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Multi-product economic lot scheduling problem with manufacturing and remanufacturing using a basic period policy

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ABSTRACT

In this research we study the multi-product Economic Lot Scheduling Problem (ELSP) with manufacturing and remanufacturing opportunities. Manufacturing and remanufacturing operations are performed on the same production line. Both manufactured and remanufactured products have the same quality thus they fulfil the same demand stream. Tang and Teunter (2006) firstly studied this type of Economic Lot Scheduling Problem with Returns (ELSPR) and presented a complex algorithm for the optimal solution. More recently Teunter, Tang, and Kaparis (2009) proposed several heuristics to deal with the same problem using more computational efficient approaches. However, both studies have limited the attention to the common cycle policy with the assumption that a single (re)manufacturing lot is used for each item in each cycle. Relaxing the constraint of common cycle time and a single (re)manufacturing lot for each item in each cycle, we propose a simple, easy to implement algorithm, based on Segerstedt (1999), to solve the model using a basic period policy. Several numerical examples show the applicability of the algorithm and the cost savings.

1. Introduction

The Economic Lot Scheduling Problem (ELSP) refers to the challenge of accommodating several items to be produced on a single machine in a cyclical pattern, with the goal of minimising the total set-up and holding costs. This ELSP was first proposed by Rogers (1958), who identified the need of joining the Economic Lot Quantity (ELQ) problem of different items, with the aim of scheduling them on single production centre in order to minimise the total set-up and holding costs. During the past decades a significant amount of research has been reported on this problem, with various directions of extensions. Bomberger (1966) introduced the upper and lower bounds for the total cost, together with a dynamic programming procedure, in order to find a feasible scheduling solution, illustrated with examples which are widely used in later ELSP studies. Doll and Whybark (1973) relaxed the common cycle policy and introduced a model with different production frequencies for different items, named Basic Period (BP) policy; they also proposed an iterative procedure to find the near optimal frequencies, resulting in a reduction of total cost.

Elmaghraby (1978) provided a comprehensive review for the ELSP problem, dividing the approaches into two main categories: analytical approaches that achieve the optimum for a restricted version of the original problem and heuristic approaches that achieve "good" solutions. Davis (1990) proposed a mixed integer programming (MIP) formulation for the ELSP, which afterwards was enhanced by Cooke, Rohleder, and Silver (2004). Nevertheless a procedure to find an optimal feasible solution for the general version of the problem is not known yet, while it is clear that it is NP-hard problem since Hsu (1983) who also showed that the NP-hardness increases with the capacity utilisation ratio. Given its difficulties, researchers approached the problem using analytic solutions to find simplified versions of the problem, or adopted heuristic methods for the original one. Dobson (1987) showed that the time-varying lot size approach often produced a feasible schedule, as well as giving a better solution quality than the basic period approach, although its computation complexity should also increase substantially. Recently Raza and Akgunduz (2008) presented a Simulated Annealing algorithm considering the time-varying lot size approach and presented a comparative study of heuristic algorithms on ELSP.

A complementary challenging problem of the ELSP model is represented by the ELSPR model (Economic Lot Scheduling Problem with Returns), which involves also remanufacturing

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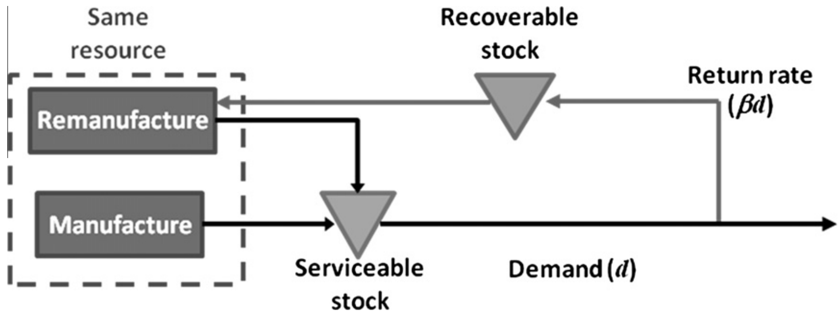

Fig. 1. ELSPR system.

