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O.R. Applications

Managing a portfolio of long term service agreements

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Abstract

Long-term service agreements (LTSAs) for the maintenance of capital-intensive equipments such as gas turbines and aircraft engines are gaining wide acceptance. A typical LTSA contract spans over a period of around 10 years making a manufacturer fully responsible for maintaining the customer equipment. In this paper, we address the management of a portfolio of such contracts from the manufacturer's perspective. The goal is to meet all the service requirements imposed by the contracts while minimizing total cost incurred. We develop a deterministic integer programming model to generate the optimal maintenance schedules that minimize the total portfolio cost. We then propose two heuristic algorithms for the problem.

Keywords: Integer programming; Heuristics; Long-term service agreements; Maintenance scheduling

1. Introduction

In today's services oriented economy, providing better services to customers is proving to be one of the main growth strategies for organizations traditionally known to be manufacturers, such as, General Electric (GE) Company, United Technologies Corporation, etc. A particular service these traditional manufacturers are providing is service agreements for their high cost, advanced technology, long-lived products. Examples of these products are locomotive engines, medical equipments, gas turbines and aircraft engines. These service agreements are meant to give the customers a guarantee and/or ease of use of the products over an extended contract period. Long term service agreements are also being provided by third party service companies. A service agreement is an agreement between providers and customers that makes a provider responsible for maintaining and repairing the products for a customer over a specified period of time.

Long-Term Service Agreements (LTSAs) transfer the risk in maintaining equipments from the customers to the providers. Since the provider has multiple contracts with many customers, it can more efficiently pool the risk, thereby decreasing the maintenance cost for the portfolio of equipment. Some of the cost savings are

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usually passed on to the customers, thus making LTSAs attractive to them. However, the challenge for the providers is to efficiently manage several agreements sold to one or more customers. To achieve this goal, they need to develop good maintenance strategies and spare part inventory management policies based on the reliability characteristics of the equipment. For instance, the provider needs to schedule the times for changing certain critical parts from the units before the units suffer a breakdown, since damage to these critical parts can result in very costly breakdowns and losses. An existing part in the unit, on which an LTSA is extended, is replaced by a new part before it breaks down. In most cases, the removed parts may be re-used in other units after parts are refurbished. In this paper, we consider the problem of managing a portfolio of LTSA contracts. The objective is to develop maintenance and part replacement schedules for units in the portfolio to minimize the total cost of maintenance of the portfolio of contracts.

The problem of managing LTSAs bears similarity with two problems addressed in the literature, the machine replacement problem and the maintenance scheduling problem. The *machine replacement problem* deals with determining the optimal time for replacing old machines with new ones. As a machine gets older, it will be increasingly more costly to operate, both from the operational cost and the maintenance cost perspectives. Costs can be reduced by replacing an old machine by a new one as the machine reaches a certain age or condition. The *maintenance-scheduling problem* considers developing optimal maintenance and repair schedules for equipment subject to budget constraints, work force constraints, etc.

In machine replacement literature, the replacement problem is categorized into either a serial or a parallel replacement problem. The serial replacement problem considers replacing single machine (asset) with another. This situation is relevant when there is no economies of scale in replacing multiple machines simultaneously. Since the cost of machine replacement is linearly proportional to the number of machines replaced, replacement of single machine (asset) is considered. Dynamic program formulations have been developed in the literature to solve the serial replacement problem (Bean et al., 1985; Chand and Sethi, 1982; Oakford et al., 1984).

The parallel replacement problem deals with replacing multiple assets simultaneously due to economies of scale among assets. The providers incur a certain fixed cost for each replacement as well as a variable cost depending on the number of assets replaced. Researchers have proposed dynamic programming formulations to solve the parallel replacement problem also. However, the state space of the dynamic program becomes very large as the number of assets increases. In order to reduce the state space, they grouped machines using an age criterion and developed certain replacement rules. One such rule is the "No Splitting Rule," where a group of machines can only be replaced together. Under another rule, called the "Older Cluster Rule," newer groups of machines are replaced only after older groups of machines are replaced. Lastly, under the "All or Nothing Rule" all machines are kept or replaced together regardless of age (Hopp et al., 1993; Jones et al., 1991; Tang and Tang, 1993).

Chen (1998) considered the parallel replacement problem in both finite and infinite horizon settings. He modeled the parallel replacement problem as a binary program and used Bender's decomposition to solve it. Hartman (1997) studied the difference between the parallel replacement economic models, such as, "Fixed Cost model," "All Units Discount model", and "Incremental Units Discount model". Karakabal et al. (1994) added a budget constraint to the parallel replacement problem. They modeled the problem as a network program with binary variables and solved it using a Lagrangian relaxation. Later in Karakabal et al. (2000), they considered a more realistic size of the problem and solved it using a dual Lagrangian relaxation approach. Demand and budget constraints for the replacement problem are also studied by Hartman and Lohmann (1997) and Hartman (2000). A series-parallel replacement problem was studied by Hartman and Ban (2002). They found that their integer program formulation was difficult to solve to optimality and used an LP relaxation to obtain a lower bound of the problem.

In the maintenance scheduling literature, various objective functions are studied depending on the context of the problem. Literature reviews of the area of maintenance-scheduling can be found in Kralj and Petrovic (1988) and Paz and Leigh (1994). Escudero (1982) studied maintenance scheduling for a thermal unit in a power system. He proposed an integer programming formulation for the problem with a quadratic objective function and demand constraint. Joshi and Gupta (1986) used the failure history of equipment to add routine maintenance into production scheduling to prevent failures. Dickman et al. (1990) studied opportunistic replacement as an integer program, where a machine replacement is done during a regular scheduled maintenance based on the state of the machine. Duffuaa and Al-Sultan (1997) studied maintenance scheduling with a