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Ship replacement decision: A comparative study

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ABSTRACT

Scrap and operation research models are the main models for optimising ship replacement decisions.The scrap models optimise time or ageto waste the shipout of service. The scrap models compare the costs or profits during finite or infinite planning horizons and determine the time or the age that optimises the replacement decision. Operation research models compare the sequences of decisions during finite horizons and determine the sequence of decisions that maximises profit or minimises cost.Dynamic programming is the technique that dominates operation research (OR)models to optimise the replacement decision.

INTRODUCTION

Ship replacement decisions are critical decisions that managers must grapple with in intensive ship companies [1]. The ship replacement decision is not a simple matter but a complex process that needs to be optimised to achieve excellence in management and improve the companies' objectives[2]. The literature found four main mathematical models, each with a unique approach crucial in optimising ship replacement decisions. The first type is the model that uses economic life [3], the second is the model that uses age replacement [4], the third is the model that uses repair limits [5], and the fourth is the model that usesoperation research[6].This study investigates and categorises the main mathematical models to optimise the ship replacement decision.

1. Scrap models

The scrap models compared the costs or profits during finite or infinite planning horizons and determined the time or the age that optimises the replacement decision[7].

2-1: Economic life

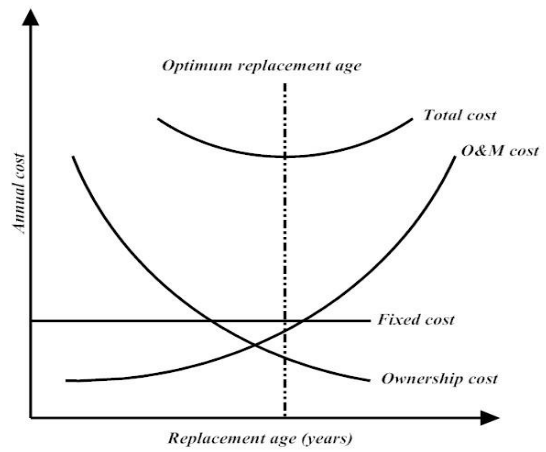

Figure 1: Economic life replacement

The first to develop an economic life model to optimise the replacement decision was [3]. The economic life model assumes that ship deterioration is measured by increased operation and maintenance costs[4]. Finally, the operation and maintenance costs will reach when it becomes economically justifiable to replace the ships. The economic life optimal replacement decision is the one that minimises the total discounted costs derived from the operation, maintenance, disposal[8].

2-2:Age replacement

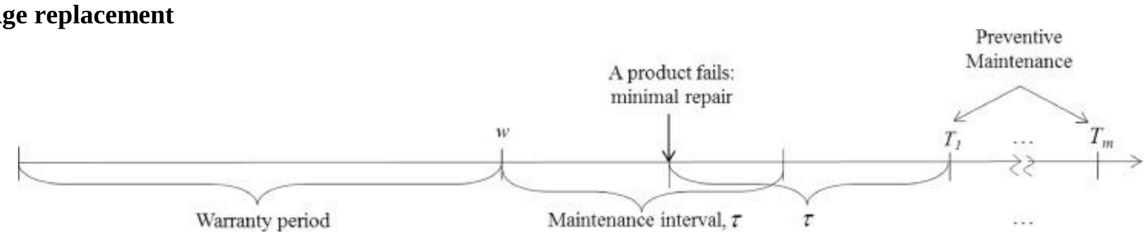

Figure 2: Age replacement

[4]Producedtheage-replacement model. Since failure is unexpected, the age replacement model assumes that failure costsexceedpreventive replacement costs. To reduce the costs of failures, a ship's preventive replacements are scheduled at a specific age[9]. Preventive replacement occurs when the ship has been used for a particularperiod of failures.When a failure occurs, the time is reset to zero [10]. The age replacement model balances the cost of the preventive replacements against their benefits, and this is done by determining the optimal preventive replacement age for the ship to minimise the total expected cost of replacements per unit of time[11].

