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Investigating maintenance decisions during initial fielding of rolling stock

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Abstract

Successful organizations align technology with their competitive strategy. The challenge is first to make the right and timely decisions when acquiring new technology. Next, organizations must make decisions that help configure the maintenance services to fit the technology they acquired. Ideally, new technology should fit seamlessly with company practices and ways of working. In practice, this is rarely the case and there is misalignment. For maintenance service providers, the problem of fitting maintenance of new capital assets to traditional ways of working is especially important. This paper examines the decisions made by a maintenance service provider to maximize cost efficiency during initial fielding of rolling stock. We explore the different decisions made to design the support organization around newly acquired trains used for passenger service.

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Keywords: maintenance decision-making; rolling stock maintenance; fielding rolling stock.

1. Introduction

This paper presents an initial framework of maintenance decisions involving acquisitions of passenger service rolling stock, i.e. passenger service vehicles that operate on a railway. In addition, we show which strategic decisions are made during initial fielding of rolling stock. Such decisions can have an important impact in maintenance performance during the life cycle of complex capital assets.

Maintenance, and thus maintenance performance, is important. For the Netherlands Railways (NS) –the main railway operator in the Netherlands– overhaul plus regular maintenance of rolling stock represents together an approximate 27% of the annual operating budget. The company invests approximately 12% of the annual budget in rolling stock acquisitions. Therefore, costs for maintenance related activities are more than double the acquisition investment every year. These figures show the relevance of considering the cost of ownership of rolling stock, and for NS to find the correct balance between the investment costs and the other operating costs [1].

After liberalization of the railways in Europe, most in-house service providers separated from the rolling stock operators. This was the case for NedTrain, the main maintenance service provider for the NS. Today, most of the worldwide maintenance, repair and overhaul (MRO) market for rolling stock is still dominated by the old in-house service providers. As a result, most original equipment manufacturers (OEMs) and system integrators have short-lived knowledge of rolling stock maintenance and support. The knowledge of train manufacturers is sometimes limited to the warranty period. Measures such as maintainability or supportability of rolling stock are of recent concern to manufacturers [2], since they are entering competition in the after sales market. Today, it is important for the operator, the manufacturer and the maintenance service provider to collaborate. It is important that the maintenance service provider bring in its knowledge during acquisition projects.

This paper is the result of research performed as a part of the so-called "Rolling Stock Life Cycle Logistics" research and development program, funded by NS/NedTrain. NedTrain, like other maintenance companies, is interested in developing tools and methods that help it evaluate the fit of

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new capital assets to the existing support infrastructure. Such methods and tools can aid decision makers in assessing the ability of an existing organization to fulfill maintenance needs of new assets. Therefore, assets may be acquired that can be supported effectively and efficiently. In order to develop such methods and tools, a first requirement is to understand how the support infrastructure is designed and fitted to newly acquired assets. This research aids in that, since we look at the strategic decisions that are made concerning the support organization when acquiring and fielding new assets. We use the term capital asset, meaning a special type of assembled product. Capital assets are also known as product-service systems, integrated solutions or complex systems.

There is a large body of literature addressing maintenance management decision making. Pintelon and Gelders provide a framework for research on decision support [3]. Pintelon and Van Puyvelde provide an extensive overview of the field of maintenance decision-making [4]. Many of the trade-offs involved in maintenance decisions are also approached from the perspective of optimization. Dekker and Scarf review the use of maintenance optimization models [5]. More recently, Sharma et al. report emerging trends in simulation and other optimization techniques [6]. For a supportability engineering design program, Jones provides a prescriptive decision process mapping the relevant decisions to the stages in the life cycle of the capital asset [7].

Maintenance management decisions can be strategic, tactical and operational. The case of designing maintenance services involves strategic decision making. Management makes many of such decisions upon initial fielding of capital assets. Our main contribution is to show the decisions made in practice. In addition we contribute with an initial framework to help structure the decision making process: what are the key decisions, what types of decisions are there and when do maintenance experts and managers make such decisions in practice? This constitutes a first, but important step towards identifying information needs, and knowledge required by organizations to specify, select, acquire and field capital assets.

