BS EN 16646:2014

BSI Standards Publication

Maintenance — Maintenance within physical asset management

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National foreword

This British Standard is the UK implementation of EN 16646:2014.

BSI, as a member of CEN, is obliged to publish EN 16646:2014 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK committee voted against its approval as a European Standard.

The standard provides guidance for establishing effective maintenance management as part of an asset management strategy. However, it is the opinion of the UK committee that it does not give sufficient detail to enable the successful development and implementation of a system of maintenance management within an organization.

Specifically, the phrase "maintenance function" is considered problematic. It is not clear if the phrase refers to maintainers (carrying out physical maintenance), maintenance planners, analysts (analysing data from maintenance activities), designers who determine the maintenance schedule, the IT systems which support the maintenance process, or some subset of these functions. Those seeking to apply this standard should therefore give careful consideration to the exact meaning of this phrase in the context given.

The UK committee also has concerns that the standard does not fully address the systems that are required to support maintenance activities, such as maintenance management systems, feedback systems and data analysis systems to allow experience to improve the maintenance of the asset in order to deliver increased benefit.

The UK participation in its preparation was entrusted to Technical Committee DS/1, Dependability.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Maintenance - Maintenance within physical asset management

Maintenance - Maintenance dans le cadre de la gestion des actifs physiques

Instandhaltung - Instandhaltung im Rahmen des Anlagenmanagements

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 16646:2014) has been prepared by Technical Committee CEN/TC 319 “Maintenance”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2015 and conflicting national standards shall be withdrawn at the latest by June 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Why do we need ‘physical asset management’ today more than before? There are some very good reasons to develop ‘physical asset management’ in all its aspects. There are also good reasons to clarify interrelationship between physical asset management processes and maintenance processes. Some of the reasons why physical asset management and maintenance as a part of physical asset management has become a more essential part of the organizations’ activities during the last decades are for example:

— globalization and increasing competition;

— growing financial, safety and environmental risks;

— radical change in business strategy – long term vs. short term;

— attitudes towards physical assets have changed – nowadays it is more common that the length of the ownership is not the same as the length of the whole item life;

— growth of capital intensity in some areas of industry;

— growing turbulence in the market;

— pressure for higher profitability and return on assets;

— aging of asset systems;

— increased pressure to improve added value of maintenance;

— more complicated and uncertain decision environment;

— increased requirements from the safety and environmental point of view;

— ‘silo’ behaviour which keeps maintenance and other life cycle processes separated.

In addition to the above mentioned trends in the market behaviour and technological development, there are many benefits which can be achieved with physical asset management activities:

— economically more efficient and effective use of capital: “turnover of capital”;

— more profitable business: “return on assets”;

— more sustainable use of capital;

— more accurate long term life cycle decisions;

— direction to maintenance strategies and operations;

— integrated investment and maintenance planning;

— influence of maintenance function on asset creation development (design and engineering);

— integrated approach for production function (assets, operation and maintenance);

— improved position for the maintenance function among the other company functions;

— improved assessment of performance and control;

— enhanced reputation.

Further and maybe even greater benefits are now being found through improved credibility in the eyes of customers, regulators and other stakeholders. Physical asset management also results in much greater engagement and motivation of the workforce, and in more sustainable, continual improvement business processes. Physical asset management builds up the required link between maintenance management and organizational strategic plan and gives direction to maintenance activities.

1 Scope

This European Standard introduces physical asset management as a framework for maintenance activities. It also introduces the relationship between organizational strategic plan and maintenance management system and describes the interrelations between maintenance process and all the other physical asset management processes. It addresses the role and importance of maintenance within physical asset management system during the whole life cycle of an item.

This European Standard can be applied to production organizations of all sizes. However, if specific standards exist for a particular application or field of industry, those documents should also be considered.

This European Standard consists of guidance and recommendations and is not intended to be used for certification, regulatory, or contractual use.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13306, *Maintenance - Maintenance terminology*

ISO 55000, *Asset management — Overview, principles and terminology*

ISO 55001, *Asset management — Management systems — Requirements*

ISO 55002, *Asset management — Management systems — Guidelines for the application of ISO 55001*

EN 60300-3-3, *Dependability management - Part 3-3: Application guide - Life cycle costing (IEC 60300-3-3)*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13306, ISO 55000, EN 60300-3-3 and the following apply.

3.1.1
asset solution
the result of concept definition

3.1.2
business environment
all the external factors within the market, technology and community influencing on the decision making of the organization

3.1.3
creation of physical asset
acquisition process, which can include concept definition, design, manufacturing, installation, commissioning

3.1.4
key success factor
attribute required for an organization to ensure the success of an organization

3.1.5
life cycle of a physical asset
period of value realization from a physical asset by an organization including needs identification, creation or acquisition, utilization, maintenance, modernization and disposal

Note 1 to entry: Life cycle of an item may contain several life cycles of a physical asset. An item can have several sequential owners during its life cycle.

Note 2 to entry: Realization of value will normally involve a balancing of costs, risks, opportunities and benefits.

3.1.6
life cycle of an item
series of stages through which an item goes, from its conception to disposal

3.1.7
maintenance task
maintenance action
sequence of elementary maintenance activities carried out for a given purpose

3.1.8
modernization
modification or improvement in the case of nonconformity of the asset, taking into account technological advances, to meet new or changed requirements

3.1.9
operating conditions
physical loads and environmental conditions as experienced by the asset during the entire life cycle

Note 1 to entry: Operating conditions can vary during the asset's life cycle.

3.1.10
operating constraints
characteristics of the asset, which set limits for the use of the asset and may determine requirements for maintenance activities

Note 1 to entry: These characteristics are the results of design and construction of the assets and are influenced by the operational mode and operation conditions.

3.1.11
operational mode
way a physical asset is operated and utilized during the entire life cycle determined by the numbers of units of use (hours, starts/stops, transients)

Note 1 to entry: Operational mode determines the frequency, load, continuity and performance rate of utilization.

3.1.12
physical asset
item that has potential or actual value to an organization

Note 1 to entry: Examples of physical assets are components, machines, plants, construction works, buildings.

3.1.13
physical asset management
coordinated activities of an organization to realize value from physical assets

Note 1 to entry: Realization of value will normally involve a balancing of costs, risks, opportunities and benefits.

Note 2 to entry: In the life cycle context, physical asset management is the optimal life cycle management of physical assets to sustainably achieve the stated business objectives.

3.1.14
technical depreciation
difference between the asset replacement value and actual value

Note 1 to entry: Technical depreciation should be based on the asset replacement value but not on asset book value.

Note 2 to entry: Technical depreciation can be calculated as a ratio of asset replacement value and expected life.

Note 3 to entry: Technical depreciation measures and depicts technical aging of the assets in money terms.

3.2 Abbreviations

List of abbreviations used in this standard is given in Table 1.

Table 1 — List of abbreviations

Abbreviation	Meaning
CMMS	Computerized maintenance management system
KPI	Key performance indicator
OEE	Overall equipment effectiveness
TCO	Total cost of ownership

4 Overview of physical asset management

4.1 What is physical asset management

Physical asset management is defined as coordinated activities of an organization to realize value from physical assets. More specifically physical asset management is “the optimal life cycle management of physical assets to sustainably achieve the stated business objectives”. Physical asset management does not focus on the asset itself, but on the value that the asset can provide to the organization. Value is organization specific and depends on the organizational context. In the general context, asset is something that has potential or actual value to an organization.

The nature and purpose of the organization and the internal and external environment where it operates have a strong bearing on the type of assets that the organization requires and the physical asset management capabilities that it needs to develop in delivering its business objectives. The market dynamics and speed of technological change varies from one sector to another and this fact has a great influence on the physical asset management challenges and activities.

4.2 Hierarchy of physical assets: asset portfolio, asset systems and individual assets

An “individual physical asset” is defined as a physical item that has potential or actual value to an organization. A “physical asset system” refers to a set of interconnected assets (of one or multiple asset types) working together and can be regarded as an asset in itself. Examples of asset systems are production plants and production lines. Grouping of several physical asset systems into a “physical asset portfolio”

enables a holistic approach to be used in the delivery of organizational objectives. Examples of the asset portfolios are the fleet of production plants of a business division and corporate production system which is a collection of several plants. Assets form often a hierarchical system.

