Research Statement

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Users of capital equipment are interested in its function. They want to be able to use that function as much as possible, against the lowest possible costs. The goal of equipment developers is thus first to develop equipment that fulfils the right function and second to do that such that the equipment will be available as much as possible against the lowest possible costs over its total life cycle. The latter means that equipment developers should consider, for example, the usage of common components and required reliability levels of components, i.e., they should design-for-maintenance.

Given a product design, a maintenance plan can be developed, by addressing, amongst others, the following problems:

- Maintenance policy selection: For the various components, it should be decided which maintenance policies to use. Examples of maintenance policies are periodic time-/usage-based maintenance or condition based maintenance (also called predictive maintenance), in which the passing of time or a certain condition passing a threshold triggers maintenance, respectively.
- Line replaceable unit definition: If a component needs to be replaced preventively or upon failure, the component itself can be replaced, but it can be more economical to replace a module that contains the component. Replacing such a module can be faster, for example if it is time consuming to find the exact component that has failed. The component or module that is replaced is called the line replaceable unit.
- Maintenance policy optimization: Given the line replaceable units and the maintenance policies that are used for all units, the policy parameters can be optimized. For example, if a usage-based policy is followed for a line replaceable unit, i.e., the unit is replaced after every so many running hours, this number of running hours should be determined. Further, the maintenance actions for all units have to be coordinated, in order to keep the number of maintenance visits acceptable.

With a product structure and a maintenance plan in place, it is time to think about the service logistics that are required to support the maintenance. First, the service supply chain or repair network needs to be designed, which includes the choice of locations of facilities at multiple echelon levels (e.g., local, intermediate and central repair and stocking locations). Next, the level of repair analysis can be performed, in which it is decided where to repair each type of component in the repair network and where to install capabilities such as test and repair equipment. After that, the locations and number of required resources can be determined: the spare parts inventory levels can be set, and the required numbers of service engineers and pieces of tooling can be determined.

The research that I propose to work on in the next ten years can roughly be divided into two types. First, the research on maintenance & service logistics. For that research, typically other disciplines are relevant and research projects will be interdisciplinary. However, the second type of research is itself of an interdisciplinary kind: There are many problems on the interface of maintenance & service logistics and other disciplines that I find interesting. Both types are discussed next.

I. Research on maintenance & service logistics

For me, the key questions in the field of maintenance & service logistics are: How to design and optimize maintenance plans, how to design a service supply chain and how to determine the locations and numbers of required resources. These questions can be answered using techniques from stochastic operations research, e.g., inventory theory, Markov decision processes and renewal-reward processes. I am specifically interested in how decisions interact. Below, I give some examples of this in my past research. One important decision that greatly influences other decisions is whether or not to invest in new technologies, such as drones, big data, the internet of things, and additive manufacturing (i.e., 3D printing). For example, the use of additive manufacturing technology means that spare parts can be printed on demand close to the capital equipment, which greatly influences the design of the service supply chain and the numbers of spare parts to stock. It is important to understand under which conditions it is beneficial to use the new technology.

I have worked on the combination of level of repair analysis and spare parts inventory levels (Basten et al., 2012, 2015) and on jointly determining the spare part stock level for a repairable spare part and the expediting policy in the repair shop (Arts et al., 2016). Specifically interesting is the interaction between on the one hand unplanned, corrective maintenance and planned, preventive maintenance and on the other hand required numbers of spare parts stocks. I have worked on spare parts inventory control for both planned and unplanned maintenance when allowing flexibility in rescheduling planned maintenance (Basten & Ryan, 2015) and I am currently working on optimizing jointly maintenance and spare parts decisions with Postdoc Sena Eruguz. With PhD student Bram Westerweel I am working on the effects on the service supply chain when choosing between a regular production technique and additive manufacturing. The relation between the line replaceable unit definition and spare parts inventories is something that I like to work on in the near future. Master students that I have supervised have already worked on this topic at various companies; I have worked on the line replaceable unit definition by itself (Parada Puig & Basten, 2015).

There is a lot of interest in these problems in industry. This gives good opportunities to get research funded, especially through the TKI Dinalog. Many problems also fit under Smart Industry. Given the relevance of the research and given that many of the combinations of topics have not been treated in the literature, it is definitely possible to publish the results in good journals.

II. Research on the interfaces with maintenance & service logistics

There are many important interfaces with maintenance & service logistics. I find it interesting to work on those topics, using other research methodologies, and I believe that it helps to better model the problems of the first type, making results in that category more relevant. I distinguish three lines of interdisciplinary research to work on in the next ten years.

First, when desiginging new capital equipment, it is important to already consider the later maintenance & service logistics, i.e., design-for-maintenance. How to do this, is a question that can be answered with interdisciplinary research with people in design engineering. I have worked with two PhD students on topics in the area of design-for-maintenance. One of them is Wienik Mulder, whom I supervised together with Juan Jauregui Becker (University of Twente), who has a background in design engineering. My knowledge on maintenance and service logistics has helped the project, while the project has helped me to better understand how product developers work and where models from operations research can contribute. I'd like to continue this research and I have ongoing discussions about this with Juan. This research can get funded through Smart Industry calls.

Second, methods and algorithms that are developed in the first type of research are implemented in decision support systems (DSS), but users of DSS often deviate from the advice generated by the DSS. To find out why this happens and how to resolve this, interdisciplinary research is required with people in human performance management or human technology interaction. The key question is how to improve the acceptance and effectiveness of inventory planning systems or other decision support systems. A PhD student on this topic, Bregje van der Staak, has started in September 2016, and a Postdoc will be hired per September 2017. Because of the combination of empirical work and mathematical modeling, this research has the potential to be published in top journals. The potential impact in practice is significant too, since there is a lot of potential to improve the way in which models are implemented and used. The research can be funded through the TKI Dinalog.

Third, companies that develop and maintain capital equipment need to be able to make money. More and more, original equipment manufacturers do not only sell a product, but they are also responsible for the spare parts supply (e.g., vendor managed inventory) or the complete upkeep of the products that they have sold (e.g., performance based logistics). Servitization is the process in which companies develop from selling products to selling services. This process needs to be supported jointly by people who have an understanding of maintenance & service logistics, and people in marketing or game theory. Using cooperative game theory, I have already worked on the pooling benefits between multiple users of the same spare parts, and how to share the costs and benefits (Karsten & Basten, 2014). I am interested in the question of whether or not performance based contracts induce the supplier of a system to improve the reliability of its system. Again, this research requires both empirical and modeling work. Because of that and because of the relevance of the topic, this research has the potential to be published in top journals. The potential impact in practice, given the amount of money that users spend on maintenance annually, and the interest that I see in this topic in practice, is significant too. The research can be funded through the TKI Dinalog.