The structure of this paper is as follows. The next section, Section 2, presents the research problem and our research question. Section 3 presents the research methodology, including our research approach, the research design and data sources. Next, in Section 4, we present the preliminary case study findings. Finally, we present our concluding remarks and prospects of this ongoing research in Section 5.

2. Research problem

This research explores strategic decisions involving the design of maintenance services when fielding new capital assets. These are long-term decisions, and they appear during the fielding of new assets. Therefore, with our research we try to answer the following question:

What are the key trade-off decisions that maintenance experts make during initial fielding of new assets?

Our case involves a maintenance organization from the railways sector. We limit the scope of this paper to strategic decisions that involve fielding of capital assets. The capital assets that we refer to are passenger service rolling stock. We take the point of view of the maintenance function, because it is in a strategic position in the acquisition process. Maintenance organizations have the knowledge that is required to assess maintenance characteristics of a new asset. If consulted, maintenance organizations can help decision makers to select the most cost efficient option.

With this research, our objective is to develop insights into strategic maintenance decisions made during initial fielding of rolling stock. Strategic decisions are not made frequently, e.g. they are only made once every couple of years. These decisions can tie up significant amounts of capital, and have long-term impact on organizational performance. Specifically, we target those decisions destined to fit maintenance services of new capital assets to the capabilities of maintenance organizations. Such insight is very useful in model building research, and can aid decision makers in assessing and improving supportability in the operational phase of capital assets. The development of better methods for assessing supportability, and the ability to support purchasing decisions, will give a competitive advantage to organizations that want to achieve world class performance [8]. We want to understand which are in practice the key decisions influenced or directly made by the maintenance organization.

3. Research methodology

In this section, we describe the methodology. We present the methodology in Fig. 1. For convenience, two subsections show the research approach, research design and data sources separately. The first subsection describes the literature review and the second subsection describes the case study. We address the research question using an explorative case study and a literature review. However, the literature review is not reported in this paper. Performing the case while going back to the literature has shown the emerging theme decisions made, the timing of decisions, and the knowledge required to make them. This is our second phase of the research, and is ongoing work. Our third phase of the research involves the formal (feedback) check of our framework. This will involve further interviews and/or workshops with key informants.

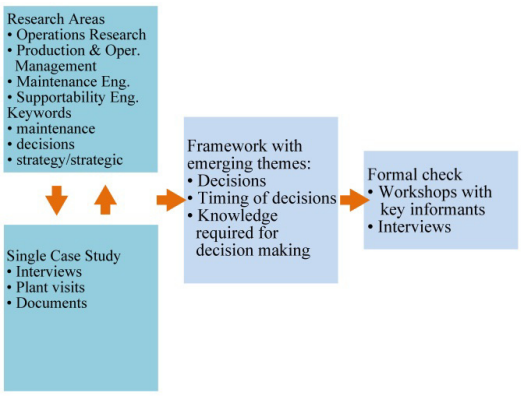

Fig. 1. Research methodology.

3.1. Literature review

The research is framed by existing stream of literature. In Fig. 1 we position the literature review in our research methodology. A literature review helps to establish the main decision areas, as well as the key strategic decisions reported in the literature. We use the literature to create an inventory of different types of strategic decisions that are core to strategy in maintenance operations. The sources are listed in Table 1. We focus on journal papers in the areas of operations research (OR), production and operations management (POM), maintenance engineering (ME) and supportability engineering (SE). We use a combination of keywords such as strategic maintenance decisions, maintenance decision making and maintenance management decisions. We also include books known to discuss the topic of maintenance decision making.

Table 1. List of journals.

Journal	Research Area
Journal of Operations Management (JOM)	POM
International Journal of Production Research (IJPR)	POM
International Journal of Operations and Production Management (IJOPM)	POM
Production and Operations Management Journal (POM)	POM
International Journal of Production Economics (IJPE)	-
Decision Sciences (DS)	POM/OR
Management Science (MS)	POM/OR
Operations Research (OR)	OR
Computers and Operations Research	OR
European Journal of Operations Research (EJOR)	OR
Naval Research Logistics	OR/SE
Systems Engineering	SE
International Journal of Quality in Maintenance Engineering (IJQME)	ME
Reliability Engineering and Systems Safety (RESS)	ME

3.2. Case study

The research that followed the literature analysis is mainly empirical. Conducting empirical research is important because it closes the gap between practitioners and researchers, and because it allows for theory building and verification. We use a case study for its strength in answering "what" questions [9]. We attempt to gain full understanding of the acquisition process. The case probes into maintenance decisions that support rolling stock acquisitions at NS. Emerging from the interviews, the case has helped identify and describe the key decisions made in practice by experts of the maintenance organization. Our main effort was to isolate those decisions made during fielding of new capital assets. We describe the roles of one maintenance organization during important acquisition projects.

