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A hybrid fuzzy goal programming approach with different goal priorities to aggregate production planning

Abouzar Jamalnia *, Mohammad Ali Soukhakian

Department of Industrial Management, Faculty of Management, Economics and Social Sciences, Shiraz University, Shiraz 71946, Iran

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ABSTRACT

In this study a hybrid (including qualitative and quantitative objectives) fuzzy multi objective nonlinear programming (H-FMONLP) model with different goal priorities will be developed for aggregate production planning (APP) problem in a fuzzy environment. Using an interactive decision making process the proposed model tries to minimize total production costs, carrying and back ordering costs and costs of changes in workforce level (quantitative objectives) and maximize total customer satisfaction (qualitative objective) with regarding the inventory level, demand, labor level, machines capacity and warehouse space. A real-world industrial case study demonstrates applicability of proposed model to practical APP decision problems. GENOCOP III (Genetic Algorithm for Numerical Optimization of Constrained Problems) has been used to solve final crisp nonlinear programming problem.

1. Introduction

Aggregate production planning (APP) is a medium range capacity planning that typically encompasses a time horizon from 3 to 18 months and is about determining the optimum production, work force and inventory levels for each period of planning horizon for a given set of production resources and constraints. Such planning usually involves one product or a family of similar products with small differences so that considering the problem from an aggregated viewpoint is justified. Planners in the process of APP make decisions that regard overall production levels for each product category to meet the fluctuating or uncertain demands in near future and also regard policies and decisions about the issues of hiring, lay off, overtime, backorder, subcontracting and inventory. APP is an important technical level planning in a production management system. In the field of planning, it falls between the broad decisions of long-range planning and the highly specific and detailed short-range planning decisions. Other forms of family disaggregation plans, such as master production schedule, capacity requirements planning and material requirements planning all depend on APP in a hierarchical way (Ozdamar, Bozyel, & Birbil, 1998).

APP has attracted considerable attention from both practitioners and academia (Shi & Haase, 1996). Since Holt, Modigliani, and Simon (1955) proposed the HMMS rule in 1955, researchers have developed numerous models to help to solve the APP problems, each with their own pros and cons. In real-world APP problems, the input data or parameters, such as demand, resources, costs and the objective functions are imprecise/fuzzy because some information is incomplete or unobtainable(Wang & Liang, 2004). Fuzziness is a type of imprecision that has no well-defined boundaries for its description. It is particularly frequent in the area where human judgment, evaluation and decisions are important, such as decision making, reasoning, learning and so on (Bellman & Zadeh 1970). Fuzzy sets theory is very applicable to dealing with such ill-defined situations. Zadeh (1965) proposed the fuzzy sets theory providing a highly effective means of handling with imprecise data. A decision maker can integrate this datum into linear programming systems to simultaneously reduce information costs and avoid unrealistic modeling (Wang & Fang, 2001).

Zimmermen (1976) first introduced fuzzy sets theory into conventional linear programming problems. That study considered linear programming problems with a fuzzy goal and fuzzy constraints. Zimmermen (1978) also presented the application of fuzzy sets theory to linear programming problems with several objective functions and with using min-operator introduced equivalent linear programming model to original fuzzy multi objective problem. Narasimhan(1980) illustrated the application of "fuzzy subsets" concepts to goal programming in a fuzzy environment. This research first considers a fuzzy goal programming (FGP) problem with multiple goals having equal weights associated with them. A solution approach based on linear programming is developed. Next, the solution approach is extended to the case where

* Corresponding author. Tel.: +98 9179914685; fax: +98 7116276372.
E-mail address: a_jamalnia@yahoo.com (A. Jamalnia).

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unequal fuzzy weights are associated with multiple goals. Hannan (1981) applied fuzzy sets theory in goal programming problems. In particular he demonstrated that how fuzzy or imprecise aspirations of decision makers can be quantified through the use of piecewise linear and continuous membership functions and then presented models for the use of FGP with preemptive priorities, with Archimedean weights, and with the maximization of the membership function corresponding to the minimum goal.

Subsequent researches on FGP include Leberling (1981), Luhandjula (1982), Rubin and Narasimhan (1984), Tiwari, Dharmar, and Rao (1987), Sakawa (1988), Mohamed (1997), Wang and Fu (1997), Kim and Whang (1998), Chen and Tsai (2001), Chanas and Kuchta (2002), Hashemi, Ghatee, and Hashemi (2006), Yaghoobi and Tamiz (2007), Aköz and Petrovic (2007), Hop (2007), Chang (2007), Hu, Teng, and Li (2007) .

