Expert Systems with Applications 39 (2012) 7102–7109

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Using modified IPA to evaluate supplier's performance: Multiple regression analysis and DEMATEL approach

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ARTICLE INFO

Keywords:
Supplier Quality Performance Assessment
Supplier Performance Rating System
Importance-Performance Analysis
Decision Making Trial and Evaluation Laboratory
Multiple regression analysis
Order-winners and qualifiers

ABSTRACT

This paper provides a methodology of Supplier Quality Performance Assessment (SQPA) for the industrial computer industry that introduces modified Importance-Performance Analysis (IPA) which uses the multiple regression analysis and Decision Making Trial and Evaluation Laboratory (DEMATEL) techniques, and creates value for all members through optimizing order-winners and qualifiers to promote supplier quality improvement and solve complex problems using the cause-effect relation. The techniques used in SQPA activities are easily understood. A case involving an industrial computer manufacturer is illustrated to show the benefits of our model.

1. Introduction

From the past two decades, supplier selection and performance assessment have played an important role in supply chain management. Suppliers have always been an integral component of a company's management policy (Bhutta & Huq, 2002). Numerous academic researchers have paid much attention to this topic. Levary (2007) asserted that the process of evaluating suppliers must include the risk of disruption to the manufacturing assembly operation. Choy and Lee (2002) researched the methods and tools for supplier selection. Choy and Lee (2003) presented an intelligent generic supplier management tool using the cost-based reasoning technique for supplier selection decision making. De Boer, Labro, and Morlacchi (2001) performed similar research. Verma and Pullman (1998) investigated whether the selection criteria were consistent with the perceived importance in the eyes of purchasers. Lee, Yen, and Tsai (2008a) developed a new Importance-Performance Analysis model to evaluate supplier performance in the semiconductor industry. Ansari and Modarres (1988) researched weighting the evaluative criteria and setting the relative importance based on specific supply in the presence of trade-offs between similar suppliers. They claimed that the analysis of trade-offs among quality, price and deliver reliability is particularly important in JIT environments. Lamming, Cousins, and Notman (1996) discussed the benefits and problems of vendor assessment systems. Thompson (1991) recommended the Thurstone Case V scaling technique as an extremely useful tool for scaling the importance weights associated with evaluative criteria and the probable performance of suppliers. Wang, Du, and Li (2004) used the six sigma method to develop suppliers. Giunipero and Brewer (1993) developed criteria to assess supplier performance. Ellram (1996) used the total costs analysis method to evaluate suppliers. Kahraman, Cebeci, and Ulukan (2003) used the Fuzzy Logic method to evaluate suppliers. Petroni and Braglia (2000) proposed using the statistical method to make precise weight assessments of supplier performance. De Boer et al. (2001) showed that the AHP method usually uses models in these research works. Bayazit (2006) provided a good insight into the use of ANP in evaluating supplier selection problems and multiple criteria decision-making methodology. Kahraman et al. (2003) integrated fuzzy logic and AHP to identify supplier with the highest potential for meeting a firm's needs consistently and at acceptable cost. Kannan and Tan (2002) verified that a supplier's willingness and ability to share information has a significant impact on performance. Yen, Chung, and Tsai (2007) provided a customer oriented framework for management by objectives on ISO 9001: 2000 quality management systems in the whole supply chain. All of these studies included wide discussions on the SQPA dimensions and rating techniques in previous researches. However, there are several problems that have not been considered as follows: (1) for the purpose of long-term cooperation in buyer-supplier relationship, there was no after-trading assessment and quality improvement activities discussed for SQPA and (2) the influence of cause and effect relationship on quality improvement had not been discussed in SQPA activity.

This paper therefore provides an SQPA methodology for the computer industry through introducing Hill's (2000) order-winners and qualifiers framework, Importance-Performance

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doi:10.1016/j.eswa.2012.01.034

Analysis (IPA) and Decision Making Trial and Evaluation Laboratory (DEMATEL) techniques to optimize a rating system for supplier quality performance, promote supplier quality improvement and solve complex problem with cause-effect relation.

2. Materials and methodology

This paper provides a modified IPA and makes extended use of IPA in assessing a supplier's quality performance. The benefits of introducing DEMATEL into IPA is that the DEMATEL considers the cause and effect relationships among quality characteristics to re-define its importance, and determines the solution on such a complicated and contradictory problem in practice with the cause-effect relation. Moreover, the benefit of introducing IPA into SQPA, the buyer will get lots of information to take purchasing action and the supplier will understand precise directions for continuous quality improvement.

2.1. Decision Making Trial and Evaluation Laboratory

The Decision Making Trial and Evaluation Laboratory (DEMATEL) was developed by Battelle Memorial Institute of the Geneva Research Center (Fontela & Gabus, 1976; Gabus & Fontela, 1973). DEMATEL was used to solve sophisticated problems such as race, famine, environmental protection, energy and others (Fontela & Gabus, 1976). Recently it was used comprehensively in other domains (Hajime, Kenichi, & Hajime, 2005; Hu, Chiu, & Yen, 2009; Hu, Lee, & Yen, 2009; Hu, Lee, Yen, & Tsai, 2009; Kim, 2006; Lee, Hu, Yen, & Tsai, 2008; Lee, Li, Yen, & Huang, 2010; Tamura, Okanishi, & Akazawa, 2006). Here is a brief explanation of the DEMATEL framework and arithmetic by Lee, Hu, Yen, and Tsai (2008), Hu, Chiu, Cheng, and Yen (2011) and Lee, Li, Yen, and Huang (2010).

