BS EN 15341:2019

BSI Standards Publication

# Maintenance - Maintenance Key Performance Indicators

# National foreword

This British Standard is the UK implementation of EN 15341:2019. It supersedes BS EN 15341:2007, which is withdrawn.

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.

BSI, as a member of CEN, is obliged to publish EN 15341:2019 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.

The committee voted against the standard at the final stage. It draws users' attention to the following.

A significant number of technical errors in the standard were identified by the international community that could not be corrected before publication.

The introductory clauses of the standard provide only a very generalized presentation of issues surrounding the definition and delivery of maintenance requirements within the structure of a maintenance function. Many factors are listed as requiring 'consideration', but no guidance is given concerning of what such considerations should consist and how this may affect the application or derivation of performance indicators. The number of indicators presented is so large that they cannot be considered as truly 'key' in the organizational management sense. The exact meaning of many of the factors used to derive the indicators is often vague and open to misunderstanding or cannot be explicitly calculated, making them of little or no value.

The major failure of the standard is that it gives no indication of what should be done with any of the indicators listed or what may be expected of them. For example, having derived an indicator, it is not clear whether an organization should strive to make it larger or smaller. Some values are a simple statement of fact and will not normally change (e.g. redundancy). The lack of guidance concerning application of indicators and the potential for misunderstanding the indicators themselves result in this standard being considered by the committee to be of little practical value.

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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**Compliance with a British Standard cannot confer immunity from legal obligations.**

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# EUROPEAN STANDARD
# NORME EUROPÉENNE
# EUROPÄISCHE NORM

**EN 15341**

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English Version

# Maintenance - Maintenance Key Performance Indicators

Maintenance - Indicateurs de performance clés pour la maintenance

Instandhaltung - Wesentliche Leistungskennzahlen für die Instandhaltung

This European Standard was approved by CEN on 14 July 2019.

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## European foreword

This document (EN 15341:2019) 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 February 2020, and conflicting national standards shall be withdrawn at the latest by February 2020.

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

This document supersedes EN 15341:2007.

The main technical changes compared to the previous EN 15341:2007 are the following:

— the standard was fully revised;

— the vision on all the Maintenance Components was enlarged, structuring the standard in a more complete way maintaining the economical, technical, organizational KPI of the previous edition.

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

# Introduction

Maintenance Key Performance Indicators (KPI) of the Maintenance Function apply to all the physical assets either industrial, infrastructures or civil buildings or transportation systems, etc.

These indicators should be used to:

a) measure the status;

b) compare (internal and external benchmarks);

c) diagnose (analysis of strengths and weaknesses);

d) identify objectives and define targets to be reached;

e) plan improvement actions;

f) regular measurement of changes over time.

Maintenance of software alone is not covered in this document. However, maintenance of items and systems containing software is considered.

# 1 Scope

This document lists Key Performance Indicators (KPIs) of the Maintenance Function and gives guidelines to define a set of suitable indicators, to appraise and to improve effectiveness, efficiency and sustainability in the maintenance of the existing physical assets either industrial, infrastructures, facilities, civil buildings or transportation systems, etc. in the framework of the external and internal influencing factors.

# 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13306:2017, *Maintenance — Maintenance terminology*

EN 15628:2014, *Maintenance — Qualification of maintenance personnel*

IEC 60050-192:2015, *International Electrotechnical Vocabulary (IEV) — Part 192: Dependability*

# 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13306:2017 and in IEC 60050-192:2015, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

**3.1**
**asset**
<physical> item that has potential or actual value for the organization

[SOURCE: EN 13306:2017, 3.2]

**3.2**
**main area**
fundamental part of a management discipline, which represents the more important knowledge and competence to achieve and maintain an excellent status within existing influencing factors

**3.3**
**indicator**
quantitative or qualitative measure of a characteristic or a set of characteristics of a phenomenon or performance of activities, according to defined criteria or a given formula or questionnaire

Note 1 to entry: The indicator is a tool for development and implementation of a strategy for monitoring progress towards the goals outlined in the strategy.

**3.4**
**item**
part, component, device, subsystem, functional unit, equipment that can be individually described and considered

[SOURCE: EN 13306:2017, 3.1]

**3.5**
**key performance indicator**
**KPI**
indicator considered significant

**3.6**
**time**
generally used to describe time units related to the physical assets-equipment and its performance

**3.7**
**man-hour**
points the hours of labour spent in delivering maintenance activities

**3.8**
**work order**
document used by the maintenance function

Note 1 to entry: It specifies the deliverables, scope and cost of the approved work.

Note 2 to entry: It contains a pre-defined set of activities with specified materials, spare parts, tools and labour required to complete the job.

## 4 Maintenance function

The Maintenance Function is operating in various industrial plants, facilities, infrastructures, acting in different frameworks and contexts with different sizes, structures, objectives, specific constraints and influencing factors (see 5.2 and 5.3).

In this context, it is suitable to define an organizational Model of Maintenance Function, as standard reference to be implemented in relation with required objectives, available resources, and existing constraints.

This Model of Maintenance Function is reported in Figure 1.

The Model considers that for the Maintenance function to achieve the assigned objectives and excellence, it shall use an appropriate combination or parts of the various disciplines as HSE (Health Safety Environment), Administration, ICT (Information and Communication Technology), etc.

It is Management task:

a) to implement the appropriate resources, knowledge, rules, procedures activities;

b) to select how the maintenance needs to build and organize the various matters and disciplines in the following Sub Functions/Areas:

   — HSE on Maintenance;

   — Maintenance Management;

   — Maintenance People Competence;

— Maintenance Engineering;

— Organization and Support for Maintenance;

— Administration and Supply.

The maintenance function maintains the physical assets so that it can perform the required functions and consequently, the management shall act in a core framework that involves:

— The company

— The available resources

— The application of ICT and Enabling Technologies (e.g. Industry 4.0)

Acknowledging the fast development within maintenance, both from organizational and technological point, this document provides an overview of the content of sub-functions, activities, and tools to be considered when establishing activities and indicators to reach the targets.

It is suitable to use all the disciplines of Maintenance Function in the integrated framework to achieve the objectives assigned to the Maintenance of the Physical Assets with the support of ICT and Enabling Technologies (e.g. Industry 4.0).

