Preventive Maintenance Scheduling: Decision Model Development and Case Study Analysis

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ABSTRACT

In this work, the effectiveness of preventive maintenance scheduling (PMS) decisions was reported based on a techno-economic model that reflects cost objective function for ship maintenance activities. With a potential to impact on both transportation businesses and users of transportation services, the model provides an alternative to the combined classical literature problems of spare-parts inventory management and control, failure prediction and reliability. The PMS model developed incorporates separate and combined functions of indirect, direct and factor maintenance costs. Idleness period for various formulated schedules are evaluated and compared. First, a general form of the preventive maintenance cost function incorporating unit cost of maintaining ships, a set of cost function parameters and variables was developed. The operations research framework for the problem is then applied to obtain test cases in which cost parameter(s) was/were used for scheduling decisions. Monte Carlo simulation is applied to generate additional test problems. Practical data were used to validate the model. For each problem, optimal schedules based on one to four cost parameters were determined. For each schedule, the total maintenance cost, cost of idleness, total ship idle period and total ship operation period were computed under inflation, opportunity and combined opportunity and inflation and compared with the values corresponding to maintenance cost parameter using t-test (p<0.05). Thus, the use of combined data from maintenance, opportunity and inflation for preventive maintenance scheduling of a fleet of ships is more effective than direct maintenance cost approach.

Keywords: Decision Model, Fleet of Ships, Maintenance Scheduling, Opportunity Inflation Cost, Preventive Maintenance.

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INTRODUCTION

One problem with the shipping industry is the sudden failure of vessels at sea due to maintenance-related problems, which may result in incidents causing enormous loss of lives, limbs, valuable properties, operating hours and customer goodwill. Other consequences may include cost of ship retrieval and customer claims; rise in company insurance costs; and business survivability problems. Considering the running of a large fleet of ships, clearly, maintenance-related failures at the field of operation pose serious management problems. One solution approach to this problem is to apply a preventive maintenance system for a fleet of transportation ships. Associated with such preventive maintenance system are the following issues: (1) supply of spare parts for repairs or replacement; (2) prediction of an appropriate time to return an operating ship for preventive maintenance; and (3) provision of maintenance centres with adequate capacity to simultaneously handle arriving ships for preventive maintenance activities.

The first issue has been traditionally handled by defining and solving a spare parts inventory control problem. The second too has attracted an enormous amount of research effort. Consequently, a large number of models for predicting the period that a ship is due for preventive maintenance has been developed (Zhou et al., 2004). In a situation with small fleet of ships and large number of parallel maintenance stations, the third issue too poses no problem as every ship arriving for maintenance may immediately receive attention. In real life, this is hardly the case. Maintenance facilities for setting up even a single preventive maintenance station are very expensive. Consequently, transportation firms with many parallel maintenance stations are not common worldwide. Most reported firms have a large fleet of aircrafts or ships but a few parallel maintenance stations (Alfares, 1999; Cheung et al., 2005). In this case, many aircrafts/ships may arrive and remain in a long queue waiting to be maintained with obvious losses in revenue and heavy-operating capital tie-down.

Judicious decision has to be taken as to which of the waiting ships should first be maintained on the available stations before the rest receive the attention of the maintenance personnel. This is the preventive maintenance-scheduling decision problem for a fleet of ships. If suitable decision parameters are not selected and then an inappropriate decision model applied to derive schedules, a firm’s operations may suffer serious setback, as many high profit-yielding ships may tend to wait too long at a maintenance system. Others may fail to pick up or deliver cargo on time which may lead to heavy demurrage and contract penalty charges as well as loss in customer goodwill. It is a worldwide problem. Many nations pay close attention to this problem because of global competition. The quality of shipping services and the revenue are greatly enhanced with good preventive maintenance schedules. The maintenance scheduling methods utilised in solving problems include heuristics (Kabi et al., 2002), deterministic, multi-population cultural, multiobjective, fuzzy reliability, stochastic programming (Duffuaa & Al-Sultan, 1999; Mohanta et al., 2004; Westman et al., 2001a), memetic algorithm (Burke & Smith, 1999; Burke et al., 1998), integer programming (Lee, 1991; Dapazo & Merrill, 1975), probabilistic programming, genetic system, games theory, message-passing interface portable, tabu search (Huang et al., 2004) and genetic-evolved fuzzy approaches (Huang, 1997,1998). Billinton and Abdulwahab (2003) and others have presented probabilistic approaches to solving power generator and hydraulics problems. The use of artificial intelligence in maintenance scheduling was extensively reviewed by Dahal and McDonald (1997b). The use of simulated annealing, linear programming and hybrid evolutionary technique have also gained the interest of researchers (Wasa et al., 1999). Mathematical programming has also been used to schedule maintenance by Al-Khamis and Yellen (1995).

The investigation by Al-Khamis and Yellen (1995) utilised an integer program of the 0-1 optimisation problem, and then used the branch and bound technique to solve the problem of refinery unit maintenance scheduling by deter-
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