Profit-Driven Maintenance for Physical Assets

third edition

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Foreword

The aim of this book is to provide all those involved in maintenance with the tools to demonstrate the real contribution that this maintenance function can make to the profit or profitability of their organization. The book is the result of lectures, research and investigations into the applicability of maintenance methods to demonstrate possible profitability and the added value of the maintenance function for a company.

During my professional career, when applying a number of well-known methods for developing maintenance concepts and maintenance plans, I discovered some years ago a missing element in most of these methods, namely that a direct line to improvements or even the profit of the organization was not clear as a result of their application. Often I have heard the questions, why are we applying this method and where can the profit be found? This is the main focus of this book and is also my main research subject. The question is: is it possible to demonstrate that maintenance as a business function can make its contribution visible to the profit of an organization? With the help of the developed simplified business relation model, the overall equipment efficiency and the concept of maintenance need, it is possible to create a direct line to potential profits for each well-known maintenance method.

Supported by the ideas of Integrated Design and Engineering, and of Operational Excellence, it is also possible to create a 'House of Excellent Maintenance' which can be used to qualify the quality of the maintenance function for each organization. In addition to these maintenance methods, continuous improvement, information technology, and organizational and personal skills also belong to this House of Excellent Maintenance.

In this book, the maintenance function is considered purely as a business process, which means that not only are the technical aspects important, but also the financial ones. There must be a balance between these two aspects of technique and economics, which is indicated as 'technomics'. For all maintenance people this balance requires a major change in attitude, *a real paradigma shift*, from a pure technician to that of a business technomist.

A wide range of practical investigations have been carried out over the years by my students about the applicability of the developed methods, and the results demonstrate a significantly improved level of profitability for the maintenance function. Huge increases in the Overall Equipment Efficiency (OEE), and significant decreases in the costs of maintenance and man-hours, are found. All the case study examples contained in this book are based on these investigations, undertaken in a wide range of industries, including the building environment, energy generation, transport and public services. At this point I should mention the investigations of Mark Tammer, Herbert Kreuzen, Cor Vogel, Frits Neuteboom, Martijn van den

Heuvel, Frank Verkuijlen, Jan Stoker, Danny Hartman, Andreas Casanova, Gerwin Luiken, Peter Lens, Peter Loos and Klaas Knol, among many others.

I am also very grateful to my colleagues from the Masters course in Maintenance and Asset Management at HU University of Applied Sciences (HUUAS), who have given their comments on parts of the content of this book, especially Gerard van Gils, Peter Van Gestel, Auke Hofstra and Cyp van Rijn. In addition, I would also like to thank Marc Pallada and Mark Tammer for their helpful comments.

Thanks to the management at the Department of Life Sciences and Technology of the HUUAS for their stimulus to write this book, especially Andre Henken, Annemarie Slootweg, Lydia van Dalen and Sil Bruijsten, and also my former secretary Janny Bakker. They have all given me tremendous support over the years, in addition to promoting the ideas and concepts about integrated design and engineering.

Special thanks are due to my dear wife Ine for the many hours she lent me to empty my mind of numerous ideas about maintenance as a high quality business function.

Main questions about Maintenance and Asset Management

In this book I have attempted to provide answers to the following main questions around the maintenance function:

- Does our company possess the appropriate physical assets to fulfill the company's mission, vision and goals in terms of highest Return of Investment (ROI), highest production output, and lowest operational and Life Cycle Costs?
- Does our company satisfy the requirements of the International Asset Management Standard ISO 55000?
- Does our company fulfill the maintenance function required by the assets to generate the highest possible output at the lowest possible maintenance cost? Is this achieved within the limits of environmental, health and safety laws, rules, and regulations?
- How much maintenance is just enough to fulfill our mission, vision and main goals?
- Does our maintenance department apply the correct methods to ensure that profitable maintenance concepts and plans are visible?
- Does our maintenance department possess the right people with the proper skills to fulfill the maintenance function in a profit-driven manner, and can it communicate the results in a business economic way?

