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An optimal algorithm for solving the dynamic lot-sizing model with learning and forgetting in setups and production

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Abstract

This paper studies the problem of incorporating both learning and forgetting in setups and production into the dynamic lot-sizing model to obtain an optimal production policy, including the optimal number of production runs and the optimal production quantities during the finite period planning horizon. Since the unit production cost is variable due to the effects of learning and forgetting, the first-in-first-out (FIFO) inventory costing method is used in our model. After deriving the relevant cost functions, we develop the multi-dimensional forward dynamic programming (MDFDP) algorithm based on two important properties that can be proved to be able to reduce the computational complexity. A numerical example is illustrated and solved using our refined MDFDP algorithm. The results from our computational experiment show that the optimal number of production runs decreases with the increase of the learning or forgetting rates, while the optimal total cost increases with the increase of one of the above four rates. Production learning has the greatest influence on the optimal total cost among the four parameters. The interactive effects of five demand patterns and nine relationships generated by the four rates on the optimal number of production runs and the optimal total cost are also examined.

Keywords: Learning and forgetting effects; Dynamic lot-sizing model; FIFO inventory costing method

1. Introduction

Owing to the increasing emphasis on time-based competition, the importance of learning and forgetting effects on manufacturing has been widely recognized. Both effects on the continuous review system with a constant demand rate have been studied by Keachie and Fontana (1966), Spradlin and Pierce (1967), Adler and Nanda (1974), Carlson (1975), Sule (1978, 1981), Axsäter and Elmaghraby (1981), Elmaghraby (1990), and Jaber and Bonney (1997a, 1998, 2001). The above studies only considered learning and forgetting effects on production. Another study conducted by Li and Cheng (1994) was more general in that the economic production quantity (EPQ) model involved learning in setups and both learning and forgetting in production. Jaber and Bonney (1999) surveyed the above models and suggested possible extensions to the

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lot size problem in which both learning and forgetting are incorporated into both setups and production. They also suggested that their earlier work may be extended to the model of Wagner and Whitin by including a finite planning horizon with zero inventories at the beginning of the initial cycle and the end of the last cycle. However, few papers have incorporated both effects into the dynamic lot-sizing problems with discrete time-varying demand. Chand and Sethi (1990) considered the dynamic lot-sizing problem in a pure setup learning environment in which only setup costs were susceptible to improvements. They developed a forward dynamic programming algorithm, which can be used on a rolling horizon basis, for infinite horizon problems. Tzur (1996) extended Chand and Sethi's work to a more general model, which allows the total setup cost to be a general nondecreasing (but not necessarily concave) function of the number of setups. Recently, Chiu (1997) incorporated learning and forgetting effects on production into the dynamic lot-sizing model. Furthermore, he also extended the optimal Wagner and Whitin (1958) algorithm and three existing heuristic models.

Unlike previous works, this paper studies the problem of incorporating both learning and forgetting in setups and production into the dynamic lot-sizing model to obtain an optimal production policy, including the number of production runs, lot sizes, and time points for starting setups and production. Since the period-demand and finite periods of the planning horizon are assumed in this paper, but setups and production times are scheduled continuously, the proposed model is virtually a mix of discrete and continuous models. As far as we know, few papers have studied this model.

The setup time and unit production time are assumed to have learning phenomena, and are represented as power functions of the cumulative number of repetitions. The forgetting effect is mainly caused by a break between two consecutive production runs and leads to retrogression in learning. Besides the quantity produced to date and the length of the interruption, other factors such as the availability of the same personnel, tooling, and methods that have a direct effect on the degree of human forgetting were also considered in Anderlohr (1969) and Cochran (1973). Globerson et al. (1989) showed that the degree of forgetting is a function of the break length and the level of experience gained prior to the break in a laboratory experiment. In fact, a variety of factors influence the forgetting effect like the break length, previous experience, job complexity, the work engaged in during the interruption period, the cycle time of the task, the relearning curve, and a single relearning observation (e.g., repair or maintenance) (Dar-El, 2000, pp. 83–92). Jaber and Bonney (1996) proposed a mathematical model in which the forgetting slope is dependent on three factors (i.e., the equivalent accumulated output of continuous production by the point of interruption, the minimum break under total forgetting, and the learning slope). They (Jaber and Bonney, 1997b) also compared their model with two existing models. Their model is more realistic, and their predicted time was very close to the experimental data provided by Globerson et al. (1989). For simplicity, we assumed fixed forgetting rates in setups and production, as adopted by Li and Cheng (1994), to make our proposed multi-dimensional forward dynamic programming (MDFDP) algorithm more tractable. Since the production cost of each unit is not identical due to learning and forgetting, the FIFO inventory costing method is used in this paper.

In the next section, the notations used throughout this paper are defined, and basic assumptions are given. Section 3 then presents a general description of the model and formulates relevant cost functions for each production run. Subsequently, Section 4 develops the refined MDFDP algorithm by applying two important properties, and an example is also provided. An experiment conducted to analyze the effects of relevant parameters on the optimal solution is discussed in Section 5. Finally, Section 6 concludes the paper with a brief summary of the results.

2. Notations and assumptions

The following notations will be used throughout this study: