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Multi-objective aggregate production planning with fuzzy parameters

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ABSTRACT

In this paper, a direct solution method that is based on ranking methods of fuzzy numbers and tabu search is proposed to solve fuzzy multi-objective aggregate production planning problem. The parameters of the problem are defined as triangular fuzzy numbers. During problem solution four different fuzzy ranking methods are employed/tested. One of the primary objectives of this study is to show that how a multi-objective aggregate production planning problem which is stated as a fuzzy mathematical programming model can also be solved directly (without needing a transformation process) by employing fuzzy ranking methods and a metaheuristic algorithm. The results show that this can be easily achieved.

1. Introduction

Aggregate planning is the determination of production rate and the best strategy to meet the demand by considering sales forecasts, production capacity, inventory levels and work force for a medium period, often from 3 to 18 months in advance [1]. The aims of aggregate production planning (APP) are; to set overall production levels for each product category to meet fluctuating or uncertain demand in the near future and to set decisions concerning hiring, layoffs, overtime, backorders, subcontracting, inventory level and determining appropriate resources to be used [2]. APP is an important upper level planning activity in a production management system. Other forms of family disaggregation plans, such as master production schedule, capacity plan, and material requirements plan all depend on APP in a hierarchical way [3,4].

All traditional models of APP problems can be classified into six categories according to Saad [5]; linear programming, linear decision rule, transportation method, management coefficient approach, search decision rule and simulation. In practical production planning systems, aggregate planning generally have conflicting objectives with respective to the use of the resources [2].

In real world APP problems, the input data or parameters, such as demand, resources, and cost are generally imprecise because some information is incomplete or unobtainable [2]. These imprecise parameters can be defined as random numbers with probability distribution, fuzzy numbers or interval numbers [3]. A great deal of knowledge about the statistical distribution of the uncertain parameters is required to define the parameters as random numbers with probability distribution. So, using fuzzy numbers for imprecise parameters is more efficient and/or practical in real world settings.

In the literature, there are various studies on the solution of fuzzy multi-objective APP problem. But, in these studies generally only the goals are defined as fuzzy values and the fuzzy model is solved by transforming the fuzzy model into classical crisp mathematical programming problem. Wang and Fang [6] handled a fuzzy APP problem which tries to maximize profit and to find the production quantity of products. In their study, the APP problem is defined as a fuzzy linear programming problem; the resources are defined as fuzzy numbers and for the objective function a fuzzy goal is defined. The fuzzy APP problem is transformed into a crisp linear programming problem using Zimmermann's max–min approach. After the transforming process, instead of finding an exact solution, Wang and Fang proposed an inexact approach which imitates the human decision making process by generating a family of inexact solutions within an acceptable level as candidates for decision maker to consider. In order to generate a family of inexact solutions, a genetics based algorithm is proposed in their work. In the study of Tang et al. [3], a multi-product APP problem with fuzzy demands and fuzzy capacities was modeled. The demand and capacities are considered as fuzzy numbers. For obtaining a solution, the fuzzy model was converted into its crisp equivalent by using defuzzification of soft equations according to satisfaction of membership functions at a defined degree of truth. Wang and Fang [7] presented a novel fuzzy linear programming method for