4.3 Item and asset life and life cycle of physical assets

The life of an item is defined as the period from its conception to its disposal. An item can be an asset for several organizations during its lifetime. The life of physical asset is defined as a period from its conception or acquisition to its disposal or hand over to the other responsible organization. They often pass through identifiable life stages. The description (and naming) of the stages can differ between assets or items, their applications and organizations.

When managing its physical assets the organization should consider all the life cycle stages (these stages are explained in detail for all the three asset levels in Clause 6):

a) needs and feasibility assessments for assets;

b) concept definition;

c) determination of asset solutions;

d) design of assets;

e) manufacturing or acquisition of assets;

f) installation and commencing;

g) utilization of assets;

h) maintenance of assets;

i) modernization;

j) decommissioning, retirement, and/or disposal of assets.

However, one shall notice that the detailed structures of life cycle stages are different at the three levels of physical assets: asset portfolio, asset system and individual asset. Also, different kinds of technological environments may demand for different kind of stage structure. In the case of standard machines the stages - b), d) and e) can be replaced by the acquisition of an individual asset.

4.4 Organizational context

The role of maintenance management contains two-way influence:

— the organizations' business environment, strategies, plans and decisions direct maintenance activities, but

— on the other hand the maintenance functions influences organizations strategies, plans and decisions on the physical assets.

The maintenance management system is a part of management system for physical assets. The activities which the maintenance management plans, decides and implements depend directly from the organizations' business and technological environment. In the stable market and technological environment maintenance activities have different focus compared with the dynamic business and technological environment. On the other hand at the early stages of equipment life cycle maintenance priorities differ from the priorities of the aged equipment having overtime compared with planned useful life.

The maintenance function should:

— have significant role when planning and deciding physical asset solutions (however, a less significant role at asset portfolio level);

— have sufficient power to affect the design solutions during the investment process in order to optimize life cycle activities of the investment and meet safety and environmental requirements;

— contribute to the mode of operations of the production function in question in order to assist the whole organization to optimize its operations.

5 Management system for physical assets

5.1 Purpose of physical asset management system

An asset management system (management system for physical asset) is a set of interrelated or interacting elements of an organization, that establish asset management policies and objectives, and the processes needed to achieve those objectives. A physical asset management system is not simply an information system; it also includes the organization structure, roles, responsibilities, business processes, plans, operation.

Organizations should establish, utilize and improve asset management system for physical assets. The elements of asset management system are described in details in ISO 55000 and ISO 55001 following the general structure of ISO management systems standards. Guidelines of for the application of ISO 55001 are illustrated in ISO 55002. The asset management system requirements in ISO 55001 have been organized into seven specific elements:

— organizational context;

— leadership;

— planning;

— support;

— operation;

— performance evaluation and

— improvement.

5.2 Interaction between organizational context, physical asset management and maintenance management

Four factors affect significantly requirements which should be defined for physical asset management activities:

— characteristic and objectives of the company in question;

— market;

— community and

— technology.

First, organizations' objectives, strategies and economic and technological characteristics have a great influence on physical asset management and maintenance management (see Figure 1). Examples of these factors are listed in Figure 1.

Secondly, the specific features of the market where the organization is acting have remarkable impact on the requirements the physical asset management is facing (see Figure 1). For example fast growing demand requires different kind of strategies than slow growth environment. Typical factors belonging to category are listed in Figure 1.

In addition to the market, the community where the assets are located have several kinds of impacts on the physical asset management requirements and solutions. Examples of these factors are listed in Figure 1.

Such technological factors as construction, inherent dependability and economic life cycle stage of equipment influence also on the physical asset management strategies and practices (see Figure 1), for example very aged equipment differs a lot from brand new technology from the physical asset management and maintenance management point of view.

The four strategic dimensions and influencing factors are utilized as input in strategic analyses and strategy process. The strategic physical asset management process results in the carefully analysed set of requirements for physical assets and asset management. These requirements can be expressed by using for example different indicators or measures presented in Figure 1.

The factors listed above can be expressed in a more precise way using key performance indicators (KPIs). These KPIs can be used for internal purposes when developing the performance of the physical asset management and maintenance functions or when implementing benchmarking projects.

Determination of critical requirements on physical assets gives framework and basis for asset strategy formulation and planning. The physical asset management strategy and asset management plans can be derived straightforward from these requirements and controlled with KPIs. As soon as the physical asset strategy and asset management plans have been determined it gives direction to maintenance management. Therefore, as the next step it is possible to define maintenance strategies and maintenance plans and needed KPIs.

As physical asset management is an iterative process, feedback from maintenance management to physical asset management and further to strategic analyses is paramount. The iterative strategic process is carried out continually across the whole life cycle of assets and not only when new assets or assets systems or asset portfolio are acquired. Consequently, the maintenance strategy shall be adjusted along with changing requirements.

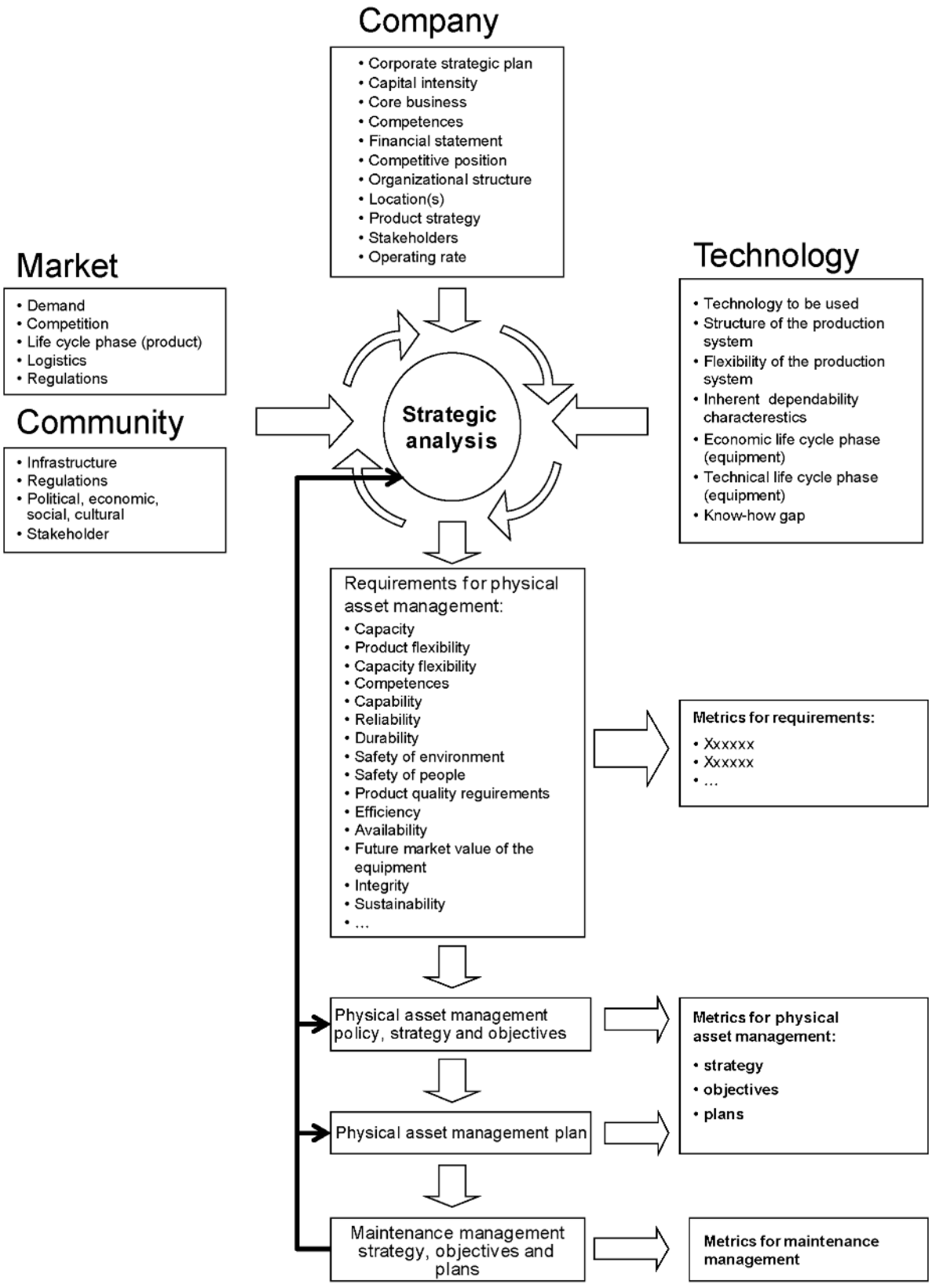

Figure 1 — Interaction between organizational context, physical asset management system and maintenance management system

5.3 The influence of organizational context at the different levels of physical assets

Asset portfolio, asset system and individual asset have very specific management challenges. Also the tasks carried out in the different life cycle stages differ. The role of maintenance depends on the asset level and specific organizational context.

Physical asset strategies, policies, objectives and plans are first determined for the asset portfolio level. At the asset portfolio level the asset strategy may give directly tasks for various asset systems of the organization. It is e.g. possible that all asset systems produce the same product mix or various asset systems are specialized in certain products or product groups or intermediate products for the other corporate production units. At the portfolio level asset strategy should also determine which kind of technology will be used and what will be expected economic useful life for each asset system of the organization. At the portfolio level asset strategy may also define the practices used in the management control of asset portfolio and asset systems and how various management functions and areas should be managed. The maintenance function can give valuable contribution, e.g. to the determination of economic useful life of asset systems and the influence of the asset solution to the life cycle activities and life cycle costs of the equipment. An important contribution is also active influence on the creation and development of the asset and maintenance management systems. The maintenance function has an important role also when planning and scheduling coordinated corporate wide maintenance activities (e.g. major shutdowns) for the whole fleet of the asset systems.

As the next step derived from the asset portfolio level decisions, strategies, policies, objectives and plans for each asset system of the portfolio can be decided. The asset strategy of the physical asset system gives direction and requirements for the individual asset level modes of operations. Asset system level strategy should also determine which kind of technology will be used and what will be the expected economic useful life for each asset of the asset system. Therefore, effective life cycle management is one of the key responsibilities of production and maintenance management at the asset system level. The asset system strategy should also determine the management practices to manage the physical asset system and individual assets, and how various management functions linked to life cycle management should be taken care of. At the individual asset level the role of maintenance is very significant. At the asset level, replacements and disposals belong to the key tasks of the maintenance function.

This management chain from the portfolio level down to the asset level is depicted in the more detailed way in Clause 6.

5.4 Management of maintenance process

The management of maintenance process is based, as described above, on the physical asset management solutions and asset management policies, strategies and plans which reflect the business objectives and requirements of the organization in question. Requirements for the maintenance processes and maintenance objectives spring from the above mentioned business requirements. The system of the maintenance process consists of separate sub-processes:

— maintenance objectives and strategies;

— planning of maintenance activities;

— resources management and development;

— maintenance implementation;

— follow-up and continuous improvement.

Follow-up and continuous improvement compares objectives and requirements for maintenance with performance, makes needed conclusions and plans development actions.

5.5 Maintenance management responsibilities

Requirements for maintenance activities do not stay stable, but change when business and technological environments change. Therefore, the maintenance function should continually evaluate its objectives and its modes of operations and modify them when needed. This means updating of maintenance plans, developing and restructuring of resources and evaluating of processes and refining of the existing ones. The maintenance function should also give feedback to the other functions of the organization about nonconformity with requirements for assets. This nonconformity may concern e.g. maintenance objectives, company policies, technological solutions or operation of equipment. The maintenance function should also give feedback about physical asset management practices, systems of cooperation, management of change and other nonconformities influencing the effective use of assets.

From physical asset management processes point view the contribution, responsibilities and tasks of the maintenance function can be defined in connection to life cycle stages (see Tables 2 to 4).

6 Physical asset management processes

6.1 Physical asset management processes and life cycle stages

Physical asset management processes produce sustainable value following the requirements of the organization. These processes are managed according to physical asset management policy, strategy and plans. They need support to be operated. Therefore much information is exchanged between these different parts of the physical asset management system. The purpose of this clause is to list the interrelationships between the maintenance process and the other parts of the system (see Figure 2) and to explain why they are important and how they are used.

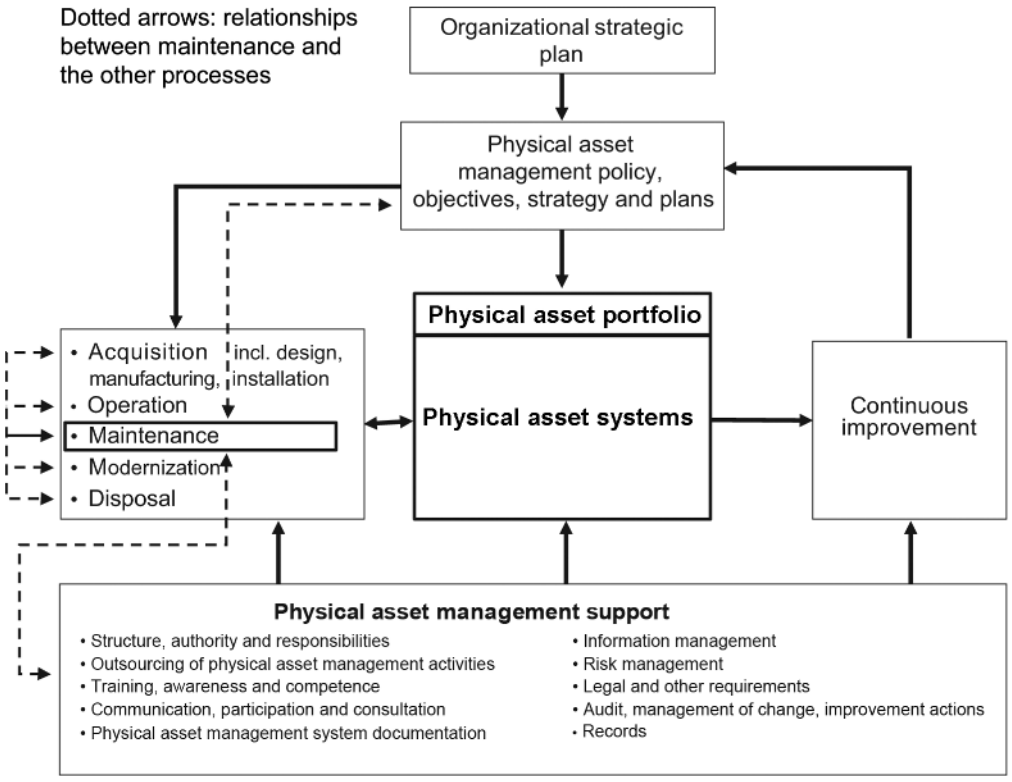

Figure 2 — Interrelationships between maintenance process and the other processes of the physical asset management system

All the processes are organized in order to satisfy organizations' needs. Figure 2 shows the core processes which are directly dedicated to the objectives. These core processes are:

— acquire appropriate physical assets, if they exist in the market, in order to satisfy the organizations' needs, or create the physical assets if they do not exist in the market at acceptable economic conditions;

— operate the assets to optimize the value created for the organizations;

— maintain the assets to optimize the value created for the organizations;

— modernization (upgrade) of the assets to obtain the greater value over the life cycle of the global asset;

NOTE Modernization process contains all the same phases of life cycle as the whole asset system.

— decommissioning and/or disposal of the assets when the end of useful life is reached.

In addition to core processes, support processes, which are generally hidden from the users, are necessary. Support processes provide resources (e.g. human, information and material), manage information, control the risks, assess performances and make possible improvements. A management process is needed to establish, implement and maintain the physical asset management policy, strategy, objectives and plans.

Maintenance is one of the core processes. It is in close relation with all the others processes and it is paramount to identify its inputs and outputs to be monitored in order to check the performance of the physical asset management system.

