



MAINTENANCE: BODY *of* KNOWLEDGE

*Issues, methods, techniques and
practices to be known by stakeholders
of the maintenance process*



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PREFACE

This booklet is the result of a work produced by the European Federation of National Maintenance Societies (EFNMS), non-profit organisation created in 1970, gathering the National Maintenance Societies (NMS) of 24 European countries. Its members share their experiences and collaborate to develop the maintenance profession and create a European maintenance culture.

To achieve these objectives, EFNMS carries out various activities and in particular the lead of six committees working on key areas of maintenance (asset management, certification of personnel, training, health-safety & environment, maintenance indicators and assessment, digitization and new technologies). It also organizes every two years in a European city, in partnership with a selected NMS, the Euromaintenance conference which gathers experts and companies from all over the world.

These activities aim to collect and develop maintenance knowledge in order to increase the visibility of this field and its professions which are an essential lever for the sustainable development of our industries and economies.

To complete and structure the results of its works, EFNMS has decided to create a Maintenance Body of Knowledge (BoK). The objective of the BoK is to define the landscape, scope and boundaries and the content of maintenance, so that this area is better understood, better identified and its importance within organisations appear more clearly. This BoK is based on the European maintenance standards, to which EFNMS actively contributes, and in particular the terminology and standards that describe the maintenance process and its relationship within asset management.

The BoK is indeed built on the basis of these standards by combining the maintenance actions and the knowledge necessary to accomplish them (industrial issues, methods, techniques, practices, etc.). It constitutes a catalogue of maintenance knowledge which has been listed especially from Euromaintenance conferences, the European standard on the qualification of maintenance personnel, works of the EFNMS Committees and specialist opinions. The subjects are described by texts written by European experts and validated by a Reading committee. These texts contain short summaries of the subjects and provide bibliographies which allows the

reader to access much more detailed information. The links with the maintenance processes are indicated, which makes it possible to better identify the competences that are expected from technicians, engineers, maintenance managers and asset managers.

This BoK is a collaborative document intended to be regularly supplemented, updated and improved by any expert reader of a particular subject who wishes to propose changes, under the supervision of the Reading committee.

The ambition of this work is to constitute a living reference that clearly explains the content of maintenance and its relationship with other processes of companies or any organisations, and thus contribute to the development of maintenance for the benefit of European and global populations.

Readers are invited to communicate their points of view, clarify descriptions, correct or supplement subjects with the intention of developing the culture of maintenance.

Antoine Despujols,
EFNMS BoK coordinator



INTRODUCTION



INTRODUCTION

OBJECTIVE OF THE EFNMS MAINTENANCE BODY OF KNOWLEDGE (BOK)

Maintenance is present wherever failure mechanisms or out-of-dimensioning events affect items and lead to failures and faults that can be avoided or repaired. Therefore, it concerns all industrial sectors as well as buildings and infrastructure where, even if the techniques used may be different, the processes implemented are similar.

EFNMS mission is developing maintenance in all areas where it is performed and participating in the development of a common European maintenance culture. To achieve this objective, it is essential to clearly define the maintenance landscape, in other words the maintenance scope and boundaries, its content and its interactions with the other areas in relation.

Technical, administrative, and managerial actions that constitute maintenance are carried out by technicians, engineers, supervisors, asset managers who have appropriate knowledge that must also be precisely defined. Indeed, in addition to their basic knowledge and their soft skills, these people must know how to implement the methods, techniques, good practices, and tools that are the basis of successful maintenance.

To gather these fundamentals, EFNMS has undertaken the development of a Maintenance Body of Knowledge (BoK), independent of company organisations and intended for all stakeholders involved in maintenance. Indeed, if the responsibility for maintenance is often entrusted to a specific entity (department, etc.), other entities (e.g., operation, human resources, etc.) of the company also participate in this generic process and the people concerned must also have a required knowledge and competences.

To describe the BoK, we must first present the other areas, included in the “maintenance landscape”, to which maintenance contributes, then more specifically the maintenance process itself. The required knowledge can thus be more easily identified and structured.

THE MAINTENANCE LANDSCAPE

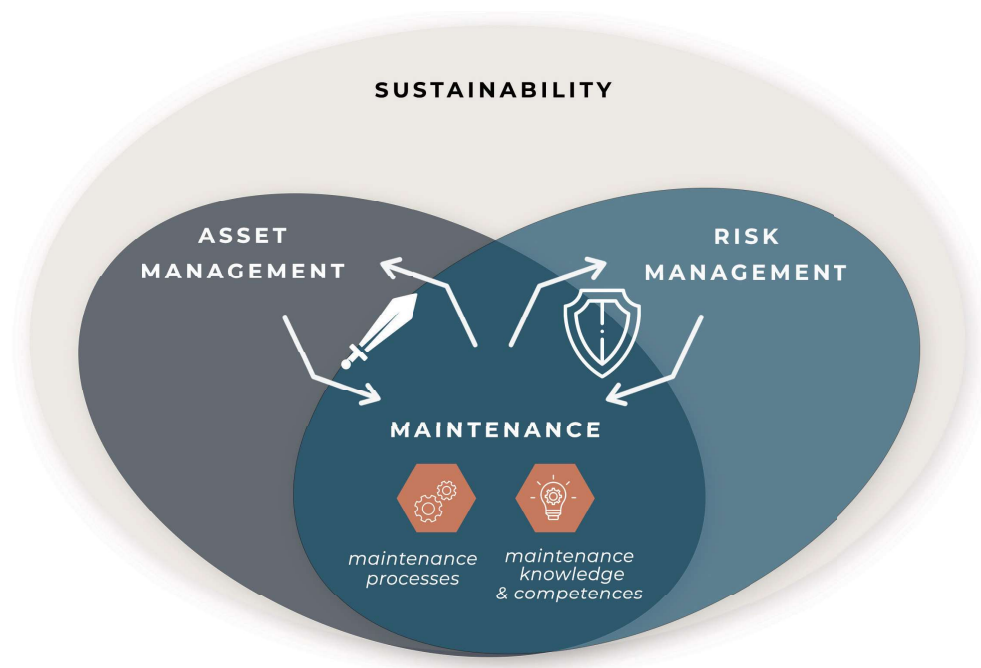


FIGURE 1: THE MAINTENANCE LANDSCAPE

Items (equipment, systems, installations) are subject to constraints or attacks due to:

- their operation (start / stop, nominal operation, transients, etc.);
- their environment (humidity, pollution, vibrations, etc.);
- external events (overvoltage, failures of other items, operating or maintenance errors, etc.).

This results in failure mechanisms (wear, fatigue, aging, etc.) or stresses (overpressures, heating, overloads, etc.) which can exceed their resistance capacities and they end up not fulfilling their functions properly. As does entropy in thermodynamics, the degradation of items increases inexorably over time. Without maintenance, all items degrade more or less quickly and those which are active stop operating.

Maintenance is therefore essential and concerns all industrial sectors as well as buildings and infrastructure. It contains the technical, managerial, and administrative activities that make it possible to avoid failures and to restore items while limiting the consequences of their unavailability.

These activities are described in the standards and in particular in EN17007 which gives a generic description of the maintenance process in the form of a management

process, realisation processes which are the reason of being of maintenance, and support processes providing the necessary resources and activities for all processes. They thus delimit the maintenance scope and boundaries and specify its content.

But maintenance is not isolated and, in its landscape, there are in particular three other domains in which it plays a leading role (figure 1):

