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Possibilistic programming in production planning of assemble-to-order environments

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Abstract

For the sake of alleviating the influences of demand uncertainty in assemble-to-order (ATO) environments, the strategies of regulating dealers' forecast demands, determining appropriate safety stocks, and deciding the numbers of key machines are usually adopted by manufacturers. In this paper, we propose a possibility linear programming model to manage these production planning problems. The proposed model accomplishes forecasting adjustments, material management, and production activities. Because of price fluctuations, material obsolescence, and the time value of capital, the ambiguity of cost is considered in the objective function of the model. We substituted the fuzzy objective function with three crisp objectives: minimizing the most possible cost, maximizing the possibility of obtaining lower cost, and minimizing the risk of obtaining higher cost. Zimmermann's fuzzy programming method is then applied for achieving an overall satisfactory compromise solution. Finally, an example is given to illustrate our model. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Assemble-to-order; Forecast demands; Safety stock; Possibility programming

1. Introduction

A manufacturing strategy where materials and subassemblies are made or acquired according to forecasts, while the final assembly of products is delayed until customer orders have been received is commonly referred to as assemble-to-order (ATO) [4–6, 8, 13]. In such environments, a rolling schedule method is generally applied for supervising the newest market information, satisfying customer requirements, and maintaining the lowest inventory [1]. In a rolling schedule process, at period t, dealers are usually requested to place their firm order FD_{tp0} and perform their demand forecasts for the next few periods; e.g. 2 periods, $FD_{(t+1)p1}$ and $FD_{(t+2)p2}$ as shown in Table 1. $FD_{(t+1)p1}$ and $FD_{(t+2)p2}$ are used as references for ordering materials with acquisition lead time $l_c = 1$ and 2 for final assembly that will be performed at period $t+1$ and $t+2$, respectively. These forecasting demands are temporary and will be updated in the next forecasting cycle. That is, at period $t+1$, the dealer places a firm order $FD_{(t+1)p0}$ and presents forecasts $FD_{(t+2)p1}$ and $FD_{(t+3)p2}$,

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Table 1
The rolling schedule with demand forecasts for the next 2 periods

Current period \ Forecast period	t	$t+1$	$t+2$	$t+3$	$t+4$	…
t	FD_{tp0}	$FD_{(t+1)p1}$	$FD_{(t+2)p2}$			
$t+1$		$FD_{(t+1)p0}$	$FD_{(t+2)p1}$	$FD_{(t+3)p2}$		
$t+2$			$FD_{(t+2)p0}$	$FD_{(t+3)p1}$	$FD_{(t+4)p2}$	
⋮				⋮	⋮	⋮

where $FD_{(t+1)p1}$ is updated by firm order $FD_{(t+1)p0}$, and $FD_{(t+2)p2}$ is updated to $FD_{(t+2)p1}$. The remainder can be deduced in the same manner. The production schedule is named a "rolling schedule" because demand forecasts are updated periodically. Fig. 1 depicts the relative activities based on the time horizon in ATO circumstances.

However, forecasts are rarely accurate. The accuracy of forecasts does affect the performance of the production system. Underestimating causes material deficiencies that may create final product stockouts. On the other hand, overestimating will result in excess of materials which may lead to increases in inventory holding costs. To compensate for forecasting inaccuracies, two material management processes are generally executed by manufacturers. The first involves preparation of appropriate levels of material safety stocks to absorb the influences of demand uncertainty. The second involves regulating forecast demands by modifying forecasting activities. Besides, the numbers of key machines should be decided for forecasted production [2, 3]. However, three managerial decisions are commonly determined subjectively in practice. Shieh [16] developed a semi-analytical model to solve such situations. Considering the characteristics of product life cylce, Hsu and Wang [9] modified Shieh's model to reflect the dynamic nature of the market. All of the models take into account crisp cost parameter values.

The managerial decisions in material management are essentially conditioned by product stockout costs and inventory holding costs. In general, the profit rate is the decisive factor for the former, while material price and the inventory holding rate influence for the latter. For capacity analysis, the idleness of key machines has a vital impact upon investment utilization. Because of price fluctuation in a dynamic market, material obsolescence, and the time value of capital, assigning a set of crisp values for parameters is no longer appropriate for dealing with such ambiguous decision problems. Fortunately, possibility distribution offers an effectual alternative for proceeding with inherent ambiguous phenomena in determining cost parameters [7, 10, 12, 14, 17, 20]. Therefore, in this study we constructed a possibilistic linear programming model to determine appropriate safety stocks of materials, regulation of forecast demands and the numbers of key machines. Next, we transformed the possibilistic linear programming model into a crisp multiple objective linear programming model. Finally, Zimmermann's fuzzy programming method [21] is applied to obtain a composite single objective.

The remainder of this paper is organized as follows. In Section 2 we describe the production system. In Section 3 we formulate and explain the production possibilistic programming model and the approach for solving the proposed model. In Section 4 a numerical illustration is presented. Finally, Section 5 provides some concluding remarks.

2. Problem statement

The production system considered in this paper is a single stage assemble-to-order factory. That is, all materials are procured from suppliers, and the final assembly of the products is initiated after receiving the