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A fuzzy multiple objective programming approach for the selection of a flexible manufacturing system

E. Ertugrul Karsak*, Onur Kuzgunkaya

Department of Industrial Engineering, Galatasaray University, Ortaköy, Istanbul 80840, Turkey

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Abstract

Global competition in manufacturing environment has forced the firms to consider increasing the quality and responsiveness to customization, while decreasing costs. The evolution of flexible manufacturing systems offers great potential for increasing flexibility and changing the basis of competition by ensuring both cost effective and customized manufacturing at the same time. This paper presents a fuzzy multiple objective programming approach to facilitate decision making in the selection of a flexible manufacturing system (FMS). Fuzzy set theory is introduced in the model to incorporate the vague nature of future investments and the uncertainty of the production environment. Linguistic variables and triangular fuzzy numbers are used to quantify the vagueness inherent in decision parameters, e.g., increase in market response, improvement in quality, reduction in setup cost, and so forth. The model proposed in this paper determines the most appropriate FMS alternative through maximization of objectives such as reduction in labor cost, reduction in setup cost, reduction in work-in-process (WIP), increase in market response and improvement in quality, and minimization of capital and maintenance cost and floor space used. These objectives are assigned priorities indicating their importance levels using linguistic variables. A numerical example is presented to illustrate the application of the model developed in this paper. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Multiple-objective decision making; Fuzzy sets; Investment decision analysis; Flexible manufacturing systems

1. Introduction

Recently, the expanding competitiveness in manufacturing due to the globalization has forced the manufacturers to increase their product types and respond to the changes in demand very quickly. Flexible manufacturing systems (FMSs) provide the means to reach these objectives. Robots, CNC machines and automated material handling systems controlled by dedicated computers are the main components of an FMS. The main benefits of an FMS can be listed as increase in product types, enhancement in quality, and reduction in WIP and setup costs. Before investing in such advanced manufacturing technologies requiring substantial capital expenses, both the dollar-denominated consequences and those effects not readily reduced to monetary terms have to be considered.

Within the past decade, a number of articles have been published for justification and selection of advanced manufacturing technologies. These studies can be classified in three main groups: economic

* Corresponding author. Fax: + 90-212-259-5557.
E-mail address: karsak@gsunv.gsu.edu.tr (E.E. Karsak).

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analysis, strategic techniques, and analytical methods. Although major strategic benefits such as early entry to market, market leadership, innovation, improved flexibility and quality are extremely important for the growth and survival of the manufacturing firm, they are not readily expressed in cash flow terms [1]. Hence, economic analysis methods such as payback period and discounted cash flow (DCF) techniques are not suitable on their own for the justification of FMS since they disregard tactical and strategic benefits such as improvement in market response, increase in quality and product flexibility, etc. Strategic methods generally consider the main objectives of the firm and they do not offer a generalized solution procedure. Analytical methods attempt to take into consideration both the qualitative and quantitative benefits. However, the mathematical programming, which is one of the frequently used analytical methods, falls short of modeling the linguistic expressions corresponding to strategic and qualitative benefits.

In this study, the FMS alternatives have been evaluated incorporating their strategic and economic benefits using a fuzzy multiple objective programming technique.

2. Literature survey

Justification methods for advanced manufacturing technologies can be classified into economic analysis techniques, analytical methods, and strategic approaches [2]. Economic analysis methods are classical engineering economy evaluation techniques such as return on investment (ROI), internal rate of return (IRR) and net present value (NPV). The economic analysis has long been quite popular in investment justification. Fotsch [3] states that the payback and ROI methods have been used by 91% of the firms. In a survey performed in the US manufacturing industry, Small and Chen [1] indicate that these two methods are still used by the majority of the manufacturers. The most widely used method after these two techniques is the DCF analysis. The popularity of the DCF technique is due to the ease in data collection and its intuitive appeal respected by most of the users. Miltenburg and Krinsky [4] analyze the application of traditional economic analysis techniques to the evaluation of FMS alternatives.

The main drawback of the economic analysis techniques is that they do not take into account strategic and non-economic benefits. Another obstacle facing these methods is that they only consider a single objective of cash flows, and ignore other objectives such as quality and flexibility. Recently, several authors have introduced strategic benefits in the economic methods by transforming them into cash flows through application of techniques that are named as 'modified DCF analysis'. Modified DCF analysis integrates non-financial quantitative effects into the analysis, whereas it generally ignores qualitative benefits [5]. Fuzzy set theory is suggested as an effective tool to incorporate strategic performance measures in manufacturing [6].

Strategic justification methods are generally used with economic or analytical methods, and require less technical data. The major benefit of these methods is that they use the general objectives of the firm. Technical importance, business objectives, competitive advantage, and research and development are the four main approaches used at strategic justification [2]. When strategic approaches are employed, the justification is made by considering long-term intangible benefits. Hence, using these techniques with economic or analytical methods would be more appropriate.

Analytical approaches generally require more data, and they are usually more complex than the economic analysis. Uncertainty of the future and the multi-objectivity can be incorporated into these methods. Using analytical methods, subjective criteria as well as more than one objective function can be introduced into the modeling phase. Value analysis, scoring models and mathematical modeling are the main applications of the analytical approaches [7,8]. In the 1980s single-objective mathematical programming models and scoring methods have been mainly used for justification of FMS. The analytic hierarchy process (AHP) is the most widely used scoring model that evaluates the advanced manufacturing technology alternatives by pairwise comparisons with respect to one of the criteria at a time. Wabalickis [9] develops