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Stochastic dynamic lot-sizing problem using bi-level programming base on artificial intelligence techniques

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ABSTRACT

Simulation is generally used to study non-deterministic problems in industry. When a simulation process finds the solution to an NP-hard problem, its efficiency is lowered, and computational costs increase. This paper proposes a stochastic dynamic lot-sizing problem with asymmetric deteriorating commodity, in which the optimal unit cost of material and unit holding cost would be determined. This problem covers a sub-problem of replenishment planning, which is NP-hard in the computational complexity theory. Therefore, this paper applies a decision system, based on an artificial neural network (ANN) and modified ant colony optimization (ACO) to solve this stochastic dynamic lot-sizing problem. In the methodology, ANN is used to learn the simulation results, followed by the application of a real-valued modified ACO algorithm to find the optimal decision variables. The test results show that the intelligent system is applicable to the proposed problem, and its performance is better than response surface methodology.

1. Introduction

Determining proper production and replenishment quantity is one of the critical and active research topics of supply chains. To increase competitiveness and efficiency, upstream and downstream members of the packing industry usually integrate as a supply chain. Because of weather conditions, the acquired quantity of industrial raw materials tends to be non-deterministic and uncontrollable during the farming process. Such raw materials also deteriorate easily. Therefore, in this complex environment, decision makers need a method to determine a proper budget and reduce the raw material deterioration. In previous studies, replenishment problems seldom considered non-deterministic raw material and demand. Vidal and Goetschalckx [1] reviewed some important works about production and distribution models. This paper adopted artificial intelligence techniques to solve a stochastic replenishment problem.

This paper proposes a bi-level programming problem. The upper level problem is stochastic. This section determines the budget to reduce raw materials' deterioration rate. The lower level problem is a replenishment problem during simulation. Ben-Ayed et al. [2] introduced the characteristics of the bi-level programming problem. Kalashnikov and Ríos-Mercado [3] proposed a direct algorithm to solve mixed integer bi-level linear programming. Their problem is a deterministic model. Campêlo and Scheimberg [4] adopted the simplex method to solve a deterministic linear bi-level program. Mishra and Ghosh [5] proposed an interactive fuzzy programming method to solve bi-level quadratic fractional programming problems. Colson et al. [6] proposed an approximation algorithm to discover a near-optimal solution for nonlinear bi-level programming. The

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aforementioned works utilized local optimization methods, and their problems are all deterministic models. This paper uses a novel method to solve a stochastic replenishment problem. The proposed problem obtains expected cost by simulation model, and the simulation process is an NP-hard problem. Main contributions of this paper include: (1) proposing a bi-level programming model for NP-hard stochastic replenishment problem, (2) adopting a novel method and solution to proposed problem, (3) providing an illustrative example to demonstrate the methodology, and (4) notices for using the method under numerical analysis.

This paper proposes a stochastic dynamic lot-sizing problem with asymmetric deteriorating commodity (SDLSPADC). Artificial intelligence techniques are becoming more and more advanced and widely implemented. This paper adopts an intelligent decision system based on artificial neural network, data mining and ant colony optimization (neuro-DM&ACO) to solve the proposed bi-level programming. During the simulation process, this simulation-based optimization system includes an NP-hard replenishment problem (i.e., lower level problem). The organization of this paper is as follows: Section 2 formulates SDLSPADC. Section 3 constructs the neuro-DM&ACO model to solve SDLSPADC. Section 4 compares performances of neuro-DM&ACO and response surface methodology. Section 5 summarizes the results and presents recommendations for further research.

2. Literature review

2.1. Stochastic replenishment problem

In the past, the stochastic replenishment problem was seldom solved with bi-level programming. The deterministic replenishment problem is also a popular research topic. Jaruphongsa et al. [7] adopted dynamic programming to solve a two-stage dynamic lot-sizing problem with time windows. Hsieh et al. [8] solved a deterministic inventory model with time-dependent backlogging rate and power-form stock-dependent demand rate. Gao et al. [9] studied a coordinated lot-size problem with deterministic dynamic demand. Lee et al. [10] considered a two-stage dynamic lot-sizing problem with transportation costs at a third-party warehouse. Özdamar and Birbil [11] solved a capacitated lot-sizing problem with overtime and setup times. The aforementioned replenishment problems are all deterministic models. This paper extends the model proposed by Wong et al. [12], and further proposes a stochastic decision problem. They already prove that this is an NP-hard problem. For non-deterministic problems, simulation methods are usually adopted to evaluate inventory policy performance. Soman et al. [13] analyzed a hybrid make-to-order (MTO) and make-to-stock (MTS) production system with simulation methods. Such a model assumes that demand is uncertain. They tested various scheduling approaches to evaluate the performance in the MTO-MTS system. Chandra and Grabis [14] adopted the simulation model to analyze the forecasting approach impact on the bullwhip effect in a supply chain. Alstrøm and Madsen [15] used simulation to evaluate various tracking signals' performances in inventory control. Jammemegg and Reiner [16] improved supply chain process performance through inventory management and capacity management, and adopted simulation models to achieve their test results. To evaluate the impact of electronic data interchange on the bullwhip effect, Machuca and Barajas [17] used the simulation model to measure inventory costs, orders placed and the cumulative cost in supply chain. Fleisch and Tellkamp [18] adopted simulation models to examine the impact of inventory inaccuracy on performance in the supply chain. By reviewing these works, it's clear that past studies adopted simulation methods to evaluate inventory policy performance for replenishment problems. Ravichandran [19] proposed a simulation method to optimize the joint ordering policy for stochastic demand in the supply chain. In his model, strategy choices include a periodic review policy, a reorder point, economic an order quantity and Newsboy approximation. However, his decision system is not for bi-level programming. The problem proposed in this paper is a stochastic bi-level programming problem, and the simulation process includes a replenishment problem. The replenishment problem is NP-hard.

2.2. Review methodology (relevant literature)

This paper adopts an artificial intelligence technique to solve a stochastic bi-level programming problem (SDLSPADC). An artificial neural network (ANN) is used to simulate a two-stage replenishment system, which is an NP-hard problem. To omit the solving of NP-hard problem, ANN learning can efficiently obtain expected cost. This artificial intelligence technique solves the simulation model to obtain near-optimal decision variables through ACO. Past literatures often used ANN to construct simulation model to enhance efficiency of inventory management. Gumus et al. [20] applied ANN to develop a multi-echelon inventory management that considers stochastic parameters. They also made a summary of recent research topics of multi-echelon inventory management. This summary shows that simulation technique is usually applied in analyzing inventory management for stochastic multi-echelon supply chain. Rohde [21] developed a hierarchical planning system for lot-sizing problem with stochastic demands. Lee et al. [22] proposed a production quantity allocation policy with customer demands. They utilized ANN to construct a model that reduces surplus demand. Gumus and Guneri [23] applied ANN to construct inventory management framework for multi-echelon supply chains under stochastic environments. Lee and Ou-Yang [24] proposed a forecasting method on supplier's bid prices for supplier selection problem. The forecasting method is based on neural networks. In these literatures, ANN is applied to simulate inventory system for simulating and forecasting demands. However, in these literatures, their simulation process do not include NP-hard problem. NP-hard problem simulation