- The management of physical assets introduced in the ISO 55000 standard which aims to translate the strategic objectives of companies and organisations into decisions and actions. Coordinated with other processes (design, acquisition, production, modernisation, sale/disposal/dismantling) maintenance contributes to optimizing the value created. It participates in the definition of the objectives and the policy to manage the assets in an efficient and profitable way. These relations between maintenance and physical asset management are described in EN16646 and EN17485 standards.
- Risk management and dependability, to which maintenance contributes to constitute an essential preventive and protective control measure. By acting on the reliability and maintainability of items and on the logistic support, it helps prevent failures and reduce downtime which can have serious consequences. IEC60300-3-1 explains the role of maintenance in dependability management.
- Sustainable development of which maintenance is an essential pillar. Designing an item by developing and facilitating its maintenance, then by constantly maintaining it in good condition during its life cycle, is to ensure it a longer useful life. This therefore makes it possible to reduce raw materials and energy to rebuild it, which is beneficial both economically and to preserve the environment. It is also giving work locally, because maintenance is a set of local activities, which is a social advantage. The three characteristics of sustainable development are thus satisfied by maintenance. ISO 26000:2020 confirms the contribution of maintenance to sustainability.

Maintenance therefore includes defensive tasks which form a shield against serious risks to the health and safety of people and the environment and combative tasks which are a spearhead to gain competitiveness by optimizing availability and durability and reducing costs. All these tasks are clearly part of a sustainable develop-

ment process that makes maintenance professions into the professions of the future.

If maintenance is a set of actions (processes), it also encompasses the knowledge that enables them to be carried out. Defining its scope and content therefore means, not only determining maintenance activities, but also making an inventory of the methods, techniques, practices and other knowledge and competences that characterize the maintenance professions and other jobs which also participate in maintenance.

The EFNMS has been working for a long time on the competences of maintenance personnel and more particularly the European Certification Committee (ECC), which has developed and implemented since 1993 a European certification for maintenance managers and maintenance technicians, and the European Training Committee (ETC) which notably participated in the European standard EN15628 on the qualification of maintenance personnel and was one of the initiators of the European Euromaint project within the framework of the Leonardo program dedicated to education and vocational training.

Regarding the knowledge we must also mention the International Euromaintenance Conference, created by EFNMS in 1974, which is the main European and international event where maintenance knowledge is presented and discussed. The development of the BoK is part of these activities and helps to gather and structure this knowledge.

THE MAINTENANCE PROCESS

As stressed before, it is the need to perform actions that is at the origin of the knowledge and skills that the people who carry them out must have. It is therefore from the actions to be performed that we must start in order to identify the necessary knowledge for those involved in maintenance (figure 2). The EN17007 standard, which describes the maintenance processes, forms the basis of this work and allows knowledge to be structured according to its use. These thus become more concrete and directly linked to their implementation.

EN17007 standard groups the processes into three types (figure 3):

- A management process that establishes policy and strategy, defines the organisation, assigns responsibilities, negotiates budgets, manages actions, analyses data and leads a continuous improvement process.
- Realisation processes which are the reason of being of the overall process and produce the expected results. They include preventive and corrective maintenance which share a common process including preparation, scheduling, and performing tasks on items, and a third process for improving reliability and maintainability of the items.

- Support processes which are necessary for the realisation and management processes, and which include:
 - Risk management for personal health and safety and the environment when performing maintenance tasks.
 - The provision of the resources necessary for maintenance: spare parts, tools and information system, documentation, infrastructures, internal staff, external services.
 - Budget forecasts and monitoring.
 - Analyses and actions to take maintenance into account in the design and modification requirements of items.
 - Management of historical data.
 - Process optimization as part of continuous improvement.