Rinks (1982) tackled APP problems using fuzzy logic and fuzzy linguistics and developed a production and workforce algorithm using a series of approximately 40 relational assignment rules. Lee (1990) investigated potential applications of fuzzy sets theory to APP and lot sizing methods in material requirement planning. An interactive fuzzy linear programming was proposed to model and solve the single objective APP problems. In addition, an interactive fuzzy multi objective linear programming was introduced to deal with the multi-objective APP problems. Gen, Tsujimura, and Ida (1992) presented a method for solving multi-objective APP problem with fuzzy parameters. They proposed an efficient method that transforms a fuzzy multi-objective linear programming (MOLP) problem to crisp MOLP model and an interactive solution procedure that suggest the best compromise aggregate production plan for fuzzy multi-period multi-objective APP problems. Tang, Wang, and Fang (2000) introduced a novel approach to modeling multi-product APP problems with fuzzy demand and fuzzy capacities. The objective of the problem considered was to minimize the total costs of quadratic production costs and linear inventory holding costs. The multi-product APP problem with fuzzy demands and fuzzy capacities modeled into a fuzzy quadratic programming with fuzzy objectives and fuzzy constraints. The fuzzy solution approach to the model was also proposed.

Wang and Fang (2000) presented a novel fuzzy linear programming method for solving the APP problem where the market demands and unit cost to subcontract are fuzzy in nature. A specific fuzzy linear programming model was proposed. Moreover, an interactive solution procedure was developed to provide a compromise solution. Wang and Fang (2001) proposed a novel fuzzy linear programming (FLP) method for solving the APP problem with multiple objectives where the product price, unit cost to subcontract, work force level, production capacity, and market demands are fuzzy in nature. The specific FLP model was proposed. Moreover, an interactive solution procedure was developed to provide a compromise solution.

Tang, Fung, and Yung (2003) proposed an approach that focuses on a formulation and simulation analysis for multi-product APP problems with fuzzy demands and fuzzy capacities. A fuzzy multi-product APP model was transformed into a parametric programming model. A simulation of a practical instance was conducted to illustrate the model and demonstrate the performance and effect of various parameters on the optimal aggregate production plan. Fung, Tang, and Wang (2003) presented multi-product aggregate production planning with fuzzy demands, fuzzy capacities and financial constraints. A fuzzy multi-product APP model was developed and its solutions using parametric programming, best balance and interactive techniques were introduced to cater to different scenarios under various decision making preferences. Dai, Fun, and Sun (2003) presented a fuzzy linear programming approach for managing the uncertainties and imprecise information involved in industrial APP applications. A mathematical model was developed for APP practice with the fuzzy linear programming approach. It was demonstrated in this study that the employment of the fuzzy linear programming provides a great advantage in APP, if the parameters of the stochastic factors involved in the production planning are neither definitely reliable nor precise. Wang and Liang (2004) developed a fuzzy multi-objective linear programming (FMOLP) model for solving the multi-product 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. Ning, Tang, and Zhao (2006) considered multi product APP in fuzzy random environment. A fuzzy random APP model was established, in which the market demand, production cost, subcontracting cost, inventory carrying cost, backorder cost, product capacity, sales revenue, maximum labor level, maximum capital level, etc were all characterized as fuzzy random variables. Then a hybrid optimization algorithm combining fuzzy random simulation, genetic algorithm (GA), neural network (NN) and simultaneous perturbation stochastic approximation (SPSA) algorithm was proposed to solve the model. Liang (2007) introduced an interactive possibilistic linear programming (i-PLP) approach to solve multi-product and multi-time period APP problems with multiple imprecise objectives and cost coefficients by triangular possibility distributions in uncertain environments. The imprecise multi-objective APP model designed here seeks to minimize total production costs and changes in work-force level with reference to imprecise demand, cost coefficients, available resources and capacity. Additionally, the proposed i-PLP approach provides a systematic framework that helps the decision-making process to solve fuzzy multi-objective APP problems, enabling decision makers to interactively modify the imprecise data and parameters until a set of satisfactory solutions is derived. Aliev, Fazlollahi, Guirimov, and Aliev (2007) developed a fuzzy integrated multi-period and multi-product aggregate production and distribution model in supply chain. The model was formulated in terms of fuzzy programming and the solution was provided by genetic optimization (genetic algorithm).

In this study a hybrid fuzzy multi objective nonlinear programming (H-FMONLP) model with different goal priorities will be developed for multi product multi period APP problem in a fuzzy environment. Hybrid means that it includes both quantitative and qualitative objectives. This model considers qualitative objectives (stated with linguistic terms) that decision makers may have. Learning curve effects also is considered that lead to nonlinearity of the model. In addition, Product life cycle concept has been included in the model to precise forecasting of future demands. Using an interactive decision making process the proposed model tries to minimize total production costs, carrying and back ordering costs and costs of changes in workforce level (quantitative objectives) and maximize total customer satisfaction (qualitative objective) with regarding the inventory level, demand, labor level, machines capacity and warehouse space. Finally H-FMONLP model is converted to equivalent crisp nonlinear programming (CNLP) with one objective that maximizes the summation of achievement degrees of all objectives. Finally GENOCOP III (Genetic Algorithm for Numerical Optimization of Constrained Problems) that developed by Michalewicz and Nazhiath (1995) is used to solve this CNLP problem.

This paper is further organized as follows. Section 2 presents model construction, Section 3 indicates fuzzifing primary APP model, in Section 4 equivalent CNLP model for constructed fuzzy model will be presented. In Sections 5 and 6 a real-world industrial case study, model solution, sensitivity analysis and models comparison will be provided. Finally in Section 7 we will provide conclusions.