We select the case study as follows. Firstly, the case has to involve the type of organizations that give strong emphasis to the maintenance function during acquisitions. Second, we preferably target good performers, assuming that they are the best in class in managing acquisition projects. Third, a specific industry has to be selected which may very well include defense, transportation, chemical processing, manufacturing, etc. For convenience and affinity with the project, we selected the rail sector. The organization that we have selected is NS/NedTrain, generally considered a good performer in the industry.

For our case study, we used interviews as our primary source of data. In total, 17 individual semi-structured interviews were held. The sample is shown in Table 1. Ease of access to the organization also allowed for many informal conversations with key informants. Visits Staff was mostly engineers and managers that had been involved or consulted during acquisition projects, maintenance assessment and supportability. Some of the informants in key positions were interviewed several times. Interviews were conducted following the methodology in [10]. We begin asking questions about performance of a specific aspect of the process of designing the logistic support system. Next, we focus on how performance is measured to understand the design decision. We use company documents and internal reports as a means of data triangulation to increase validity. Visits were also made to one overhaul depot, four maintenance depots that perform long cycle maintenance, and to several service locations that perform daily services.

Table 2. Interview Sample.

Position	Number of Interviews
Support managers	2
Acquisition managers	6
Engineering and other managers, e.g. fleet managers	7
Senior management	1
Technical staff	1
Total	17

4. Preliminary case study findings

In this section we first present the background for our case study, i.e. the context of the maintenance service provider. Next, we explain the acquisition process used by the NS, in which its maintenance service provider –NedTrain, has an important role. Finally, we show a number of decisions made by the maintenance service provider. These decisions take place during the acquisition process, during the initial fielding –under warranty, and after the warranty period expires.

4.1. Case study background

For the NS, the total value of the domestic passenger transport in The Netherlands amounted to €1,915 million in 2012 [11]. NedTrain is in a strategic position to bring balance to rolling stock acquisitions. NedTrain services 2,850 coaches (trains & locomotives) on a 24/7 basis at 35 service locations, 4 maintenance depots and 2 overhaul depots. This maintenance organization possesses specific knowledge from

many years of experience working with the NS fleets, and this is a very valuable advantage for NS [12].

In The Netherlands, new trains are purchased on a regular basis. NS acquires these systems following the European tendering regulations. An acquisition board is made up of relevant stakeholders, including the maintenance organization, NedTrain. The role of the maintenance organization as a stakeholder in this acquisition process is that of a consultant. The maintainer has the relevant knowledge that NS can use to select the best candidate from a maintenance point of view.

4.2. Decisions during an acquisition program

Before decision-making begins, information input is required by the maintenance organization. Examples include:

- Which are the maintenance significant items?
- What are the maintenance services required by the original equipment manufacturer (OEM)?
- What type of maintenance policy should be used according to the supplier?
- What is the contract period for maintenance services?
- How many assets are to be maintained?
- What is the expected usage rate?

Once this information is known, maintenance experts take the lead performing economic trade-off decisions during maintenance assessment. *Maintenance assessment* is a process of analysis and evaluation of maintenance service needs during the contracting phase of equipment. In the literature, this process is commonly known as supportability analysis [7]. Preliminary decisions, based on estimations of the experts include:

- What is defined as a spare part?
- Which spare parts to include in the assortment?
- What is the required basestock of critical rotable components with long delivery lead time?
- Is the spare part replaced directly in the field or line maintenance?
- Where do we replace field/line replaceable items (LRUs)?
- Where do we stock field/line replaceable items?
- Where do we allocate capabilities (equipment, tools and skills) to replace them?

