

Manuscript Number:

Title: Work in progress: developing tools that support the design of easily maintainable rolling stock

Article Type: SI: TESConf

Keywords: design methods and tools; design for maintenance; maintenance knowledge; rolling stock design

Corresponding Author: Mr. Wienik Mulder, MSc

Corresponding Author's Institution: University of Twente

First Author: Wienik Mulder, MSc

Order of Authors: Wienik Mulder, MSc; Rob J.I. Basten, dr.ir.; Juan M. Jauregui Becker, dr.ir.ing; Leo A.M. Van Dongen, prof.dr.ir.

Abstract: Maintenance activities strongly influence the operational availability and life cycle costs of rolling stock. To achieve an effective and efficient maintenance process, it is essential that the design of the trains and its maintenance service are well-aligned. We conduct research on how the design of industrial equipment, such as rolling stock, and the design of its maintenance service influence the maintenance process. We use our findings for the development of methods and tools that support the use of maintenance knowledge in the equipment design process. An example of a past train development project shows that re-designing the mounting construction of a compressor has led to lower maintenance costs and a higher availability of both the trains and the maintenance resources. Based on such examples from industry and from findings in the literature, we expect that our research can contribute to better design decisions, which ultimately results in production systems that are cost-effective over their whole life time.



2nd International Through-life Engineering Services Conference

Work in progress: developing tools that support the design of easily maintainable rolling stock

Mulder, W.^{a,*}, Basten, R.J.I.^a, Jauregui Becker, J.M.^a, Van Dongen, L.A.M.^a

^aUniversity of Twente – Laboratory of Design, Production and Management
PO Box 217, 7500AE Enschede, The Netherlands

* Corresponding author. E-mail address: w.mulder@utwente.nl

Abstract

Maintenance activities strongly influence the operational availability and life cycle costs of rolling stock. To achieve an effective and efficient maintenance process, it is essential that the design of the trains and its maintenance service are well-aligned. We conduct research on how the design of industrial equipment, such as rolling stock, and the design of its maintenance service influence the maintenance process. We use our findings for the development of methods and tools that support the use of maintenance knowledge in the equipment design process. An example of a past train development project shows that re-designing the mounting construction of a compressor has led to lower maintenance costs and a higher availability of both the trains and the maintenance resources. Based on such examples from industry and from findings in the literature, we expect that our research can contribute to better design decisions, which ultimately results in production systems that are cost-effective over their whole life time.

© 2013 The Authors. Published by Elsevier B.V.

Selection and peer-review under responsibility of the International Scientific Committee of the "2nd International Through-life Engineering Services Conference" and the Programme Chair – Ashutosh Tiwari.

Keywords: design methods and tools; design for maintenance; maintenance knowledge; rolling stock design

1. Introduction

Maintenance activities on rolling stock strongly influence the operational availability and the lifetime costs of railway fleets. Both the design of the vehicles and the design of the maintenance service influence the maintenance process. Therefore, to achieve an effective and efficient maintenance process, the design of the trains and the design of its maintenance service should be well-aligned. This allows, for example, for quick and easy replacement or repair of subsystems and components, resulting in low maintenance time and costs. Especially in the early stages of train development, design decisions are made that strongly influence the future maintenance. The consequences of these decisions for the effectiveness and efficiency of the maintenance process need to be considered.

In our research, we work on the development of methods and tools that support designers of industrial equipment in making design decisions that influence the future maintenance activities. The research focuses mainly on how maintenance knowledge can be used for improving such decisions, so that equipment will be designed that can be maintained effectively and efficiently. Within this project, the development of rolling stock is one of the topics that we work on.

In this work in progress abstract we present the outline of our research project in Section 2, and illustrate the application of design for maintenance with an example in the field of rolling stock design in Section 3. Finally, in Section 4 a number of concluding remarks are given.

2212-8271 © 2013 The Authors. Published by Elsevier B.V.

Selection and peer-review under responsibility of the International Scientific Committee of the "2nd International Through-life Engineering Services Conference" and the Programme Chair – Ashutosh Tiwari.

2. Research outline

Our research focuses on the development of methods and tools that helps equipment designers in industry to design equipment that can be maintained both effectively and efficiently. To develop such support, we investigate (1) the influence of equipment design on the maintenance process and (2) how knowledge about this relationship can be exploited in the development process. We assume that use of this knowledge will improve the quality of design decisions. This assumption is based on examples found in industry (as the example described in Section 3), and findings from the literature. For example, one of the factors that prevents companies from developing products that are easy and efficient to support is, according to Goffin [1], that people from the field usually do not have the opportunity to influence the product design, although they are the ones that know support problems first-hand.

This research is much related to the research that is conducted under the theme of Product/Service-Systems (PSS) design, and in particular, Industrial Product/Service-Systems (IPS²). For example, Tan et al. [2] have researched relevant design approaches in the context of PSS design, and Aurich et al. [3] have researched PSS development process. The use of maintenance knowledge in such a development process is a topic addressed by Doultsinou et al. [4].

We conduct the research according to the Design Research Methodology (DRM) that is proposed by Blessing and Chakrabati [5]. This methodology has four research stages: (1) *research clarification* for finding indications and formulating a worthwhile research goal; (2) *descriptive study I* for describing the existing situations by reviewing the literature and/or an empirical study; (3) *prescriptive study* during which support is developed; and (4) *descriptive study II* for investigating the impact of the support.

