Preface

OVERVIEW

Asset management, once considered a tactical area, is now a matter of strategy, given the implications it has for availability of facilities and equipment, delivery time, product quality, costs, safety and the environment. In addition, the introduction of advanced manufacturing techniques and new production management systems, which lead to increased automation and reduced delivery times, has given great importance to asset management.

In manufacturing, production, finance, etc., decisions are increasingly taken based on models or techniques which provide satisfactory, objective decision making, which guarantees improved competitiveness, reducing risk and uncertainty, and that can be justified to management. However, maintenance managers have taken decisions based only on their experience or supported by the advice of system sales staff or consultants. This lack of models and techniques in the area of asset management leads to underperforming maintenance departments characterized by a reactive approach, underutilized maintenance information systems, inaccurately managed costs, no scheduled maintenance hours, feedback on work quality not being provided, etc.

This book looks to promote and address the application of objective and effective decision making in asset management based on mathematical models and practical techniques that can be easily implemented in organizations. This comprehensive and timely publication aims to be an essential reference source, building on the available literature in the field of asset management while providing for further research breakthroughs in this field. This text provides the necessary resources for managers, technology developers, scientists and engineers to adopt and implement optimum decision making based on models and techniques that contribute to recognizing risks and uncertainties and, in general terms, to the important role of asset management to increase competitiveness in organizations.

SUMMARY OF TOPICS

The relevance of maintenance in organizations has increased considerably over the last two decades; this importance is linked to the introduction of a growing number of factors with an influence on efficient asset management. The existence of increasingly complex equipment and processes, the increase in the number of assets, the speed of technological change, the need to reduce costs in the modern world, together with increases in the level of excellence of commercial goals such as quality and delivery time, and concern for the safety of workers and the environment, make asset management an important source
of benefits and competitive advantages for present and future world class enterprises. This book analyses these factors, which are divided into, although not limited to, the following categories:

- Maintenance policy selection.
- After-sales management.
- Knowledge management.
- Critical asset and infrastructure management.
- Asset life-cycle management.
- After-sales maintenance.
- Performance measurement system.
- Sensors and health monitoring systems.
- Reliability centred maintenance.
- Building information modelling.
- Advanced maintenance techniques.
- The set-up process.

Nevertheless, the areas of application of these categories should undoubtedly be underlined as having attracted few contributions, as having special characteristics, and as being of great present and future importance; these areas include:

- Operating theatre.
- District heating.
- Offshore wind farms.
- Panama Canal.
- Buildings.
- Wood-fuel energy systems.
- Aerospace industry.
- Travelling crane.

**TARGET AUDIENCE**

Industrial and manufacturing engineers, managers and plant supervisor, academicians, researchers, advanced-level students (both postgraduate and doctoral), technology developers, and managers who take decisions in this field will find in this book a source of ideas, models and techniques which mark out a path for future research in this field, and may also serve to encourage original ideas and in many cases practical application in business. *Optimum Decision Making in Asset Management* is aimed at the above-mentioned target audience worldwide and because of the number of chapters it contains and the variety of the subjects analysed, it provides an in-depth look at current global concerns.
IMPORTANCE OF EACH CHAPTER

The book is structured in two parts. The first part consists of 11 chapters which include contributions by researchers from the Spanish Network of Excellence in the management of Physical Assets, which brings together most of the best Spanish researchers in the field of asset management. The second part consists of 9 chapters with contributions by authors from different countries including: The UK, France, the Netherlands, Portugal, the Ukraine, Saudi Arabia, Chile, Venezuela, Panama, the United States and India. This gives a more complete view of the state of asset management around the world.

Of the 57 members of the editorial board and authors who have participated in this book, at least 20 have carried out activities related to asset management in different commercial organizations, bringing practical vision, but also motivating improvements, advances and new techniques to be applied to companies. This favours orientation of research towards real application in organizations, which is part of the value added by this book. There is also a significant flow of ideas and experience through collaboration as reviewers with a number of authors who have contributed to the book. The suggestions, comments and ideas they provide their colleagues have been enriching for all of us, seeding meaningful developments in knowledge. For all these reasons, we wish to thank each of them.

