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Applying genetic algorithms to dynamic lot sizing with batch ordering

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Abstract

In this paper, genetic algorithms are applied to the deterministic time-varying lot sizing problem with batch ordering and backorders. Batch ordering requires orders that are integer multiples of a fixed quantity that is larger than one. The developed genetic algorithm (GA) utilizes a new '012' coding scheme that is designed specifically for the batch ordering policy. The performance of the developed GA is compared to that of a modified Silver-Meal (MSM) heuristic based on the frequency of obtaining the optimum solution and the average percentage deviation from the optimum solution. In addition, the effect of five factors on the performance of the GA and the MSM is investigated in a fractional factorial experiment. Results indicate that the GA outperforms the MSM in both responses, with a more robust performance. Significant factors and interactions are identified and the best conditions for applying each approach are pointed out.

Keywords: Genetic algorithms; Lot sizing; Fixed quantity; Batch ordering; Silver-Meal

1. Introduction

This paper addresses the deterministic time-varying batch ordering lot sizing problem with backorders. The objective is to determine the optimum ordering plan to satisfy a set of known demands over a specific planning horizon. The optimum ordering plan is the one that minimizes the total cost. Cost elements include the ordering cost (P) charged every time an order is made regardless of the quantity, the holding cost (h) per piece per period (charged on any quantity left at the end of the period), and the backorder cost (g) charged as a shortage penalty per piece per period. In the case addressed in this paper, it is assumed that any order must be an integer multiple of a fixed quantity (Q, $Q > 1$). Other assumptions of the problem include:

1. the replenishment quantity is unconstrained,
2. cost factors are time independent,
3. replenishment is instantaneous,

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4. backorders are only allowed to make up for quantity discrepancies that result from batch ordering, and
5. an order must be placed in the first period.

As an example, assume that the demand for a planning horizon of six periods is 10, 7, 6, 9, 11, and 5 for periods one through six, respectively, and that $P = \$30$, $h = \$2$, $g = \$4$, and $Q = 6$. This demand may be covered by orders of 24, 18, and 6 in periods, 1, 4, and 6, respectively. The total cost of such a plan is $158.

A dynamic programming algorithm to obtain the optimum solution to a simpler version of this problem (assuming a variable order quantity with no backorders) was developed by Wagner and Whitin (1958). Several extensions of the original Wagner–Whitin (WW) algorithm were developed over time (Elsayed & Boucher, 1993). Of relevance to this paper are the extensions by Vander Eecken (1968), Elmaghraby and Bawle (1972), Webster (1989), Li, Hsu, and Xiao (2004). Vander Eecken (1968) extended the WW algorithm to the case where orders must be integer multiples of a fixed quantity ($Q > 1$), with the restriction of no backorders. Elmaghraby and Bawle (1972) extended Vander Eecken's work to the case where backorders are allowed, but with the restriction that the ordering cost is constant over time. Webster (1989) developed a backorder version of the WW algorithm using dynamic programming. Several authors provided extensions to Elmaghraby and Bawle's work (Bitran & Matsuo, 1986), but the most general extension was developed by Li et al. (2004) to the case where all cost elements are time varying with allowance for backordering.

Although the WW algorithm and its extensions provide the optimum solution for various versions of the lot sizing problem, they are not widely used. Instead, practitioners prefer other algorithms that are simpler, even though they may generate suboptimal solutions for the following reasons:

1. Exact algorithms are often difficult to understand by practitioners due to their complexity (Silver & Peterson, 1985).
2. Heuristics are easily tailored for various extensions of the lot sizing problem, for which no optimization algorithm has been developed yet (Jans & Degraeve, 2004).
3. In a rolling horizon situation, an optimization algorithm becomes a heuristic too, and is often surpassed by simple heuristics (Stadtler, 2000).

One of the most commonly used suboptimal algorithms is the Silver-Meal (Silver & Peterson, 1985). The original Silver-Meal (SM) algorithm finds the number of periods for which the total inventory costs per period is minimized and then orders the exact quantity to cover the demand for those periods. In this paper the SM is modified (MSM) so that whenever the total demand for a group of periods is not an integer multiple of the fixed quantity (Q), the closest two integer multiples are tried out. In the previous example, when testing the cost of an order to cover the first three periods that have a total demand of 23, the two quantities of 18 and 24 are considered. The MSM solution for the example given above is to order 18 and 30 in periods 1 and 4, respectively, for a total cost of $140.

This paper investigates the applicability of genetic algorithms (GAs) to the targeted problem and compares its performance to that of the MSM. The research is motivated by the fact that GAs have been successfully applied to several production planning problems including lot sizing. GAs have several desirable features including: generality, ease of modification and parallelism (Reeves, 1997). Aytug, Khouja, and Vergara (2003) attribute the popularity of GAs to several factors. First, GAs only require a computable objective function with no requirements of linearity, convexity, or differentiability. GAs are also easy to implement as they require no bookkeeping mechanism or theoretical bounds. Furthermore, empirical evidence shows that GAs are quite successful on computationally intractable problems, mostly with discrete solution spaces, which is usually the case with problems addressed using dynamic programming (Papadimitriou & Steiglitz, 1998). GAs generally provide good solutions to large problems in a reasonable time (Aytug et al., 2003).

Several authors have applied GAs to various versions of the lot sizing problem. As an example, Ozdamar and Birbil (1998) utilized GA, simulated annealing (SA), and tabu search to solve the capacitated lot sizing problem on parallel machines. Hung and Chien (2000) also utilized the three approaches (GA, SA, and tabu search) to solve the multi-class multi-level capacitated lot sizing problem. Khouja, Michalewicz, and Wilmot (1998) investigated the use of GAs to solve the economic lot size scheduling problem using the basic period approach. Prasad and Krishnaiah Chetty (2001) applied GAs to multilevel lot sizing and observed that under