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Int. J. Production Economics 98 (2005) 328–341
international journal of production economics
www.elsevier.com/locate/ijpe

Applying possibilistic linear programming to aggregate production planning

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Received 24 October 2003; accepted 30 September 2004
Available online 24 November 2004

Abstract

This work presents a novel interactive possibilistic linear programming (PLP) approach for solving the multi-product aggregate production planning (APP) problem with imprecise forecast demand, related operating costs, and capacity. The proposed approach attempts to minimize total costs with reference to inventory levels, labor levels, overtime, subcontracting and backordering levels, and labor, machine and warehouse capacity. The proposed approach uses the strategy of simultaneously minimizing the most possible value of the imprecise total costs, maximizing the possibility of obtaining lower total costs, and minimizing the risk of obtaining higher total costs. An industrial case demonstrates the feasibility of applying the proposed approach to real APP decision problems. Consequently, the proposed PLP approach yields an efficient APP compromise solution and overall degree of decision maker (DM) satisfaction with determined goal values. Particularly, several significant management implications and characteristics of the proposed PLP approach that distinguish it from the other APP decision models are presented.

Keywords: Aggregate production planning; Possibilistic linear programming; Fuzzy sets theory

1. Introduction

Aggregate production planning (APP) determines the best way to meet forecast demand in the intermediate future, often from 3 to 18 months ahead, by adjusting regular and overtime production rates, inventory levels, labor levels, subcontracting and backordering rates, and other controllable variables. APP has attracted considerable interest from both practitioners and academics (Shi and Haase, 1996). Since Holt et al. (1955) proposed the HMMS rule in 1955, researchers have developed numerous models to

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0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2004.09.011

help to solve APP problems, each with its own advantages and disadvantages. HMMS model is one of the extensively adopted frameworks for solving APP decision problems. Its linear decision rules attempt to specify an optimum production rate and labor levels that minimize the total costs of regular payoff, overtime, hiring, layoffs, and inventory through a series of quadratic cost curves. Saad (1982) classifies all conventional decision models for solving APP problems into six categories—(1) linear programming (LP) (Charnes and Cooper, 1961), (2) linear decision rule (Holt et al., 1955), (3) transportation method (Bowman, 1956), (4) management coefficient approach (Bowman, 1963), (5) search decision rule (Taubert, 1968), and (6) simulation (Jones, 1967). Subsequent APP decision-related works include Shi and Haase (1996), Baykasoglu (2001), Buxey (2003), Dobos (2003), Gnoni et al. (2003), Stephen et al. (2003), and Jolayemi and Olorunniwo (2004). However, the goals and model inputs when any of these APP models are used generally are assumed to be deterministic/crisp.

In real-world APP problems, input data or related parameters, such as market demand, available resources and capacity, and relevant operating costs, frequently are imprecise/fuzzy owing to some information being incomplete or unobtainable. Traditional mathematical programming techniques clearly cannot solve all fuzzy programming problems. Zimmermann (1976) first introduced fuzzy set theory into conventional LP problems in 1976. His study considered LP problems with fuzzy goal and constraints. Following the fuzzy decision-making method of Bellman and Zadeh (1970), the same study confirmed the existence of an equivalent single-goal LP problem. Since then, fuzzy mathematical programming has developed into several fuzzy optimization methods for solving APP problems. Fung et al. (2003) presented a fuzzy multi-product aggregate production planning (FMAPP) model to cater to different scenarios under various decision-making preferences by applying integrated parametric programming, best balance and interactive methods. This model can also effectively enhance the ability of an aggregate plan to provide feasible disaggregate plans under varying circumstances with fuzzy demands and fuzzy capacities. Wang and Liang (2004a) more recently developed a fuzzy multi-objective linear programming model with the piecewise linear membership function to solve multi-product APP decision problems in a fuzzy environment. The model can yield an efficient compromise solution and the decision maker's overall levels of satisfaction. Additional fuzzy APP problem solving studies include Lee (1990), Wang and Fang (1997), Tang et al. (2000), Wang and Fang (2001), and Tang et al. (2003).

Moreover, Zadeh (1978) presented the theory of possibility, which is related to the theory of fuzzy sets by defining the concept of a possibility distribution as a fuzzy restriction, which acts as an elastic constraint on the values that can be assigned to a variable. Zadeh (1978) demonstrated that the importance of the theory of possibility stems from the fact that much of the information on which human decisions is based on is possibilistic rather than probabilistic in nature. Buckley (1988) formulated a mathematical programming problem in which all parameters may be fuzzy variables specified by their possibility distribution, and moreover illustrated this problem using the possibilistic linear programming (PLP) approach. Furthermore, Buckley (1989) described a procedure for solving existing PLP problems in a standard form with no equality constraints. Lai and Hwang (1992b) developed an auxiliary multiple objective linear programming (MOLP) model for solving a PLP problem with imprecise objective and/or constraint coefficients. Tang et al. (2001) designed two types of PLP with general possibilistic distribution, including LP problems with general possibilistic resources (GRPLP) and general possibilistic objective coefficients (GOPLP). Hsu and Wang (2001) applied Lai and Hwang's PLP approach to manage production planning decision problems in an assemble-to-order environment. Other studies on PLP problems include Inuiguchi and Sakawa (1996), Hussein (1998), Tanaka et al. (2000), and Jensen and Maturana (2002).

This work develops a novel interactive PLP approach for solving the multi-product APP decision problem with imprecise forecast demand, related operating costs and capacity. The proposed