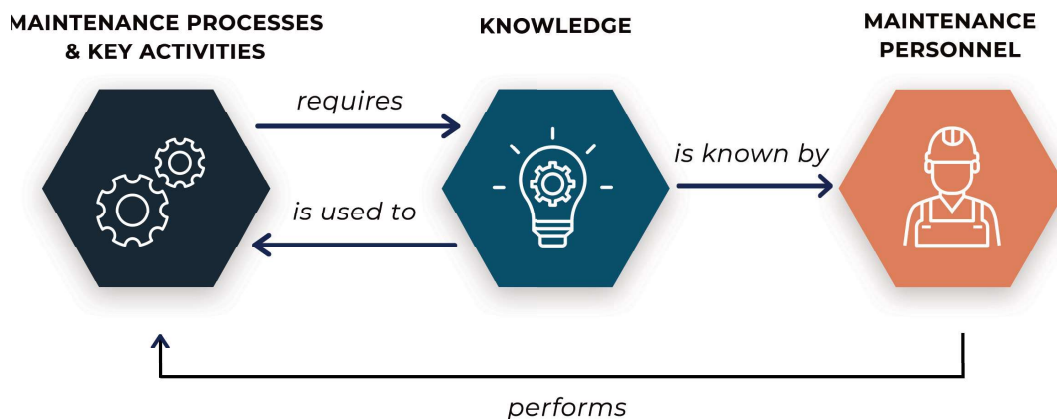


FIGURE 2: RELATIONSHIPS BETWEEN MAINTENANCE PROCESSES, KNOWLEDGE, AND PERSONNEL

The standard breaks down all these processes into actions by indicating their inputs-outputs. The products of the actions (outputs) are the inputs of other actions, all the links between the various processes are thus established, which provide a complete model of the maintenance process (figure 4).

In total, more than a hundred actions are identified in the standard and they are a good basis for determining the knowledge that is necessary or useful to carry them out.

