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Multi-objective supply planning for two-level assembly systems with stochastic lead times

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ABSTRACT

This paper considers two-level assembly systems whose lead times of components are stochastic with known discrete random distributions. In such a system, supply planning requires determination of release dates of components at level 2 in order to minimize expected holding cost and to maximize customer service. Hnaien et al. [Hnaien F, Delorme X, Dolgui A. Multi-objective optimization for inventory control in two-level assembly systems under uncertainty of lead times. Computers and Operations Research 2010; 37:1835–43] have recently examined this problem, trying to solve it through multi-objective genetic algorithms. However, some reconsideration in their paper is unavoidable. The main problem with Hnaien et al. proposal is their wrong mathematical model. In addition, the proposed algorithms do not work properly in large-scale instances. In the current paper, this model is corrected and solved via a new approach based on NSGA-II that is called Guided NSGA-II. This approach tries to guide search toward preferable regions in the solution space. According to the statistical analyses, the guided NSGA-II has the higher performance in comparison with the basic NSGA-II used by Hnaien et al. Moreover, the wrongly reported characteristics of the Pareto front shape provided by Hnaien et al. are modified.

1. Introduction

In assembly systems, one of the most important issues is to keep a suitable inventory level of components to minimize holding and stockout costs. Thus, the time to order components from suppliers must be determined carefully. Often in researches, for simplicity, lead times of components are considered zero or fixed. However, usually in practice, unexpected conditions vary lead times. Therefore, the actual costs of executing an ordering plan cannot be determined precisely. Furthermore, stockout leads to decrease in the system credibility, loss of customer, etc. that have intangible costs, eventually making it difficult to estimate the unit of stockout cost. Finally, it would appear more helpful to consider the stochastic lead times and stockout probability rather than fixed lead times and stockout cost.

Table 1 gives a brief review of main points in some papers regarding supply planning in uncertain environment. In Hnaien et al. [1], supply planning problem for two-level assembly systems under lead time uncertainties has been modeled. Using genetic algorithm to solve the problem, the authors have considered an objective which consists of the summation of holding and stockout costs. In Hnaien et al. [2], the same problem has been studied with objectives of minimizing the holding cost and the stockout probability and two multi-objective genetic algorithms have been applied to solve the problem. However, the mathematical models proposed in these papers appear to be incorrect.

Substituting an appropriate model, this paper explains the inaccuracies of the model presented in Hnaien et al. [2]. Then, since the basic NSGA-II, used in Hnaien et al. [2], appears to be unable to solve the model for large-scale instances, a heuristic is proposed for guiding search to preferable regions in the solution space. The basic NSGA-II and the guided NSGA-II are applied to solve a variety of instances. The algorithms are compared based on some performance measures for multi-objective optimization by means of statistical analysis. Finally, it is specified that the conclusions about the Pareto front shape of the problem, reported in Hnaien et al. [2], are wrong.

The rest of the paper is organized as follows. Section 2 describes the supply planning problem with stochastic lead times. Section 3 corrects the mathematical model proposed in Hnaien et al. [2] and Section 4 deals with the proposed algorithms to solve the model. Section 5 describes the design of computational experiments and analyzes the results. Finally, Section 6 is devoted to the conclusions and some perspectives of the future studies.

2. Problem description

In a two-level assembly system, the finished product is produced from components themselves obtained from other components.

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Table 1
A brief review of some past researches regarding supply planning in uncertain environment.

