

Preface

This book is based on a Ph.D. research that has been conducted at the Delft University of Technology in the Netherlands in collaboration with Dutch Electricity & Gas Distribution Network Operator, Stedin. This book was written as a result of wider interest that was shown by different industry groups on this topic after its public defence. This inspired the author to modify and publish a practical version of the research for a greater international audience. Therefore, the content of this book is intended for a double audience, on the one hand for those interested in the organisational and management aspects of maintenance. On the other hand for those interested in practical-developed methods for applying maintenance concepts such as reliability-centred maintenance (RCM) within the risk management regime of the organisation, statistical tools for predicting failure behaviour and the upcoming role of condition monitoring, hence a more concept- and a technology-oriented aspects of maintenance. The intent has been to provide the reader with an in-depth treatment but without excessive specialisation. Because of the research nature of the book and in order to avoid a purely qualitative treatment, some numerical and analytical methods together with real case studies are discussed.

The author spent about four years writing the thesis that also resulted in this book. The material in this book evolved from a large number of practical asset management and academic engagements between the author and researchers, utility engineers, managers and C-level decision-makers. Hopefully, this collaborative process that took place over the years has resulted in a book that is both interesting and practical for researchers, engineers, managers and educators in the field of asset maintenance management.

The author wishes to the many people that have, directly and indirectly, helped and supported this research process. Specifically, the author would like to thank Stedin (Dutch Distribution Network Operator) and Delft University of Technology in the Netherlands for the great collaboration, support and research funds. The author would also like to that Springer for supporting the preparation of this book

and the pleasant cooperation. Last but not least, the author would like to offer a special thanks to his families and friends for their invaluable inspiration and support.

Presently, the maintenance of assets is widely undergoing changes towards well-founded forms of maintenance management in infrastructure utilities such as electricity, gas and water. These are mainly driven against the backdrop of stringent regulatory regimes, ageing asset base, increased customer demands and constrained financing. Therefore, it becomes imperative for infrastructure utilities to strive towards more effective and efficient operation and maintenance approaches. In this light, new asset management approaches such as risk management are gaining more interest worldwide. In this research, the focus has been on the further development of maintenance management in electricity network organisations. It covers the development and practical application of enabling factors for maintenance management such as organisation capabilities and maturity levels, structured and comprehensive frameworks for assessing maintenance policies and decision-making support tools and technologies. Thus, an integral, multidisciplinary approach towards maintenance management needs to be established, which is a challenge that has been taken up in this thesis for electricity network companies.

Well-founded and effective maintenance management for existing electricity network assets provides a blueprint for sustainable investments in the future. In this context, risk-based maintenance regimes are intended to ensure higher efficiency and ultimately establish a broader view on maintenance as a business function. From this research, we have found that electricity network organisations who strive towards well-founded maintenance management as a business function will need to have structured frameworks in order to find efficient and practical mixes of maintenance activities beyond the sole technical aspects of maintenance. It is recommended that maintenance departments will need to function in a broader sense and move away from “silos” thinking. This requires systematically adopting multidisciplinary organisation domains into maintenance management and the continuous measurement of the development and improvement of these dimensions by means of maintenance maturity models and maintenance key performance indicators (KPIs). Risk-based maintenance management is recommended and will need structured comprehensive frameworks, analytical tools and technological methods for developing and supporting maintenance management decisions.

In current maintenance organisations, we observe shortcoming and gaps between strategic, tactical and operational levels. In many cases, not all organisation-related factors are thoroughly considered in the strategy for maintenance, which results in an unclear situation when translating these factors to maintenance concepts, policies and actions. In this research, an organisation-wide (multidisciplinary) maintenance management structure has been introduced and evaluated in practice. In this structure, the approach has been to add organisational aspects of influence, which are not confined to technical factors only. Improvements will be steered from a point of view which interacts with other non-technical, however, essential, aspects of maintenance management, e.g. aspects such as, organisation and processes, information systems and data requirements, portfolio planning, compliancy, policy

and criteria. A Maintenance Management Maturity Model (M4) has been introduced and practically implemented. Principally, the M4 is developed for assessing and monitoring a set of multidisciplinary domains which are necessary for maintenance management professionalisation. With the aid of this model, the maturity levels have been assessed in 2012 and 2014 for gas and electricity network assets. Reviewing these maturity levels makes insightful which domains have improved or not. This approach enables continuous improvement for maintenance management organisations on strategic levels.