The size and the depth of utilization depends on the maturity degree of each maintenance department and from its commitment to develop Maintenance activities towards the excellence.

During the life of each physical asset and its components, it is necessary to carry out maintenance activities to repair the failures, contain the degradation and wear with appropriate preventive actions, so as to lengthen the life of the unit and meet the required level of performance.

The Maintenance Function is an integration of 6 Sub-functions with the addition of methodology of Physical Asset Management and hardware and software of the Information and Communication Technology (see Figure 1).

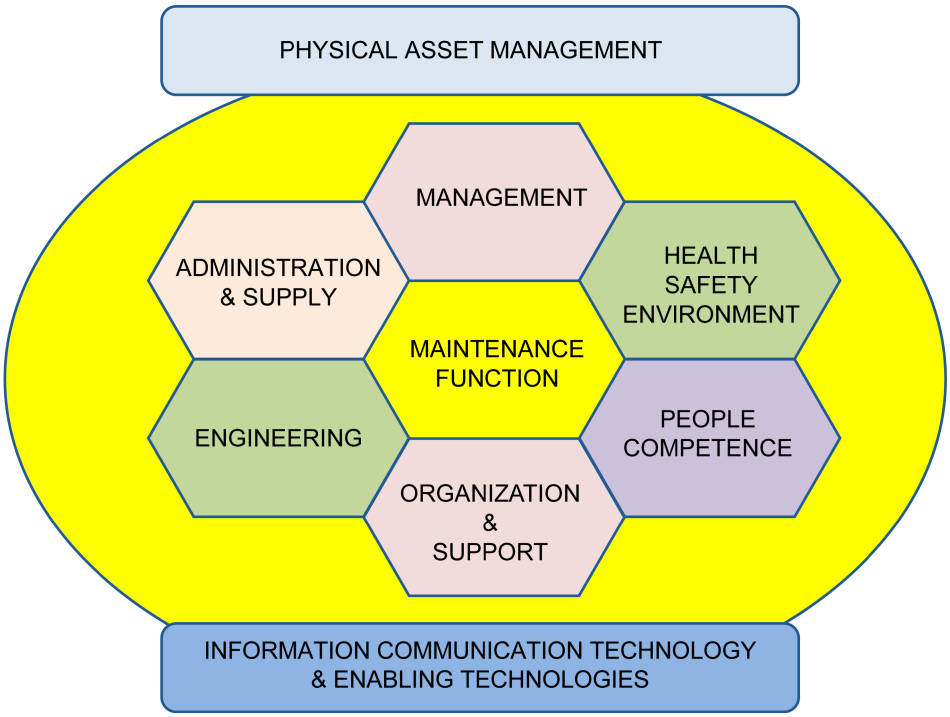



**Figure 1 — Maintenance function and core framework**

In this integrated maintenance system each sub function shall be developed in order to achieve the objectives assigned to the Maintenance Function. These objectives can include e.g. H.S.E. issues, integrity and competitiveness of the physical assets, balancing productivity, costs and service.

In order to cover all the major aspects of physical assets management the key performance indicators are structured into eight groups, one for physical asset management, six dedicated to maintenance sub-functions, and the last one for the information communication technologies.

# 5 KPIs and their objectives

## 5.1 General

When the actual or expected performance is not satisfactory, management shall define objectives and strategies to improve the resources utilization of involved sub-functions using the KPIs, allowing the organization to:

a) define the objectives;

b) measure the performance;

c) compare the performance versus the historical value of benchmarks;

d) identify strengths and weaknesses;

e) control progress and changes;

f) define plan and strategies of improvements;

g) make regular measurement of changes over time;

h) share the results.

These indicators can be used:

- on a periodic basis, for instance by preparing and following-up a budget, during performance assessment, comparing results in many ways: budgeted, expected, predicted, planned, actual, etc.;

- on a spot basis, for instance within the framework of specific audits, studies and/or benchmarking.

The period of time to be considered for measurement depends on the organization policy, aims and time constants of measured phenomena; it can be: day, week, month, quarter, semester, year, etc.

The KPIs can be often calculated as a ratio between factors (numerator and denominator) measuring the activities, resources or events, according to a given formula, but can also be the result of the quantitative or qualitative questionnaire.

The numerical values, the qualitative and the quantitative data to calculate each KPI shall be collected and elaborated based on available methods and procedures of general industrial accounting and specific management accounting rules, applied to the maintenance function.

These indicators are used to measure any qualitative or quantitative characteristics of an item or a process to create a homogeneous base to compare and set objectives to improve.

In some cases it is suitable to use specific pre-prepared questionnaire to give to the managers and experts the possibility to carry out qualitative assessments in a simple and efficient way.

## 5.2 Influencing factors

The Influencing factors are variable conditions outside of Maintenance Function which have an impact on the measured indicator. They can be general or specific, internal or external, controllable or non-controllable.

Examples of external influencing factors are:

a) location,

b) society culture,

c) national labour policies and costs,

d) market and economy,

e) laws and regulations,

f) sector / branches,

g) stakeholders,

h) technology,

i) environmental conditions.

Examples of internal Influencing factors are:

j) organization culture,

k) organization scale,

l) organization objectives,

m) criticality of the physical asset,

n) severity and complexity of the process,

o) product mix,

p) physical assets scale and complexity,

q) utilization rate,

r) age of physical asset.

These factors shall be considered as reference conditions to understand the framework where maintenance is operating. It is necessary to consider the influence and the impact of factors, in order to achieve homogeneous and appropriate evaluations without misunderstandings and misleading.

## 5.3 Maintenance Resources

The maintenance resources are:

— competence of direct and indirect people;

— labour internal and external;

— spare parts and materials;

— diagnostics and predictive technologies;

— maintenance tools and equipments;

— engineering knowledge;

— good maintenance practices to repair, restore, prevent and improve;

— information technology systems: hardware and software and enabling technologies (e.g Industry 4.0);

— supply and supporting services.

The role of management is to achieve the best maintenance performance, in line with the stated company objectives, using and dosing the appropriate resources, optimizing all the management, organizational and administrative aspects with an integrated information system.