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August 2016

Introduction

In company boardrooms the word *maintenance* often gives board members an uneasy feeling. Why is this the case? The main reason in my opinion is the way in which top management think about doing business. They generally think, speak and discuss opportunities, profits, risks, added value, and costs for their business. On the contrary, the maintenance manager generally thinks in terms of techniques, failures, technical problems, and workforce schemes, and not purely in costs and benefits. Maintenance costs are seen as penalties from 'on high' and maintenance as a function is not seen as an opportunity for business improvements, or even as a quality factor.

On the other hand, we have a bizarre maintenance paradox. Top managers often own luxury private assets such as houses, cars, yachts and aeroplanes. When you consider how they handle these assets in relation to maintenance and operation activities, a completely different attitude is evident. There are no low or lowering maintenance costs, no savings on personal or operational expenses. These assets have to show an excellent performance when the owner is displaying them in the public environment. We see a big gap between these two worlds, and the main intention of this book is to try to bridge the gap, in the way that maintenance should be treated as a business process to fulfill the company's main goals in a profitable way.

The ownership of physical assets, such as production plants, machines, buildings, cars, power generating plants, etc., involves a source of continuous care and attention by the owner in order to maintain the function of these assets to the intended level of output for which they were bought. The operation of these assets, together with outside influences such as weather conditions, means that they will continuously show forms of wear and tear and other forms of deterioration. By carrying out restoration or repair activities it is possible to bring these assets back to their original level of operating or original functional level. This is a never-ending process and is known as 'maintenance'. So, maintenance is a process of continuously maintaining the function or state of a physical asset. The maintenance function is fulfilled by a department which has the objective to organize the maintenance or restoration activities for the assets involved in the most profitable way, or in other words 'to reach the highest level of output against the lowest possible operating cost', or lowest Total Cost of Ownership and highest Return on Investment.

In this book we will treat the maintenance function as a pure business-driven process to fulfill the challenge of organizing the maintenance activities for the asset owner in the most profitable way, so that the owner can be as equally proud of his business assets, as he already is of his private ones.

The developed House of Excellent Maintenance, which is based on the principles of Integrated Design and Engineering and Operational Excellence, provides the guidelines which the maintenance function can follow to ensure that it is really

profit-driven. All the methods that are presented are related to business models and they have to prove their capabilities to generate profit for the company. Most of these methods are already well known, but in this case are always applied in relation to making profit for the maintenance function.

For top managers and senior staff this book can give an insight into why maintenance has to be continuously undertaken on the company's assets, and how it is really possible to control the maintenance function as a high quality, profitable business process.

For maintenance managers this means having a view of the maintenance function whereby it is not only technical matters about the physical assets that are important, but where the business context within which these assets are working also needs to be considered, including the economic and business way of thinking about the assets. So we present a lot of business economics beneath the methods for developing the best maintenance plans for the business. This view also means that the maintenance manager has to communicate with top management on the subject of business economics to fill the aforementioned gap. In addition, attention is given on how to present and implement improvement ideas in an organization, and the importance of information technology as an information source and knowledge instrument.
For maintenance and reliability engineers these methods are presented in order to improve their capabilities of making the maintenance function profitable. Integrated Design and Engineering and Operational Excellence are the guidelines through which the maintenance function can really be made profit-driven.

Calculation methods are introduced to evaluate project proposals on the basis of business economic issues and reality. Continuous improvement instruments are presented for improving the maintenance function in a profitable way.

The book can also be used as an introductory text for lectures, on the subject of maintenance management, in universities and higher education courses. It is applicable not only for engineers, but also for business administration. It contains many examples, case studies and exercises. Already thousands of students are trained in this way of thinking about profitable maintenance.

For manufacturers of equipment it presents methods to create added value for both the client as well as the manufacturer, by means of long life service co-operation.

Also, service organizations that tender for maintenance outsourcing activities will find a range of ideas on how to make their offers, for every form of outsourcing, more profitable. This is applicable to both the asset owners and the contractors themselves.

Guide for the reader

This book is written for everybody who deals with the maintenance function of their organization; so it is not only for maintenance people, but also for top management and senior staff, especially the financial staff members. The maintenance function of an organization, if it is correctly organized, will be a proven profit and quality factor for the daily production operations. This is because it maintains and improves the output of the physical assets in terms of production rates of high volume and quality against the lowest possible operational costs, so creating maximum added value for a company. In addition to profitability, it also creates the right attitude and surroundings for aspects such as low Life Cycle Costs, high assurance rates, a safe working environment, low energy consumption figures, sustainability and durability.

This book is based around the ideas of Operational Excellence and Integrated Design and Engineering. When these two are combined, a 'House of Excellent Maintenance' can be constructed. An important factor in making this house a success is the structure of the organization. Those organizations with a strong hierarchical structure, incorporating high walls around divisions and departments, will have difficulty in adopting and implementing these ideas of high quality maintenance. To reach the level of Operational Excellence it is necessary to break down these walls. The first requirement is that all departments of the organization must join in and co-operate in an intensive and open manner.

A high quality maintenance function can show its profitability for an organization in terms of high quality production output, and lowest-in-class maintenance and operational costs. The maintenance function, therefore, should be a factor considered at board level because of the impact it can have upon both quality and profit.

The boardroom table is mostly made of high quality wood. And above this table is where the top management take its decisions ('above the wood' in Dutch is '*bovenhoud'* and this word is a 'speech clipping' of the Dutch word *'onderhoud'* which in English means maintenance). It is also here where the maintenance function must show its value as a contributory factor to the profit. So let them know you are out there. If the maintenance function does not exist on the top management agenda, it will be treated as a simple lubrication function and the maintenance manager as a lubricator (the man with the oil can).

High quality maintenance must have a balance between business economics and technique, which in this book is referred to as '***technomics***'.

For maintenance management the application of the ideas of profit-driven maintenance mean that a totally different attitude is required for the maintenance function, in that it has to be turned from pure technique to a business economic attitude. From pure technique orientation to a technomic attitude, with the mission,

vision and main goals as guidelines, and business considerations and calculations as the basis for its decisions. Also part of this change is how best to bring the proposals for improvement to the table of top management with the right business economic arguments underpinning the technical ones. This transformation in attitude is required not only from management, but also from reliability and maintenance engineers. It also requires another way of communicating to the other departments and top management, with difficult technical problems explained in a business language focusing on the solutions of problems with possible profits, lower costs and added value; in short a 'profit-driven language'.

Advice to the reader on how to use this book

For top management and senior staff it is recommended to read, in particular, chapters 1, 2 and 3, and perhaps chapter 5.

Maintenance managers are advised to read all of the chapters.

Reliability and maintenance engineers are advised to read chapters 3, 4, 5 and 6 in particular.

For students on maintenance courses, it is particularly advisable to read chapters 1, 2, 3, 4 and 5.

Brief content description based on the eight Operational Excellence aspects

Chapter 1: House of Excellent Maintenance
Mission, vision and goals of an organization as the guidelines for each maintenance function. Ideas of Operational Excellence and Integrated Design and Engineering are presented and combined as the 'House of Excellent Maintenance'. Ideas about Asset Management from the international standard ISO 55000 are introduced and compared with those of the House of Excellent Maintenance.

Chapter 2: Selection of the Right Assets to Meet the Company's Goals
How can the best assets be selected to fulfill the mission, vision and goals? Or do we have the best possible assets in-house to fulfill our job? This selection is also a typical technomic activity, because financial, economic and technical factors have to be in balance for the correct choice. A simplified business model is presented which makes it possible to link the outcomes of the maintenance activities to the profit and the ROI. The ISO 55000 standard is also applied here, to give guidelines for managing physical assets.

Chapter 3: Maintenance Policy
How to derive the right maintenance policy in line with the mission, vision and goals of the organization? The introduction of the concept of 'maintenance need' makes it possible to construct a very elegant model to show a direct relationship between maintenance activities and the contribution to the profit of an organization. A pyramid of KPIs for connecting maintenance activities to the ROI of a company is presented.

Chapter 4: Maintenance Concepts and Execution Plan
A number of well-known methods, including TPM, RCM and FMECA are combined with the ideas of Integrated Design and Engineering, and applied to construct the right maintenance concepts for a given situation, making it possible to derive the basic maintenance plan and the maintenance execution plan. These are also both necessary to make the right decisions for outsourcing, and for manufacturers of equipment to draw up the appropriate long life service contracts.

