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A robust lot sizing problem with ill-known demands☆

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Abstract

The paper deals with a lot sizing problem with ill-known demands modeled by fuzzy intervals whose membership functions are possibility distributions for the values of the uncertain demands. Optimization criteria, in the setting of possibility theory, that lead to choose robust production plans under fuzzy demands are given. Some algorithms for determining optimal robust production plans with respect to the proposed criteria, and for evaluating production plans are provided. Some computational experiments are presented.
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1. Introduction

Nowadays, companies do not compete as independent entities but as a part of collaborative supply chains. Uncertainty in demands creates a risk in a supply chain as backordering, obsolete inventory due to the bullwhip effect [1]. To reduce this risk two different approaches exist that are considered here. The first approach consists of a collaboration between the customer and the supplier and the second one consists of an integration of uncertainty into a planning process.

The collaborative processes mainly aim to reduce a risk in a supply chain [2]. This is done by enforcing a coordination in a supply chain. Two approaches can be applied: vertical and horizontal. The vertical approach is a centralized decision making that synchronizes a supply chain (the most common way to coordinate within companies). The horizontal one refers to the collaborative planning, in which a supply chain can be seen as a chain, where actors are independent entities [3]. The industrial collaborative planning has been standardized for implementing a cooperation between retailers and manufactures. This process is called *Collaborative Planning*, *Forecasting and Replenishment* (CPFR) [4]. More precisely, the collaborative processes are usually characterized by a set of point-to-point (customer/supplier)

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relationships with a partial information sharing [2,5]. In the collaborative supply chain, a procurement plan is built and propagated through a supply chain. Namely, the procurement plan is composed of three horizons: freezing, flexible and free ones [2]. Quantities in the freezing horizon are crisp and cannot be modified, quantities in the flexible horizon are intervals and can be modified under constraints imposed by a previous procurement plan. In the free horizon quantities can be modified without constraints. Another way to reduce a risk in a supply chain is to integrate the uncertainty in a planning process. In the literature, three different sources of uncertainty are distinguished (see [6] for a review): *demand*, *process* and *supply*. These uncertainties are due to difficulties to access to available historical data allowing to determine a probability distribution.

In this paper, we focus on the collaborative supply chain (a supply chain, where actors are independent entities) under uncertain demands. In most companies today, especially in aeronautic companies, actors use the *Manufacturing Resource Planning* (MRPII) to plan their production. MRPII is a planning control process composed of three processes (the production process, the procurement process and the distribution process) and three levels [7]: the strategic level (computing commercial and industrial plans), the tactical level (the *Master Production Scheduling* (MPS) and the *Material Requirement Planning* (MRP)) and the operational level (a detailed scheduling and a shop floor control). MRPII have been also extended to take into account: the imprecision on quantities of demands (MPS) [8], the imprecision on quantities of demands and uncertain orders [9] (MRP) and the imprecision on quantities and on dates of demands with uncertain order dates [10] (MRP).

In this paper, we wish to investigate the part of the MRPII process. Namely, the procurement process in the tactical level in the collaborative context. Our purpose is to help the decision maker of a procurement service to evaluate a performance of a given procurement plan with ill-known gross requirements and to compute a procurement plan in a collaborative supply chain (with and without supplier capacity sharing due to a procurement contract) with ill-known gross requirements.

Several production planning problems have been adapted to the case of fuzzy demands: *economic order quantity* [11,12], *multi-period planning* [8–10,13–17], and the *problem of supply chain planning* (production distribution, centralized supply chain) [18–23]. In the literature, there are two popular families of approaches for coping with fuzzy parameters. In the first family, a *defuzzification* is first performed and then deterministic optimization methods are used [20,21]. In the second one, the objective is expressed in the setting of *possibility theory* [24] and *credibility theory* [25]. We can distinguish: the possibilistic programming (a fuzzy mathematical programming) in which a solution optimizing a criterion based on the *possibility* measure is built [16,17], the *credibility* measure based programming in which the credibility measure is used to guaranty a service level (chance constraints on the inventory level) [26] or the goal is to choose a solution that optimizes a criterion based on the credibility measure [13] and a decision support based on the propagation of the uncertainty to the inventory level and backordering level [8–10]. Here, we restrict our attention to uncertainty propagation in MRP (the tactical level) [8–10] and we propose methods both for evaluating a procurement plan in terms of costs under uncertain demands and for computing a procurement plan which minimizes the impact of uncertainty on costs, since the approaches proposed in the literature are not able to do this.

Popular setting of problems for hedging against uncertainty of parameters is *robust optimization* [27]. In the robust optimization setting the uncertainty is modeled by specifying a set of all possible realizations of the parameters called *scenarios*. No probability distribution in the scenario set is given. The value of each parameter may fall within a given closed interval and the set of scenarios is the Cartesian product of these intervals. Then, in order to choose a solution, two optimization criteria, called the *min–max* and the *min–max regret*, can be adopted. Under the min–max criterion, we seek a solution that minimizes the largest cost over all scenarios. Under the min–max regret criterion we wish to find a solution, which minimizes the largest deviation from optimum over all scenarios.

In this paper, we are interested in computing a robust procurement plan (with and without delivering capacity of the supplier sharing). The delivering capacity are composed of two bounds: the lower one being the minimal accepted quantity that is sent to the customer and the upper bound which is due to a production capacity of the supplier. Moreover the customer accepts to have backordering but it is more penalized than inventory. This problem is equivalent to the *problem of production planning* with backordering, more precisely to a certain version of the *lot sizing problem* (see, e.g. [28,29]), where: the procured quantities are production quantities, a *production plan*; delivering constraints are production constraints, *capacity limits on production plans*; and the gross requirements are *demands*. Thus, the problem consists in finding a production plan that fulfills capacity limits and minimizes the total cost of storage and backordering subject to the conditions of satisfying each demand. It is efficiently solvable when the demands are precisely known

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