### 5.4 Maintenance Processes

The maintenance processes are the various actions used by each sub-function to implement the activities to achieve the best competitiveness and suitable results according to the stated aim of the organization, see EN 17007.

## 6 Maintenance KPIs Matrix

Table 1 shows the KPIs of Maintenance within a Physical Asset Management, the 6 maintenance Sub-functions and the Information Communication Technology.

The KPIs reported in the matrix related to each subsystems/methodology are divided in areas, which represent the fundamental contents or characteristic to be measured, controlled and improved to achieve a quantitatively and qualitatively excellent assessment.

Most indicators can be used at different aggregation levels depending on whether they are used to measure the performance of physical assets, production lines, given equipment, item, etc.

The indicators can be split by professional levels in relation to the organizational structure established by each organization.

**Table 1 — Maintenance KPIs matrix**

| SUB FUNCTIONS, TOOLS AND METHODOLOGIES | KPIs | MAIN AREAS | | | |
|---|---|---|---|---|---|
| Maintenance within physical asset management | $PHA_i$ | Sustainability<br>i = 1 to 3 | Capacity<br>Effectiveness<br>Integrity<br>i = 4 to 11 | Service Level<br>i = 12 to 13 | Economics<br>i = 14 to 20 |
| Sub-function 1<br>Health - Safety Environment | $HSE_i$ | Laws- Rules conformity<br>i = 1 to 3 | Statistical Records<br>i = 4 to 12 | Safe Practice<br>i = 13 to 17 | Prevention and Improvements<br>i = 18 to 22 |
| Sub-function 2<br>Maintenance Management | $M_i$ | Strategy<br>i = 1 to 3 | Function<br>i = 4 to 10 | Technical Assessment<br>i = 11 to 16 | Continuous Improvement<br>i = 17 to 22 |
| Sub-function 3<br>People Competence | $P_i$ | Maintenance Manager<br>i = 1 to 3 | Maintenance Supervisor/<br>Maintenance Engineer<br>i = 4 to 9 | Maintenance Technician Specialist<br>i = 10 to 12 | Education<br>i = 13 to 21 |
| Sub-function 4<br>Maintenance Engineering | $E_i$ | Capability<br>Criticality<br>i = 1 to 3 | Durability<br>i = 4 to 9 | Preventive Maintenance<br>i = 10 to 16 | Engineering Improvements<br>i = 17 to 19 |
| Sub-function 5<br>Organization and Support | $O\&S_i$ | Structure and Support<br>i = 1 to 8 | Planning and Control<br>i = 9 to 22 | Productivity Effectiveness<br>i = 23 to 28 | Quality<br>i = 29 to 30 |
| Sub-function 6<br>Administration and Supply | $A\&S_i$ | Economics<br>i = 1 to 6 | Budget &Control<br>i = 7 to 19 | Outsourcing services<br>i = 20 to 25 | Materials and spare parts<br>i = 26 to 29 |
| Information Communication Technology,<br>Enabling technologies | $ICT_i$ | Management<br>i = 1 to 6 | Administration and Supply<br>i = 7 to 10 | Organization and Support<br>i = 11 to 13 | Engineering<br>i = 14 to 20<br>TEC 18.20 |

## 7 KPIs of "Maintenance within Physical Asset Management"

Maintenance within physical asset management allows the optimal life cycle management of physical assets to sustainably achieve the stated organization objectives.

The Maintenance activities play a significant role in the life cycle management of physical assets, because the maintenance function takes care of their integrity for the majority of the life.

Physical asset management indicates the appropriate importance of maintenance in the various life cycle stages and helps the maintenance management to define effective long term maintenance strategy.

The physical assets management provides the interrelations between the maintenance and the other physical asset processes, in order to measure the performances through the whole asset life, in line with vision, mission, values and organization objectives.

The main KPIs, named $PHA_i$, shared by driven areas as reported in Table 2 are the following:

— Sustainability: PHA1, PHA2, PHA3;

— Capacity, Effectiveness, Integrity: PHA4, PHA5, PHA6, PHA7, PHA8, PHA9, PHA10, PHA11;

— Service Level: PHA12, PHA13;

