Information Sciences 266 (2014) 199–217

Contents lists available at ScienceDirect

Information Sciences

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

A fuzzy integral-based model for supplier evaluation and improvement

James J.H. Liou [a], Yen-Ching Chuang [a], Gwo-Hshiung Tzeng [b,c,*]

[a] Department of Industrial Engineering and Management, National Taipei University of Technology, No. 1, Section 3, Chung-Hsiao East Road, Taipei, Taiwan
[b] Graduate Institute of Urban Planning, National Taipei University, 151, University Rd., San Shia District, New Taipei City 23741, Taiwan
[c] Institute of Management of Technology, National Chiao Tung University, 1001, Ta-Hsueh Road, Hsinchu 300, Taiwan

ARTICLE INFO

Article history:
Received 30 April 2012
Received in revised form 15 July 2013
Accepted 1 September 2013
Available online 3 October 2013

Keywords:
Supplier selection
MCDM
ANP
DEMATEL
DANP
Fuzzy integral

ABSTRACT

Decisions related to supplier improvement and selection are inherently multiple criteria decision making (MCDM) problems and are strategically important to companies. Although efforts have been made to discover systematic methods to select the proper supplier, these efforts have assumed that the criteria are independent, which is not actually the case. Some studies that have treated the criteria as interdependent use additive models to obtain aggregate performance. We propose a novel fuzzy integral-based model that addresses the interdependence among the various criteria and employs the non-additive gap-weighted analysis. The structure of the relationships among the criteria and the criteria weights are developed using Decision Making Trial and Evaluation Laboratory (DEMATEL) combined with a fundamental concept of an analytic network process (ANP) called DANP. The fuzzy integral is then used to aggregate the gaps using the weights obtained from the DANP. The proposed model addresses the shortcomings of prior models and provides a more reasonable representation of the real world. The method is demonstrated using supplier evaluation and improvement data from a Taiwanese company.

1. Introduction

Supplier evaluation and improvement processes are the most significant variables in the effective management of globalization, as they improve organizations through the channels of high-quality products and customer satisfaction. The traditional approach has been to rank and select suppliers solely on the basis of price. However, moving from ranking/selection to selection/improvement decisions in the contemporary supply-chain network is complicated, as potential options for selection/improvement decisions are evaluated using multiple criteria. Therefore, supplier selection/improvement has become an MCDM problem that includes several tangible and intangible factors [3,54]. Recently, these criteria have become increasingly complex, interdependent, and dynamic as environmental, social, political, and customer satisfaction concerns have been added to the traditional factors of quality, delivery, cost, and service. Additionally, traditional MCDM methods have generally only employed an additive model to evaluate, rank, and/or select the alternatives. More important, and from a practical standpoint, solving the problem of criteria gaps (gaps between actual performance and aspiration levels) while incorporating a non-additive (or super-additive) framework to address interdependence and feedback problems is a current trend within the MCDM field. Kahneman and Tversky [23] developed the basic concept of non-additive (or super-additive) value-function aggregation in multi-criteria problems. This concept has led researchers to an important question on how

* Corresponding author. Address: Graduate Institute of Urban Planning, College of Public Affairs, National Taipei University, 151, University Road, San Shia, New Taipei City 23741, Taiwan. Tel.: +886 2 86741111 ext. 67362; fax: +886 2 86715221.
E-mail addresses: ghtzeng@mail.ntpu.edu.tw, ghtzeng@cc.nctu.edu.tw (G.-H. Tzeng).

0020-0255/$ - see front matter © 2013 Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.ins.2013.09.025

these two concepts (non-additive value functions and aspiration levels) can be applied to real world inter-relationship (dependence and feedback) problems. This article contributes a novel, hybrid, fuzzy integral-based DANP (DEMATEL-based ANP) model for reducing the gaps between each dimension and criterion to reach a given aspiration level in real world inter-relationship problems.