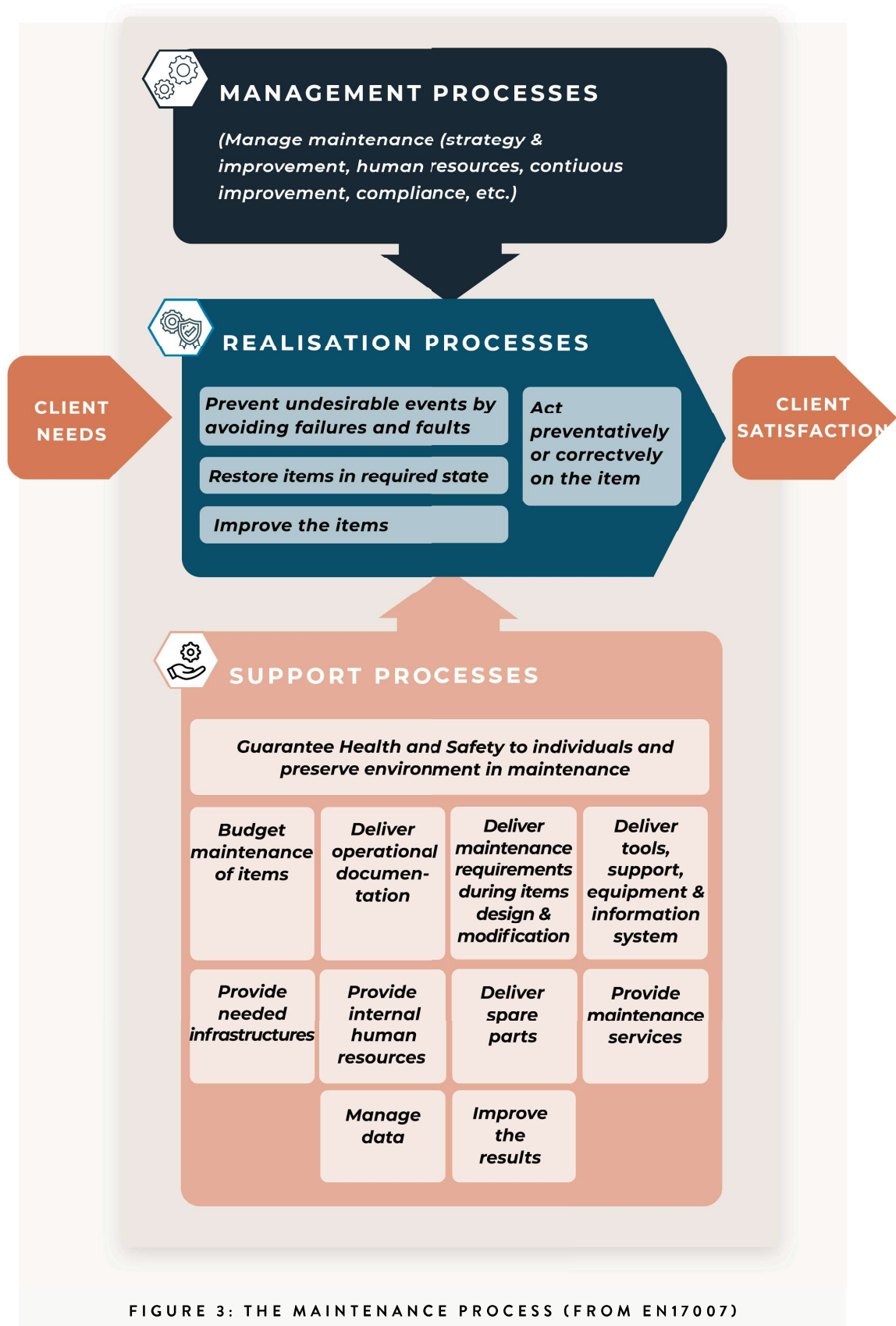
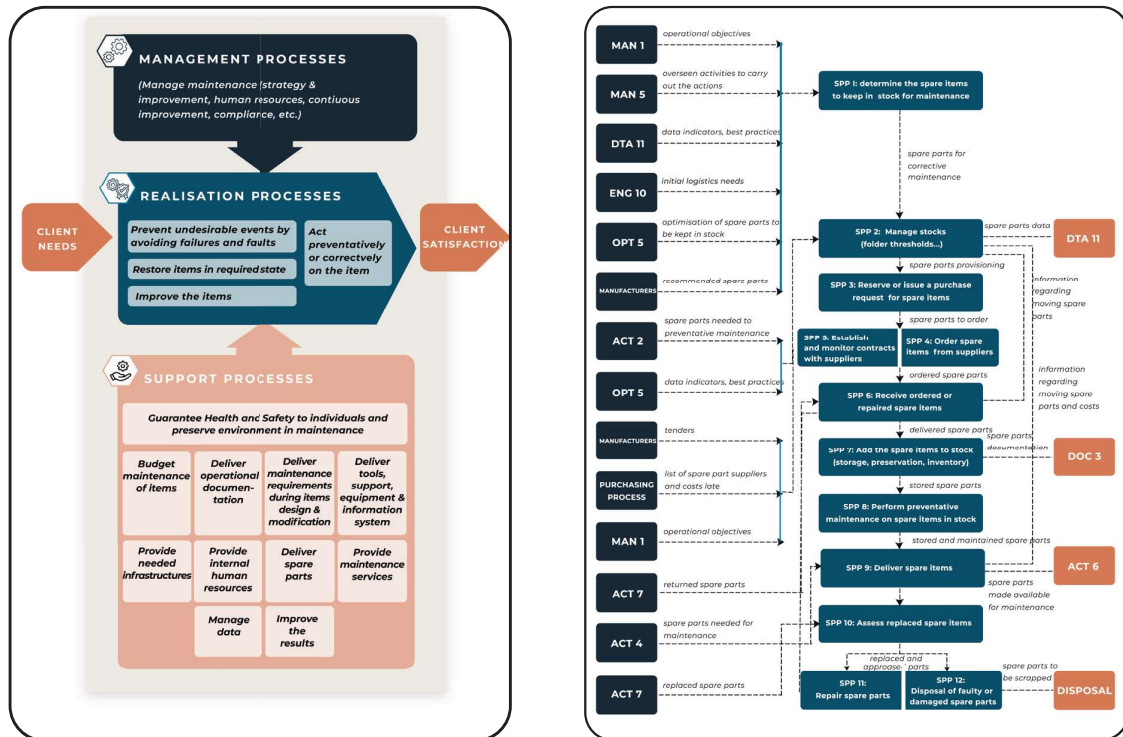


FIGURE 3: THE MAINTENANCE PROCESS (FROM EN17007)



