire for data collection of exploratory survey. Before preparing the questionnaire, the researchers with expert's assistance first scrutinized the primary data and excluded the data which was found irrelevant in mechanical manufacturing e-supplier selection area. On the basis of relevant data remained after initial screening, researchers prepared the questionnaire. Single Questionnaire is designed by considering equal weightage to all the ranking criteria. This questionnaire is designed to get the performance or ranking of each e-supplier based on all criteria. This questionnaire was forwarded to experts in online and offline basis. Google drive is used for forwarding the questionnaire for online mode. This questionnaire prepared into three segments: first part consists of a covering letter for describing the aim of the study and statement of confidentiality. The second part covers the demographic detail, e.g. company name, contact person name and their details. Third part consists of ranking criteria for assigning weights/ performance ratings of e-supplier selection.

4.5. Data collection and Analysis

The tests were performed for examining the reliability of the data obtained from experts using SPSS. The obtained value of Cronbach alpha was higher than 0.8 for the ranking and the performance ratings of e-suppliers on the basis of e-supplier selection criteria. This value of Cronbach alpha shows the level of reliability and internal consistency in between the expert's opinion. Later on, the ANOVA test was performed for comparing the means and to find out the mean variance for all e-suppliers. These entire statistical tests performed on aggregated expert's opinion and not on any individual opinion. All experts were considered equally weighted in terms of their competency, qualification and experience with negligible difference observed in terms of importance and credibility.

4.6. Performance Rating of e-supplier

The performance rating of four e-suppliers are decided on the basis of expert's opinion aggregation and ranking. All 4 e-suppliers average aggregated ratings given by experts' are given in Table 3.

Table 3
Aggregated Average Performance Ratings of e-suppliers

Criteria	e-supplier: 1	e-supplier: 2	e-supplier: 3	e-supplier: 4
Cost	3.7	3.775	2.9	4.025
Quality	4.175	2.1	3.175	4.15
Storage Handling / Delivery	4.28	2.4	3.12	4.68
Service	3.67	3.4	2.54	4.27
Manufacturing	4.47	2.45	2.87	4.47
General, Infrastructure, Environmental Mgt.	4.58	2.53	3.43	3.075
Trust, Finance, Past Performance	5	3.07	3.77	2.7
Management	4.6	3.025	3.25	4.5

4.7.Ranking and selection

The composite distance or preference index shows the closeness of each alternative e-supplier with respect to other e-supplier with the optimal solution by using the DBA method as described in section 3. On the basis of composite distance values these alternative e-suppliers are arranged in ascending/descending order. The first ranking assigned to e-supplier who has least composite distance value. The decision makers take the final decision after considering the various practical constraints, e.g. political, social and management.

5. Model Demonstration

For demonstration and validation of proposed DBA application for ranking of e-suppliers are done by taking an example of ranking and selection of e-supplier for web based supply chain. This example in which 4 e-suppliers are ranked on the basis of 52 sub-criteria grouped in 8 major categories. The e-supplier selection criteria are described in Fig. 1. The weights of all e-supplier selection criteria are considered equal. The performance ratings of all major 8 groups are given in Table 3. There are still many scopes to include other e-supplier selection criteria and e-suppliers based on the problem and priority of decision makers. The main aim behind the demonstration is to check the suitability of this model and development of an effective model application procedure. The DBA applied the ranking of 4 e- supplier is based on 8 criteria, i.e. Quality, Storage, Cost, Service, Manufacturing, General infrastructure environmental Management, Trust finance past performance, Management. The criteria matrix x_{ij} is given as:

$$[x_{ij}] = \begin{bmatrix} 3.7 & 4.175 & 4.28 & 3.67 & 4.47 & 4.58 & 5 & 4.6 \\ 3.775 & 2.1 & 2.4 & 3.4 & 2.45 & 2.53 & 3.07 & 3.025 \\ 2.9 & 3.175 & 3.12 & 2.54 & 2.87 & 3.43 & 3.77 & 3.25 \\ 4.025 & 4.15 & 4.68 & 4.27 & 4.47 & 3.075 & 2.7 & 4.5 \\ 2.9 & 2.1 & 2.4 & 2.54 & 2.45 & 2.53 & 2.7 & 3.025 \end{bmatrix}$$

From Eqs. (4-5), the attributes' average and standard deviation values are 0.7, 1.32, 1.22, 0.93, 1.12, 0.87, 0.94, 0.82 and 0.422, 0.86, 0.91, 0.623, 0.92, 0.751, 0.88, 0.712. The [Z] and [w] are as follows,

$$[z] = \begin{bmatrix} 0.237 & 0.880 & 0.725 & 0.321 & 0.978 & 1.571 & 1.55 & 1.060 \\ 0.415 & -1.535 & -1.341 & -0.112 & -1.217 & -1.159 & -0.648 & -1.152 \\ -1.659 & -0.256 & -0.55 & -1.493 & -0.761 & 0.04 & 0.148 & -0.836 \\ 1.007 & 0.907 & 1.165 & 1.284 & 0.978 & 0.433 & -1.07 & 0.920 \end{bmatrix} \quad [w] = \begin{bmatrix} 0.593 & 0.000729 & 0.1936 & 0.9274 & 0 & 0 & 0 & 0 \\ 0.351 & 5.963 & 6.298 & 1.95 & 4.818 & 7.453 & 4.83 & 4.893 \\ 7.129 & 1.353 & 2.941 & 7.712 & 3.024 & 2.344 & 1.966 & 3.595 \\ 0 & 0 & 0 & 0 & 0 & 4.016 & 6.86 & 0.20 \end{bmatrix}$$

The values of composite distance are given in Table 4.

