Applied Mathematical Modelling 39 (2015) 4463–4481

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

A fuzzy model for shortage planning under uncertainty due to lack of homogeneity in planned production lots

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ARTICLE INFO

Article history:
Received 15 January 2014
Received in revised form 10 November 2014
Accepted 19 December 2014
Available online 3 January 2015

Keywords:
Fuzzy
Mathematical programming model
Shortage planning
Order promising
Lack of homogeneity in the product
Uncertainty

ABSTRACT

Lack of homogeneity in the product (LHP) affects several sectors like horticulture, reverse logistics, furniture, ceramics and leathers, among others. Productive processes with LHP are characterized by manufacturing units of the same finished good (FG) with certain attributes that differ and are relevant to customers. This aspect leads to the existence of different subtypes of the same FG in each production lot, which provides homogeneous sublots. Due to inherent LHP uncertainty, the size of each homogeneous sublot is not known until produced. LHP becomes a problem when customers order several units of the same FG and require homogeneity among them; i.e., being served with the same subtype. Like inherent LHP uncertainty, discrepancies between planned homogeneous quantities and the real ones is quite usual. This means it is impossible to serve committed orders with the previously defined requirements of quantity, homogeneity and due date, which brings about a shortage situation. In this paper, a fuzzy mixed integer linear programming model is proposed to support shortage planning in environments with LHP (LHP-FSP model). The LHP-FSP model aims to maximize the profits of served orders by reallocating the quantities of subtypes in stock and the uncertainty future ones in the master plan among the already committed orders. One of the main contributions of the paper is to model the fuzzy interdependent coefficients that represent the fraction of each homogeneous sublot. Finally, experiments based on realistic data from a ceramic company have been designed to validate the model and to analyze its behavior in different scenarios.

1. Introduction

The ability to effectively match demand and supply is fundamental to nearly all supply chain management processes [1]. Rapid responses to customer needs, a high level of customer service and flexibility to handle uncertainties and fluctuations in both demand and supply are becoming strategic differentiators in the modern marketplace [2]. To achieve these objectives, demand fulfillment & ATP (Available-To-Promise), which include order promising and shortage planning [3], are vitally important. The order promising process (OPP) refers to the set of business activities that are triggered to provide a response to customer order requests. These activities are related to the acceptance/rejection of customer orders, and to set delivery dates (due date assignment, due date determination, or due date quotation [3]). In the OPP, it is necessary to compute if there are enough ATP quantities. Gartner [4] defines ATP as the uncommitted portion of a company's inventory or planned

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http://dx.doi.org/10.1016/j.apm.2014.12.057
0307-904X/

production, a figure that is frequently calculated from the Master Production Schedule (MPS), and is maintained as a tool for order promising. Depending on the decisions to be made during the OPP, it is possible to distinguish between order acceptance/rejection [3,5] due date assignment and order scheduling [3], among others.

In the short term, the customer orders previously committed by ATP allocation should be completed for delivery in order to meet the promised due date. Yet for different reasons, like existing supply chain (SC) uncertainties and other unforeseen events, there may not be enough available stock in the right quantities to cover these orders on time [6], which leads to a shortage situation. In the short run, not meeting customer requirements in terms of delivery dates and delivery quantities can, for example, cause lost sales and contractual penalties. Long-term impacts can lower customer retention rates and reduce the future sales potential, which may result in poorer customer lifetime values [7].

These shortage situations are more likely to appear in SCs that promise orders under high levels of uncertainty. Uncertainty refers to the unpredictability of the environmental or organizational variables that have an impact on corporate performance. A variety of uncertainty factors affect distinct organizations in different ways. In fact, SCs with lack of homogeneity in the product (LHP) have unique characteristics with inherent sources of uncertainty that have a great impact on order promising and order delivery processes. LHP is present in transformation processes that provide non uniform units of the same FG [8]. In these processes, the final homogeneous quantities for each FG in a lot will not be known until produced. Therefore, it can be stated that the planned homogeneous sublots of each finished good are subject to uncertainty. Vorst and Beulens [9] define inherent sources of uncertainty as those brought about by the SC's natural physical characteristics and they identify three possible causes:

1. Intrinsic product characteristics in LHP contexts caused by the non homogeneity of the raw materials directly obtained from nature.
2. Technological characteristics of processes, which in LHP contexts, are characterized by the existence of uncontrollable factors during transformation activities (like humidity, temperature, etc.) that have an impact on some FG attributes.
3. Logistic actor characteristics, which indicate customer preferences in some FG attributes; for instance, due to consumer eating habits.

LHP causes non homogeneity of FGs as regards certain attributes that are relevant to customers. LHP becomes a problem when customers order several units of the same FG and require homogeneity among them. In order to comply with homogeneity specifications, LHP SCs include some classification stages for sorting units of the same FGs into homogeneous subsets (subtypes). The classification criteria of an FG into subtypes depend on each sector. For instance, in the horticulture sector, the main attributes for sorting and grading fresh fruit are size, weight, ripeness, damage, color, shape and firmness [10], while, color and grain constitute the classification criteria to ensure uniformity of furniture parts in the furniture sector.

After each classification stage, the quantity of each subtype in the production lots will be known only after production has finished and FGs have been classified. Therefore, SCs with LHP will face a new kind of uncertainty: uncertainty in the homogeneous quantities of each subtype that will be available in planned production lots. This lack of homogeneity becomes a problem when customer orders are reserved based on uncommitted planned quantities (ATP), whose final homogeneity characteristics are not known when promising orders. Due to inherent LHP uncertainty, the appearance of discrepancies between planned homogeneous quantities and real ones is usual, which can make it impossible to serve committed orders according to the previously defined quantity, homogeneity and due date.

Faced with this shortage situation, it is necessary to find alternative solutions in order to cushion the negative effect on the SC and customers. Indeed, shortage planning refers to the activities to be carried out should unavailable stock of components or FGs exist [3]. These activities may include decisions on stock and planned quantities reallocation among committed orders [11], outsourcing [12], substitutive products [13] or negotiation with customers (late supply, partial shipments, etc.). A company should be able to anticipate stock-out situations and should actively manage the allocation and re-allocation of available products based on customer requirements and priorities and contractual relationships [7].

Some research has been published for order management in the LHP field. Alemany et al. [8] proposes a deterministic MILP model for promising customer order proposals (acceptance/rejection and due date assignment) based on the ATP-LHP quantities deriving from stocks and master plan lots in order to maximize profits and exhausted ATPs. With the above model, the finally rejected and committed customer orders and their promised due date are obtained. However, as explained before, discrepancies between planned and real homogeneous quantities can lead to a shortage situation, where all previously committed orders cannot be served with the initial assignment made by the order promising process. So a shortage situation occurs. In this paper a shortage planning model is proposed that takes all previously committed orders during the OPP as inputs, for instance, by a model as in [8]. The proposed shortage planning model decides about reallocating subtypes in both the updated stocks and homogeneous quantities in master plan lots, and provides the orders that can actually be served with the actual subtypes in stocks and master plan quantities. Therefore, the problem addressed in this paper differs from that of [8], although it can take its solution as an input. In this paper, LHP inherent uncertainty in production lots is also addressed and gives rise to a fuzzy model instead of a deterministic one as in [8]. Yet as far as we know, there is only one shortage planning model [6] that deals with LHP through stock reallocation among customer orders. In this paper, we extend this previous model by incorporating the following main novel aspects: (1) reallocating planned production lots in addition to stock among customer orders; (2) LHP modeling by considering splitting the master plan production lots into