6.2 Life cycle, asset and maintenance management processes

6.2.1 General

Physical asset management processes can be defined and determined for the three above mentioned levels of asset management: asset portfolio, asset system and asset. These processes and their phases at the more detailed levels are described in the Tables 2 to 4. Table 2 describes the phases of management process at the asset portfolio level. Table 3 does the same for the asset system level and Table 4 for individual asset level. In order to understand the specific tasks of maintenance in specific phases of physical asset management processes, there are relevant standards for some tasks, e.g. IEC 60300-3-10 (maintainability), EN 60300-3-11 (reliability centred maintenance) and EN 60300-3-12 (integrated logistic support).

6.2.2 Physical asset management process and maintenance management process at the portfolio level

At the portfolio level clearly defined life cycle stages cannot always be easily determined. However, all the stages of physical asset management process at this level are still valid (see Table 2). The analyses of business environment, technological environment and organizations' characteristics are of significant importance at the portfolio level.

From the physical assets point of view the target of these analyses is to determine key success factors (Table 2, row 2), and as the next step, requirements (Table 2, row 3) for physical assets. Different asset strategy options (Table 2, row 4) and optional asset solutions (Table 2, row 6) have different kinds of dependability, safety, environmental, cost and income outcomes. The maintenance function should give its contribution to strategy formulation process and determination of effective asset solutions in order to take into account the influence of these factors. Asset portfolios are combinations of asset systems. After the asset solution has been determined the task of the maintenance function is fourfold:

— to participate in asset systems' concept definition and design process (Table 2, rows 6 and 7);

— to develop the corporate maintenance management system (Table 2, row 9);

— to develop the policy of standardization (e.g. spare parts, suppliers, documents) (Table 2, row 10) and;

— to plan and develop maintenance activities for the asset systems, which form the asset portfolio in question (Table 2, row 11).

Although the major proportion of the physical asset management activities are carried out at the asset system level, portfolio level management should create and give frameworks, requirements, life cycle expectations and management systems to the asset system level. It should also support and systematize cooperation, learning and improvement (Table 2, row 8).

Table 2 — Asset portfolio level process

No.	Task or process	The role and tasks of the maintenance function
1	Organization's business strategy including market analyses and analysis of business environment	Informative and consultative role in determining the impact of various asset solutions on the performance of the assets, maintenance costs, safety and environmental risks
2	Key success factors for the asset portfolio	Informative role in identification of maintenance oriented key success factors
3	Requirements and constrains for physical assets	Informative role in identification of maintenance oriented requirements
4	Asset policy and strategy for physical assets	Consultative role in asset strategy formulation
5	Allocation of the tasks and roles to the different asset systems	Consultative role regarding the influence of the role and tasks of the asset system on the maintenance function
6	Life cycle analyses of asset systems belonging to optional asset portfolios, concept explorations, determination of physical asset solution for the asset portfolio and specification of the asset systems	Consultative role in order to take into account performance, maintenance cost and risk impacts. Consultative role in definition of life cycle costs (of each asset system) for optional asset portfolios, participation in exploration and specification of asset systems within each portfolio and participation in determining asset solution
7	Design of the asset systems within the asset portfolio	Consultative role in design of asset systems according to the organizational plan and identified requirements
8	Create physical asset management system for the asset portfolio	Active participation in the development process
9	Create maintenance management system for the asset portfolio	Active participation in the development process
10	Planning of general portfolio level maintenance support resources	Active participation in the development process
11	Maintenance planning at the portfolio level	Responsible for the task in co-operation with other technical functions (such as operation)
12	Performance evaluation, benchmarking and improvement at the portfolio level	Responsible for the task in co-operation with other technical functions (such as operation)
13	Disposal and acquisition of asset systems	Consultative role
NOTE 1 At the portfolio level it is often difficult to recognize clearly defined life cycle for the whole, because the acquisitions and disposals of the asset systems form on-going process. The portfolio in question is under continual modification. However, to the asset systems within a portfolio life cycle model can be well applied. NOTE 2 The numbering in the first column is only informative, in practice this is an iterative process, which may differ from one organization to the other.		

6.2.3 Asset, maintenance and life cycle management process at the asset system level

At the asset system level it is easier to identify various life cycle stages. At the asset system level the role of maintenance is more significant than at the portfolio level. The role of the maintenance function within the asset system level management process is depicted in Table 3. The objective of strategic analyses is to find out the key success factors and as the next step (more detailed) requirements for the asset system in question (Table 3, rows 1 to 4). The next phases are concept exploration and specification, the determination of the most effective asset solution, optimal performance rates for chosen KPIs, criticality analyses and design

of the asset system in question (Table 3, rows 5 to 7). The results of these decisions and analyses depend on the role of the asset system within the whole asset portfolio (Table 3, row 2). The role of the asset system can be diverse, e.g. the high scale production of one standard product or low scale production of numerous high value added products based on a 'niche' strategy. The role of the asset system could also be the production of intermediate products for the other corporate production units.

Table 3 — Asset system level process

		Life cycle phase of the asset system						Contribution
No.	**Task or process of the asset system**	**Concept and definition**	**Design and development**	**Manufacturing**	**Installation**	**Operation, maintenance and modernization**	**Disposal**	**The role and tasks of the maintenance function**
1	Organization's business strategy and physical asset strategy (this is partly portfolio level issue, but belongs also to asset system level)	x						Informative and consultative role in determining the impact of various asset solutions on the performance of the assets, maintenance costs, safety and environmental risks. The role of maintenance should be more active at the asset system level.
2	The role of the asset system in the asset portfolio (this has been determined in portfolio level strategies and plans)	x						Consultative role regarding the influence of the role and tasks of the asset system on the maintenance function
3	Market analyses of products and services produced by the asset system and analyses of the organization's internal factors influencing on the selection of the asset solution	x						No role in market analyses. Consultative role in assessing company specific maintenance related impacts such as cost, availability, reliability, maintainability and maintenance support
4	Key success factors for the asset system. Requirements and constrains for the asset system	x				x		Consultative role in defining key success factors for the asset system and in identification of maintenance oriented requirements. For example, the choice between cost differentiation and specialization influences maintenance policies and activities.
5	Concept exploration, specification of the asset system and obsolescence planning and management	x				x		Consultative role in exploration and specification of asset systems e.g. in the form of reliability, availability, failure rate, maintainability, life cycle costs, investment costs, in order to take into account trade-offs between various options and various requirements

		Life cycle phase of the asset system						Contribution
No.	**Task or process of the asset system**	**Concept and definition**	**Design and development**	**Manufacturing**	**Installation**	**Operation, maintenance and modernization**	**Disposal**	**The role and tasks of the maintenance function**
6	Determination of asset solution for asset system, modelling of the asset system, criticality analysis and determination of performance levels (e.g. operating rate, OEE, maintenance costs, quality)	x				x		Active participation in decision making, criticality analyses, determination of performance levels and for determining trade-offs between various performance variables
7	Design of the asset system		x			x		Active participation
8	Quality inspection and testing during the manufacturing and installation, commencing and testing of the asset system			x		x		Active participation when needed. The organization in question should consult the maintenance function while deciding if this kind of inspection and testing activity is needed
9	Creation and maintenance of physical asset management system		x	x	x	x		Active participation
10	Creation and revision of maintenance management system		x	x	x	x		Responsible for the task in co-operation with other technical functions (such as operation)
11	Definition of maintenance strategy, maintenance plan and planning of maintenance support resources		x		x	x		Responsible for the task in co-operation with other technical functions (such as operation)
12	Verification of maintenance activities and maintenance support				x	x		Responsible for the task in co-operation with other technical functions (such as operation)
13	Preparation of technical documentation, preparation and provision of training, provision of spare parts, tools, support equipment system and creation of information management and upkeep of data		x	x	x	x	x	Active participation or responsible for the task in co-operation with other technical functions (such as operation)
14	Performance evaluation, benchmarking and improvement at the asset system level					x		Responsible for the task in co-operation with other technical functions (such as operation)
15	Upgrading the asset system and maintenance strategies					x		Consultative role or active participation in planning and scheduling of upgrading
16	Decision for disposal; economic and environmental management of disposal					x	x	Consultative role in decision making process. Active participation in disposal

		Life cycle phase of the asset system						Contribution
No.	**Task or process of the asset system**	**Concept and definition**	**Design and development**	**Manufacturing**	**Installation**	**Operation, maintenance and modernization**	**Disposal**	**The role and tasks of the maintenance function**
17	Feedback to the asset portfolio level						x	Informative role. The maintenance function shall provide maintenance related information to the asset portfolio level
NOTE The numbering in the first column is only informative, in practice this is an iterative process, which may differ from one organization to the other.								

