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A comparative study of heuristic algorithms on Economic Lot Scheduling Problem

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Abstract

The Economic Lot Scheduling Problem (ELSP) has been well-researched for more than 40 years. As the ELSP has been generally seen as NP-hard, researchers have focused on the development of efficient heuristic approaches. In this paper, we consider the time-varying lot size approach to solve the ELSP. A computational study of the existing solution algorithms, Dobson's heuristic, Hybrid Genetic algorithm, Neighborhood Search heuristics, Tabu Search and the newly proposed Simulated Annealing algorithm are presented. The reviewed methods are first tested on two well-known problems, those of Bomberger's [Bomberger, E. E. (1966). A dynamic programming approach to a lot size scheduling problem. *Management Science 12*, 778–784] and Mallya's [Mallya, R (1992). Multi-product scheduling on a single machine: A case study. *OMEGA: International Journal of Management Science 20*, 529–534] problems. We show the Simulated Annealing algorithm finds the best known solution to these problems. A similar comparison study is performed on various problem sets previously suggested in the literature. The results show that the Simulated Annealing algorithm outperforms Dobson's heuristic, Hybrid Genetic algorithm and Neighborhood search heuristics on these problem sets. The Simulated Annealing algorithm also shows faster convergence than the best known Tabu Search algorithm, yet results in solutions of a similar quality. Finally, we report the results of the design of experiment study which compares the robustness of the mentioned meta-heuristic techniques.

Keywords: Economic Lot Scheduling Problem; Time-varying lot size; Simulated annealing; Tabu search; Neighborhood search

1. Introduction

The Economic Lot Scheduling Problem (ELSP) deals with the production assignment of several different products on a given single production facility to minimize the total cost. A typical ELSP as described in Maxwell (1964) has the following features:

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1. Only one product can be produced at a time on the machine.
2. Each product has a deterministic and constant demand and production rates.
3. The set-up cost and set-up times are independent of the production sequence.
4. The production facility is assumed to be capable of satisfying demand predicted during the planning horizon.
5. The inventory holding cost is directly proportional to the amount of inventory.

With the ELSP generally viewed as NP-hard, the focus of most research efforts has been to generate near optimal repetitive schedule(s). To date, several heuristic solutions have been proposed using any one of the *common cycle*, *basic period*, or *time-varying lot size* approaches.

The *common cycle* approach always produces a feasible schedule and is the simplest to implement, however in some cases, the solution when compared to the Lower Bound (LB) is of poor quality. Unlike the *common cycle* approach, the *basic period* approach allows different cycle times for different products, however the cycle times must be an integer multiple of a basic period. Although the basic period approach generally produces a better solution to the ELSP than the *common cycle* approach, but getting a feasible schedule is NP-hard (Bomberger, 1966). Lastly, the *time-varying lot size* approach is more flexible than the other two approaches, allowing for different lot sizes for the different products in a cycle. Dobson (1987) showed that the *time-varying lot size* approach always produced a feasible schedule, as well as giving a better quality solution.

2. Literature review

For more than four decades there have been a variety of articles published on the ELSP. Earlier works include Eilon (1959), Hanssmann (1962), Rogers (1958) and Maxwell (1964). In these earlier works, the LB was calculated using an independent solution approach which ignored the sharing constraint and the machine capacity issues. An improved LB approach was developed by Bomberger (1966) in which Karush Kuhn Tucker conditions were applied to the ELSP to recognize only the capacity constraint. Several researchers also re-discovered this LB (Moon, Giri, & Choi, 2002). The bulk of the ELSP research has focused on cyclic schedules which satisfy the Zero-Switch-Rule (ZSR), meaning an item is produced only if its inventory depletes to a zero level. There are some rare examples, such as Maxwell (1964) and Delporte and Thomas (1978) where the ZSR was not considered.

As noted earlier, there are three approaches to solve the ELSP. The *common cycle* approach provides an upper bound to the optimal solution and very good results to the ELSP under certain conditions (Jones & Inman, 1989; Gallego, 1990). The heuristic methods developed using the basic period approach first selected a frequency for each item (i.e., the number of times an item is produced in a production cycle). After the frequency was determined, a basic time period to satisfy this frequency was then determined. Earlier works using the basic period approach include Bomberger (1966), Doll and Whybark (1973), while Elmaghraby (1978) provided a comprehensive review. Hsu (1983) showed that using the basic period approach to solve the ELSP is NP-hard and the NP-hardness increased with an increase in the utilization ratio. Unlike the basic period approach, the time-varying lot size approach does not require equal production runs. The time-varying lot size approach was first researched by Maxwell (1964), Delporte and Thomas (1978), while Dobson (1987) developed an efficient heuristic to show that given enough time for production and set-up, any production sequence could be converted into a feasible production, however the production timing and lot size might not be equal. Gallego and Shaw (1997) provided support that the time-varying lot size approach to the ELSP was generally NP-hard. Dobson's (1987) heuristic can be integrated with Zipkin's (1991) algorithm to find a near optimal schedule (Moon et al., 2002). Several extensions have also been made to the *time-varying lot size* approach. Dobson (1992) reviewed the ELSP when set-up time is sequence dependent and proposed a heuristic solution. Wagner and Davis (2002) also studied the ELSP with sequence dependent set-up times and proposed a heuristic procedure capable of determining a range of optimal solutions. The proposed heuristic is particularly useful in precarious manufacturing environments. Gallego and Roundy (1992) considered back-orders in the ELSP. Silver (1993) offered several extensions to the existing quantitative models that can better support managerial decisions. He pointed out that in many practical situations, commonly known parameters to