Authors	Year	Number of levels	Decision variables	Objectives	Characteristic of model	Solving approach
Yano [3]	1987	2	Planned lead times		2 and 1 component in levels 2 and 1, respectively	Non-linear programming
Chu et al. [4]	1993	1	Safety lead times			Stochastic programming, iterative algorithm
Proth et al. [5]	1997	1	Lead times and order quantities		Discrete model	Priority rules
Ould-Louly and Dolgui [6]	2002	1	Initial inventory		Similar distribution functions and holding costs for components	Newsboy model
Ould-Louly and Dolgui [7]	2002	1	Planned lead times	Summation of holding cost and backorder/ stockout cost	Dynamic multi period model	Markov model, stochastic non-linear programming
Tang and Grubbström [8]	2003	2	Safety lead times		2 and 1 component in levels 2 and 1, respectively	Laplace transform procedure
Axsäter [9]	2005	2, 3	Approximate order release dates			Decomposition technique and simulation
Chauhan et al. [10]	2009	1	Order release dates		Impossibility of holding some components because of high risk or cost	Exact
Hnaien et al. [1]	2009	2	Order release dates			Genetic algorithm
Louly and Dolgui [11]	2008	1	Order release dates	Holding cost	Holding maximum service level	Exact (when component lead times have similar distribution) and a lower bound (global state)
Louly and Dolgui [12]	2009	1	Safety stocks	Holding cost	Lower bound constraint for service level	Branch and bounds method
Hnaien et al. [2]	2010	2	Order release dates	Holding cost and backorder probability		Multi-objective genetic algorithms

To describe the details of the supply planning problem in such a system, the following notations are defined:

T	due date for the finished product
D	demand for the finished product at the date T
$c_{i,j}$	component i of level j ($j=1$ or 2)
N_j	number of component types at level j
$P_{i,j}$	set of the required components to assemble $c_{i,j}$
$L_{i,j}$	lead time of component $c_{i,j}$
$h_{i,j}$	unit holding cost of component $c_{i,j}$ per unit of time
$x_{i,j}$	planned lead time of component $c_{i,j}$
$F_{i,j}(.)$	cumulative distribution function of $L_{i,j}$
$u_{i,j}$	maximum value of $L_{i,j}(L_{i,j}\in[1,u_{i,j}])$
$U_{k,2}$	maximum value of $L_{k,2}+L_{i,1}$ where $c_{k,2}\in P_{i,1}(L_{k,2}+L_{i,1}\in[2,U_{k,2}]$ and $U_{k,2}=u_{k,2}+u_{i,1})$
$d_{i,j}$	number of components $c_{i,j}$ required to assemble one unit of finished product.

In such a system, components from level 2 are delivered to level 1. These components are assembled to make some semi-finished products. Finally, the semi-finished products are assembled, and the finished product is delivered to customer in order to satisfy the demand D. All required times to prepare component $c_{i,j}$, such as processing and inspection times at level j and transportation time to the next level are considered as lead time $L_{i,j}$. It is supposed that the lead time of each component is an independent random variable. Fig. 1 shows a simple example of a two-level assembly system.

The supply planning calculates planned lead times of components where the actual lead times are uncertain. Taking into account the facts that the assembly process begins when all necessary components are available and there are different arrival times for components, a plan may cause stocks. Furthermore, if the finished product is assembled after the due date, there will be stockout. Stocks have their own computable holding costs, but stockout, in addition to fines, may have some intangible costs such as loss of customer trust, loss of system reputation, etc. Thus, it is better to replace the stockout cost with the customer service defined as 1—stockout probability. Therefore, in this paper, the planned lead times would be calculated based on the following objectives:

i. To minimize the holding cost of components.
ii. To maximize the customer service (i.e. to minimize the stockout probability of the finished product).

The details of this problem are as follows:

- The planning is designed for a single period and one finished product.
- The finished product demand, D, and its due date, T, are fixed and known.
- Lead time of each component is a discrete random variable between 1 and a limited upper bound, with known probability distribution function, which is independent of the other's.
- The assembly of each component is carried out as soon as its necessary components are available.
- The unit holding cost for each component or semi-finished product is independent, fixed and known.
- Each type of components at level 2 is used to assemble only one type of semi-finished products.

3. Model formulation

Though the mathematical model of the problem has been proposed in Hnaien et al. [2], yet, some corrections to that model are inevitable. In this section, after some preliminary explanations,