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Material Requirement Planning with fuzzy constraints and fuzzy coefficients☆

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Abstract

We propose a new fuzzy mathematical programming model for production planning under uncertainty in an industrial environment. This model considers fuzzy constraints related to the total costs, the market demand and the available capacity of the productive resources and fuzzy coefficients for the costs due to the backlog of demand and for the required capacity. The main goal is to determine the master production schedule of each product, the MRP (Material Requirement Planning) for each raw component in each period, stock levels, demand backlog, and capacity usage levels over a given planning horizon. Finally, the proposed model is tested by using data from an automobile seat assembler and compared with other fuzzy mathematical programming approaches. The experiment shows that the proposed model has not got a better behaviour than more simple fuzzy models, but the advantage is that both types of uncertainties, fuzziness and lack of knowledge or epistemic uncertainty can be considered in a model with fuzzy constraints and fuzzy coefficients.

Keywords: Fuzzy mathematical programming; MRP; Uncertainty; Fuzzy constraints; Fuzzy coefficients

1. Introduction

In industrial decision environments, there are many forms of uncertainty which can affect production planning processes such as market demand, capacity data and cost information. Along the years there have been many researches and applications aimed to model the uncertainty in production planning problems [32]. Uncertainty can be present as randomness, fuzziness and/or lack of knowledge or epistemic uncertainty (see [8]). Randomness comes from the random nature of events and deals with uncertainty regarding membership or non-membership of an element in a set. Fuzziness is related to flexible or fuzzy constraints modelled by fuzzy sets [1]. Epistemic uncertainty is concerned with ill-known parameters modelled by fuzzy intervals in the setting of possibility theory [10,46].

One of the key sources of uncertainty in any production-distribution system is the product demand [45,36,18]. The market demand is composed of firm orders and demand forecasts. The firm orders are known at the beginning of each

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planning horizon. While the foreseen demand is based on such factors as the historical sales, supplies of other sources or competitors, etc. These factors make the demand fuzzy in its nature. The capacity data neither is a crisp value because during the production processes unforeseen events such as breakdowns, faulty production or preparation delays can happen. Also, planning costs could not be measured easily since they imply a great use of the human perception for their valuation. For instance, in some manufacturing environments the planners use an average production cost per hour perceived in the calculations of the unitary production costs, what makes these costs fuzzy. The costs of undertime and overtime of the productive resources neither could be exact because the manpower can change or because mishaps or production shortcomings can take place. On the other hand, the demand backlog cost is fuzzy in its composition. This cost consists so much of the administrative cost of managing the backlog of orders as of the cost due to the loss of the clients. This type of cost is commonly estimated by using human experiences.

Here, we model a production planning problem under uncertainty through a possibilistic approach with fuzzy constraints, taking into account the fuzziness in the demand, the available capacity and the aspiration level of costs and fuzzy coefficients, the lack of knowledge of the demand backlog costs and the required capacity, based on fuzzy linear programming. In this context, the survey works by Kacprzyk and Orlovsky [25], Delgado et al. [4], Rommelfanger [39] and Zimmermann [48] show some possibilities of how the fuzzy set theory can be accommodated within linear programming.

The aim of this paper is to demonstrate the usefulness and significance of the fuzzy programming through a possibilistic approach applied to a Material Requirement Planning (MRP) problem with fuzziness and epistemic uncertainty. The main contribution of this paper to the operational research domain is a practical application of known possibilistic programming, accompanied by experiments on real data.

This paper is organized as follows. Firstly, in Section 2, we define the fuzzy problem considered for production planning in a capacity constrained MRP system. Then, a fuzzy mathematical programming model for MRP with fuzzy constraints and fuzzy coefficients is formulated in Section 3. Section 4 shows the architecture used to implement and solve the proposed model. Section 5 evaluates the behaviour of the proposed model using real data from an automobile seat assembler. In Section 6, this paper offers some conclusions and directions for further research.

2. Description of the problem

Different stochastic modelling techniques based on probability distributions have been successfully applied in production planning problems with randomness [34,11,16,26,18,41]. However, probability distributions derived from evidences recorded in the past are not always available or reliable because of market changes, which influence on demand or backorder costs, or technological innovation, which influences on capacity data. In these situations, the fuzzy set theory has been used to model systems that are difficult to define accurately [1,9,47]. This theory represents an attractive tool to support the production planning research when the dynamics of the manufacturing environment limits the specification of the model objectives, constraints and parameters. Guiffrida and Nagi [17] provide an exhaustive literature survey on the fuzzy set theory applications in production management research.

It is necessary to distinguish between fuzziness or flexibility in constraints and goals and lack of knowledge of the data or epistemic uncertainty. Flexibility is modelled by fuzzy constraints while epistemic uncertainty is modelled by fuzzy coefficients through possibilistic programming. Some applications of flexible programming in production planning problems can be found in Miller et al. [29], Pendharkar [35], Itoh et al. [24] and Mula et al. [31]. Other applications of possibilistic programming in production planning problems can be found in Gen et al. [15], Hsu and Wang [20], Wang and Fang [43], Lodwick and Bachman [27] and Wang and Liang [44]. However, previous researches mentioned above did not consider both types of uncertainty, fuzziness and lack of knowledge, at the same time.

The model proposed in this section considers the possible lack of knowledge in data and existent fuzziness jointly in the processes of production planning. It is considered a problem where epistemic uncertainty exists in the data of the cost due to the backlog of demand and the required capacity; and there is fuzziness in the goal of total costs and in the constraints of the inventory balance and the available capacity.

The linear programming model originally proposed in [31] and dubbed $M0$ is adopted as the basis to develop a new model based on fuzzy mathematical programming. $M0$ is a model for the optimization of the production planning problem in a capacity constrained MRP, multi-product, multi-level and multi-period manufacturing environment. Also, in [31] $M0$ is transformed into three fuzzy models based on flexible programming approaches, where the total cost aspiration level, the market demand and the available capacity are considered to be vague data. Here, we also consider