Reliability Engineering and System Safety 000 (2017) 1–17

Contents lists available at ScienceDirect

Reliability Engineering and System Safety

journal homepage: www.elsevier.com/locate/ress

Perspectives on trading cost and availability for corrective maintenance at the equipment type level

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ARTICLE INFO

Keywords:
Corrective maintenance
Maintenance float systems
Finite source queuing theory
Availability at risk
Maintenance cost

ABSTRACT

Characterising maintenance costs has always been challenging due to a lack of accurate prior cost data and the uncertainties around equipment usage and reliability. Since preventive maintenance does not completely prevent corrective repairs in demanding environments, any unscheduled maintenance can have a large impact on the overall maintenance costs. This introduces the requirement to set up support contracts with minimum baseline solutions that warrant the target demand within certain costs and risks. This article investigates a process that has been developed to estimate performance based support contract costs attributed to corrective maintenance. These can play a dominant role in the through-life support of high values assets. The case context for the paper is the UK Ministry of Defence. The developed approach allows benchmarking support contract solutions, and enabling efficient planning decisions. Emphasis is placed on learning from feedback, testing and validating current methodologies for estimating corrective maintenance costs and availability at the Equipment Type level. These are interacting sub-equipment's that have unique availability requirements and hence have a much larger impact on the capital maintenance expenditure. The presented case studies demonstrate the applicability of the approach towards adequate savings and improved availability estimates.

1. Introduction

The evolution of business services are strongly dependent on the correct functioning of modern technical systems. These systems warrant operational performance and efficiency which dictates the amount of maintenance required; a consequence of the design and failure modes encountered during operation [1]. Maintenance (both preventive and corrective) therefore has an impact on both cost and operational availability.

Two aligned fields that deserve mention at this point are Product Service Systems (PSS) and Health Management. PSS [35], which is also linked to servitization [3], stemmed from some OEMs transforming their business model from selling a product to selling a service. In the product scenario, income is determined from the original sale and future income is dependent on the sale of spare parts. In the service scenario, a maintenance contract is sold at the same time as the asset and hence a steady monthly income is derived, in return for effective maintenance; the OEM has become the maintainer and captured more of the value chain. Though, with the large number of equipment to maintain, OEMs and the customer need to find effective ways to handle the sheer amount of data that is available. For strategic maintenance analysis, this promotes the need to move away from component level focus to the Equipment Type (ET). ET is any set of sub-equipment, which operate together that have a unique demand profile. It can belong to various platforms, e.g. tanks or aircraft, or even role equipment that is not permanently fitted, e.g. missiles. ETs are interacting sub-equipment's, which have unique availability requirements and hence have a much larger impact on the capital maintenance expenditure. On the other hand, health monitoring arose to better inform the OEMs of the behaviour of their assets in service [4]. It provides data from sensors on the asset and processes it, via diagnostic or prognostic algorithms, into actionable information. Fig. 1 shows a generic operating environment that can be found across the engineering sectors. Within the figure, the OEM (Original Equipment Manufacturer) supplies an asset to an operator who is going to use it as part of a business to make a profit. The operator needs the equipment to be regularly maintained and the maintainer will have access to the OEM's supply chain for spare parts. This is all done with respect to certain standards, certification and policies. It demonstrates some of

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http://dx.doi.org/10.1016/j.ress.2017.05.041
Available online xxx
0951-8320/© 2017 Published by Elsevier Ltd.