From the literature review brainstorming or specialists' comments, this study lists and defines the quality characteristics of a certain complicated system and assumes that n number of quality characteristics exist. Next a scale of measurement for pair-wise comparison between the characteristics and their causation is created. The scale of measurement for the direct-relation matrix is a scalogram with 11 scales by Huang, Shyu, and Tzeng (2007), ranging from "0" as "no influence" to "10" as "great influence." If the number of quality characteristics is n, when this study makes pair-wise comparison between the causation and quality characteristic influence, the result will be an $n \times n$ direct-relation matrix "X," in which x_{ij} stands for how i quality characteristic influences j quality characteristic, and quality characteristics x_{ii} at the corner are set to 0.

$$X = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix} \quad (1)$$

After, normalization of direct-relation matrix "X", should be taken into account. The normalized direct-relation matrix has two types of arithmetic. The normalized standard is row vector and the maximum.

As:

$$\lambda = \frac{1}{\underset{1 \leqslant i \leqslant n}{Max}\left(\sum_{j=1}^{n} x_{ij}\right)} \quad (2)$$

In formulas (2) and (3), when the direct-relation matrix X is multiplied by λ, the normalized direct-relation matrix is N.

$$N = \lambda X \quad (3)$$

Under the DEMATEL supposition, the sum of at least one i row must be in line with formula (4).

$$\sum_{j=1}^{n} x_{ij} < \frac{1}{\lambda} \quad (4)$$

Hence, this study derives a sub-stochastic matrix from the normalized direct-relation matrix N and an absorbing-state Markov chain matrix. According to Papoulis and Pillai (2002):

$$\lim_{k \to \infty} N^k = O \text{ and } \lim_{k \to \infty}(I + N + N^2 + \cdots + N^k) = (I - N)^{-1} \quad (5)$$

In this, O is the null matrix and I is the identity matrix.

Since the normalized direct-relation matrix N contains properties of formula (5), indirect/direct-relation matrix, or total-relation matrix, can be derived from formula (6). Further, the indirect relation matrix H, or total-indirect-relation matrix, can be derived from formula (7).

$$T = \lim_{k \to \infty}(N + N^2 + \cdots + N^k) = N(I - N)^{-1} \quad (6)$$

$$H = \lim_{k \to \infty}(N^2 + N^3 + \cdots + N^k) = N^2(I - N)^{-1} \quad (7)$$

Suppose that t_{ij} is the quality characteristic for the total-relation matrix T, and $i, j = 1, 2, \ldots, n$, then formulas (8) and (9) can be used to determine the sum of values in the row and column of the total-relation matrix T. Also, D_i is the sum of i *row*, which means that quality characteristic i can affect the sum of other quality characteristics; R_j is the sum of j *row*, which means quality characteristic i is affected by the sum of other quality characteristics. D_i and R_j of the total-relation matrix T include direct/indirect influences.

$$D_i = \sum_{j=1}^{n} t_{ij} \quad (i = 1, 2, \cdots, n) \quad (8)$$

$$R_j = \sum_{i=1}^{n} t_{ij} \quad (j = 1, 2, \cdots, n) \quad (9)$$

When $D_k + R_k$ is prominence and $k = i = j = 1, 2, \ldots, n$, then this shows how the quality characteristic is influenced by or affects the others and how prominent quality characteristic k is in all problems. When $D_k - R_k$ is relation, then this shows the variation of the quality characteristic being influenced by or affecting on others and whether quality characteristic k is more like a cause or a result. If the result is positive, the quality characteristic is more like a cause, or otherwise a result.

DEMATEL aims to present the direct/indirect causation and degree of influence of quality characteristics by comparing their interrelationships as a reference when one makes decisions. DEMATEL can turn a complicated system into clear cause and effect, and quantify how one quality characteristic affects another in identifying core problems and improvements. According to the benefits of DEMATEL, this paper introduces DEMATEL into SQPA activity to solve complex cause and effect problem and improve supplier's quality performance.

2.2. Importance-Performance Analysis

IPA was introduced by Martilla and James (1977) as a method for developing effective marketing programs. Through such simple data processing, organizations can directly examine different types of quality characteristics and form strategies and plans, based on each of the four quadrants in the IPA map. Several famous scholars provided numerous modified IPA models after the first IPA issue by Martilla and James (1977), for example the researches by Eskildsen and Kristensen (2006) integrated the Taguchi loss function, Kano's model and regression analysis to enhance the IPA model. Tonge and Moore (2007) used the importance-satisfaction model and gap analysis to evaluate the quality of visitors' experience, as well