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Fuzzy multi-objective decision model for calibration supplier selection problem

Nihal Erginel [a,*], Ayse Gecer [b]

[a] Department of Industrial Engineering, Engineering Faculty, IkiEylul Campus, Anadolu University, Eskisehir 26555, Turkey
[b] İzmir Katip Çelebi University, Atatürk Training and Research Hospital, 35360 Karabağlar, İzmir, Turkey

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ABSTRACT

Quality products and competitively priced services are crucial in today's global markets. To provide quality at an acceptable price, companies seek out not only raw material and product suppliers but also calibration services suppliers. The calibration of measurement devices is one of the ISO9001 standard requirements for quality. Although companies select and manage their calibration processes as economically as possible, cost is not their only selection criterion. Technical capability, documentation competence, performance history, warranties, and communications are also considered when selecting calibration suppliers. There are numerous criteria and methods in the current literature on supplier selection, but few studies have specifically examined the selection of calibration suppliers.

This paper is the first study that specifically examines the selection process for calibration suppliers by utilizing selection criteria that were researched and presented prior to this study. Due to the varied linguistic expressions of criteria and the uncertain model parameters, this paper presents a fuzzy approach for selecting a calibration supplier. The model contains relevant calibration service quality parameters such as the weight of criteria, cost, calibration time, demand, technical capability, and number of experts. This study proposes a fuzzy multi-objective linear programming model that assigns the calibration supplier to the measurement device using two objectives: maximizing the fuzzy weight of the criteria and minimizing the fuzzy calibration cost through fuzzy calibration time, the number of certified experts, the technical capability of the company, and the measurement device demand. A two-phase approach is used to solve the fuzzy multi-objective decision model. Weight, cost, and calibration time are handled as fuzzy numbers for modelling the imprecise data. In an actual application, calibration suppliers are selected for 20 measurement device types and 161 measurement devices with the fuzzy multi-objective linear programming model.

1. Introduction

The calibration of measurement devices is essential for providing accurate measurements. Calibration is defined by The Automation, Systems, and Instrumentation Dictionary (Dimon, 2001) as "a test during which known values of measured are applied to the transducer and corresponding output readings are recorded under specified conditions." This statement defines calibration as a comparison of a measurement device against a standard instrument that is traced by the centre of measurement for providing a higher accuracy of measurement devices. Calibration is an obligation according to the ISO9001:2008 Quality Management System: Requirements (ISO9001, 2008). ISO9001 calibration requirements cover all measurement devices used for measuring the quality of products, semi-products, raw materials, and processes that enhance customer satisfaction. ISO9001 calibration requirements are a part of the Quality Management System that consistently monitors and calibrates measurement devices. Thus, the selection of calibration suppliers has gained importance in a competitive global market.

Although the methods for selecting a calibration supplier can be similar to the selection of a raw material or semi-product supplier, the criteria for a calibration supplier are certainly different. While more traditional supplier selection criteria are taking into account by purchasing decision makers, the criteria for calibration suppliers are defined by quality managers or quality engineers.

Calibration supplier selection criteria are traditionally ranked by the capability and the cost of measurement devices. Other

* Corresponding author.
E-mail address: nerginel@anadolu.edu.tr (N. Erginel).

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criteria can also be considered such as competence of documentation, on-time delivery, warranties, and communications.

Although supplier selection problems are addressed in numerous papers in the existing literature, the unique problem of calibration supplier selection has not been studied. Nevertheless, this problem should be considered in the same way as other supplier selection problems due to the rising number of calibration suppliers. A supplier selection problem addresses the purchase of raw materials, semi-products, or products, whereas calibration supplier selection seeks to acquire services from qualified suppliers. Therefore, evaluating calibration suppliers is different from raw material/semi-product supplier selection.

This study presents effective criteria for selecting calibration suppliers and proposes a fuzzy decision model to consider real-world objectives and constraints. Due to the inherent vagueness of parameters in a decision model, fuzzy set theory can be effective means for deciphering imprecise decision model information. In this study, a fuzzy multi-objective linear programming model is proposed in which the weights of calibration supplier selection criteria, calibration cost, and calibration time are modelled as fuzzy data. Fuzzy multi-objective linear programming models have two objectives (maximizing the fuzzy weight of the criteria and minimizing the fuzzy calibration cost) and three constraints (fuzzy calibration time, the number of certificated calibration experts, and the technical capability of the company) that can be used in selecting a calibration supplier process.

The next section presents a concise literature review on supplier selection criteria and methodologies. In Section 3, the methodology and results of the questionnaire for determining the calibration supplier selection criteria and the weighted table of these criteria are presented. Section 4 presents a fuzzy multiple-objective linear programming model for selecting the calibration supplier. A real-world application for selecting a calibration supplier in the biomedical sector is provided in Section 6. Finally, conclusions and directions for future research are provided in Section 7.

