3 Modeling and Metrics

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3.1 Introduction

Selection of appropriate maintenance actions and strategies for preventive maintenance depends on our ability to accurately predict component deterioration, and its impact on overall system performance. The ability to predict component and system behavior under uncertainty depends on the selection of appropriate modeling methodologies that allow decision-makers to represent the complex system interactions at required fidelity and capture the impact of component deterioration or failure on overall system performance. Another important factor affecting the selection of an appropriate modeling framework is the performance metric or objective function used to monitor the performance of maintenance plans. In most cases, selection of appropriate modeling tools and metrics is key to developing successful predictive maintenance systems.

This section presents a collection of four papers that cover a range of modeling methodologies and metrics used to quantify maintenance management performance. The modeling approaches presented in this section range from analytical to computational, and the performance metrics considered range from myopic or local to long-term and global. The first two papers (Dubi, and Borgia et al.) present the use of novel analytical modeling methodologies for maintenance management optimization. The second set of papers (Zille et al., and Caputo et al.) use state-of-the-art computational modeling frameworks to capture the interactions between components in complex systems and assess the performance of various maintenance strategies and consider performance metrics that are quite different from the standard criteria used to evaluate maintenance management systems. Contributions of each of the papers are highlighted in the following paragraphs.

The first paper (Dubi) presents the use of Monte Carlo methods for solving complex maintenance optimization problems. The author describes the maintenance problem in a logistics and service part delivery setting, where not only the field service operations are modeled but also the logistic envelope that is necessary to support the maintenance operations in the field is modeled. Various objective functions and constraints are considered, ranging from spare part levels, waiting time, to repair resource limits. This paper highlights the efficacy of Monte Carlo methods for solving the joint spares and maintenance optimization problem, which would be extremely difficult to solve using traditional methods.

The second paper (Borgia, De Carlo, Peccianti, Tucci) presents the use of Dynamic Object Oriented Bayesian Networks (DOOBN) for modeling reliability of
complex systems where the conditional probabilities of success/failure of system components are time dependent. The object oriented formalism allows one to encapsulate sections of the causal network into single nodes, thereby simplifying the complex graph into a series of small ones. Borgia and colleagues demonstrate the capabilities of the DOOBN modeling approach using the case study of a compressed air production system. The case study clearly shows the advantages of modeling time dependent probabilities in estimating the reliability of the compressed air system during summer and winter months.

The third paper (Zille, Berenguer, Grall, Despujols, Lonchampt) uses Stochastic Synchronized Perti Nets (SSPN) coupled with Monte Carlo simulation to develop a computational framework to accurately capture component deterioration, system operation, system dysfunction, and maintenance actions. The component level model and the three system level models are developed and validated independently. They are then coupled by means of interactions in order to simulate the complete system behavior in presence of specific maintenance actions. The strength of this approach lies in the ability to create models of detailed component behavior separately from the maintenance actions.

The final paper (Caputo, Pelagagge) presents a quantitative approach that integrates risk and cost-benefit analyses in order to select cost effective maintenance policies that have acceptable levels of risk. The methodology presented by Caputo and Pelagagge is based on quantifying top level events using fault trees, then conducting sensitivity analysis on the occurrence of these events, and finally using this information to compare corrective measures based on cost and effectiveness criteria. They present the application of this methodology that explicitly incorporates risk in the selection of maintenance policies using a case study of a chemical processing plant that uses highly toxic and flammable materials. This case study highlights the need to consider risk as a performance criteria in addition to overall cost when selecting maintenance policies.