



Exploring maintenance policy selection using the Analytic Hierarchy Process; An application for naval ships



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ARTICLE INFO

Article history:

Received 20 October 2014

Received in revised form

27 January 2015

Accepted 25 April 2015

Available online 2 May 2015

Keywords:

Maintenance

Maintenance policy selection

Analytic Hierarchy Process

Naval ships

ABSTRACT

In this paper we investigate maintenance policy selection (MPS) through the use of the Analytic Hierarchy Process (AHP). A maintenance policy is a policy that dictates which parameter triggers a maintenance action. In practice, selecting the right maintenance policy appears to be a difficult decision. We investigate MPS for naval ships, but our results have wider applicability. For our study we cooperate with the owner and operator of the ships, as well as with a shipbuilder and an original equipment manufacturer of naval ships. We apply a structured five step approach to obtain the relevant criteria that may make one policy preferable over another. The criteria are drawn from both literature and a series of interviews at several navy related companies and are structured into a hierarchy of criteria usable with the AHP. Additionally, we organize three workshops at the three different companies to test the AHP-based MPS approach in practice. We conclude that the AHP is well suited for maintenance policy selection in this broad setting, and that it provides a structured and detailed approach for MPS. Adding to that, it facilitates discussions during and after the sessions, creating a better understanding of the policy selection process.

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1. Introduction

Maintenance is an important contributor to reach the intended life-time of technical capital assets, as maintenance is defined as all activities which aim to keep a system in or restore it to the condition deemed necessary for it to function as intended [1,2]. By technical capital assets we mean capital intensive, technologically advanced systems that have a designed life-time of at least 25 years, such as trains, ships and aeroplanes.

This paper focusses on naval ships, considered a distinguishable ship type within the classification of ships [3,4]. In the Netherlands, the owner, operator and foremost maintainer of these ships is the Royal Netherlands Navy (RNLN). At the time of writing, detailed information on 27 of the RNLN's fleet of ocean going vessels is publicly available. With a designed life-time of 25 years, the average age of the vessels is 17 years, of which the oldest vessel went into service in 1985 and the youngest in 2013 [5,6]. To keep these ships operational and up to date throughout their life-time, maintenance plays a crucial role.

A maintenance policy is a policy that dictates which parameter (for example, elapsed time or amount of use) triggers a maintenance action.

Selecting the right maintenance policy appears to be a difficult decision. Namely, current selection methods do not always fit companies well and the need for tailored maintenance concepts is raised in the literature [7,8]. Furthermore, current, mostly quantitative, maintenance optimization and decision models have low applicability in practice, creating a gap between academia and practice: the scarcity of practical approaches to maintenance modelling was already pointed out in 1992 [9], and not much has changed since. Although maintenance is something that should be done in practice, several authors argue that practical studies are still under-represented [10,11].

In the 1990s, a novel approach to maintenance decision making emerged. Arguing that decision theory has become a useful tool to many professionals including engineers, and many maintenance challenges can be modelled as multiple criteria decision making (MCDM) problems, the use of MCDM methods has been suggested for maintenance decision making [12,13]. Selecting the right maintenance policy is one of these challenges for which MCDM could be applicable.

In this paper we set out to investigate naval maintenance policy selection (MPS) through the use of the Analytic Hierarchy Process, a well established MCDM method that hierarchically structures the goal, criteria and alternatives of the decision problem. We take a five-step approach to structure the investigation:

1. review the literature on the use of the AHP for maintenance policy selection;

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- define maintenance policies and construct a list of maintenance policies to use as alternatives;
- obtain the relevant criteria from both literature and a series of interviews, and structure them into a hierarchy usable with the AHP;
- organize three sessions in industry (at the RNLN, a shipbuilder and an OEM) to test the AHP-based MPS approach in practice; and
- evaluate these sessions and analyse these evaluations.

AHP-based approaches have been followed by others, but only for single case studies focussing on the final policy selected (see Section 2). The main question that this paper aims to answer is if the AHP can be put to a broader use for MPS. And if so, in what situation it is applicable. By broadening and following a structured approach, this paper contributes in four ways:

- the asset: we focus on a type of asset, namely naval ships, instead of one specific asset;
- the company: we look at the perspective of various companies, instead of one specific company, using the same hierarchy of criteria: owner, shipbuilder and original equipment manufacturer;
- the process: we also focus on tailoring of, and gaining insight in the selection process, and not on merely the outcomes of the process, by explicitly taking into account both the goals of the maintenance and the fit of the maintenance process to the company; and
- the approach: we apply a structured approach, where five steps are proposed and subsequently followed to systematically investigate naval MPS using the AHP. Contrary to other studies, for example, the structured approach that we propose can easily be repeated by others to find the relevant criteria.