After the installation and commencing of the asset system (Table 3, Row 8), typical tasks are to create physical asset management and maintenance management systems (Table 3, rows 9 and 10) which follow the frameworks, requirements, guidelines, life cycle expectations and principles of the portfolio level management system.

The role of the maintenance function at the asset system level is very significant. That does not only apply to the very technical and maintenance oriented activities, but also the early phases of asset system level management process (e.g. concept exploration and specification, the determination of the most effective asset solutions, optimal performance rates for chosen KPIs, criticality analyses and design of the asset system in question).

6.2.4 Physical asset management process, life cycle and maintenance management at the asset level

Asset level activities have significant maintenance focus. These activities are physical asset management tasks which however demand active, systematic and planned contribution of the maintenance function. The same applies to replacements of machineries or major components. The physical asset management processes is described in a more detailed way from the contribution and information sharing point of view in 6.3. In this standard the focus is on the relationship between physical asset management and maintenance management and therefore special topics of maintenance management are not covered here.

Table 4 — Asset level process

		Life cycle phase of the asset						Contribution
No.	**Task or process on the asset**	**Concept and definition**	**Design and development**	**Manufacturing**	**Installation**	**Operation, maintenance and modernization**	**Disposal**	**The role and tasks of the maintenance function**
1	Criticality analysis and determination of planned useful life (done at the asset system level)	x						Active participation in criticality analysis and in useful life estimation
2	Required reliability, maintainability, and testability (done at the asset system level)	x						Active participation in defining required reliability, maintainability, and testability
3	Load analysis (done at the asset system level)	x						Active participation in load analysis
4	Concept definition, specification and life cycle cost analysis	x						Active participation when needed and possible
5	Design of the asset in question if needed		x					Active participation when needed and possible
6	Manufacturing			x				Active participation when needed and possible
7	Installation and commencing				x			Active participation or responsible for the task in co-operation with other technical functions (such as operation)
8	Management of documentation		x	x	x	x		Active participation or responsible for the task in co-operation with other technical functions (such as operation)
9	Definition of maintenance environment, definition of maintenance strategy and maintenance tasks: e.g. reliability centred maintenance, failure modes and effects analysis		x			x		Responsible for the task in co-operation with other technical functions (such as operation)
10	Planning of maintenance support and resources, management of training, management of spare parts, tools and support equipment, management of maintenance-related information		x	x	x	x		Responsible for the task in co-operation with other technical functions (such as operation)
11	Maintenance task preparation and execution					x		Responsible for the task
12	Performance evaluation for maintenance improvement					x		Responsible for the task in co-operation with other technical functions (such as operation)

		Life cycle phase of the asset						Contribution
No.	**Task or process on the asset**	**Concept and definition**	**Design and development**	**Manufacturing**	**Installation**	**Operation, maintenance and modernization**	**Disposal**	**The role and tasks of the maintenance function**
13	Maintenance improvements/modifications					x		Active participation or responsible for the task in co-operation with other technical functions (such as operation)
14	Replacement / disposal						x	Active participation or responsible for the task in co-operation with other technical functions (such as operation)
15	Maintenance activities related to disposal						x	Responsible for the task in co-operation with other technical functions (such as operation)
NOTE The numbering in the first column is only informative, in practice this is an iterative process, which may differ from one organization to the other.								

6.3 Interrelationship between maintenance and other processes at asset and asset system level

6.3.1 Interrelationships between maintenance and acquisition/creation process

6.3.1.1 General

For relationship between acquisition and creation process and maintenance process, see Figure 3.

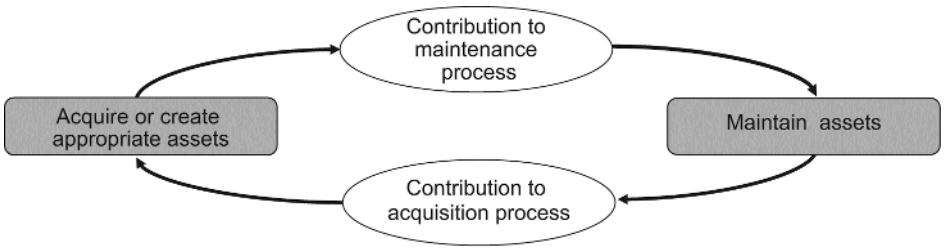

Figure 3 — Relationship between acquisition and creation process and maintenance process

6.3.1.2 Contribution to maintenance

The process “Acquire or create assets” provides the following inputs to the maintenance process (see Figure 3):

— The list of the assets (technical hierarchy) which compose the portfolio of the asset system. Assets of the list are broken down into components (sub-assets) at different levels and especially those corresponding to a main elementary function on which maintenance actions are expected to be done (for example: a pump, a valve, a motor). These assets have a reference code and an associated technical

documentation. All these assets will be considered to establish the maintenance plans according to the maintenance policy and strategy.

— The costs of the assets at each indenture level. These costs are used especially to make decisions between replacements or repairs and to determine the spare parts to be provisioned. They are used to estimate e.g. the forecasted maintenance costs.

— The characteristics of the assets in terms of materials, technology, geometry, weight, which are needed to determine the possible failure mechanisms and the possible maintenance actions. Mechanical drawings are also provided to the maintenance process.

— A functional analysis is done by engineering. It identifies the required functions, the operating conditions and constitutes a base for the analysis of the failure modes and their criticality which is part of the maintenance process.

— Expected operational modes are specified as well as environmental conditions. These data often constitute influencing factors which can initiate mechanisms or increase failure rate. The expected useful lives of the assets are also important data to determine maintenance plans.

— Risk analyses are sometimes done during the design phase. Maintenance is concerned with safety requirements produced by these analyses.

— Dependability characteristics and specifically availability of the asset system are the basis for the allocation of reliability and maintainability requirements to the components of the asset.

— Documentation of assets at different indenture levels coming from manufacturers and engineering (such as manufacturer operation and maintenance guidelines, mechanical and electrical system drawings).

— All other requirements set for physical assets (e.g. operational, safety and environmental constraints).

6.3.1.3 Contribution from maintenance

The maintenance process provides outputs which are inputs for the acquisition or creation process (see Figure 3). These outputs are important to determine appropriate assets solutions. They are:

— Maintenance strategy based on organizational strategic plan of the company through physical asset management strategy. It defines especially what resources are allocated to, what is outsourced, what kind of methods shall be used. This information shall be considered during the creation of the assets or when they are acquired.

— Availability of tools, infrastructures and qualified personnel. Creation or acquisition of assets shall take into account the resources the company already has regarding maintenance and available external resources.

— Requested levels of operational reliability of the components of the assets. These levels result from allocation of reliability among the assets in order to reach the requested availability which is an input of the maintenance process. They can be defined for example through expected failure rates, useful life of the assets, (transformation of intrinsic reliability to operational reliability through maintenance).

— Requested levels of maintainability of the components of the assets which, as reliability levels, result from allocation of maintainability among the assets in order to reach the requested availability. Maintainability can be specified through a number of different requirements which are:

  — Maintenance level which indicates the maximum complexity expected for the maintenance tasks (five levels are usually defined, see e.g. EN 13306).

— Maintenance echelon which designates where the maintenance actions are supposed to be realized (field, warehouse, manufacturer).

— Time to restoration. That means creation or acquisition should consider the complete time between the failure and the instant when the ability to perform is re-established (restoration). Logistic and technical delays (possibly administrative delays) shall be taken into account.

— Maintenance costs which include especially the labour costs and the cost of the spare parts. These costs are important in the life cycle costing of the assets. Acquisition or creation costs are not the only economic data to consider when making acquisition or creation decisions.

— Ability to detect degradations. This requirement allows preventive maintenance tasks to apply and this is an important point to specify in the design phase.

— Ability to detect failures and faults. Consequences of hidden failures or faults can be very serious and it is sometimes paramount to provide devices (e.g. alarms, tests) for early detection.

— Ability to have predetermined maintenance. That supposes, that counters or any other kind of devices to measure the relevant units of use, are installed within the assets.

