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Fuzzy sets to model master production effectively in Make to Stock companies with Lack of Homogeneity in the Product

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Abstract

Supply chains (SCs) with Lack of Homogeneity in the Product (LHP) present inherent sources of uncertainty due to the heterogeneity of raw materials and uncontrollable productive factors. LHP SCs are characterized by producing units of the same finished goods that are not homogeneous. However, the exact quantity of each one in a production lot will only be known when it is produced. These SCs must classify finished goods into subtypes according to customer requirements. In this paper, a fuzzy mathematical programming model is proposed. To match homogeneity customer requirements with the sizing of production lots, the proposed master plan considers two main aspects: 1) forecast demand is expressed in terms of number of orders with a similar order size; 2) LHP is modeled by considering that each production lot is split into several homogeneous sub-lots. Then uncertainty is considered by means of fuzzy sets in order sizes and homogeneous sub-lots quantities. The fuzzy model is evaluated by emulating real conditions and is compared with the equivalent deterministic one to assess its robustness. The results demonstrate that the fuzzy approach outperforms the deterministic one and that it is more effective for handling real situations when LHP is present.

Keywords: Master planning; Make to Stock; Fuzzy mathematical programming; Lack of Homogeneity in the Product; Fuzzy sets; Uncertainty modeling

1. Introduction

One of the most important objectives of companies is the fulfillment of customer requirements. Traditionally, customer requirements have been expressed in terms of quantities, due dates and quality levels. However, there are situations in which customers request homogeneity among ordered units of finished goods (FG) with respect to certain attributes because they have to be used, shown, placed or consumed jointly [1]. The customer may need homogeneity among components of a product, such as diamonds on a bracelet or among units of the same product, for example ceramic tiles on the floor. Lack of Homogeneity in the Product (LHP) appears in production processes which include raw materials that directly originate from nature and/or production processes with operations that give the heterogeneity of the characteristics of the outputs obtained, even when the inputs used are homogeneous [2]. Alarcón et al. [1]

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define Lack of Homogeneity in the Product (LHP) as the absence of the homogeneity requested by the customer in the products.

Companies with LHP should include one classification stage or several during their productive process to sort units of the same item in a lot into homogeneous subsets (subtypes) based on attributes that are relevant to customer requirements. The classification criteria of an FG into subtypes depend on each sector. Indeed, LHP in lots appears in very different sectors in several ways. For instance, in fruit supply chains there are several classification (sorting and grading) stages located at different points during the productive process which aim to eliminate waste and to classify fruits into several qualities based on different attributes. The main attributes for sorting and grading fresh fruit are size, weight, ripeness, damage, color, shape and firmness. In the ceramic sector, LHP is due to the non-uniformity of raw materials (clays) and some components (frits and enamels), along with some uncontrollable productive variables. As customers require homogeneity in units of the same ceramic wall or tile, these companies locate one classification stage at the end of the process. In this stage, ceramic pieces are classified based on the following attributes: quality, tone and gage. In short, the total number of existing subtypes of each LHP-item depends on the attributes used in the classification stage and their possible values. Historical data can provide the number of subtypes obtained, but in other cases this number can be a priori unknown.

These LHP characteristics complicate system management in different ways: 1) the customer homogeneity requirement introduces new constraints to be accomplished, which complicates the identification of not only the optimal solution, but also of a feasible one; 2) the existence of several subtypes of the same item increases the number of references and the volume of information to be processed; 3) after each classification stage, the quantity of each subtype in production lots will be known only after production has finished and FGs have been classified. Therefore, companies with LHP face a new kind of uncertainty: uncertainty in the homogeneous quantities of each subtype that will be available in the planned production lots.

The master plan (MP) definition plays a crucial role in balance demand and supply at the tactical level. The MP determines the inventory levels at the customer order decoupling point (CODP), which links planned production with specific customer orders [3]. Traditionally, the homogeneous subsets (sub-lots) from classified items are not normally taken into account at the MP level. However, LHP SCs have to serve customers not only the right quantities and on due dates, but also in the requested homogeneity terms. In this context, it is essential that the homogeneous quantities manufactured should complete a whole FGs order size efficiently. To fulfill this objective, the MP should anticipate these homogeneous quantities as much as possible in order to better size production batches and improve the customer service level. Moreover, order size becomes a very important LHP factor because the larger the customer order size, the harder it is to meet the homogeneity requirement among all its units. For these reasons, it is worthwhile defining the forecasted customer demand in terms of the expected order number of a specific customer class. Each customer order class is characterized to request a similar order quantity (order size) of an FG. This represents another differentiated aspect because demand forecasts at the MP level are usually expressed in an aggregate manner by product families or FGs [4].

In this paper, modeling LHP uncertainty in lots and customer order size by fuzzy sets is proposed. The Fuzzy Set Theory provides a means to represent uncertainties and is a marvelous tool for modeling the kind of uncertainty that is associated with vagueness, imprecision, and/or lack of information on a particular element of the problem at hand [5]. For LHP contexts, the unpredictable characteristics of raw materials and/or the existence of uncontrollable productive factors make knowledge of the homogeneous quantities of each subtype available in future planned lots imprecise. Furthermore, it is sometimes not feasible or is very costly to measure them reliably. In these cases, the use of Fuzzy Sets is appropriate. As described in Section 3, it is necessary to apply the Fuzzy Theory to dependent technological coefficients when modeling this type of LHP uncertainty. Up to our knowledge, the uncertainty modeling by Fuzzy Sets has been limited to independent fuzzy coefficients. Therefore, this aspect constitutes another contribution of this paper.

Thus, the main objectives of this paper are summarized as follows:

(i) introducing a novel fuzzy mathematical programming model for master planning companies with LHP and,
(ii) assessing the impact of LHP uncertain modeling by applying it to a ceramic company and analyzing its behavior under realistic conditions.

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