— Economics: PHA14, PHA15, PHA16, PHA17, PHA18, PHA19, PHA20

**Table 2 — KPI of maintenance within physical asset**

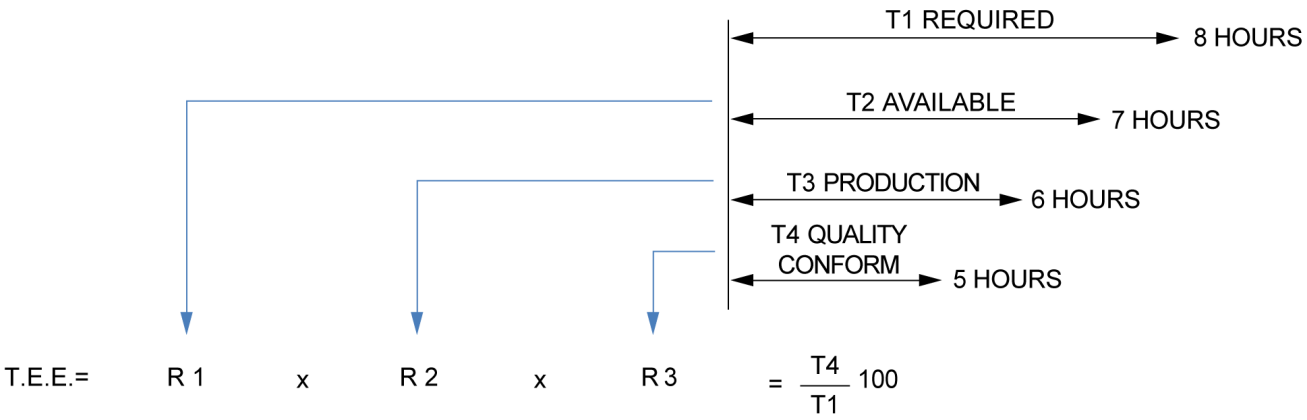
| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| PHA1 Maintenance contribution to improve sustainability (%) | Annual maintenance cost to improve sustainability | The cost of maintenance resources spent yearly to improve the sustainability |
| | Physical assets turnover | Annual turnover generated by the physical asset |
| PHA2 Maintenance issues-projects included in the strategic life plan (%) | Maintenance issues/projects included in the strategic life plan | Maintenance issues/projects included in the strategic life plan of the physical assets |
| | Maintenance issues-projects proposed | Strategic issues/projects evaluated and proposed by maintenance in the budget |
| PHA3 Capital intensity required to generate turnover | Physical asset turnover | Annual turnover generated by the physical asset |
| | Physical asset replacement value | Estimated amount of capital(quantity of money) that would be required to replace the physical asset to required function |
| PHA4 Utilization rate of production capacity (%) | Actual production output | Total effective output |
| | Standard production capacity | Production capacity in term of output is pre-defined production standard capacity for a period of time according to manufacturing rules |
| PHA5 Rate of replacement (%) | Replacement costs | Annual expenditures to replace the existing physical assets |
| | Physical assets replacement value | Estimated amount of capital that would be required to replace the physical assets to required function |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| PHA6<br>Total equipment effectiveness[1]<br>R1 x R2 x R3<br>(%) (see Figure 2) | R1<br>Maintenance effectiveness<br>(availability defined in IEC 60050-192:2015)<br>(%) | Required time less down time due to maintenance reasons as:<br>– stoppages due to failures,<br>– anomalous situations as reduction of quality, quantity and speed,<br>– preventive actions: predictive, on condition predetermined,<br>– maintenance improvements |
| | | Required time fulfilling the expected technical standard and product characteristics |
| | R2<br>Manufacturing effectiveness<br>(%) | Required time less down time due to maintenance less lost time due to manufacturing causes as:<br>– start up,<br>– shutdown,<br>– change over,<br>– speed reduction,<br>– less quantity and quality for operations reasons |
| | | Required time less lost time due to maintenance reasons as:<br>– failures stoppages,<br>– anomalous situations as reduction of quality, quantity and speed,<br>– preventive actions: predictive, on condition, predetermined,<br>– maintenance improvements |
| | R3<br>Quality effectiveness<br>(%) | Lost time due to non conformity of quality materials, and process yield with technical standard |
| | | Manufacturing time less lost time due to manufacturing reasons as a start-up, shutdown, change over, speed reduction, quality defects of materials and poor quality for operation mistakes |

1) T.E.E., time based, see Figure 2. Named also Overall Equipment Effectiveness =O.E.E.

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| PHA7<br>Integrity | -High<br>-Medium<br>-Sufficient<br>-Insufficient<br>-Poor | The appraisal values due to the compliance of existing physical asset to:<br>a) laws,<br>b) regulations,<br>c) international standard,<br>d) physical status measured by:<br>1) integrity tests<br>2) predictive analysis<br>3) non-destructive tests |
| PHA8<br>Operational availability due to maintenance<br>(%) | Total Operating time | Time when the physical asset is performing as required |
| | Total Operating time + Downtime | Time when the physical asset is performing as required plus the time lost due to failures and preventive maintenance activities |
| PHA9<br>Age of physical asset<br>(%) | Actual cumulative operational life | Total operating time<br>See maintenance records |
| | Expected cumulative operational life | Expected operating time<br>See management reports |
| PHA10<br>Economic life ratio<br>(%) | Total actual cumulative Life | See maintenance records |
| | Depreciation Life | See economics reports book keeping rules |
| PHA11<br>Average unavailability Costs due to maintenance reasons<br>(Euro/hour) | Total unavailability costs | Total costs direct and indirect related to the unavailability due to maintenance |
| | Total hours of unavailability | Total hours of unavailability due to maintenance reasons |
| PHA12<br>Maintenance service level<br>(%) | Achieved performance/required performance | Mix of performance as safety, operational availability, total maintenance cost, quantity of preventive maintenance, etc. measured by predefined indicators to compare the achieved versus the required |
| PHA13<br>Average maintenance cost for operational available time<br>(Euro/Hour) | Total maintenance cost | See M15 |
| | Hours of operational availability | See maintenance records |
| PHA14<br>Annual maintenance cost on annual total life cost<br>(%) | Annual maintenance costs | See M15 (annually) |
| | Annual total industrial life cost | See total industrial annual cost to keep the physical asset running |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| PHA15<br>Impact of maintenance on standard technical output<br>(Euro/output unit) | Annual maintenance cost | See M15 (annually) |
| | Annual standard technical output | Annual technical standard output of a physical asset is the quantitative output generated fulfilling the qualitative characteristics |
| PHA16<br>Return on improvements<br>(%) | Saving generated by improvements | See accounting reports |
| | Cost of the implemented improvements | Total expenditures due to the implementation of the improvements |
| PHA17<br>Impact of maintenance cost on an annual turnover of physical asset<br>(%) | Total maintenance cost | See M15 |
| | Annual turnover | Turnover generated by the sales of products/services developed by physical asset |
| PHA18<br>Direct and indirect cost impact of asset on annual turnover of the asset<br>(%) | Total maintenance cost + unavailability costs + depreciation | See accounting and maintenance reports |
| | Annual turnover | Turnover generated by the sales of product/service developed by the physical assets |
| PHA19<br>Proportion of maintenance time on annual planned time<br>(%) | Down time due to maintenance works | See records of maintenance |
| | Total annual planned time | See production plan records |
| PHA20<br>Contribution of capitalized spare parts on replacement value of physical asset<br>(%) | Cost of capitalized critical spare parts | Value of the annual average inventory of capitalized critical spare parts.<br>The critical spare parts are the spare parts having high unit value, long lead time, whose unavailability could create big production loss |
| | Physical Asset Replacement Value | See PHA3 |




**Key**

$R1 = \frac{T2\ AVAILABLE}{T1\ REQUIRED}$ Lost time due maintenance reasons: failures, predictive, preventive, quantity and quality out of standard

$R2 = \frac{T3\ PRODUCTION}{T2\ AVAILABLE}$ Lost time due to production reasons: start- up, shutdown, change over, speed and quality under standard

$R3 = \frac{T4\ QUALITY\ CONFORM}{T3\ PRODUCTION}$ Lost time due to quality not conform because of quality of materials and process yield

**T.E.E. =** 7/8 (= 87,5 %) X 6/7 (=85,7 %) X 5/6 (= 83,3 %) = 62,45 %

Standard time based 8 h/shift fulfilling technical standards and products characteristics

**Figure 2 — Total Overall Equipment Effectiveness (T.E.E.) (example)**

## 8 KPIs of Sub-function "Health-Safety-Environment (HSE)" on Maintenance

This sub-function concerns the implementation of policies, procedures by the maintenance management using adequate resources to prevent injuries and losses and be compliant with laws, rules and company objectives.