This paper is structured according to the five-step approach explained above. We explain the AHP and the reasons for selecting the AHP in Section 2. Maintenance policies are discussed in Section 3, where we construct a concise and consistent list to be used with the AHP. In Section 4, we present the hierarchy of criteria that we distill from both the literature and a series of interviews. In Section 5, we discuss the set up of the three sessions that are organized to test the AHP-based MPS approach. We present the results of these sessions in Section 6, where we discuss the final policy preferences for the sessions and the evaluations of the sessions by the session participants. In Section 7, we draw conclusions and present recommendations for further research.

2. The Analytic Hierarchy Process

The use of MCDM methods has been proposed for maintenance decision making, because decision theory has become a useful tool to many professionals and because many maintenance challenges can be modelled as MCDM problems [12,13].

MCDM, and the analysis thereof, focusses not only on making a decision, its goal is also to provide insight in the decision process [14]. MCDM contributes to analyzing the decision making context, and organizing the process, increasing coherence on the goals and the final decision, and cooperation between the decision makers, leading to a better mutual understanding and debate [15].

In this paper we investigate naval MPS through one of these MCDM methods: the Analytic Hierarchy Process (AHP). The AHP is developed by Saaty in the 1970s and is a multiple criteria decision method in which the criteria are arranged in a hierarchical structure [16–18]. It decomposes decision-making into the following four steps.

- Define the problem and determine the kind of knowledge sought.

For example, which new car to buy: Car A or Car B.

- Structure the decision hierarchy from the top, from the goal of the decision, then the criteria that play a role in the decision (if necessary, clustered into sets of related sub-criteria beneath umbrella criteria on which they depend), to the lowest level (which is a set of the alternatives).

In the example and illustrated in Fig. 1, the top level and goal is selecting the best new car, the criteria then might be the top speed, the design and the safety of the car. The lowest level is the alternatives: Car A and Car B.

- Obtain priorities for criteria and alternatives: for each element in the hierarchy (elements here are the goal, the criteria, and, if present, sub-criteria) compare the elements in the level immediately below it with each other.

Following the example, under best new car, our goal, compare the three criteria: one might favour safety 2 times over top speed and 6 times over design, and favour top speed 3 times over design (inconsistency can easily arise, but a little inconsistency is not a problem; see for a detailed discussion [18, Chapter 3]). Under each of the three criteria, compare the two alternatives: for example, the top speed of Car A might be 2 times as high (which means that this element scores $\frac{2}{3}$ for car A and $\frac{1}{3}$ for car B), and its design may be 3 times as attractive as that of Car B, while Car B might be 3 times as safe.

- Obtain the final priorities of the alternatives, using the priorities obtained for the elements at one level to weigh the priorities of the elements in the level immediately below them. Do this recursively for the complete hierarchy.

Concluding the example, we find that Car A gets a priority of 0.425, while Car B gets a priority of 0.575, so that we favour Car B. We get to this number by noticing that the criteria get weights of $\frac{3}{10}$, $\frac{1}{10}$ and $\frac{6}{10}$ for top speed, design and safety, respectively, which means that Car B scores, relatively to Car A, $\frac{3}{10} \cdot \frac{1}{3} + \frac{1}{10} \cdot \frac{1}{4} + \frac{6}{10} \cdot \frac{3}{4} = \frac{23}{40} = 0.575$.

For the pairwise comparisons, a ratio scale is used to indicate how many times more important or dominant one element is over another: 1 to indicate an equal importance, 2–9 to indicate a higher importance and their reciprocals to indicate a lower importance. To facilitate the AHP, various software packages are available. For this paper the SuperDecisions software is used, which is freely available for non-commercial use [19].

The AHP was selected for this research because it is a well-established multiple criteria decision-making approach, both in academia and industry [20–22], and its specific benefits fit the issues described in Section 1, as the AHP [23,14,18]:

- is designed to integrate objective, subjective, qualitative and quantitative information;
- creates a thorough understanding of the problem by structuring the problem hierarchically;
- compares the criteria and alternatives pairwise, providing simplicity and ease of use; and
- produces plausible and defensible results.

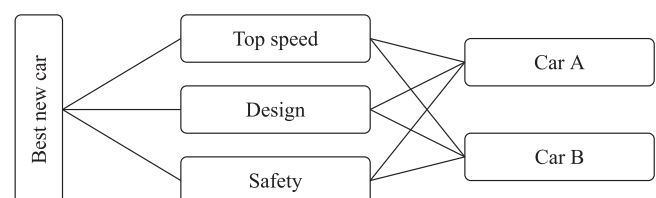


Fig. 1. An example decision hierarchy.

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