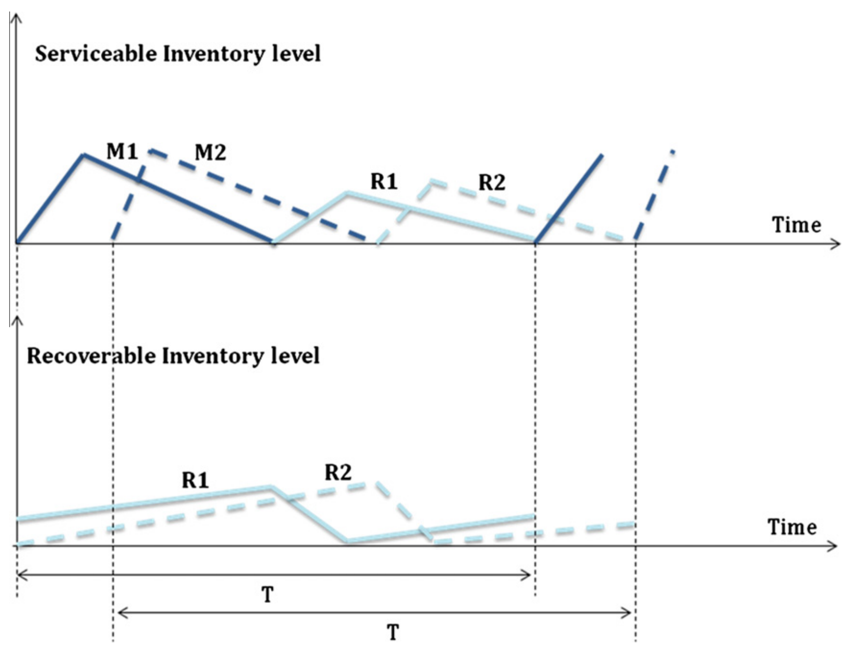

Fig. 2. Serviceable and recoverable inventory patterns for ELSPR system with two items under a common cycle policy (M = Manufacturing, R = Remanufacturing).

operations on returned items, performing both manufacturing as well as remanufacturing activities on a single production line.

Fig. 1 represents the system components involved in an ELSPR model and the main relationships among them. There is a single resource (production line) that provides manufacturing and remanufacturing operations of some items, which are then sent to the serviceable stock, and finally to the market in order to satisfy the demand (d). After they enter the market, a certain amount of returns (βd) comes back to the production facility in order to be remanufactured, and a recoverable stock is available to collect them.

The serviceable and recoverable inventories' profiles for two items, with a common cycle policy (that is a single manufacturing lot followed by a single remanufacturing lot) are reported in Fig. 2. During serviceable stock filling from manufacturing process, the returns are collected into the recoverable stock. This recoverable stock increases till remanufacturing lot starts.

This Economic Lot Scheduling Problem with Returns (ELSPR) was first introduced by Tang and Teunter (2006). They studied a specific case of a company which was involved in car parts manufacturing for service markets. The items produced were new items as well as remanufactured returned products. Moreover manufacturing as well as remanufacturing operations for all items were performed on the same production line, according to the ELSP base model.

Main difference of the ELSPR compared to the ELSP is represented by the presence of two stock points (recoverable and serviceable) that have to be properly managed. In the ELSPR, not only the lot size, but also the production schedule influences the inventory level, while for the traditional ELSP, at least for low utilisation problems (high capacity compared to expected demand) most schedules lead to the same stock level patterns and average stock levels. The relevance of scheduling for the ELSPR makes it a bit more complex problem than the ELSP. These peculiarities imply that solving the ELSPR problem is rather complicated compared with the classic ELSP model even under the common cycle assumption. Tang and Teunter (2006) firstly developed an algorithm for the ELSPR with the formulation of a mixed integer linear program (MIP). Their study is based on a common cycle policy and the solution method combines the search for the optimal value of the cycle time and schedules for all items. They further reminded that MIP formulation is rather complex to perform, and its programming is quite tedious; further the algorithm iteration procedure may be too time consuming, depending on the problem size. By dropping the exact problem formulation, Teunter et al. (2009) developed heuristics to enhance the solution efficiency. They generated 120 sets of data to test their heuristics' performance. We also refer to these 120 sets of data in this paper, with the same purpose. Teunter, Kaparis, and Tang (2008) further presented the ELSPR considering two separate production lines for