LEVEL 1: MAINTENANCE PROCESSES



LEVEL 2: ACTIONS OF A MAINTENANCE PROCESS

PROCESS DESCRIPTION

Name of the process	
Purposes of the process	
Key activities / elementary components of the processes	
Input data/products	Output data/products
Stakeholders	Interfaces with other processes
Constraints related to realisation of the processes	
Potential indicators related to the process	
Observations	

FIGURE 4: MAINTENANCE PROCESS MODEL

CONTENT OF THE EFNMS MAINTENANCE BODY OF KNOWLEDGE

The personnel performing maintenance activities must possess knowledge, competences and abilities which are described in the European standard EN15628. Knowledge is a body of facts, principles, theories, and practices that results from the assimilation of information through learning. Competences, for their part, are the intellectual and practical aptitudes to use this knowledge as well as the personal dispositions adapted to social behaviour.

We thus find the different types of knowledge and competences that are required to carry out actions, and in particular to effectively contribute to maintenance activities:

- learning to know (basic knowledge) not specific to maintenance but essential for the personnel who carry out their activities (communication & writing, mathematics, physics, chemistry, etc.).
- Learning to do (know-how) which contains maintenance methods, techniques, practices including Maintenance Engineering.
- Learning to be and to live together which includes the human relations, goodwill, teamwork, respect of the rules, integration, curiosity, initiative, etc.

The BoK mainly focuses on “learning to do” (know-how) although other knowledge and competences are also essential and should be carefully assessed when looking for qualified personnel. The know-how is established from maintenance subjects which are commonly presented at conferences or seminars, or published in books or magazines, or which are taught in universities. The list was enriched by experts who added subjects, as well as from the content of EN15628. These contain methods, techniques and practices that are used by the various maintenance processes.

Over 75 subjects have been listed and briefly defined. They are linked to the maintenance processes (level 1) and activities (level 2) described in EN17007. The result is given below in Table 1.

To describe in more detail the content of the listed subjects, the EFNMS launched a call for experts asking to write short and didactic texts, easily understandable by non-specialists. These subjects are broad and could be the titles of conference sessions, university lectures, or book chapters, or even complete books, and would require lengthy texts to be fully exposed, but the aim of the BoK booklet is to make

a general and introductory description of maintenance. This is why the text size is limited to 2-3 pages and a bibliography containing reference standards, books and conference papers for readers who want to know more.

The subjects that have been listed concern:

- industrial issues (e.g., "Life cycle management", "Maintenance & sustainability", "Education and training in maintenance", "Assessment of occupational risks in maintenance", etc.),
- methods or techniques (e.g., "Total Productive Maintenance", "Fault Diagnosis", "Root Cause Analysis", "FRACAS", "Remaining Service Life Assessment", "Benchmarking", etc.),
- areas of knowledge and practices (e.g., "Negotiation techniques and industrial relations", "Fundamentals of project management and control", "Preparation & scheduling of work", "Budget control", "Good practices in Health and Security", etc.).

These subjects constitute a set of useful or necessary knowledge for maintenance and make it possible to understand its scope and content. To constitute this booklet, they have been grouped into chapters which correspond to maintenance functions, that is to say roles and responsibilities often entrusted to entities within organisations (figure 5):

- Maintenance Management associated with a broader vision of Maintenance within Physical Assets Management.
- Execution of Maintenance.
- Control of occupational and environmental risks (HSE function).
- Maintenance Engineering which includes methods, techniques, and practices.
- Maintenance Support covering the provision of necessary resources.