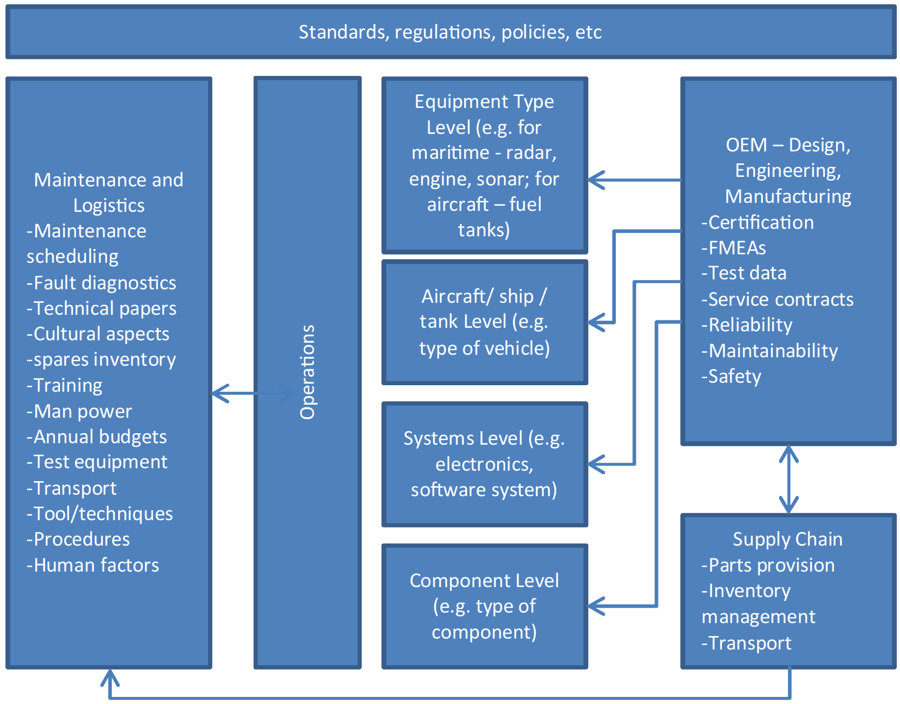

Fig. 1. The operating environment.

the interactive complexities that can arise during a service, which must be investigated to manage system availability and reduce surplus costs (Erkoyuncu et al., 2015). Accordingly, the figure also demonstrates that the ET level involves e.g. a radar, engine, and sonar; as compared to the aircraft level, system level or component level. This means that an ET could be present in multiple equipment's and may vary over time based on the customer demand profile.

Within the overall operating environment, the effectiveness of each constituent system becomes important. System effectiveness is the ability for a system to achieve its required operational capability, from either a cost or availability viewpoint. This is in order to embrace the constituent parts of availability – namely reliability, maintainability and logistics support [26]. The primary aim over here is to define, deliver and evaluate how an optimal system performance (e.g. availability) can be achieved at affordable through-life costs. Having an integrated (and iterative) setup can help develop a comprehensive support strategy to optimize functional support, leverage existing resources, and quantify life cycle costs (demand for logistics). Such an integrated logistics support is widely used in commercial services organisations [22]. This is used as a business case for judging an optimum balance between the time invested in performing certain actions – such as Preventive Maintenance (PM) and Corrective Maintenance (CM). In this context, the UK Ministry of Defence (MoD) is developing several approaches to manage its high value equipment/assets; this is indicative of a growing awareness of the problem – rooted in the need to:

- Improve the availability of equipment and vehicles [15],
- Reduce the turn-around times for aircraft [2],
- Provide an efficient and cost effective maintenance service [4,29],
- Mitigate against the cost impact of warranty claims [24].

There are three driving forces at work here. The first relates to the collapse of the world economy since 2008. For example, in aerospace the economic downturn has led to rising fuel costs and increasing taxes. Cost savings have therefore had to be found and tackling wasteful and inefficient maintenance has become a prime target for cost reduction [23]. Likewise, government spending cuts, particularly evident within the UK, have significantly downsized both armed forces personnel and the purchasing of spare parts. This forces maintenance activities to modernize and become smarter. The second driving force is the increase in contracting for availability. Here maintenance and repair is the responsibility of a 3rd party who guarantees the customer that they will have a specific availability for their equipment or vehicle. Maintenance plays an important role in contracting for availability, as the commercial contracts needs to define who is responsible for these costs: re-test, re-certification, etc. The final driving factor is down to the increased complexity of engineering systems coupled with a reduction in the skill-set of the relevant maintenance personnel.

So the availability of equipment is an essential driver. Within the defence sector, availability is influenced by several factors which include logistics, equipment, personnel, information and facilities [21]. The authors of this paper are studying these issues by focusing on selected subsystems – that are referred to, within the UK MoD and in this paper, as Equipment Type (ET).

Each ET produces available days (Equipment Available Days or EADs) during a certain planning period. The process is managed by the Equipment Support Continuous Improvement Team (ESCIT) of the UK MoD who estimate the resources required for maintenance to meet an availability target for an equipment type at affordable levels. Therefore, MoD ESCIT's requirements are:

- To develop an analytical model that is simpler and faster to run,
- To establish a budgetary baseline, generally for short term planning (e.g. one year) and with the possibility of ongoing inputs updates and recalculation,
- To obtain a benchmarking criterion even when data maturity is not enough to run more complicated models: modelling at equipment type level requires simplified high level inputs.

1.1. Contributions and importance of this work

The aim of this article is threefold: (1) to develop a methodology to estimate the cost of maintenance resources required to achieve a certain availability level, (2) to assess the maturity level and confidence levels on the prediction availability, and (3) to validate the analysis and result.