A brief description of the twenty chapters, with regard to their research material and the conclusions reached, are collected and summarized as follows:

Chapter 1 describes a maintenance and reliability management model for the project: Design and Construction of the Third Set of Locks in the Panama Canal. This model consists of eight sequential management building blocks. The first three building blocks are concerned with condition maintenance effectiveness, the fourth and fifth ensure maintenance efficiency; blocks six and seven deal with maintenance and asset life-cycle cost assessment, and finally block number eight ensures continuous maintenance management improvement. This chapter could be used to assist different plant teams in designing the optimal strategies for maintenance and inspection of the assets; additionally, recommendations for optimizing the processes in the areas of maintenance and reliability management are also included.

Chapter 2 presents a multicriteria model constructed by means of Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) to select the most suitable combination of maintenance policies in the different subsystems that make up an operating theatre. A decision-making group including the Hospital’s technical services, environmental and occupational risk prevention managers, healthcare managers (operating theatres and health activity programming), healthcare staff, technicians, purchasing services managers and Hospital executives was used to determine the relevant decision criteria and their weightings. Markov chains were used to calculate the mean availability for repairable systems. This is aimed at increasing the availability of the operating theatre, thereby increasing physical safety during patient operations and reducing the number of delayed operations due to technical malfunctions.

Chapter 3 focuses on critical infrastructures which are basic service providers for society and so need to be effectively protected against hazards. Current economic and political trends mean that private companies are nowadays the owners or operators of most critical infrastructure. The prevention activities required to anticipate or reduce the impact of critical events affecting critical infrastructures are analysed. Additionally, this chapter explains the main reasons why public-private partnerships are sometimes valuable for ensuring that critical infrastructures are correctly maintained. The aim is to promote the sharing of resources and information between partners involved to enhance the overall resilience level of critical infrastructures and achieve better decisions by critical infrastructures managers.
Chapter 4 describes the Graphical Analysis for Maintenance Management (GAMM) method, which uses a non-parametric estimator of the reliability function using historical data. GAMM provides a visual representation and graphical analysis of data from a complete or partial historical record of the maintenance work performed, allowing anomalous behaviour in equipment, whether caused by its own operations, maintenance activities, improper use of equipment or even as a result of design errors, to be identified. Different patterns can be observed, providing useful information for decision making and problem solving. A set of rules has been developed to provide a proper and objective interpretation of the GAMM method results.

Chapter 5 analyses how maintenance departments of companies generate, transfer and use knowledge, and the impact this can have on the organization. Maintenance workers essentially work based on their experience or tacit knowledge, which is difficult to measure or express, but nevertheless this untransmitted knowledge can lead to high costs for the company because of increased stoppage times for production and services, loss of energy efficiency, or an increase in adaptation time of new staff. This chapter describes the factors which influence knowledge management in maintenance engineering, and their effect on industrial production, as well as identifying how knowledge management in asset management works, and how it may be impeded or made more efficient.

Chapter 6 shows how maintenance management for buildings has become a research area of great interest because they are required to operate efficiently. However, while traditionally building information models have mainly addressed the construction sector, recently the research focus has shifted from early life-cycle stages to maintenance, refurbishment, deconstruction and end-of-life considerations, especially of complex structures. Asset management tools such as facilities management provide the approach and required elements to achieve greater efficiency and effectiveness in building life-cycle management. This chapter introduces the application of asset management in buildings and how the development of building information modelling is the key element in allowing effective implementation.

Chapter 7 describes the concept of Industry 4.0 in which machines can monitor and transmit information about their operating conditions, both to internal control mechanisms and to other machines or external systems for analysis, decision making or maintenance activity. This chapter shows a reference model developed from a number of case studies (sheet-metal processing machines, tool machines, special machinery, aerogenerators, compressors, etc.), which allows efficient management of the after-sales service. This model relates after-sales service technology with product technologies (Industry 4.0) in the area of after-sales maintenance. Three levels have been identified at which companies in the machine goods sector may be classified, depending on the level of excellence of the after-sales maintenance service.