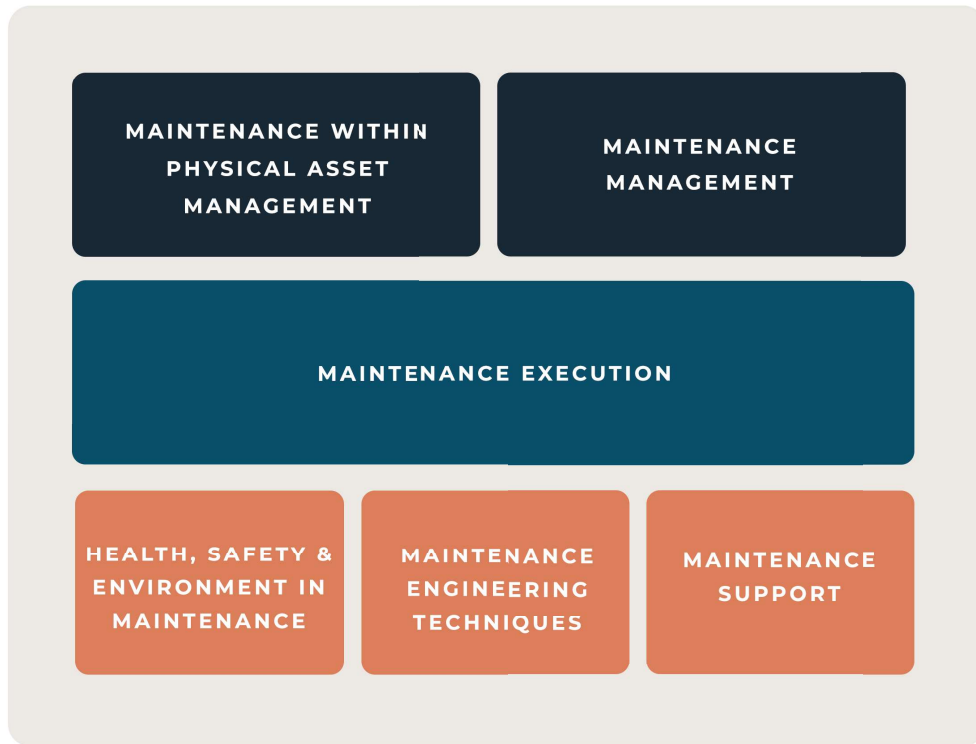


FIGURE 5: BOK CHAPTERS

THE EFMNS BOK: A TOOL FOR COLLECTING KNOWLEDGE AND BEST MAINTENANCE PRACTICES TO MANAGE THE MAINTENANCE PROCESS

The BoK is a tool intended for maintenance stakeholders (companies, organisations, universities, vocational schools, etc.). This tool must be living, that is to say be enrich with new subjects and update existing descriptions to continuously improve them. Experts who wish to participate in this work are therefore welcome and can propose modifications to the EFMNS Reading Committee whose role is to analyse, validate and include the contributions in the BoK.


Furthermore, this tool, based on the description of the maintenance process and the associated knowledge, is a starting point for other functionalities in close connection with the works carried out by the EFMNS committees.

The ETC and ECC committees are directly concerned by the knowledge collected in relation to their activities intended to:

- support, develop and promote education and training in maintenance,
- develop the certification of maintenance engineers and maintenance technicians to guarantee a high level of knowledge in maintenance.

The EAMC (European Asset Management Committee), EHSEC (European Health, Safety and Environment Committee) and ECM4.0 (European Committee Maintenance 4.0) have developed numerous documents (best practices, guides, training materials, surveys, etc.) in relation to BoK subjects and maintenance processes. The BoK provides a structure that helps to identify and include these material and information in the knowledge related to the maintenance actions described in the processes.

The EMAC (European Maintenance Assessment Committee) has developed GloMe, a guide on maintenance indicators, as well as surveys. This work can be put in relation with the BoK to evaluate the maintenance processes, the performance of the maintenance implemented on the items and thus guide towards the application of methods or practices described in the BoK.



To successfully carry out the various technical, administrative, and managerial maintenance activities, stakeholders, and especially maintenance technicians, engineers, managers, and asset managers, must have specific competences that include understanding of industrial issues and knowledge of methods, techniques and practices.

The Maintenance Body of Knowledge (BoK) is a catalogue of this knowledge associated with maintenance activities to define the skills required from stakeholders. This knowledge is presented in the form of 75 subjects, shortly described and linked to bibliographies allowing the reader to deepen them.

The BoK is a collaborative document intended to be regularly supplemented, updated and improved to constitute a living reference which clearly explains the content of maintenance and its relations with other processes. It thus contributes to the development of a common maintenance culture for the benefit of companies and organisations.