Chapter 5: Continuous Improvement
In modern organizations continuous improvement is the backbone of innovations in existing activities and processes. The driving force is how to make our activities continuously more profitable. With the help of the simplified business model an innovation agenda can be put together. Also here, a technomic attitude will be necessary to make improvements profitable. A number of well-known methods, such as Lean, Six Sigma, Value Engineering, etc., are presented, and their role in improving the maintenance organization is discussed. Small group activity and working in multi-disciplinary teams composed from all relevant departments are the

basis for ensuring successful improvement activities. An introduction to improving the performance of business processes is presented, complete with a guideline on 'how to implement improvements in the organization'.

Chapter 6: Maintenance Information Systems
It is always astonishing to see how poorly information technologies and systems are implemented in technical surroundings. This is not only the case in the field of maintenance, but also within design and engineering departments where the same situation exists. Information quality urges for an organizational attitude of co-operation between departments, with open walls between them, and also for standardization of methods. Methods are presented to develop proper information structures, models, and codes that make it possible to use information as a knowledge storage and generator for the maintenance function. Developments such as the Internet of Things, Cyber Physical Systems, augmented reality, and virtual reality, are changing the way in which maintenance departments work.

Chapter 7: The Maintenance Organization as a Business Unit
This chapter looks at organizational and competency issues. Depending upon the situation of a company, elements are developed to make it possible to create the best organizational structure for a maintenance organization. In addition, the necessary competencies required to make a maintenance organization world-class, or operationally excellent, are presented.

Each chapter ends with summaries of the following points: where is the profit, what did we learn, and what kinds of skills and competencies do we need?

Table of Contents

Somewhere in the middle

The real test of integrated, optimized Asset Management is when the top-down managerial expectations, budget-setting and performance targets, and the bottom-up capabilities, opportunities and prioritization, are lined up and transparently linked. This is where the lubrication and human issues become so important (every company that has really established a successful asset-centered performance leap says that this turned out to be the critical bit). The tools and techniques, reorganizations and performance measures all help to make things possible, but ultimately, it is people who make them happen. So, in conclusion, the hearts, minds and collaborations are where good Asset Management lies: don't stint on *education*, *communication* and *cross-functional teamwork*!

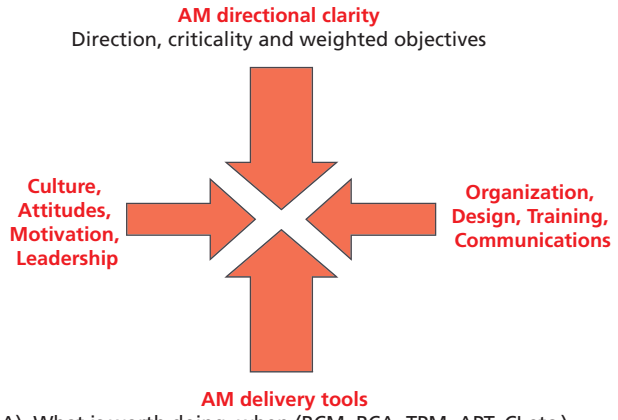

Figure 1.16 Top-down, bottom-up and middle-lubricated

1.5.14 Profit-driven maintenance and Asset Management

The ISO 55000 standard provides guidelines for organizations to set up an Asset Management system, with only the 'what' of the system, but it does not provide further information and specifications of 'how' to do so. The same applies for GFMAM's guidelines (the Asset Management Landscape with 39 subjects; see 1.5.7.2), which describes a body of the Asset Management knowledge; information on how to estabish this body of knowledge is also lacking here. This means that organizations have to figure out for themselves how to fill these standards (empty boxes) with the right content and ways to implement these standards.

Many of the ideas formulated in the Asset Management documents presented in this book (ISO 55000, PAS 55 and GFMAM) are very similar to those of Integrated Design and Engineering, Operational Excellence, the House of Excellent Maintenance and Profit-driven maintenance. This is particularly true in relation to the following aspects of business: an organization with an open approach where departments are working simultaneously together; the drive to make profits and continuous improvement; the

by creating a functional decomposition of the asset (system) and investigating how critical each (sub) function of the system is for the whole system. The criticality can be determined by the Criticality Matrix (section 4.6.3). So, for each functional failure we will investigate if this failure will stop or create a serious problem for the main function. Only the critical functional failures will be further investigated on criticality, and for all other functional failures we will go directly to task selection. This means in practice up to 80% less paperwork and a better overview.