Effective supplier selection/improvement demands robust analytical methods and tools that are applicable to the supplier decision and able to analyze multiple subjective and objective criteria [2]. A series of literature reviews has summarized the criteria and decision methods that have appeared in papers since the mid-1960s. For example, in an exhaustive review of 76 articles, Weber et al. [53] found that 47 articles address the involvement of more than one criterion. Two journal articles [10,59] reviewed the literature regarding supplier evaluation and improvement/selection models. Ho et al. [16] extended these reviews by surveying multi-criteria supplier evaluation and improvement/selection approaches through a literature review and a classification of international journal articles from 2000 to 2008. They concluded that only extensive, multi-criteria decision-making approaches have been proposed for supplier selection. The approaches include the analytic hierarchy process (AHP), analytic network process (ANP), data envelopment analysis (DEA), fuzzy set theory, genetic algorithms (GA), mathematical programming, the multi-attribute rating technique (i.e., gray relation, VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), technique for order preference by similarity to an ideal solution (TOPSIS), and their hybrids.

Prior studies have made significant contributions to supplier selection; however, they have assumed the criteria to be independent when modeling the supplier selection problem. In the real world, the criteria are seldom independent. In fact, the relationships between the criteria are all, to some extent, interactive and occasionally include dependence and feedback effects [20,36,46]. Others [19,27,30,18,29,12] have accounted for this interdependence (i.e., by using the ANP) but nonetheless employed additive models (i.e., VIKOR, gray relation or TOPSIS) to aggregate performances and weights. However, these methods are inconsistent with the assumption that the criteria are interdependent. A means of avoiding this inconsistency is to apply non-additive fuzzy integrals to integrate the interdependent performance values. In this study, we improve on prior research in three ways. First, the interdependent relationships between, and weights of, the criteria are constructed and calculated using DEMATEL and a fundamental concept of the ANP called DANP. This method can derive weights directly from the DEMATEL results and accommodate the different degrees of influence across dimensions. It also avoids the time-consuming process of performing pair-wise comparisons between criteria required in the original ANP analysis. Second, based on the concepts of VIKOR, the traditional relative good solution from the existing alternatives is replaced by the aspiration levels to avoid the "Choose the best among inferior choices/options/alternatives", i.e., avoid "Pick the best apple among a barrel of rotten apples" option. Third, a non-additive fuzzy integral is used to obtain influence weighted gaps that enable managers to better measure and understand the gaps between aspiration levels and actual levels and establish improvement priorities. Using this hybrid model, we can remedy the inconsistency in our prior studies [18,29] that assume interdependent criteria but apply additive models. This study may present the first model that integrates the concepts of a non-additive value function and interdependence with feedback effects in the supplier selection problems. Moreover, the emphasis in the MCDM field has shifted from ranking and selection when determining the most preferable approaches to performance improvement. Our model provides a systematic approach to identify the source of problems rather than addressing the systems of the problems. We used data from a Taiwanese company to demonstrate this model. This generic model can be easily extended to other industries to aid other types of firms in selecting their optimal suppliers.

2. A brief review of the existing literature

Over the last two decades, various decision-making methods have been proposed to address supplier evaluation and selection problems. Critical reviews have summarized the criteria and decision methods employed in the supplier selection process, for example, Ho et al. [16], De Boer et al. [9], Degraeve et al. [10] Wu et al. [55] and Weber et al. [54]. Based on prior studies, we categorize the methodologies used to analyze the supplier selection problem as follows: (1) multi-attribute decision-making, (2) mathematical programming models, (3) intelligent approaches, and (4) integrated approaches.

2.1. Multi-attribute decision-making (MADM)

The most popular multi-attribute decision-making methods are the AHP and ANP. Shaw et al. [40] applied a fuzzy AHP to analyze a low carbon supply chain decision. The factors they considered are cost, quality, rejection percentage, late delivery percentage, green house gas emissions and demand. Bertolini et al. [3] used the AHP to select the best discount rate in defining a proposal for a public works contract. A hierarchical structure comprised of 31 criteria is reported to illustrate the performance and characteristics of the proposed technique. Chan and Kumar [4] developed a fuzzy AHP model to identify and discuss some of the important and critical decision criteria including risk factors for the development of an efficient system for global supplier selection. Although the AHP assumes independent criteria, other researchers applied the ANP to consider interdependent criteria when constructing their models. Vinodh et al. [51] proposed a fuzzy ANP approach for the supplier selection process. The study employed an Indian electronic switch manufacturing company as a case study to demonstrate the model. Hsu and Hu [17] presented an ANP approach to incorporate the issue of hazardous substance management (HSM) into supplier selection. The simple multi-attribute rating technique (SMART) is another MADM method. Barla [2] conducted a five-step approach based on SMART to evaluate and select suppliers for a glass manufacturing company. They used seven