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solving the fuzzy APP problem with fuzzy market demands and fuzzy subcontracting cost. The market demands and the unit cost to subcontract are defined as trapezoidal fuzzy numbers. Wang and Fang [7] proposed an interactive solution procedure to provide a compromise solution. The fuzzy APP problem is transformed into its crisp equivalent according to Zimmermann's approach and solved. After the solution of the crisp equivalent, the interactive decision process was applied. Wang and Fang [8] presented a fuzzy linear programming method for solving the fuzzy APP problem with multiple objectives. In their problem, some of the parameters in the objective functions, in the left hand and right hand side of the constraints are defined as trapezoidal fuzzy numbers. For the fuzzy objectives, L type and R type fuzzy numbers are defined as fuzzy goals and the upper and lower bounds of fuzzy goals are determined according to Rommelfanger [9]. The fuzzy APP problem is converted into its crisp equivalent according to Zimmermann's approach. In another study, Wang and Fang [10] modeled an APP with fuzzy variables and presented its solution. In their fuzzy APP problem, the decision variables, the demands and subcontracting cost are accepted as triangular fuzzy numbers. According to interval arithmetic and partial ordering of fuzzy numbers, the fuzzy APP problem decomposed into a two-level multi-objective programming problem and solved. Fung et al. [4] solved a fuzzy multi-product APP problem in their paper. They accepted demands and capacities as triangular fuzzy numbers. Their fuzzy multi-product APP problem has only one objective (minimizing the total cost) and only the demands and the capacities are defined as fuzzy. Using the membership functions of the fuzzy parameters, the problem is converted into a crisp parametric programming problem. The resultant crisp problem is solved by using parametric programming and the proposed interactive method. Wang and Liang [2] developed a fuzzy multi-objective linear programming model for solving the multi-product APP problem in a fuzzy environment. The handled problem has three objectives, minimizing total production costs, minimizing carrying and backordering costs and minimizing rate of change in labor levels, and for the objectives fuzzy aspiration levels were defined. Piecewise linear membership functions were specified for the fuzzy goals. The other parameters of the problem were assumed to be certain. Fuzzy multi-objective linear programming problem is converted into its crisp equivalent by using Zimmermann's approach. In their model, the decision maker can interactively modify the membership functions of the objectives until a satisfactory solution is obtained. Wang and Liang [11] handled a fuzzy multi-product APP problem in their work. The multi-product APP problem is modeled as a multi-objective linear programming problem and all of the objectives are defined as fuzzy with imprecise aspiration levels. The other parameters of the problem were considered to be crisp. The fuzzy multi-objective linear programming problem was transformed into its crisp equivalent according to Zimmermann's max–min approach. The obtained crisp equivalent linear programming problem was solved with classical approaches. In their approach, after the solution process, the decision maker can interactively modify the fuzzy data and related model parameters until a satisfactory solution is obtained. Tavakkoli-Moghaddam et al. [12] presented a fuzzy APP model for make-to-stock environments. In their model, the aspiration level of the objective, one of the right hand side parameters of the constraints (the demand) and one of the left hand parameters of the constraints (average usage rate) were considered as fuzzy numbers. The fuzzy problem is converted into its crisp equivalent using Zimmermann's approach and a defuzzification method for the left hand parameter. Then the crisp equivalent is solved using any classical approach. Baykasoglu and Göçken [13] proposed a multi-objective tabu search (TS) based solution method to solve fuzzy goal programs and they applied their approach to a fuzzy multi-objective APP problem. In their application only the goals of the problem were defined as triangular fuzzy numbers. Three different methods, namely the pre-emptive method, the max–min method and the additive method, were used to handle fuzzy goals within the proposed TS algorithm.

In the present study, a multi-product fuzzy multi-objective APP problem is handled. The parameters of the problem are defined as triangular fuzzy numbers. Differently from the previous approaches the fuzzy multi-objective APP problem is solved directly by employing four different fuzzy ranking methods and the TS algorithm of Baykasoglu et al. [14]. Ranking methods for fuzzy numbers are used to rank the objective function values and to determine the feasibility of the constraints. In Section 2, the employed TS algorithm is explained briefly. In Section 3, the ranking methods for fuzzy numbers which are used in the solution of the present problem are explained. In Section 4, the fuzzy multi-objective APP problem is explained. In Section 5, the direct solution process for the present fuzzy multi-objective APP problem is explained and the obtained results are presented.

2. A brief overview of the employed TS algorithm

TS has its origins in combinatorial procedures applied to nonlinear covering problems in late 1970s. TS is a higher level heuristic procedure for solving optimization problems, designed to guide other methods to escape the trap of local optimality. TS is a stochastic neighborhood search algorithm that is first suggested and applied by Glover [15,16]. The basic TS algorithm starts from a randomly selected or a known feasible solution. From this initial solution, a set of neighborhood solutions are generated using a number of previously determined movement strategies. The objective function is evaluated for each solution in the set of neighborhood solutions and the best neighbor replaces the current solution, even though it may be worse than the initial solution: in this way it is possible to escape from the local minima (or maxima) of the objective function. The algorithm iterates, repeating the procedure with the new solution, until some given stopping condition(s) is reached. However, the algorithm as described above may recycle. To avoid this situation, certain attributes of the last k replaced solutions are stored in a list, which is called the tabu list. The neighbors of the current solution that satisfy conditions given by the tabu list are systematically eliminated unless they meet an aspiration criterion, so at each iteration the algorithm is forced to select a point not recently selected. The main stages of a TS algorithm are; initial solution, generation of neighbors, selection, aspiration, and updating.

One of the first attempts was made by Baykasoglu et al. [17] to adapt TS algorithm for solving multiple objective optimization problems. The solution structure of the TS algorithm enables to work with more than one solution (*neighborhood solutions*) at a time. This situation gives the opportunity to evaluate multiple objectives/goals simultaneously. To enable the original TS algorithm to work with more than one goal the selection and updating stages are redefined. Other stages are identical to the original TS algorithm [14,17]. In this study, for solving fuzzy aggregate production planning problem the TS algorithm of Baykasoglu et al. [14] is used as the main search mechanism. The main steps of the TS algorithm can be defined as follows.

Initial solution: An initial random feasible solution vector (*or a previously known feasible solution vector*) that satisfies all hard constraints.

Generation of neighborhood solutions: A neighbor solution is obtained by changing the value of a randomly selected decision variable from the solution vector. TS works with population of solutions therefore; this action is performed repetitively to obtain previously determined numbers of neighbor solutions (S^*). To