Chapter 8 performs experimental analysis of crack propagation by fatigue in high resilience steels. The life of the components of a structure containing premature cracks can be determined by the degree of subcritical crack propagation. One problem of high resilience steels is their low toughness in the HAZ, when they are welded with a high heat input. This chapter analyses nine specimens that have been welded by a submerged arc welding process to check that the parameters that indicate the values of fracture mechanics in the HAZ, after the heat cycle steel has undergone, in a process with a maximum heat input of 2,327kJ /mm, are still valid. A correlation between the theoretical and experimental values is confirmed. The experimental work carried out ensures that the parameters regulating the mechanism of fracture remain valid under the rules compatible with the design of the base material and that as far as possible a correlation is established between welding parameters and those obtained in fracture tests, so that if the results of the tests are not satisfactory, the appropriate solution may be applied to the welding for the parameters governing fracture tests to be acceptable.
Chapter 9 analyses different indicator systems such as the balanced scorecard, the Alsyouf Model, the maintenance scorecard model, the metrics of the Maintenance of the Society of Maintenance and Reliability Professionals and European Standard EN-15341, through which maintenance management can be evaluated. Additionally, the chapter proposes a maintenance-management indicator system based on the definition of indicators for the various hierarchical levels and different functions and processes taking place in a maintenance department. This system provides an assessment of these aspects at all levels of the organization and shows the relationship between the various indicators to understand the overall performance of maintenance management and thus align departmental objectives with the strategic objectives. The chains of key performance indicators for maintenance are carried out by means of the C-KPI-M model which defines the sequence of key indicators in maintenance management directly contribute to the achievement of maximum economic value added.

The development and the implementation of advanced actuation systems such as electromechanical actuators has increased because they intensify the ease of control of the system, provide options for re-configuration, maintain functionality during faults, and make it possible to carry out advanced diagnostics and prognostics for a more intelligent maintenance, leading to an increase of aircraft availability with long-term planning for maintenance activities. Chapter 10 shows how to develop health-monitoring algorithms based on AI and statistical technologies to detect and predict early stages of failure in a gearbox, taking into account vibration signals obtained from the electromechanical actuators by means of tri-axial accelerometers in on-ground testing. The testing is experimental, involving data collection of healthy and faulty gears and extraction of a set of features with different pre-processing techniques.

Chapter 11 presents four complementary approaches to quantify the interpretation of signals exchanged in a network of sensors in the presence of uncertainty. The aim is to be able to assess measurement error and the corresponding risk in order to reduce oversizing of the monitoring architectures and better define the level of confidence placed in the information received from the network. A comparative analysis is presented, according to different criteria of quality, quantity and/or type of data collected by the sensor network between Bayesian networks, Transferable Belief Model (TBM), Directed Evidential Networks (DEN) and Deep Belief Networks (DBN). This includes the resources necessary to implement each method in order to understand measurement or to reduce errors related to uncertainty in a sensor network. This analysis will assist in identifying the most suitable method for each problem detected by a sensor network.

Chapter 12 sets out a number of implications for practitioners of asset management, such as that is a multidisciplinary and strategic practice which should look at the complete lifetime of assets, and where best practice is to close the loop of objectives, performance, interventions, expected performance, and new performance figures, taking account of the knowledge of experts. It presents a practical twelve-step approach and develops an asset life-cycle plan in which sessions with experts are used to identify the main lifetime impacts that may be useful in guaranteeing or increasing the value of the asset to the company.

Chapter 13 provides insights into real-life applications of advanced maintenance techniques, in order to support companies and practitioners in moving towards better-informed maintenance decision making. Three case studies are introduced, corresponding to companies with different maturity levels in the usage of advanced maintenance techniques, to highlight typical problems businesses experience in the application of prognostic techniques. A four-step procedure is described that guides practitioners in the application of advanced maintenance techniques, thereby overcoming the difficulties of application.

Chapter 14 focuses on improving energy efficiency in district heating by implementation of information technologies. The models, features and existing tools of energy management, which represent
the state of the art of district heating management, are set out here. This includes the decision support system HeatCAM for making decisions on energy management for district heating system operation in the demand-driven model. This system can provide real-time monitoring and decision making on the regulation of heat consumption modes of the particular building or group of buildings as required by the consumer.