2-3: Repair limits

Figure 3: Repair limits

[5]The first developed a repair limits model to optimise the replacement decision. Aside from the running costs, the cumulative cost of purchasing and maintaining a ship varies with the ship's age,asshown schematically inFigure 3[12]. (0 to A) represents the acquisition cost, and the remainder of the curve rises in steps as repair costs occur in discrete amounts at discrete intervals. Repair costs are a function of one variable: the ship's age. The average cost per year up to ageis given by dividing thecumulative costby the ship's age.

2. Operation Research

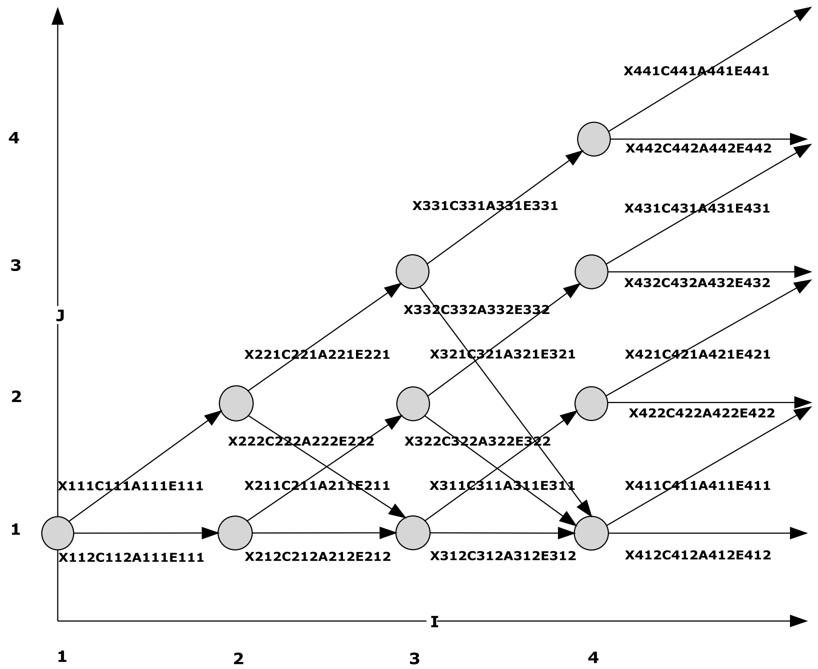

Figure 4: Operation research

Operation research models compare the sequences of decisions during finite horizons[13], and determine the sequence of decisions that maximises profit or minimises cost.Dynamic programming is the technique that dominates operation research (OR)models to optimise the replacement decision[6].

Dynamic programming

Dynamic programming provides a systematic procedure for determining the optimal sequence of decisions[14]. In most cases, dynamic programming obtains the optimal sequence of decisions by propagating backwards through the replacement decision's network, thus breaking up large sequences of decisions into more miniature tractable stages[15]. After the resolution of each stage, the optimum sequence of decisions can be achieved through the state variables. The state variables represent the links between stages, allowing one to take the optimum sequence of decisions for the remaining stages without checking the effect of future decisions or decisions previously made. In other words, dynamic programming is based on a multistage decision process where a decision at one stage will affect the decisions at subsequent stages[16]. In contrast to other mathematical techniques, there is no standard mathematical formulation for optimising the replacement decision by dynamic programming. However, it is a general strategy for optimisation rather than a specific set of rules; consequently, the equationsare developed to fit each formulation[17].

CONCLUSION

The scrap models compared the costs or profits during finite or infinite planning horizons anddetermined the decision that optimises the time or the age. The scrap modelsdo not contribute to improving organisations' objectives but optimise time or ageto waste the shipout-of-service[18][5].The mainshortcomings in scrap models include optimising the replacement decision to achieve a single objective and neglecting the change in objectives' coefficients in the future[9].Multi-objective optimisation and fuzzy sets theory are the main methods for treating theseshortcomings.Multi-objective optimisation and fuzzy sets theory jointly form fuzzy multi-objective programming.The multi-objective optimisation uses the concept of domination to determine the efficient solution which achieves a multi-objective[19].The fuzzy sets theory introduced by [20] is equivalent to multivariable sensitivity analysis and determines the objectives' coefficient range due to uncertainty in the future [21]. Some operation research models address these shortcomings[22].

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