— Abilities for adjustment and for cleaning which are important characteristics of assets to allow easy and qualified maintenance actions.

— Accessibility to components on which maintenance shall be done. This accessibility can lead to requirements in terms of dimensions and distances between assets.

— Ability to identify and locate the assets on the field without risks of errors which could possibly involve maintenance actions on a wrong place or item.

— Ability of the assets to be dismantled and reassembled, in order to achieve the repairs or replacements of components. This characteristic can be specified by a number of components to dismantle, needed tools, weight and size of component.

— Ability of the assets to be repaired which often depends on the balance between the price of an asset and the cost of its repair.

— Interchangeability of the assets or component of them. This quality shall be considered during the acquisition phase and one shall take care of interfaces with other assets or components.

— Ability to standardization which leads to prefer acquiring or building assets which can be employed in different locations.

— Modularity which is important to limit the down times giving the possibility to quickly replace a set of components which can be refurbished in a scheduled way in the workshop.

— Ability of the assets to tolerate the faults. This characteristic is sometimes realized with assets redundancies.

— Ability to be recovered. Requirements shall be sometimes specified to limit the run down time before repairs and the ramp up time after the repairs.

— Ability to test the assets, which are totally or partially in standby, is analysed by maintenance and may lead to specific measurements and devices (e.g. built-in test).

— Set of documents and information to be considered in the acquisition of any assets in order to allow maintenance tasks.

— Strength of the assets vis-à-vis the risks of obsolescence. Maintenance analysis may provide information to assess the risk of obsolescence. It depends especially on the consequences of unavailability of an asset and the needed time to find a solution (such as other manufacturer or redesign,).

— Requested level of safety for maintenance personnel. Maintenance tasks realization leads often maintenance personnel to face risks for their health and safety. The maintenance tasks specified in the maintenance plans shall be analysed (considering, for example, residual energy, hazardous substances, risk analysis) to specify the safety requirements (such as protection devices or personnel protective equipment).

— Generally, maintenance should give information regarding the impacts of different asset solutions on the life cycle costs of the asset system.

6.3.2 Interrelationships between maintenance and operation

6.3.2.1 General

For relationship between operation and maintenance processes, see Figure 4.

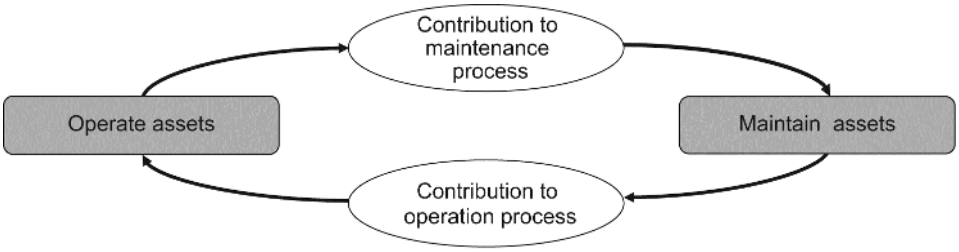

Figure 4 — Relationship between operation and maintenance processes

6.3.2.2 Contribution to maintenance

The process “Operate assets” provides the following inputs to the maintenance process (see Figure 4):

— Operational modes and production plans (e.g. product mix) established for the plant over a given period. They involve operating profiles for each asset which determine the numbers of units of use (such as hours, starts/stops, transients) that may cause degradations. That also determines the required time when invasive preventive maintenance actions shall not be done. Maintenance plans shall use this information especially to calculate the periods of the preventive maintenance actions and the schedule of the tasks.

— Environmental conditions. These conditions can depend on where and when the assets are operating. These environmental conditions are influencing factors of failure mechanisms and shall be considered by maintenance process.

— Operator involvement in monitoring and maintenance. It’s important for maintenance to have operators involved at the first maintenance level to execute some routine maintenance actions and to detect degradations and failures.

— Operational modes in degraded states shall be known to assess the criticality of the failures. If it is possible to continue to perform at non-nominal operating conditions then the consequences of a failure can be less severe. The acceptable thresholds (e.g. volume of leakage, vibration levels), the acceptable times to repair without mandatory shutdown are important information for maintenance process.

— Other deficiencies in the operation process, which impact on integrity of the asset system (e.g. strikes, social conflicts, new raw materials, changes in organizational patterns).

— Emergency procedures can lead to particular conditions of performance of the assets and some maintenance tasks shall be done to test them regularly.

— Information about risk analyses. Analyses carried out by operating team provide information which should be used by maintenance process to identify the failure modes of the assets and their criticality.

6.3.2.3 Contribution from maintenance

The maintenance process provides inputs for the operation process (see Figure 4). The following outputs are important to determine appropriate operating profiles and safety procedures:

— Operating constraints on items in order to avoid or to accelerate failure mechanisms. Physical quantities to be respected are given by the manufacturers (e.g. acceleration, velocity, temperature gradients) but constraints can be added due to observations made by maintenance personnel that can reveal degradation levels higher than expected.

— Times to restoration (after a failure) which includes time required to detect the fault, to provide the logistic support, to repair and to restart the asset, shall be known by operators. Preventive maintenance times which may have an impact on availability or on the operating mode shall be known as well. These times are taken into account by operators to manage operations during down states or degraded states.

— Preventive maintenance schedule resulting from the preventive maintenance plan applied to the asset system is communicated to the operating team for discussion. The dates of achievement of the tasks should be fixed considering the expected operating mode.

— Maintenance can allocate some maintenance tasks to operators, who are in a better position to detect precursor symptoms of failure modes. These monitoring tasks as monitoring in control room or patrol inspections are identified through the maintenance plans and the operating staffs are requested to perform them.

— When a maintenance action, that causes a risk for the safety of individuals, shall be carried out, safety procedures for maintenance execution such as padlocking are executed by operating staff. A demand is sent by the maintenance personnel.

6.3.3 Interrelationships between maintenance and modernization

6.3.3.1 General

For relationship between modernization and maintenance, see Figure 5.

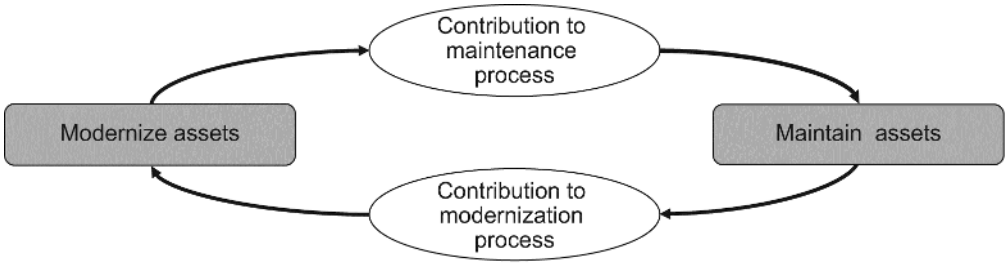

Figure 5 — Relationship between modernization and maintenance

6.3.3.2 Contribution to maintenance

The processes “Modernize assets” provides the following inputs to the maintenance process (see Figure 5):

— New requirements for the assets. Changes in business environment and technology may demand modernization of equipment and new maintenance strategies and plans.

— Life cycle costs of the new asset. In the case of modernization that does not change the function of the installed asset, information concerning life cycle cost of new equipment should be made available to maintenance process. This makes it possible to make comparisons between present and new equipment. Comparison shall take into account all direct and indirect costs that can be expected over a period of operation.

— Date of modernization. That is needed to adjust the maintenance plan of the installed assets and to establish the new preventive maintenance schedule after renewal.

— Characteristics of the new assets. Information on materials, technology, geometry, weight, is needed to determine the possible failure mechanisms and the possible maintenance actions. Mechanical drawings are also provided to the maintenance process as well as functional analysis of the new asset.

— Expected operational modes and loads. These are specified for the new assets in order to analyse the risks of failures.

— Expected useful lives of the assets. This data are important data to determine e.g. maintenance plans and life cycle costs.

— Safety requirements. Requirements resulting from risk analyses are important to establish maintenance procedures.

— Dependability characteristics and especially the expected reliability and maintainability. These are needed to determine the maintenance tasks and respective maintenance schedule.

— Documentation of assets at different indenture levels. These documents coming from manufacturers and internal or external engineering organizations (such as manufacturer's operation and maintenance guidelines, mechanical and electrical system drawings).