Currently, we are in *descriptive study I*, in which we study how different companies address the use of maintenance knowledge in the design process of the equipment they design or use. The empirical research in the industry consists of several interviews with both the manufacturers and the maintenance providers of equipment. From both perspectives we investigate whether or not the particular equipment can be maintained effectively and efficiently. By comparing the outcomes of the interviews, we will learn what knowledge has already been brought into the design process and what knowledge still needs to be brought in. The findings of this research will be the starting point for the third stage of the research. In that stage, the focus will be on the development of a method or a tool for the integration of maintenance knowledge from the field in the development process. We will then decide whether the development of such a methods or tool will be for a particular company or a particular type of equipment, or that we will focus on a generic applicable method or tool.

Within the context of the railway industry, research is conducted at the maintenance provider of the Netherlands Railways, NedTrain. At this company, we will work on a specific case study: the improvement of a tool for the prediction of the reliability, maintainability, and their effects

on the life cycle costs, for a fleet of double decker trains. The fleet consists of 400 coaches. These were built in the early 90's and are now completely overhauled. Several technical systems are upgraded or renewed and the complete interior is modernized. In the case study, we will compare the performance of the old and the overhauled trains, and relate these to the changes in the design. The findings should be used to update the model, so that a more accurate prediction of the reliability, maintainability and life cycle costs of these train sets can be made.

3. Example for rolling stock design

Maintenance of trains that are operated by the Netherlands Railways is carried out at the workshops of NedTrain (for example the workshop presented in Figure 1). In these workshops different types of trains are maintained using the available maintenance equipment. During the development process of both completely new trains and renovation of currently used train sets, the maintenance aspects are addressed in relation to these available resources.



Fig. 1. A workshop of NedTrain

Examples of past train development projects show that thoroughly studying the maintainability aspects of the trains, has a great effect in helping to reduce maintenance times, maintenance costs, and the need for special maintenance equipment. For example, re-design of the construction of the mounting of compressors on the underside of a train (shown in Figure 2), has led to significant reduced maintenance times, resulting in increased availability of the train for passenger service.

In the initial design, the compressor was fitted at ninety degrees with respect to the driving direction. This made it impossible to exchange the compressor on rails above a standard service pit. Special lifting equipment, that is available at the workshop, would have been required to replace the compressor. Table 1 presents the differences in maintenance times and costs for both design solutions. For the initial design, both the maintenance times and costs are much higher, because using the special equipment requires more preparation time and specially trained personnel.

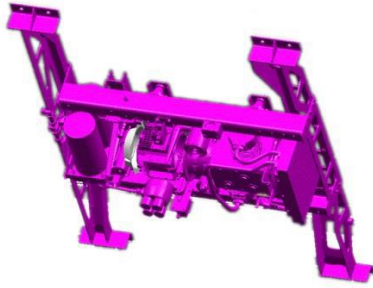


Fig. 2. Train compressor and construction of its mounting

The complete fleet of this train type consists of 130 trains. The compressors are replaced, on average, seven times during the thirty year life time of the train. Therefore, the total savings will be about 700,000 euro over the whole life time of the trains. Besides the savings in time and costs, it is also a big advantage that the special is not required for exchanging compressors. Such equipment is very expensive in comparison with a standard service pit, and therefore each workshop has only one of them. The utilization rate is already about 85 per cent. When it will be also used for maintenance on the compressor systems, the utilization rate would increase up to more than 90 per cent. This would make planning of the maintenance actions much more difficult, and the probability of delays high.

Table 1. Replacement time and cost compressor

Maintenance times and costs exchange of compressor	Replacement time (hours)	Replacement cost (euro)
Initial design	7 hours	1200 euro
Redesign	3 hours	400 euro

4. Concluding remarks

In this work in progress abstract, we have presented the outline of the research project that we work on. The main topic of the project is the development of methods and tools to support the design of equipment used in production systems in such a way that it is easy to maintain. The design of rolling stock is one of the types of equipment that we work on. The example of the design of the mounting constructing for the

compressor of trains shows the importance of addressing maintenance already during the design of the train. We expect that current design methods and tools can be improved when relevant maintenance knowledge from the field will be brought into the design process. These improved methods and tools, on the one hand, will lead to improved quantitative evaluations of the effect of design decisions on maintenance times and costs. On the other hand, they also help to make designers aware of the consequences of the design decisions that they make, and therefore stimulate that designers will consider changes in the design of the equipment in relation to the design of the maintenance service. We expect this to lead to a more effective and more efficiently maintenance process, and ultimately to cost-effective production systems over their whole lifetime.

Acknowledgements

The authors gratefully acknowledge the financial support given by Lloyd's Register Foundation (LRF). LRF supports the advancement of engineering-related education, and funds research and development that enhances safety of life at sea, on land and in the air.

References

- [1] Goffin, K. Design for supportability: an essential component of new product development. *Research-Technology Management* 2000;43:2, pp. 40-47.
- [2] Tan, A., Matzen, D., McAloone, T., Evans, S. Strategies for designing and developing services for manufacturing firms. *Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS²) conference, Cranfield, Cranfield University 2009*
- [3] Aurich, J.C., Fuchs, DeVries, M.F. An approach to life cycle oriented technical service design. *CIRP Annals – Manufacturing Technology* 2004;53:1, pp. 151-154.
- [4] Doultsinou, A., Roy, R., Baxter, D., Gao, J., Mann, A. Developing a service knowledge reuse framework for engineering design. *Journal of Engineering Design* 2009;20:4, pp. 389-411
- [5] Blessing, L.T.M., Chakrabati, A. *DRM, a design research methodology* 2009, Springer