The H.S.E. laws, rules and procedures are fundamental requirements for Maintenance to carry out Risk Analysis and to do preventive actions, keeping the integrity of each equipment in the condition that enable them to run (operate) in a sustainable way according to requirements of law and standards.

The whole can be considered a subsystem that involves so much maintenance because is widely recognized prone to accidents in any field of activities.

It means that the Operational Availability of the Physical Asset includes conformity to HSE requirements to prevent any unacceptable risk and unassessed danger to people and environment.

The Failure and Injury Risk Analysis is a Tool to be used as preventive action in each corrective, proactive, predictive, on condition, preventive maintenance work or technical improvement.

The Main Contents and knowledge to be complied are:

— Laws, Policy and Strategy on HSE,

— HSE Responsibility, Objectives and Plans,

— HSE Risk Analysis and RAMS [2)] evaluations,

— HSE Procedure and Device to Prevent Accidents,

— Risk Analysis and Hazard Assessment,

— HSE Records and related Indicator,

— Failure Mode, Effects and criticality analysis,

— Good practices in health- safety- environment,

— Protective Equipment (collective and personal),

— Safety manual and Handbook,

— Emergency Plan,

— Accident report and Investigation report,

— Occupational Diseases and Accidents,

— Safety Education and Training.

It includes the HSE performance and competence of maintenance personnel, internal or external both insourced and outsourced, in order to meet the requirements of influencing factors (see 5.2).

The 4 main driven areas of HSE, related to the Maintenance performances and the KPIs, named HSE1-22, are:

— Conformity to Laws and Rules: HSE1, HSE2, HSE3,

— Statistical Records: HSE4, HSE5, HSE6, HSE7, HSE8, HSE9, HSE10, HSE11, HSE12,

— Maintenance safety practices HSE13, HSE14, HSE15, HSE16, HSE17,

— Prevention-Improvements: HSE18, HSE19, HSE20, HSE21, HSE22.

**Table 3 — KPI of health-safety-environment on maintenance**

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| HSE1<br>Conformity of maintenance activities to standards, procedures, law and rules<br>(%) | HSE laws and rules implemented | By results of HSE audits to the physical asset |
| | Law and rules required | HSE laws and rules required to be implemented |
| HSE2<br>Completion of failures risk analysis<br>(%) | Risk analysis performed | Risk analysis of potential failures |
| | Risk analysis required | Risk analysis of potential failures generated by physical asset status, configuration and operation plans |

2) RAMS means Reliability, Availability, Maintainability, Safety.

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| HSE3<br>Unavailability due to non HSE conformity<br>(%) | Down time due to non-conformity to HSE | Shutdown and lost time of physical asset due to non-conformity to HSE |
| | Total required operating time | See operating plan |
| HSE4<br>Frequency of maintenance injury<br>(Number/ Man hours worked) | Number of injuries of maintenance people | See safety maintenance records |
| | Total man-hours worked by maintenance people | See safety maintenance records |
| HSE5<br>Contribution of maintenance frequency index to the site frequency index<br>(%) | Frequency of injuries of maintenance personnel | See safety maintenance records |
| | Frequency of injuries for the whole site | See safety site reports |
| HSE6<br>Severity of injuries of maintenance<br>(%) | Total lost work days due to injuries | See safety site reports |
| | Total number of recordable incidents generating lost work days | See maintenance records |
| HSE7<br>Contribution of maintenance severity index on site severity index see OSHA<br>(%) | Maintenance severity index | See maintenance safety records |
| | Site severity index | See safety site records |
| HSE8<br>Injury frequency of external maintenance<br>(Event/Hour) | Number of injuries of external maintenance | See safety records of external personnel related to maintenance |
| | Total man-hours worked by external maintenance (see HSE6) | See maintenance reports |
| HSE9<br>Injury severity of external maintenance (%) | Lost days + % Invalidity times 7500 + 7500 by fatality | See safety records |
| | Total working days of external maintenance | See maintenance reports |
| HSE10<br>Frequency of failures causing injuries to people | Number of failures causing injuries (including fatalities) to people | See failure reports |
| | Actual working time | See production records |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| HSE11<br>Incidence rate | Number of failures causing injuries (including fatalities) to people | See maintenance reports |
| | Total number of maintenance people | See production records |
| HSE12<br>Exposure to occupational diseases | Number of maintenance people exposed to occupational disease X number of days of exposure | See maintenance reports |
| | Total work days of maintenance people in a given period of time | See production records |
| HSE13<br>Frequency of item failures causing damage to the environment | Number of failures causing damage to environment | See company reports and specific criteria of evaluation |
| | Total number of failures | See maintenance records |
| HSE14<br>Environmental near miss (%) | Number of potential failures causing damage to the environmental | See failure reports |
| | Total number of failures | See maintenance records |
| HSE15<br>Preventive culture within HSE | -High<br>-Medium<br>-Sufficient<br>-Insufficient<br>-Poor | According to background and preventive competence necessary to prevent injuries |
| HSE16<br>Safe work permit required (%) | Number of safe work permit issued | See safety reports and records |
| | Number of safe work permit required | See safety maintenance records and a definition of permissions related to the processes, laws and /or Internal rules |
| HSE17<br>Safety control rate (N°/man-hours) | Number of safety audits performed | See safety plan and report |
| | Maintenance annual man hours worked | See maintenance records |
| HSE18<br>Safe working procedure rate (%) | Number of safe working procedure defined | See safety and engineering records |
| | Number of safe working procedure required | See safety and maintenance plan |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| HSE19<br>Environmental working procedure<br>rate (%) | Number of environmental working procedure defined | See environmental and maintenance operational procedure defined as good practice to prevent environmental damages |
| | Number of environmental working procedure required | See environmental and maintenance engineering records |
| HSE20<br>Injury prevention rate for HSE reasons<br>(%) | Items replaced before failure | See maintenance records |
| | Items to be replaced before failure | See risk analysis and preventive maintenance plans |
| HSE21<br>Safety and health improvements<br>rate (%) | Maintenance cost spent to improve H.S. level | All the resources internal and external spent to ensure HSE level |
| | Total maintenance cost | See M15 |
| HSE22<br>Environment improvements rate<br>(%) | Maintenance expenditures to reduce environmental risks | All the resources internal and external spent to improve environment |
| | Total maintenance cost | See M15 |