— Modernization procedure. This can have an impact on the maintenance activities and should be known by maintenance staff.

6.3.3.3 Contribution from maintenance

The maintenance process provides inputs for the modernization process (see Figure 5). The following contributions are important to determine appropriate modernization of assets:

— Cost information for comparison of new and old assets or in case of modernization. Maintenance costs (preventive and corrective) and disposal costs of the installed assets shall be compared to the expected overall cost of new assets (acquisition/building costs + Installation costs + preventive and corrective maintenance costs). Analysis shall take into account all direct and indirect costs that can be expected over a period of operation. The decision should be based on this comparison as well as other aspects such as safety, required functions, environment preservation.

— Evolution of intrinsic reliability. Degradation and failures constitute important indicators of the ageing of the assets. These data should be taken into account to determine the possible date of modernization.

— Maintenance time due to corrective and preventive maintenance actions. This can reveal a low level of maintainability that could be improved by modernization of asset.

— List of obsolescent components. This list includes also those components which are expected to become obsolescent soon. This information can justify modernization of assets.

— The same contribution from maintenance to acquisition process shall be considered for the modernization process, e.g. requirements caused by changed operating mode, operating constraints and operating conditions.

6.3.4 Interrelationships between maintenance and disposal

6.3.4.1 General

For relationship between disposal and maintenance, see Figure 6.

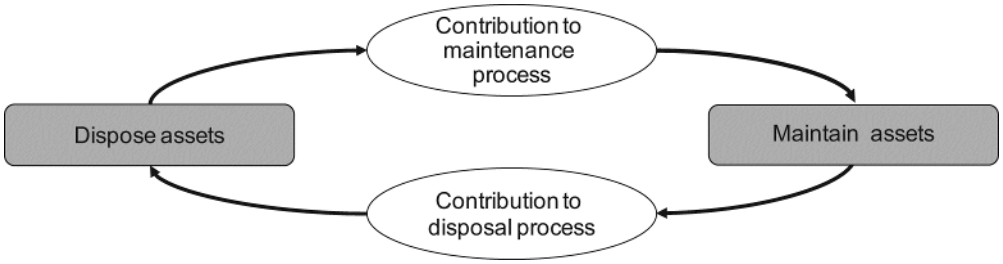

Figure 6 — Relationship between disposal and maintenance

6.3.4.2 Contribution to maintenance

Here a case is considered when disposal is not in direct relation with modernization of assets and is not included in the modernization process. Sometimes disposed asset will be replaced by a functionally similar asset and in that case life cycle starts from the acquisition phase.

The disposal process provides the following inputs to the maintenance process (see Figure 6):

— Disposal schedule. The maintenance plan of the installed assets shall be adjusted in order to minimize expenses.

— The disposal procedure can have an impact on the maintenance activities and should be known by maintenance staff (e.g. disposal procedure may require the same resources as maintenance activities). When disposal includes different steps before dismantling (e.g. cooling period) then a residual maintenance plan can be needed and definition of new operating conditions shall be given to the maintenance staff.

— During the disposal period it is possible to look for spare parts which can be sent to the warehouse. When disposing the asset some of the components can be refurbished and reused.

6.3.4.3 Contribution from maintenance

The maintenance process provides inputs for the disposal process (see Figure 6). The following outputs are important to determine disposal actions:

— Maintenance costs (preventive and corrective) expected before the disposal date shall be estimated in order to confirm or possibly to modify the disposal date.

— Any maintenance information which could have an impact on health and safety of individuals and on the environment during the disposal phase shall be given to personnel in charge of disposal.

— Information concerning dismantling and handling components to be disposed in order to reuse them.

6.3.5 Interrelationships between maintenance and physical asset management supports

6.3.5.1 Contribution to maintenance

For relationship between physical asset management supports and maintenance process, see Figure 7.

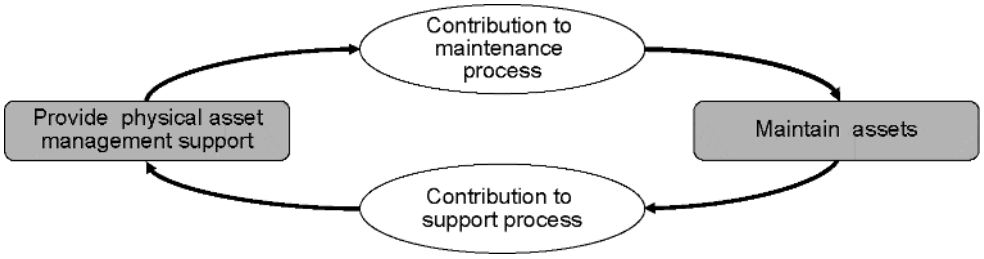

Figure 7 — Relationship between physical asset management supports and maintenance process

6.3.5.2 Contribution to maintenance

To be carried out maintenance needs logistic support which is provided by the process “provide physical asset management support” (see Figure 7). The following inputs are needed:

— Qualified staff according to the required maintenance activities. The qualification of personnel depends on the maintenance policy (e.g. level of outsourcing), level of maintenance and maintenance echelon.

— List of subcontractors. This list should be available to maintenance personnel to facilitate contracting.

— Provision of training. Training should be provided to update the competences of maintenance staff and to reach the required level of skills.

— Communication support. This is needed to give information from maintenance department both internally to the maintenance personnel and externally to the other departments and outside the company.

— Support for documentation. Documentation support services shall be provided to maintenance process and updated in due time.

— Information systems. These services are needed to collect, to store, to transmit and to treat data should be available continuously to carry out maintenance activities.

— Maintenance facilities. Maintenance needs rooms, warehouses, workshops, road, storage areas, which are supplied with energy, information, water and other required materials.

6.3.5.3 Contribution from maintenance

Maintenance process provides the following contributions for the process “provide physical asset management supports” (see Figure 7):

— Qualification profiles of maintenance personnel required to carry out the maintenance activities at all the levels of the organization (technician specialist, engineer/supervisor, manager). Based on these requirements the “provide physical asset management supports” process can look for and propose qualified maintenance personnel.

— Specification of maintenance actions to be outsourced is established to make possible contracting with a service provider.

— Skills and knowledge necessary to perform maintenance activities are defined to allow finding suitable training on the market.

— The information from the maintenance to be communicated to other entities of the organization or outside the company is given to the “provide physical asset management supports” process to be controlled and transmitted.

— Requirements for information system are expressed and published in order to get an efficient and updated CMMS.

6.3.6 Interrelationships between maintenance and management of assets

6.3.6.1 Contribution to maintenance

For relationship between management of assets and maintenance, see Figure 8.

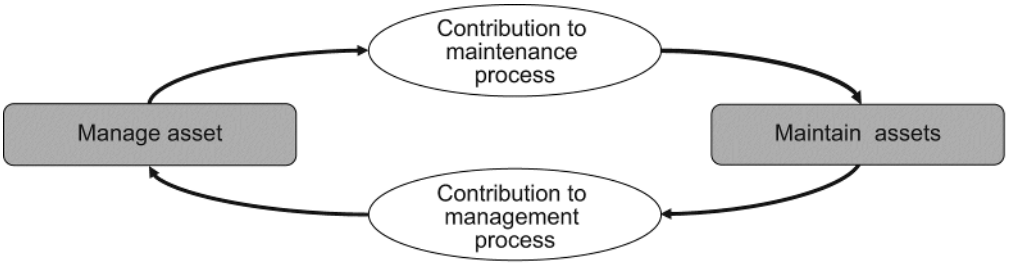

Figure 8 — Relationship between management of physical assets and maintenance

6.3.6.2 Contribution to maintenance

Maintenance shall be aligned with the organizational strategic plan and physical asset management's strategies and plans and has therefore relations with the physical asset management process. Especially, the following contributions are needed (see Figure 8):

— Physical asset management and maintenance organization structure. That is established by the top management. It defines the maintenance department organization, responsibilities, skills levels, administrative procedures, partners in other departments.

— Objectives, policy, strategy and physical asset management plans are paramount to determine maintenance strategy and plans.

— Methods, procedures or control systems to be applied to different life cycle stages of assets (e.g. business or KPIs, economic calculations, decision making rules).

