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Justification of manufacturing technologies using fuzzy benefit/cost ratio analysis

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Abstract

The application of discounted cash flow techniques for justifying manufacturing technologies is studied in many papers. State-price net present value and stochastic net present value are two examples of these applications. These applications are based on the data under certainty or risk. When we have vague data such as interest rate and cash flow to apply discounted cash flow techniques, the fuzzy set theory can be used to handle this vagueness. The fuzzy set theory has the capability of representing vague data and allows mathematical operators and programming to apply to the fuzzy domain. The theory is primarily concerned with quantifying the vagueness in human thoughts and perceptions. In this paper, assuming that we have vague data, the fuzzy benefit–cost (B/C) ratio method is used to justify manufacturing technologies. After calculating the B/C ratio based on fuzzy equivalent uniform annual value, we compare two assembly manufacturing systems having different life cycles.

Keywords: Economic justification; Fuzzy set theory; B/C ratio

1. Introduction

Many authors give the economic justification approaches of manufacturing systems: Meredith and Suresh [1], Lavelle and Liggett [2], Soni et al. [3], Kolli et al. [4], Boaden and Dale [5], Khouja and Offodile [6], Proctor and Canada [7], etc. Kolli et al. [4] classify the approaches into two main groups: single criterion and multi-criteria approaches. These two main groups are then divided into two subgroups: deterministic and nondeterministic approaches. Simple criterion and deterministic approaches contain discounted cash flow techniques (NPV, JRR, PP, etc.). Single criterion and nondeterministic approaches contain sensitivity analysis, decision tree, Monte Carlo simulation, etc. Multi-criteria deterministic approaches contain scoring, AHP, goal programming, DSS, dynamic programming, and ranking methods (ELECTRE, PROMETHEE, …). Multi-criteria nondeterministic approaches contain fuzzy linguistics, expert system, utility models, and game theoretic models. Wilhelm and Parsaei [8] use a fuzzy linguistic approach to justify a computer-integrated manufacturing system. Kahraman et al. [9] use a fuzzy approach based on the fuzzy present value analysis for the manufacturing flexibility.

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To deal with vagueness of human thought, Zadeh [10], first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one.

Quite often in finance future cash amounts and interest rates are estimated. One usually employs educated guesses, based on expected values or other statistical techniques, to obtain future cash flows and interest rates. A statement like "approximately between 10% and 15%" must be translated into an exact amount such as "12.5%". Appropriate fuzzy numbers can be used to capture the vagueness of "approximately between 10% and 15%" [11].

A tilde ' $\sim$ ' will be placed above a symbol if the symbol represents a fuzzy set. Therefore, $\tilde{P}$, $\tilde{r}$, $\tilde{n}$ are all fuzzy sets. The membership functions for these fuzzy sets will be denoted by $\mu(x|\tilde{P})$, $\mu(x|\tilde{r})$, and $\mu(x|\tilde{n})$ respectively. A triangular fuzzy number (TFN), $\tilde{M}$ is shown in Fig. 1. A TFN is denoted simply as $(m_1/m_2, m_2/m_3)$ or (m_1, m_2, m_3). The parameters m_1, m_2 and m_3 respectively denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event.

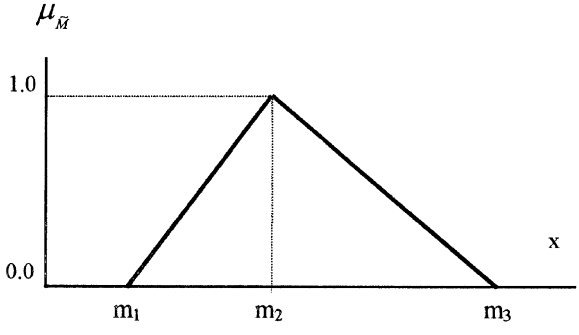

Fig. 1. A triangular fuzzy number, $\tilde{M}$.

Each TFN has linear representations on its left and right side such that its membership function can be defined as

$$\mu(x|\tilde{M}) = \begin{cases} 0, & x < m_1, \\ (x - m_1)/(m_2 - m_1), & m_1 \leqslant x \leqslant m_2, \\ (m_3 - x)/(m_3 - m_2), & m_2 \leqslant x \leqslant m_3, \\ 0, & x > m_3. \end{cases} \quad (1)$$

A fuzzy number can always be given by its corresponding left and right representation of each degree of membership:

$$\tilde{M} = (M^{l(y)}, M^{r(y)}) = (m_1 + (m_2 - m_1)y, m_3 + (m_2 - m_3)y) \quad \forall y \in [0, 1], \quad (2)$$

where l(y) and r(y) denotes the left side representation and the right side representation of a fuzzy number, respectively. Zimmermann [12] gives the algebraic operations with triangular fuzzy numbers. Many ranking methods for fuzzy numbers have been developed in the literature. They do not necessarily give the same rank. Two ranking methods are given in the appendix.

Buckley [11], Ward [13], Chiu and Park [14], Wang and Liang [15], Kahraman and Tolga [16] are among the authors who deal with the fuzzy present worth analysis, the fuzzy benefit/cost ratio analysis, the fuzzy future value analysis, the fuzzy payback period analysis, and the fuzzy capitalized value analysis.

2. Fuzzy benefit/cost ratio analysis

The benefit–cost ratio can be defined as the ratio of the equivalent value of benefits to the equivalent value of costs. The equivalent values can be present values, annual values, or future values. The benefit–cost ratio (BCR) is formulated as

$$\text{BCR} = B/C, \quad (3)$$

where B represents the equivalent value of the benefits associated with the project and C represents the project's net cost [17]. A B/C ratio greater than or equal to 1.0 indicates that the project evaluated is economically advantageous.