Upon *first article inspection*, during the implementing agreements stage, the maintenance organization can begin making repair & overhaul decisions. Decisions regarding shop replaceable units, discard options, etc. are not considered until after the warranty period expires. Therefore, many of the *maintenance optimization decisions* typically occur 2 years after fielding of equipment. These decisions include:

- When do we replace a particular item?
- Do we repair or discard LRUs?
- Do we repair in-house or do we outsource repair?
- Where do we perform each type of repair?
- Where do we discard?
- Where do we stock spare parts?
- Where do we allocate repair capabilities?

Decisions made during the acquisition process can positively influence operational performance of capital assets. However, they are not the only strategic decisions that can influence maintenance performance. Sufficient resources must be supplied to maintain the fleet, both for existing train series and for new ones. Many of these choices do not depend on a particular train series. In fact, many continuous improvement decisions that have long term impact on fleet performance are made independent of any particular acquisition program. These are decisions that we will continue to study, and will be part of our future research.

5. Concluding remarks

We present in this section our conclusions and recommendations for future work. This paper contributes with a case study on decisions made to design maintenance services for rolling stock. We have exposed two categories of decisions. On the one hand, some key decisions are made by maintenance organizations during initial fielding of rolling stock. On the other hand, there are decisions made to improve the cost efficiency of maintenance services. We give our focus to the first category. We present preliminary findings of trade-off decisions made by NedTrain, the main rolling stock maintenance service provider in The Netherlands. The research in this paper is relevant because it involves current practices, it gives insights into maintenance decision making and it involves the fielding of new equipment – a challenge to all organizations that service capital assets. Generalizing the decisions found in this case to other types of capital assets with long lifetimes and similar complexity is important for our future research.

Our future research will investigate further the types of strategic maintenance decisions made to improve overall performance of the NS fleet. For NedTrain, improving maintenance efficiency has involved investment in increasing in-house capabilities. In addition, optimization and improvement programs to redesign the NedTrain maintenance network have resulted in the inclusion of new technical centers. Other changes in service design include modifications of workstations and technology: pit tracks vs. raised tracks, roof access vs. non roof access, single wheel set versus double wheel set lathes, number of workstations, etc. Continuing research will help clarify what drives other important decisions. For example, opening a new facility location can be related to an individual high profile acquisition project. However, it is driven by a long term business strategy. An example of this decision is the construction of Watergraafsmeer (dedicated facility for high-speed trains). Future research will be devoted to the decisions made to implement improvements to the design of maintenance services of rolling stock, a special type of product-service system.

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References

[1] Van Dongen LAM, Lutters D, van Houten FJAM. Maintenance as an integrated optimization criterion in development life cycles. In: 44th CIRP Conference on Manufacturing Systems; 2011.
[2] Durand, Y. The Maintainability Approach at ALSTOM Transport. In: World congress on Railway Research (WCRR 2001); 2001.
[3] Pintelon J, Gelders LF. Maintenance management decision making. European Journal of Operational Research 1992; 58:3; p. 301–317.
[4] Pintelon L, van Puyvelde F. Maintenance decision making. 1st ed. Leuven: Acco, 2006.
[5] Dekker R, Scarf PA. On the impact of optimisation models in maintenance decision making: the state of the art. Reliability Engineering & System Safety, 1998; 60:2, p. 111–119.
[6] Sharma A, Yadava GSS, Deshmukh SGG. A literature review and future perspectives on maintenance optimization. Journal of Quality in Maintenance Engineering 2011; 17:1, p. 5–25.
[7] Jones JV. Supportability engineering handbook: implementation, measurement, and management. SOLE Logistics Press/McGraw-Hill; 2006.
[8] Goffin K. Design for Supportability: Essential Component of New Product Development. Research-Technology Management, 2000; 43:2, p. 40–47.
[9] Voss C, Tsikriktsis N, Frohlich M. Case research in operations management. International Journal of Operations & Production Management, 2002; 22:2, p. 195–219.
[10] Schotborgh WO, McMahon C, Van Houten FJAM. A knowledge acquisition method to model parametric engineering design processes. International Journal of Computer Aided Engineering and Technology, 2012; 4:4, p. 373-391.
[11] NS Groep NV, "Annual report 2012," Utrecht, The Netherlands; 2012.
[12] Caniëls MCJ, Roeleveld A. Power and dependence perspectives on outsourcing decisions. European Management Journal, 2009; 27:6, p. 402–417.