6.3.6.3 Contribution from maintenance

Maintenance process provides the following contributions to the physical asset management process (see Figure 8):

— Dependability characteristics of asset or asset system. Reliability, maintainability and safety shall be known by the management to make decision related to the organizational strategic plan.

— Life cycle cost characteristics of assets. These include costs such as maintenance cost, including direct and indirect costs and are important information for the management of assets.

— Impact of maintenance strategies on assets. These include e.g. ratio between corrective and preventive actions and the trade-offs between short and long term performances of assets.

— Impact of maintenance strategies and activities on assets management policy, strategy and plans. For example the level of competences required by maintenance actions may have an effect on decisions related to outsourcing and maintenance level.

7 Performance monitoring

7.1 General KPIs of physical asset management

In order to facilitate contributions as described in Clause 6 performance monitoring and control systems are needed. Requirements presented in Figure 1 (e.g. capacity, reliability, safety) can be expressed more precisely using KPIs. In this standard, these KPIs are called specific performance indicators.

In addition to requirements for physical assets presented above, e.g. the following risks could be avoided by using KPIs (in this standard, these KPIs are called general performance indicators):

— ‘silo’ behaviour of individual functional departments (sub-optimization of activities of separate organizational functions);

— lack of holistic picture of success of physical asset management activities;

— wrong allocation of resources to various functions of an organization;

— wrong decisions regarding replacements and improvements;

— decisions based on investment cost (purchasing cost) instead of life cycle cost or profit;

— incorrectly estimated length of asset's useful life in financial calculations;

— improper financial decision making criteria for investment decisions and maintenance;

— uncertainty in decision making.

It is important to notice that certain performance indicators can be used for several purposes and at the different levels of the organization.

In order to manage its assets in line with its objectives, business environment and technological environment and to avoid risks mentioned above the organization should define and choose KPIs which support holistic and coordinated behaviour in the all functions of the organization. These indicators should then give the maintenance function and processes understanding of the requirements set on physical assets and physical asset management and understanding of the needs of the holistic and coordinated behaviour in the organization. Examples of these indicators are listed below. Company management should communicate relevant KPIs and objectives to all the functions, including maintenance, and communicate means how these functions can influence the objectives.

— Return on physical assets. This supports cooperation between all the functions and diminishes ‘silo’ behaviour;

— External criticality of production assets (e.g. customer satisfaction or competition point of view). These give common direction to physical asset management activities including maintenance activities (for

example, which sub-processes of the production system are critical from the value creation point of view: e.g. life cycle profits or quality, durability, reliability of the services or products delivered);

— Internal criticality of equipment (e.g. bottlenecks). These give common direction to physical asset management activities including maintenance activities (for example which sub-processes of the production system have the greatest influence on OEE, availability or life cycle costs);

— OEE (overall equipment effectiveness). OEE supports cooperation within operation, maintenance and development of production equipment (OEE is the product of availability, performance rate and quality rate);

— Total dependability costs of ownership (unavailability costs + replacement costs + maintenance costs + losses during the life cycle of equipment). This supports holistic view on dependability costs instead of separate functional focuses (see for example EN 15341);

— TCO or life cycle costs of production equipment. This supports cooperative behaviour within the organization and takes into account long term effectiveness and efficiency of production equipment instead of investment costs (see also Figure 2).

The organization should define leading indicators which helps it to make efficient long term decisions over the whole useful life. This can help to find the optimal trade-off of investment costs and other life cycle costs. This can also help to make right investments in the right moment to support the organization's objectives and to support requirements for its physical assets. Examples of these leading indicators are:

— useful life estimate for the equipment;

— life cycle profit estimates;

— life cycle cost estimates;

— combination of several indicators (e.g. payback time, length of useful life and net present value) to support effective decision making on investments and replacements understanding.

The organization should also define lagging indicators which together with leading indicators support the physical asset management activities. Examples of these indicators are:

— actual life cycle profit;

— actual life cycle cost;

— comparison of annual investments and annual technical depreciation which might give indication of degradation of the production equipment;

— KPIs, which give information on equipment renewal rate.

7.2 Specific performance indicators

Company management should communicate these KPIs and objectives to all the functions, including maintenance, and communicate means how these functions can influence the objectives.

In order to plan and implement physical asset management activities according to the identified requirements for physical assets the organization should define KPIs which are needed to manage and improve the performance of asset portfolio, asset systems or individual assets. There are numerous general well known KPIs which can be chosen and be used (see for example EN 15341). There is also room for the creation of organization specific indicators.

The exact form of KPIs (equation) for each requirement and effective combination and trade-offs of various indicators depend on the industrial sector, used technology and even on the life cycle phase of the production equipment and the life cycle of the business sector in question. Some of these indicators can also be used for organizational purposes such as to diminish 'silo' behaviour. The list of specific requirements is presented in Clause 5.

After the requirements for physical asset have been determined the next step is to define appropriate alternative KPIs for each requirement. For each factor (requirements) listed in Clause 5 many alternative KPIs can be found depending on the specific requirement and objectives of the organization.

8 Organization and people enablers: organizational competences

8.1 Structure and procedures

Management of physical assets includes several separate dimensions which should be managed in an effective or even in optimized way. These dimensions include:

— processes of transforming business environment (market, community, technology and company characteristics) and business objectives in an optimal way into requirements for the physical assets of the organization in question (see Figure 1);

— processes of transforming portfolio level requirements into asset system level and the latter into asset level requirements (see Tables 3 to 4);

— processes of physical asset management system to produce maintenance strategies, plans and activities from physical asset management policies and strategies (see Tables 2 to 4);

— internal cross-functional cooperation, information sharing and joint decision making to govern in an optimal way the divergent objectives of various functions (see Clauses 5 and 6);

— processes of optimizing life cycle activities over the whole scale of useful life (see Clause 6);

— processes to manage and control uncertainties associated with external and internal influencing factors and the outcomes of all physical asset management activities.

The effective management of the previous dimensions demands (in addition to well defined and planned physical asset management processes) clear definition of responsibilities and authorities for top management, middle management and key functions of the organization. Furthermore, procedures for and culture of cooperation, awareness of the particular business requirements of the organization in question and competences to cope with these organizational demands are needed (see ISO 55001 and ISO 55002).

8.2 Competences

8.2.1 General

Required specific competences depend on the level of physical asset management system: asset portfolio, asset system and individual assets.

8.2.2 Asset portfolio and asset system levels

Portfolio and asset system level top management and functional management (such as finance, marketing, engineering, production, operation, maintenance and purchasing), particularly nominated physical asset management and/or asset management teams should possess competence:

— to understand the requirements of the above mentioned internal and external influencing factors set for the physical assets of the organization;

— to transform asset portfolio and asset system level requirements into asset solutions according to the process described in Tables 2 and 3;

— to determine the KPIs to support the implementation of the determined requirements;

— to plan, build up and implement physical asset management and maintenance management system for asset portfolio and asset system level;

— to understand the impact of different physical asset solutions on the portfolio and asset system level business strategies (including life cycle profits and total maintenance costs);

— to use internal cross-functional cooperation and information sharing to govern in an optimal way the divergent objectives of various functions (see Clauses 5 and 6);

— to utilize the procedures of optimizing life cycle activities over the whole scale of the useful life of asset systems (see Figure 2);

— to utilize processes to manage risks and uncertainties associated with external and internal influencing factors and the outcomes of all physical asset management activities;

— to understand the impact of asset system level impacts (including the maintenance function) on the portfolio level physical asset management processes and the impact of individual asset level impacts (including maintenance function) on the asset system level physical asset management processes.

8.2.3 Asset level

Asset system level specified functional management (such as finance, engineering, production, operation, maintenance and purchasing), particularly nominated asset system level physical asset management and experts such as maintenance engineers and supervisors should possess competence:

— to understand how requirements on asset system level solutions have been determined;

— to understand how asset level requirements influence on asset solutions (see Table 4);

— to understand the impacts of various life cycle phases on the total life cycle costs and to take into account these impacts when asset solutions are determined;

— to use internal cross-functional cooperation and information sharing to govern in an optimal way the divergent objectives and knowledge of various functions;

— to understand and to pass on the impacts of asset level maintenance activities on the asset system level asset solutions.

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