Chapter 15 explores offshore wind projects considered to be megaprojects, that is, with a high level of complexity, especially at the beginning, which accumulate high risks resulting in a higher likelihood of failure. The current literature regarding offshore wind projects fails to address the planning aspect, in particular the risks and uncertainties occurring in this phase. In this chapter, a Delphi study is described, involving interviews with 26 experts from a variety of backgrounds in the offshore wind industry in The Netherlands. A framework is presented that depicts the planning phase of an offshore wind project, along with ten risks and seven uncertainties that are commonly found in offshore wind projects. The structure of the project and the role of government is also analysed.

Chapter 16 analyses the process by which the machinery is prepared, so that the product is available in the quantity and at the moment required by the customer. These set-up activities have traditionally been considered a wasteful operation, as are other logistical operations in companies; however, it is in fact of great importance in the modern competitive world. This chapter analyses the variables that can affect the development of set-up process, the typology of operations in the set-up process, the times involved, a methodology for analysis and improvement of the set-up process and a control system for the improvements gained.

Chapter 17 describes an amenable management of risk, considering all the types of risk that can be applicable to asset management through a holistic approach, which is a key element in taking optimal decisions. It analyses different factors that determine whether risk assessment has been done effectively, such as process information availability, understanding of risks, internal control, change management and personnel management. It presents, in addition, a practical approach using a Sarbanes - Oxley (SOX) framework in order to implement a proper internal control framework, which is sustainable and adaptable to each company or case.

Chapter 18 introduces the reliability-based maintenance philosophy with the goal of enhancing the reliability of the asset under consideration at optimal cost. This mostly qualitative methodology can determine maintenance intervals based on past experience and age-exploration methods. The method provides a quantititative way of determining maintenance intervals using the principles of reliability engineering for repairable systems. This is data-based, relying on failure and other data generated by assets. It complements the reliability-centred maintenance philosophy while helping to improve the efficiency and effectiveness of industrial asset maintenance.

Chapter 19 analyses the wood-fuel energy systems which represent around 70% of the energy consumed in Mozambique. These systems require design tools to support the strategic and optimised used of available socio-ecological resources/assets, and which also include the various agents involved in the decision. This chapter therefore develops a novel tool for the strategic design of wood-fuel energy systems, called 2MBio. 2MBio is a participatory conceptual design tool that provides: a formalized common space for dialogue, allowing participants to express their knowledge and experience on the question of “why” and “how” to address problems and solutions, and facilitates participatory conceptual design of comprehensive and integrated strategies, policies, projects and solutions for wood-fuel energy systems.

Chapter 20 focuses on discussing the occurrence of faults where the root cause cannot be determined, usually called no-fault-found problems. In the aerospace industry this is an important topic. When faced
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with no fault found issues, how organisations make decisions to control them (regulations and control of the amount of time, resources and budget to be spent), and how impact information flows within organisations, (organisational issues and gaps that will require extensive research efforts, etc.) are explained.

CONCLUSION

At the current time making better-informed maintenance decisions is of key importance for organizations. Thus, the process of data collection, treatment and management is increasingly important over the life-cycle of assets, in accordance with asset management standards such as PAS 55 and ISO 55000. This can be seen in the contributions in this book, which analyse areas ranging from the interpretation of signals provided by a network of sensors, through algorithms to determine the fatigue of the structure and to detect and predict early stages of failure, to different approaches to strategic decision making in asset life cycle management. This book analyses from specific operational decisions relating failure mechanisms and detection, to strategic decisions involving the whole life-cycle of industrial plants. This is all done without losing sight of the risks and uncertainties involved in any real-life decision-making process.

This book, therefore, will stimulate the idea that decisions related to the management of physical assets should cease to be based purely on empirical evidence from experience and understanding of maintenance engineers and managers, and should begin to incorporate techniques, tools and models using integrated mathematical techniques, together with better data and analytical and clarification techniques, the judgements of experts, and common sense. This should lead not only to satisfactory or good decisions, as optimal decisions do not generally exist, due to frequently conflicting criteria, but it will also lead to efficient and effective maintenance systems which separate world class companies from the rest.

The interplay of techniques required to achieve this, the application to ever more complex and exclusive areas, and the inclusion of risk and uncertainty in decision making are questions whose analysis this book attempts to address, and they represent a challenge for future research in asset management.

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