## 9 KPIs of Sub-function “Maintenance Management”

Maintenance Management is a combination of the resources, disciplines, knowledge, competences and tools to define a medium term plan in line with the industrial company plan. It is the coordination and control of activities implemented on physical assets to achieve the established objectives in the existing framework and constraints.

The Maintenance Management applies theories, applications and practices of management, available internal and external resources to coordinate the activities of the maintenance in order to achieve the best suitable maintenance performances. The physical assets are utilized in the existing framework, according to the vision, mission, values, policies and stated objectives of the organization.

The Maintenance Management has:

— to comply with the laws, HSE, rules and company procedure;

— to define the maintenance strategy and implement it, see ISO 55001;

— to manage the Maintenance Function and the related sub-functions;

— to optimize people competence, productivity of maintenance resources, effectiveness and efficiency of the processes;

— to improve the technical standard;

— to achieve the ”best added value” for plants, facilities and infrastructures in the optimal life cycle, established by industrial strategies and physical asset management;

— to consider the external and internal influencing factors that are fundamental to understand the status of the organization /site /plant and his evolution towards the excellent organizational models.

The main driven areas and related KPIs, named M, are the following:

— Maintenance Strategy: M1, M2, M3;

— Management of Function: M4, M5, M6, M7, M8, M9, M10, M11, M12, M13;

— Technical Assessment: M11, M12, M13, M14, M15, M16, M17, M18, M19;

— Continuous Improvement: M20, M21, M22.

The indicators M1, M2, M3, M4, M5, M6, M7, M8, M9 are qualitative, not defined by a formula.

In order to get a qualitative value it is recommended to use an "Evaluation Questionnaire" to appraise the specific degree of the subject in each specific reality for each indicator.

In this way it will be possible to assess the position of maintenance function in the framework of maintenance maturity model and estimate the level with votes of merit.

**Table 4 — Maintenance management Key Performance Indicators**

| KPI | DEFINITION AND MAIN CHARACTERISTICS | APPRAISAL METHOD, EXAMPLES AND DEFINITIONS |
|---|---|---|
| M1<br>Maturity of maintenance function | VOTES OF MERIT<br>High = 5<br>Medium = 4<br>Sufficient = 3<br>Insufficient = 2<br>Poor = 1 | **MAINTENANCE MODELS EVOLUTION EXAMPLES**<br>Maturity degree established by audits of maintenance experts providing a quantitative or qualitative merit (vote) for each site, plants,company,etc in relation with existing situations |
| | | **1. REACTIVE**<br>Activities based on corrective actions immediate or postponed and planned. Control based on effectiveness |
| | | **2. RATIONALIZED**<br>Planning and control, preventive and predetermined actions, budget, efficiency control, external maintenance, open service, spare parts warehousing |
| | | **3. PROACTIVE**<br>Criticality analysis, diagnostic, FMECA preventive on condition, outages optimization |
| | | **4. WORLD CLASS MAINTENANCE**<br>TPM, predictive and condition monitoring, spare parts optimization, RCM, lean organization, continuous improvements.<br>Full Service, Standards ISO and CEN |
| | | **5. TECHNOLOGICAL AND COMPUTERIZED**<br>Software, KPIs and Cockpit, RMAS, info-mobility remote control and maintenance, global service |
| | | **6. ICT INTEGRATED**<br>Application of enabling technologies:<br>Big data, learning machine, M2M, prognostic |

| KPI | DEFINITION AND MAIN CHARACTERISTICS | APPRAISAL METHOD, EXAMPLES AND DEFINITIONS |
|---|---|---|
| M2<br>Integration of maintenance strategy in strategic industrial plan | High = 5<br>Medium = 4<br>Sufficient = 3<br>Insufficient = 2<br>Poor = 1 | • Prepared, approved, integrated in long term basis<br>• Prepared, approved, integrated in short-terms basis<br>• Prepared but non integrated<br>• Prepared but non approved<br>• Partially prepared |
| M3<br>Maintenance strategy implementation | Quantitative accomplishment<br>% | Maintenance strategy is showing the main maintenance objectives, the resources as well plans and actions to achieve them<br>Quarterly or annual % of quantitative accomplishment |
| M4<br>Benchmarking frequency | Once every 6 months<br>Once every year<br>Once every 3 years | Number of internal + external benchmarking performed |
| M5<br>Frequency of management audits | 1) Higher frequency than the one for the organisational planning process<br>2) Following the frequency of the organisational planning process<br>3) Lower frequency than the one for the organisational planning process, but regularly<br>4) Carried out coincidentally<br>5) Never | Number of audits performed in relation to the objectives and the life cycle status |

| KPI | DEFINITION AND MAIN CHARACTERISTICS | APPRAISAL METHOD, EXAMPLES AND DEFINITIONS |
|---|---|---|
| M6<br>Frequency of technical assessments | 1) Higher frequency than the one for the management audits<br>2) Following the frequency of the management audits<br>3) Lower frequency than the one for the management audits, but regularly<br>4) Carried out coincidentally<br>5) Never | Number of technical assessments performed per year to measure the main conformities in relation to the technical sectors |
| M7<br>Position of maintenance function in the company structure | Level 1 (plant/site manager)<br>Level 2 (management group level)<br>Level 3 (level reporting to level 2)<br>Level 4 (level reporting to level 3) | Maintenance manager/chief is reporting to the company management in relation to size, structure and policy of the company |
| M8<br>Maintenance involvement on investment projects | • Leading role<br>• Permanent team member<br>• Temporary team member<br>• Opinion required (consultative role)<br>• No role | Roles of representatives of maintenance in the projects of the organization |
| M9<br>Outsourcing degree (%) | Total man-hours outsourced | Considering all the outsourced works and services |
| | Total man-hours worked | Considering inside and outside people |
| M10<br>Time based availability (%) | Achieved up-time during required time | Time when the physical assets are able to perform the required function. Includes standby time but not idle time |
| | Required time | See EN 13306:2017, 9.4 |