Table 4
Overall Ranking of E- Suppliers

e- Suppliers	S1	S2	S3	S4
Sum	1.71473	36.538	30.064	10.896
Composite Distance (CD)	1.3095	6.045	5.4831	3.3009
Ranking	1	4	3	2

The composite distance value of alternate e-supplier based on eight criteria for ranking individually considering the ranking criteria is determined by using DBA methodology. The CD values and ranking of e-suppliers based on individual criteria are given in Table 5.

Table 5
Category wise E-suppliers Ranking Results

e-Suppliers	COST		Quality		Delivery/ Handling		Service		Manufacturing		General, Infrastructure		Trust, Finance, Past Performance		Management	
	CD Value	Rank	CD Value	Rank	CD Value	Rank	CD Value	Rank	CD Value	Rank	CD Value	Rank	CD Value	Rank	CD Value	Rank
S1	4.353	3	1.840	1	1.545	2	2.258	2	0.953	1	0.396	1	0	1	1.529	1
S2	3.863	2	7.345	4	5.551	4	3.380	3	5.892	4	6.415	4	5.064	3	6.724	4
S3	6.036	4	4.344	3	3.795	3	4.151	4	4.867	3	4.286	2	3.442	4	5.920	3
S4	3.21	1	2.631	2	0.482	1	0.966	1	1.272	2	5.483	3	6.079	2	2.218	2

6. Methodology Validation

For the validation of the results obtained from the proposed DBA approach, the same problem was also resolved using other techniques like TOPSIS (Lin et al., 2003), Matrix method (Jarial & Garg, 2012) and AHP (Ghodsypour & O'Brien, 1998). The final ranking obtained for four suppliers, namely S1, S2, S3, and S4, based on eight criteria using DBA, TOPSIS, Matrix and AHP were estimated and compared. The comparisons show that the results of the proposed methodology are similar to the results given by other three methods.

7. Results

According to adopted methodology, the lower composite distance value shows the best alternate of e-suppliers. Fig. 2 shows the ranking of all four e- suppliers based on eight criteria, namely Cost, Quality, Delivery, Service, Manufacturing, General infrastructure, Trust finance past performance and Management.

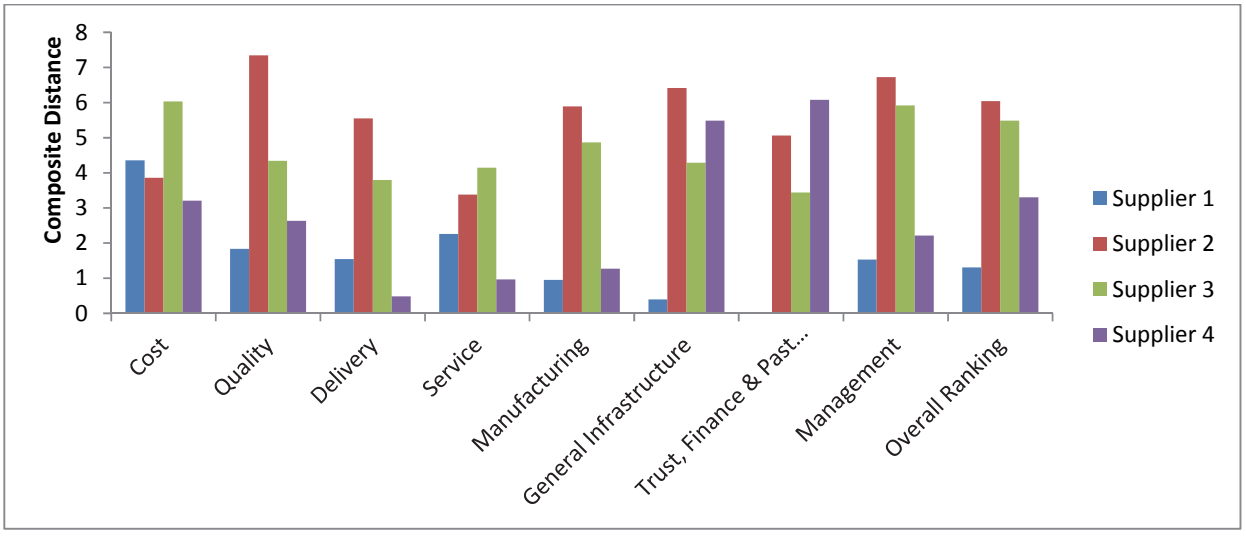

Fig. 2. Ranking of e-Suppliers

This chart shows that e-supplier no 1 (S1) is ranked no 1 & supplier 3 (S3), Supplier 4 (S4) ranked no. 3 & 2 in Manufacturing based on composite distance value. So, by this chart, it is easy to identify ranking of all four e-suppliers by considering individual criteria. It also depicts the aggregate ranking of e- suppliers by considering all criteria together. So, on the basis of overall ranking e- supplier no-1 ranked 1 and e-supplier-2 ranked 4 as depicted in the end of this chart.

8. Conclusion

The major issues rising due to e-supply chain in e-supplier selection process was mainly covered by this paper. e- Supplier selection was a multi-criteria decision problem. The final decision has been achieved only by considering a set of various e-supplier selection criteria. Distance based approximation approach was applied only after identification of all comparison criteria. The proposed methodology allows the Decision makers to select ranking criteria according to their preference. This model has enabled to rank various e- suppliers based on a number of criteria taken simultaneously. DBA approach is quite efficient, less time consuming and most suitable for solving multi criteria decision problem than TOPSIS, AHP and matrix method. It is a simple mathematical calculation and matrix operation and hence quiet useful approach for solving ranking problem.

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