Available online at www.sciencedirect.com
SCIENCE DIRECT®

Computers & Industrial Engineering 46 (2004) 17–41

computers & industrial engineering

www.elsevier.com/locate/dsw

Application of fuzzy multi-objective linear programming to aggregate production planning

Reay-Chen Wang*, Tien-Fu Liang

Department of Industrial Management, National Taiwan University of Science and Technology, 43 Keelung Road, Section 4, Taipei 106, Taiwan, ROC

Accepted 19 September 2003

Abstract

This study develops a fuzzy multi-objective linear programming (FMOLP) model for solving the multi-product aggregate production planning (APP) decision problem in a fuzzy environment. The proposed model attempts to minimize total production costs, carrying and backordering costs and rates of changes in labor levels considering inventory level, labor levels, capacity, warehouse space and the time value of money. A numerical example demonstrates the feasibility of applying the proposed model to APP problem. Its advantages are also discussed. The proposed model yields a compromise solution and the decision maker's overall levels of satisfaction. In particular, in contrast to other APP models, several significant characteristics of the proposed model are presented.

Keywords: Aggregate production planning; Multi-objective linear programming; Fuzzy multi-objective linear programming; Decision maker

1. Introduction

Aggregate production planning (APP) deals with matching capacity to demand of forecasted, varying customer orders over the medium term, often from 3 to 18 months in advance. APP aims to (1) to set overall production levels for each product category to meet fluctuating or uncertain demand in the near future, and (2) to set decisions and policies concerning hiring, layoffs, overtime, backorders, subcontracting and inventory level, and thus determining appropriate resources to be used (Lai & Hwang, 1992). APP has attracted considerable attention from both practitioners and academia (Shi & Haase, 1996). In the field of planning, it falls between the broad decisions of long-range planning and

* Corresponding author. Tel.: +886-2-7376353; fax: +886-2-7376344.
E-mail address: rcwang@im.ntust.edu.tw (R.-C. Wang).

0360-8352/$ - see front matter
doi:10.1016/j.cie.2003.09.009

the highly specific and detailed short-range planning decisions. APP is one of the most important functions in production and operations management. Other forms of family disaggregation planning involve a master production schedule, capacity requirements planning, material requirements planning, which all depend on APP in a hierarchical way.

Since Holt, Modigliani, and Simon (1955) proposed the HMMS rule in 1955, researchers have developed numerous models to help to solve the APP problem, each with their own pros and cons. According to Saad (1982), all traditional models of APP problems may be classified into six categories—(1) linear programming (LP) (Charnes & Cooper, 1961; Singhal & Adlakha, 1989), (2) linear decision rule (LDR) (Holt et al., 1955), (3) transportation method (Bowman, 1956), (4) management coefficient approach (Bowman, 1963), (5) search decision rule (SDR) (Taubert, 1968), and (6) simulation (Jones, 1967). When using any of the APP models, the goals and model inputs (resources and demand) are generally assumed to be deterministic/crisp and only APP problems with the single objective of minimizing cost over the planning period can be solved. The best APP balances the cost of building and taking inventory with the cost of the adjusting activity levels to meet fluctuating demand.

However, in real-world APP problems, the input data or parameters, such as demand, resources, cost and the objective function are often imprecise/fuzzy because some information is incomplete or unobtainable. Conventional mathematical programming schemes clearly cannot solve all fuzzy programming problems. The current APP model represents information in a fuzzy environment where the objective function and parameters are incompletely defined and cannot be accurately measured. In 1976, Zimmermann (1976) first introduced fuzzy set theory into conventional LP problems. That study considered LP problems with a fuzzy goal and fuzzy constraints. Following the fuzzy decision-making method proposed by Bellman and Zadeh (1970) and using linear membership functions, that same study confirmed that there exists an equivalent LP problem. Thereafter, fuzzy linear programming (FLP) has been developed into a number of fuzzy optimization methods for solving the APP problem. Hintz and Zimmermann (1989) presented an approach based primarily on FLP and approximate reasoning to solve APP, releasing of parts and machine scheduling problems in flexible manufacturing systems. Additional references on the use of FLP to solve APP problems include Lee (1990), Masud and Hwang (1980), Rinks (1982), Tang, Wang, and Fung (2000), and Wang and Fang (2000, 2001).

However, in practical production planning systems, the many functional areas in an organization that yield an input to the aggregate plan normally have conflicting objectives governing the use of the organization's resources. These objectives minimize costs/maximize profits, inventory investment, customer service, changes in production rates, changes in work-force levels and utilization of plant and equipment (Krajewski & Ritzman, 1999). Moreover, the solution of fuzzy multi-objective optimization problems benefits from considering the imprecision of the decision maker's (DM's) judgments such as, 'the objective function of the annual total production costs should be substantially less than or equal to 5 millions', or 'the changes in labor levels should be substantially less than or equal to 200 man-hours'. Especially, these conflicting objectives are required to be optimized simultaneously by the DM in the framework of fuzzy aspiration levels.

In 1978, Zimmermann (1978) first extended his FLP approach (Zimmermann, 1976) to a conventional multi-objective linear programming (MOLP) problem. For each of the objective functions of this problem, assume that the DM has a fuzzy goal such as 'the objective functions should be essentially less than or equal to some value'. Then, the corresponding linear membership function is defined and the minimum operator proposed by Bellman and Zadeh (1970) is applied to combine all objective functions. By introducing the auxiliary variable, this problem can be transformed into the equivalent conventional