| KPI | DEFINITION AND MAIN CHARACTERISTICS | APPRAISAL METHOD, EXAMPLES AND DEFINITIONS |
|---|---|---|
| M11<br>Availability based on operating time<br>(%) | Operating time | Time interval throughout which an item is performing as required. |
| | Required operating time | Required operating time is the interval throughout which the item is required to be in an up-state and operating. It excludes standby time and idle time<br>It excludes lost operating time due to external reasons such as market demand, laws, business reasons, lack of resources, working time |
| M12<br>Availability based on time to restoration | Operating time (OT) | During a given period of time, this ratio measures the percentage of time during which an item performed when required excluding when it did not perform due to other reasons than faults |
| | Operating time + Time to restoration (OT + TTR). | Time to restoration includes active repair time and delays and ramp up times |
| M13<br>Production based availability | Actual production | See EN 13306:2017, Figure C.1 |
| | Required production, or any other reference level, over a specified period of time | Other reference levels can be<br>• Total production at nominal capacity during the period of time;<br>• Total production at nominal capacity during the period of time excluding when necessary external resources are missing;<br>• Total production at nominal capacity during the period of time excluding when necessary external resources are missing and unavailability of production is planned |
| M14<br>Cumulative depreciation rate<br>(%) | Cumulative depreciated value | See accounting |
| | Total value to be depreciated | See accounting |
| M15<br>Frequency of maintenance shutdown No/year | Number of shutdowns | See maintenance records |
| | Year | See operations records |

| KPI | DEFINITION AND MAIN CHARACTERISTICS | APPRAISAL METHOD, EXAMPLES AND DEFINITIONS |
|---|---|---|
| M16<br>Variation of production standard capacity<br>(%) | Annual standard production capacity | See production records |
| | Previous year's standard capacity | Annual production standard capacity is the value of technical production, recognized as standard capacity for one or part of the year |
| M17<br>Contribution of total maintenance cost on technical capacity rate<br>(Euro/unit output) | Total maintenance cost | Total maintenance cost includes costs referred to:<br>a) wages, salaries and overtimes for managerial, supervision, support staff and direct staff<br>b) payroll added costs for the above mentioned persons (taxes, insurance, legislative contributions)<br>c) spare parts and materials consumables charged to maintenance including freight costs<br>d) tools and equipment non capitalized or rented<br>e) external maintenance, rented facilities<br>f) consultancy services<br>g) administration cost for maintenance<br>h) training and education<br>i) costs for maintenance activities performed by production or services people<br>j) costs for transportation, hotels<br>k) documentation<br>l) c.m.m.s. (computerized maintenance management software)<br>m) energy and utilities<br>n) depreciation of maintenance capitalized equipment and workshops, warehouse for spare parts and materials<br>o) exclusions:<br>1) costs for products or service change over or transaction time as exchange of dies<br>2) depreciation of strategic spare parts<br>3) down time costs |
| | Technical capacity | Annual technical design capacity |

| KPI | DEFINITION AND MAIN CHARACTERISTICS | APPRAISAL METHOD, EXAMPLES AND DEFINITIONS |
|---|---|---|
| M18 Annual renewal rate (%) | Annual investment to replace physical asset | See capital expenditures |
| | Total asset replacement value | See economic records |
| M19 Rate of results (%) | Achieved objectives | Based on annual effective results |
| | Assigned objectives | According to the management plans |
| M20 Contribution of continuous improvement in maintenance (%) | Effective man-hours spent in improvements activities | See projects reports |
| | Total effective worked maintenance man-hours | See maintenance records |
| M21 Number of continuous improvement activities N°/YEAR | Number of improvements performed | See records of maintenance |
| | Year | See calendar |
| M22 Annual return on continuous improvements (%) | Cost savings | See generated savings as: energy, labour, spare parts, materials, production time, etc. |
| | Costs of improvements | See costs of projects reports |

# 10 KPIs of Sub-function “People Competence”

## 10.1 General

The competence of maintenance people is a priority, because the Maintenance is a function where the labour is a fundamental resource in term of quantity and quality.

It is necessary to develop two kinds of competence:

1) one related to the specific knowledge of company sectors:energy,oil and gas, pharmaceutical, food, transportation, etc.

2) one related to the knowledge of each maintenance sub function.

There are two steps in the process to improve the competence and consequently the level of professionalism.

## 10.2 Qualification

EN 15628:2014 provides a formal outcome of an assessment and validation process of the competence of maintenance personnel, provided by institute or school authorized by an external certification body and determines that an individual has obtained:

— the required degree of education;

— the required work experience and skill on the job;

— the required knowledge of maintenance discipline.

The Qualification is classified by EU Recommendation as follows:

— EQF LEVEL 4-5 Maintenance Technical Specialist;

— EQF LEVEL 5-6 Maintenance Supervisor / Maintenance Engineer;

— EQF LEVEL 6-8 Maintenance Service Manager / Maintenance / Maintenance Function Manager.

Competence includes methods, applications and practices to achieve the best level of professionalism through education, field experience and specific knowledge of maintenance discipline, according to EN 15628.

The related KPIs, named P, are:

— Maintenance Manager: P1, P2, P3;

— Maintenance Supervisor / Maintenance Engineer: P4, P5, P6, P7, P8, P9;

— Maintenance Technician Specialist: P10, P11, P12;

— Education Plans: P13, P14, P15, P16, P17, P18, P19, P20.

1) Education:

The outcome of the assimilation of information through learning. principles, theories by school and university following programs related to the technical, management, economics and engineering disciplines.

2) Experience:

Ability to use good maintenance practices, personal, social and/or methodological behaviour, work or study in professional and personnel development.