Evaluating our goal of professionalising management of maintenance, we have found that the adoption of systematic and methodical approaches, especially on tactical level, is essential. In this research, a structured and methodical maintenance management model has been established. This model is based on the well-known reliability-centred maintenance (RCM) method which has been expanded to include and interrelate to the corporate risk management model and business values. The established model provides a method in which risk is added to the traditional RCM method in order to cope with the consequences of functional asset failures on multiple corporate business values. Once such a risk-related maintenance concept is introduced, any (existing or new) maintenance policy and maintenance action can be assessed and expressed on its financial, technical and other business values such as safety, image and environmental consequences in terms of risks. This new method we developed is named utility risk-linked RCM. The method has been applied to a case study for power transformers and has been found to be a practical and comprehensive method for utility risk-based maintenance management.

The utility risk-linked RCM encompasses a comprehensive integrated approach for risk-based maintenance management. For practical robustness, we have investigated additional analysis methods and technological tools to support data-driven decision-making. Statistical life data analysis (LDA) has been applied, which forms a method to deal with the failure behaviour of assets, which is highly stochastic. We have found that failure data and in-service data of assets, when recorded, can be processed to give useful estimates of statistical failure distributions. These statistical approaches are useful for the analysis of populations of assets providing information on failure rates, probability of failures and age-based remaining life of (large) populations. This is known as a top-down approach and forms an important link between tactical and operational levels.

In the bottom-up approach, the upcoming role of condition monitoring technologies, which have been provided in terms of asset management implications, has been described as well as the perception of utilities towards the adoption of these technologies. We have observed that distribution network utilities are rather reluctant regarding large-scale deployment of such technologies. In many cases, this is due to high initial investment cost, data interpretation challenges, unclear frameworks to relate condition data to strategic implications or the readiness and reliability of the technology itself. However, in recent years, technologies have developed and are becoming financially and technically more attractive. Frameworks are needed, as has been found from benchmark surveys, to understand and interrelate the upcoming role of condition monitoring into the overall

maintenance management organisation. A condition monitoring framework is developed which forms the basis for establishing condition-based maintenance regimes. Such a framework can be adopted by asset management companies as a guiding principle for identifying the relationship between failure modes, ageing processes and to select amongst condition monitoring methods.

The research objective and questions, which have been addressed throughout this research, show the apparent gap between maintenance management and operational parts in electricity distribution utilities. Each research question is addressed by means of empirical research approaches which include survey studies, practical case study on implementation, data analysis methods, field measurements and development of methods based on field observation and analysis. Based on the addressed research question and the applied research methods, the overall objective of this research has been addressed on aspects such as enabling well-founded organisation of maintenance management, the introduction of risk management and business values into maintenance and the application of statistical and sensor-based analysis of failure behaviour of assets. Further progress can still be made in several areas, and therefore, we recommend future research in areas such as expanding the utility risk-linked RCM method by modelling external (third party) risks into it, which will require different sources of data. The predictive nature of risk and condition-based maintenance management implied a possible new era for OPEX budget planning methods, a research area that is recommended for future work. In the quest towards advanced management of infrastructure utilities, a research recommendation is to answer the question how decisions that are made in the present time (investments, maintenance, replacements, etc.) ensure over a certain period of time the output that is expected from network companies by regulators and whether this supports, restrains or discourages investments in technologies. Research of network capacity and maintenance planning, which are nowadays separated, is needed given the increasing complexity of electricity networks.

Having concluded and said this, we want to highlight that at the moment of writing the electricity sector is amid a continuous process of quickly changing environments due to unbundling of organisations, process improvements, takeovers and mergers, partnerships, outsourcing, etc. This is due to the dynamic business environment in which electricity network businesses operate. Therefore, we want to emphasise the continual developments in the area of maintenance management of electricity networks, hence the nature of this research is an ongoing research area for coming decades.

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