The Hamburger model of the full system gives us, by colouring these hamburgers from green, via yellow and orange to red, a direct insight in the criticality of the whole system. Green stands for 'no problem, things work even better than expected'; yellow means normal, as expected; orange tells us that there is room for improvement, and red means trouble. So in one view everybody can see what the areas of attention are. We call this method the Functional critically RCM Method (*Fc*-RCM method).
See figure 4.21 for a simple example, a bike.

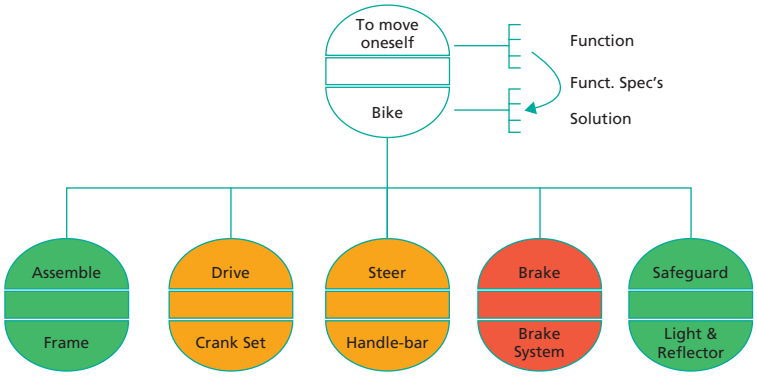

Figure 4.21 Hamburger model for an overview of possible problems

To develop the maintenance concept on the basis of the *Fc*-RCM method we apply the following eight steps (see also figure 4.22):

1 System selection and sampling of information about the system.
2 System boundaries, what is in the system and what is not.
3 System functions description, and functional block diagram and decomposition.
4 System functions and functional failures.
5 Functional critical Failure Mode and Effect Analysis (*Fc*-FMEA).
6 Establish criticality of the functions by Functional Consequence Analysis (FCA).
7 Maintenance task selection.
8 Basic maintenance plan.

Firstly we shall discuss the Criticality Matrix (step 5 and step 6), the *Fc*-FMEA (step 5) and FCA (step 6) methods. In section 4.7 we will illustrate with an example how we can apply the eight steps of *Fc*-RCM for the development of a maintenance concept.

corrective actions that might be taken to prevent an accident; a validation column is applied to check on whether the recommended solution has been realized.

Hazard Analysis Table

In the Netherlands a lot of companies have developed tables (sometimes even named the FMECA table!) for use in their internal analysis when investigating hazardous situations. See the 'as an example' matrices shown in table A3.5, and table A.3.6 indicating the way in which the Dutch railways apply such a table.

Table A3.5 Risk management matrix

Potential consequences						Failure frequency with consequence				
						1	2	3	4	5
Severity	Safety	Health	Environment	Economics	Quality	< 1×5 year	> 1×5 year	> 1×1 year	> 1×1 month	> 1×1 week
1										
2										
3										
4								Not acceptable		
5										

Table A3.6 Risk management matrix (Dutch railways)

Financial damage (in euro)	Impact on availability of trains	Security (perceived feeling)	Safety (effect of accident)	Image (infringement of)	Does not occur f = 0	Sporadic f = 1× / 10 yr	Occasionally f = 1 × / 1yr	Frequent f = 4 × / 1 yr
< 10,000	0 - 25	normal	frightening	local media attention				
10,000 – 50,000	25 - 50	less convenient	minor injury	limited regional attention	acceptable			
50,000 – 100,000	50 - 100	in-convenient	severe injury	regional attention				
100,000 – 1,000,000	100 - 150	unsafe	1 fatal accident	limited national attention		Avoid/ decrease		
1,000,000 – 10,000,000	150 - 200	very unsafe	1 - 10 fatalities	national attention				
10,000,000 – 50,000,000	200 - 250	fearful, alarming	10 - 100 fatalities	limited international attention		Not acceptable		
50,000,000 – 100,000,000	250 - 300	life en-dangering	> 100 fatalities	international attention				