2. Literature review

Papers on supplier selection have been published in two major categories in the current literature: determining the criteria for supplier selection and making selections using these criteria. Dickson conducted wide-ranging research on determining the criteria for supplier selection, and many papers have used the results of this study (Dickson, 1966). He introduced the concept of quality, delivery, performance history, warranties, and price as important criteria. In addition, capacity, price, technical capability, and financial position were important criteria for selecting raw material or parts suppliers. Weber et al. compiled a literature review of supplier selection problems from 1966 to 1991 and determined that price, delivery, quality, production capacity, and location were addressed in many papers (Weber, Current, & Benton, 1991). Boer et al. extended the Weber et al. study by publishing a review of methods supporting supplier selection (Boer, Labro, & Morlacchi, 2001). In addition, Tam and Tummala (2001) proposed significant criteria for the telecommunications sector such as quality, cost, problem-solving capability, proficiency, and reputation. They weighed these criteria by means of AHP. Supplier selection criteria have changed with shifting requirements over the years, and several papers have addressed these changes.

The existing literature on supplier selection shows that there is a multi-criteria problem. Several authors have used either linear weighted methods (Tullous & Munson, 1991; Wilson, 1994), the analytic hierarchy process (Barbarosoğlu & Yazgac, 1997; Narasimhan, 1983; Tam & Tummala, 2001), the analytical network process (Bayazıt, 2006; Demirtas & Ustun, 2009; Gencer & Gürpınar, 2007; Sarkis & Talluri, 2000), mathematical programming (Lin, Chen, & Ting, 2011; Talluri & Narasimhan, 2005), goal programming (Cebi & Bayraktar, 2003; Karpak, Kumcu, & Kasuganti, 2001; Wang, Huang, & Dismukes, 2004), multi-objective programming (Feng, Fan, & Li, 2011; Narasimhan, Talluri, & Mahapatra, 2006; Wadhwa & Ravindran, 2007; Wia & Wu, 2007) or fuzzy set theory (Chen, Lin, & Huang, 2006; Lin, 2012; Ozkok & Tiryaki, 2011; Wang & Yang, 2009) to weigh criteria and rank the alternatives. Haleh and Hamidi (2011) used multiple-criteria decision making (MCDM) methods to allocate suitable shares of orders to the best possible suppliers over a multi-period time. They also used a fuzzy linear programming model to optimize the price, quality, and risk objectives under cost and capacity constraints. Chu and Varma (2012) suggested a multiple-level MCDM model under a fuzzy environment to evaluate and select suppliers. Büyüközkan and Çiftçi (2012) considered green supply chain management and capability dimensions to propose an evaluation framework for green suppliers and proposed a novel hybrid MCDM approach. Karsak and Dursun (2015) developed a fuzzy MCDM based on quality function deployment (QFD) with a 2-tuple linguistic representation model for supplier selection. Amid, Ghodsypour, and O'Brien (2011) proposed a weighted max–min fuzzy model to effectively address the vagueness of input data and different weights of criteria.

However, there are few papers in the existing literature on fuzzy multi-objective linear programming (FMOLP) models for supplier selection. Yücel and Güneri (2011) suggested an FMOLP model to define the optimal order quantities for each supplier. The factors were determined with a new weighted additive fuzzy programming approach. Chen, Wang, and Lu (2011) proposed interval-valued intuitionistic fuzzy set approach to supplier selection problem. Shaw, Shankar, Yadav, and Thakur (2012) presented an integrated approach for selecting the appropriate supplier in a supply chain while addressing carbon emission issues by using a fuzzy-AHP and FMOLP model. Nazari-Shirkouhi, Shakouri, Javadi, and Keramati (2013) proposed an FMOLP model to select suppliers to minimize total purchasing and ordering costs, the number of defective units, and late delivered units ordered from suppliers under multi-price and multi-product conditions.

Although previous studies have developed approaches for supplier selection, the calibration supplier selection problem has yet to be addressed in research literature. Only a few papers have addressed calibration supplier criteria. Bessette and Dillard (2006) introduced searching for the right calibration service provider based on their experiences. In addition to cost, they determined that quality systems, technical competence, automated calibration procedures, financial stability, service delivery methods, record accessibility, turnaround time, and the ability to meet customer needs were relevant criteria. Geçer and Erginel (2012) studied the selection criteria and classified them as technical competence, documentation, on-time delivery, warranties and complaint policies, cost, communications, service features, and quality of service. Gecer (2010) researched these calibration supplier criteria and selection methods by considering multi-objectives. Erginel and Gecer (2011) solved the calibration supplier selection problem with two objective functions by using a two-phase approach, but their model parameters had crisp values. When solving multi-objective functions, the successful degree of all objectives comes from the membership function in the fuzzy approach. The fuzzy parameters in this study are also defined and used in an FMOLP model for a selection calibration supplier.

This paper proposes a fuzzy multi-objective linear programming model to incorporate imprecise and subjective information about parameters for a calibration supplier selection problem. In this FMOLP model, two objectives—maximizing the fuzzy weight