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Analysis of Maintenance Operations: A Case Application

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INTRODUCTION

Maintenance is one of the most important operations in industrial and service systems, which use various types of equipment and machinery in the production of goods and delivery of services. All systems are subject to deterioration with usage and time. As a system deteriorates, its efficiency and productivity decreases. To keep production efficiency high and to maintain good product quality, preventive maintenance is necessarily performed on systems subject to deterioration. The cost of maintenance related activities in industrial facilities has been estimated by Mobley (1990) to be as much as 40% of total costs. Due to increased automation, artificial intelligence, and information technologies, equipment has become more complex and various modes of maintenance activities are implemented by managers to keep them in available state. Basic modes of maintenance include corrective maintenance (CM), which is performed when equipment fails, and preventive maintenance (PM), which is a scheduled maintenance planned in advance. It should be noted that preventive maintenance is different from pre-emptive maintenance. While pre-emptive maintenance plans are considered at the design stage to eliminate the maintenance requirement, preventive maintenance plans are applied during equipment operation in order to eliminate failures.

Optimization of maintenance operations and minimization of related costs has been subject of extensive studies. Literature abounds with many studies in this area. Several applications and case studies show the success of maintenance modeling and analysis in improving system performance and productivity. Chan et al. (2005) discussed issues of total productive maintenance in the context of a case study in electronics industry. Maintenance models for production system with intermediate buffers have been studied by Kyriakidis and Dimitrakos (2006). Leon Hijes and Cartagena (2006) presented a maintenance strategy based on equipment classification using a multi-criterion objective and Carnero (2006) discussed a procedure for setting up a predictive maintenance program using detailed system evaluation. Baraldi et al.(2012) presented a modeling framework for maintenance optimization of electrical components based on fuzzy logic and effective age. A hybrid approach based on Monte Carlo simulation method and fuzzy logic is applied to the problem to evaluate the performance of a given maintenance policy. The proposed methodology is successfully applied to a real case dealing with a medium-voltage test network. Martorella, et al. (2010) presented a maintenance model and optimization by integrating human and material resources. An application case is studied to optimize the maintenance plan of a motor-driven pump equipment by considering maintenance and test intervals and human and material resources as decision variables. Horenbeek et al. (2010) also presented maintenance optimization models and criteria. A literature review on maintenance optimization models, with special focus on optimization criteria and objectives is presented. Factors that have influence on optimization models are made explicit and their links are established. Waeyenbergh and Pintelon (2004) studied a case for maintenance concept development. Wang, et al. (2010) studied a case of condition based maintenance modeling based upon the oil analysis data of marine diesel engines using stochastic filtering. A decision model for

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optimizing the replacement time of the diesel engines conditional on observed measurements is derived and applied to the case problem. Savsar and Youssef (2004) and Savsar (2005, 2006a, 2006b, 2008, and 2011a) developed discrete mathematical and simulation models to analyze the effects of preventive and corrective maintenance policies on serial production lines and flexible manufacturing systems. A detailed maintenance analysis in the context of a plant has also been presented by Savsar (2011b). Abdulmalek et al. (2012) discusses the effects of maintenance policies on manufacturing productivity. Savsar and Abdulmalek (2012) discuss aircraft maintenance issues in a case application.

While most of the studies related to reliability and maintenance analysis are theoretical, limited numbers of practical applications are published in the literature. In this chapter, a case application is presented with detailed discussion of maintenance modeling. Procedures are presented for applying basic formulations to estimate various maintenance related parameters from available data and to determine best maintenance for system efficiency. It is well known that equipment failures occur due to wear outs and random causes. While random failures cannot be eliminated totally, wear out failures can be eliminated by PM operations and thus a reduction in CM can be achieved. The exact effects of PM operations in reducing CM frequency are illustrated by case application. Furthermore, determination of optimum spare part order quantities for critical spares and cost analysis with respect to effectiveness of PM operations are outlined with the case problem. Procedures and analysis outlined and applied to the case example in this chapter will be useful for engineers and maintenance managers in practical applications. In particular, maintenance managers can collect operational data for the equipment and follow the same procedures outlined in this chapter to analyze system performance under various failure/maintenance conditions in order to reduce down times and improve system productivity.

CASE APPLICATION FOR MAINTENANCE MODELING

In this section, a case example from an oil filling plant is presented. In order to perform maintenance analysis, data was collected for one year from the maintenance records for both repairable and non-repairable parts. Repairable parts are listed in Table 1. Maintenance related parameters, such as Mean Time Between Failures (MTBF), Mean Failure Rate (λ), and Mean Time to Repair

Table 1. Maintenance calculation of repairable parts

Repairable Parts	$MTBM_{ct}$	$MTTR(M_{ct})$	$MTBM_{mt}$
Welding Pipe	650.000	1.730	499.05
Pipe Machining	431.041	3.436	359.04
Pipe Lathe	256.957	3.757	229.52
Pipe Cutting	1151.438	0.688	749.79
Changing Pipe	2246.833	1.833	1098.54
Blocked Pipe	4296.000	2.000	1432.66
Pump	301.771	2.417	364.62
Tank	783.250	2.179	574.05
Non-Repairable Parts	$MTBM_{ct}$	**MTTR***	$MTBM_{mt}$
Sensors	894.5	1.972	631.602
Finger	1354.0	1.770	830.70
Bob Ring	2735.0	1.750	1203.50

MTTR* = Mean Time to Replace, not Repair