Available online at www.sciencedirect.com

ScienceDirect

Fuzzy Sets and Systems 266 (2015) 157–170

FUZZY sets and systems

www.elsevier.com/locate/fss

A fuzzy quality cost estimation method

José M. Brotons Martínez *, Manuel E. Sansalvador Selles

Department of Economic and Financial Studies, Miguel Hernández University of Elche, Edificio La Galia, Avda. de la Universidad s/n, 03202 Elche (Alicante), Spain

Received 8 January 2013; received in revised form 29 December 2014; accepted 31 December 2014

Available online 8 January 2015

Abstract

Quality cost control is one of the most important aspects in the development of a quality management system. This paper presents a method for the estimation of quality cost that aims to take into account the so-called hidden quality costs, which are typically unobserved or unknown. Although this is a subject that has already been approached in other studies, subjectivity and uncertainty are not included in their formal approach, which any attempt to address hidden quality costs should include. Our methodology begins by observing the position each business occupies in Crosby's Quality Management Maturity Grid. Obtaining the stage index on the basis of the experts' opinions permits the valuation of the company's membership for each of the stages of Crosby's Maturity Grid. The application of Crosby's corrector coefficient to an adequate weighting of the stage index makes it possible to obtain the fuzzy number quality cost. The measures obtained and their short-term predictions enable us to know the situation at all times and act accordingly, establishing precise corrective plans that will correct tendencies and make continuous improvement possible.

Keywords: Quality cost; Production research; Economics; Applications; Fault detection and diagnosis

1. Introduction

Measuring and reporting quality cost is an important step in a quality management program [1]. In this paper, we will develop a methodological proposal that mainly aims to facilitate the acquisition, and then the analysis and short-term prediction of reliable quality cost values.

Ever since Juran [2] introduced the concept of quality costs in the 50s, the subject has spurred an interest in many authors. Among the many existing definitions, in our opinion the one standing out because of its clarity is that by Campanella [3], who considers quality costs "the total of the costs incurred by investing in the prevention of non-conformances to requirements, appraising a product or service for conformance to requirements and failure to meet requirements." This means, as Juran and Godfrey [4] indicated, they are the costs that would disappear if there were no possibility of making mistakes.

* Corresponding author. Tel.: +34 96 665 89 67.
E-mail address: jm.brotons@umh.es (J.M. Brotons Martínez).

http://dx.doi.org/10.1016/j.fss.2014.12.014
0165-0114/

Feigenbaum [5] classified the quality cost into four broad categories, which are prevention, appraisal, internal and external failure costs. However, within the costs provoked by errors, failure costs, it is possible to introduce a new subdivision according to the components of cost. These are based on either objective criteria, and as a result, quantification should be relatively simple – *visible quality costs*, or, it may be necessary to resort to essentially subjective and totally unconventional criteria for estimation which complicates this task considerably – *invisible or hidden quality costs* [6].

In spite of the difficulty involved in measuring hidden quality costs, it is necessary to be aware not only of their existence but also of their importance [7]. It is not without reason that they have been the cause of the closure of many companies, because they are doubly dangerous. On the one hand, they represent significant amounts of money, and on the other, they remain hidden.

The hidden quality cost par excellence is the loss of income as a consequence of deterioration in the image of the company, resulting from clients' dissatisfaction because of faulty products or services [8]. In spite of their importance, costs brought about by the loss of image are not in the least the only hidden quality cost to be found in a company. In fact, as pointed out by Love and Irani [9], only some elements integrated in quality cost can be estimated with a certain degree of accuracy and objectiveness. Consequently, the real quality cost values are not only going to coincide with the calculated values by the business, but possibly may be far superior to them.

First, this paper develops a new method for the estimation of hidden quality costs based on fuzzy logic. Our method will allow any business to improve its estimations of quality costs, which is possible by observing the organization's position on Crosby's Quality Management Maturity Grid. Finally, short-term prediction of reliable quality cost values will then be made using possibilistic regression. To do so, we propose the regression method by Bisserier et al. [10]. It is clear that as the company progresses in quality management, there is a steady reduction in quality costs [11 and 12], which leads to a decrease in outspreads over time; consequently, this regression model adapts perfectly to quality cost behavior.

This paper is organized as follows: Section 2 gives a literature review; the main concepts of the fuzzy regression used are presented in Section 3; Section 4 outlines the methodological proposal for the estimation of quality costs; in Section 5, a case study is provided; and finally, Section 6 contains the concluding remarks.

2. Literature review

A great part of the literature written about the measurement of hidden quality costs stems from the study by Kotler [13], and in particular that of Albright and Roth [14], where different methods for calculating such costs are outlined. Since then, several authors have dealt with the quantification of hidden quality costs from different perspectives (see, for example [15–17] or more recently [18–20]). The papers by Kim and Liao [21] and Sedatole [22] stand out for their use of the "function of the loss of quality" by Taguchi.

However, subjectivity and uncertainty are not included in their formal approaches, which any attempt to approach hidden quality costs should include. To overcome this limitation, we propose using fuzzy logic.

The application of fuzzy set theory is a suitable approach in cases where uncertainty is due to the presence of limited and vague information. Applying fuzzy logic in management accounting is not new. Zebda [23] and Korvin, Strawser and Siegel [24] have applied fuzzy logic in cost–benefit analysis researching deviations; Kaufmann [25] did so in zero-based budgeting; Tanaka, Okuda and Asai [26] employ this instrument to resolve capital budgeting problems; Chan and Yuan [27] apply this methodology in their cost–volume–profit analysis to assist the accountant facing uncertainty and risk; Mansur [28] uses this to assess opportunity costs, and there are even application precedents of fuzzy logic toward quality costs [29–31], although dealing with work centered on the quantification of specific elements of the cost and not their posterior analysis.

Furthermore, the originality of the proposed model stand out because by simply observing the quality culture of the company, it is possible to approach the quality cost values it really has.

Subsequently, this study focuses on the analysis of the values obtained, and proposes the use of possibilistic regression to do so. To be exact, as already pointed out in the introduction, due to the behavior of quality costs, the regression method by Bisserier et al. [10] is proposed.

Fuzzy regression was introduced by Tanaka et al. [32,33]. In Tanaka and Ishibushi [34], quadratic membership functions are considered to propose an identification method of interactive fuzzy parameters in possibilistic linear systems. Fung et al. [35] propose an asymmetric fuzzy linear regression approach to estimate the functional rela-