3) Skill:

The ability to apply knowledge and use of know-how to complete task and solve problems. Skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual and the use of methods, materials, tools and instruments).

4) Training:

It is teaching or developing oneself or others in any skills and knowledge that all are related to specific and useful competencies.

Training has specific goals of improving:

— capability,

— capacity,

— productivity,

— quality,

— performance.

**Table 5 — Key Performance Indicators of competence in each position**

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| P1<br>Competence of maintenance managers<br>(%) | Achieved/Required | See EN 15628:2014 |
| | Achieved/Required | See EN 15628:2014, 5.3 |
| P2<br>Knowledge of maintenance managers<br>(%) | Achieved/Required | See EN 15628:2014 |
| | Achieved/Required | See EN 15628:2014, 5.3 |
| P3<br>Skill of maintenance managers<br>(%) | Achieved/Required | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.3 |
| P4<br>Competence of maintenance engineers<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.2 |
| P5<br>Knowledge of maintenance engineers<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.2 |
| P6<br>Skill of maintenance engineers<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.2 |
| P7<br>Competence of works supervisors<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.2 |
| P8<br>Knowledge of works supervisors<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.2 |
| P9<br>Skills of works supervisors<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.2 |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| P10<br>Competence of technical specialists<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.1 |
| P11<br>Knowledge of technical specialists<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.1 |
| P12<br>Skills of technical specialists<br>(%) | Achieved | See EN 15628:2014 |
| | Required | See EN 15628:2014, 5.1 |
| P13<br>Maintenance qualifications<br>(%) | Number of professionals qualified | See EN 15628:2014 |
| | Total number of people<br>direct and indirect | See maintenance records |
| P14<br>Certification<br>(%) | Number of professionals certified | See authorized certification bodies<br>NOTE According to EN ISO/IEC 27001. |
| | Total number of people direct and indirect | See maintenance records |
| P15<br>Training and education of managers<br>(%) | Annual man-hours of training and education | See training and education time performed |
| | Total man-hours | See number of people and working time |
| P16<br>Training and education of maintenance engineers<br>(%) | Annual man-hours of training and education | See training and education time performed |
| | Total man-hours | See manning and working time |
| P17<br>Training and education of works supervisors<br>(%) | Annual man-hours of training and education | See training and education time performed |
| | Total man-hours | See working time |
| P18<br>Training and education of technical specialists<br>(%) | Annual man-hours of training and education | See training and education time performed |
| | Total man-hours | See number of people and working time |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| P19<br>Proportion of training and education man hours<br>(%) | Total man-hours of training and education | See training and education time performed for maintenance people |
| | Total man-hours | See maintenance records |
| P20<br>Qualification degree of external maintenance (%) | Annual man-hours worked by qualified external maintenance personnel | See contracts and reports |
| | Total annual man-hours worked by external maintenance personnel | See contracts and reports |
| P21<br>Proportion of trained people<br>(%) | Total number of people trained | See training and education time performed for maintenance people |
| | Total number of people | See maintenance records |
| KPIs may be splitted per staff categories. | | |

## 11 KPIs of Sub-function "Maintenance Engineering"

Maintenance engineering is the discipline and processes applying competence, skills, methods, tools and techniques to develop and support maintenance activities in order to ensure that an item (3.4) is able to perform its required functions in a safe, sustainable and cost-effective manner throughout the life cycle.

Maintenance engineering includes preparation of systemized information about Physical assets and its components in order to provide sufficient and relevant information.

The main areas of maintenance engineering in relation with the Influencing factors of physical assets and the related KPIs, named E, are:

— Capability and Criticality of Physical Assets: E1, E2, E3;

— Durability: E4, E5, E6, E7, E8, E9;

— Preventive Maintenance: E10, E11, E12, E13, E14, E15, E16;

— Continuous Engineering Improvement: E17, E18, E19.

**Table 6 — Key Performance Indicators of maintenance engineering**

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| E1<br>Capacity to develop maintenance engineering<br>(%) | Cost of maintenance engineers | See economics of maintenance |
| | Estimated physical asset replacement value | It is the estimated amount of capital that would be required to replace the physical asset as now it is |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| E2<br>Incidence of maintenance engineering<br>(%) | Cost of maintenance engineering | See economics of maintenance |
| | Total maintenance cost | See M16 |
| E3<br>Criticality of items<br>(%) | Total number of critical items installed | See approved criticality rules |
| | Total items installed | See engineering records |
| E4<br>Redundancy<br>(%) | Existence of more than one means for performing a required function when needed in an item | See EN 13306:2017, 4.13 |
| | Total items installed | See engineering reports |
| E5<br>MTBF: meantime between failures<br>(hours) | Total operating time | See maintenance records |
| | Number of failures | See maintenance reports |
| E6<br>MRT (mean repair time)<br>(%) | Total time to repair | See maintenance records of each unit |
| | Number of failures | See maintenance report of each unit |
| E7<br>FMECA application on critical item | Number of critical considered items covered by FMECA | See engineering reports about criticality |
| | Total critical considered item | See list of critical units |
| E8<br>Rate of failures<br>N°/Year | Annual number of failures | See maintenance reports |
| | Annual operating time | See operation report |
| E9<br>Down time due to corrective maintenance (%) | Down time due to corrective maintenance | See maintenance reports and EN 13306:2017, 7.4 |
| | Total down time due to maintenance reasons | See maintenance reports |
| E9 a)<br>Improvement (%) | Down time due to improvement work | See maintenance reports |
| | Total down time due to maintenance reasons | See maintenance reports |
| E9 b)<br>Immediate corrective maintenance (%) | Down time due to immediate corrective maintenance | See maintenance reports |
| | Total down time due to maintenance reasons | See maintenance reports |
| E9 c)<br>Deferred corrective maintenance (%) | Total down time due to deferred corrective maintenance | See maintenance reports |
| | Total down time due to maintenance reasons | See maintenance reports |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| E9 d) Scheduled maintenance | Total down time due to scheduled maintenance | See maintenance reports |
| | Total down time due to maintenance reasons | See maintenance reports |
| E9 e) Un-scheduled maintenance | Total down time due to un-scheduled maintenance | See maintenance reports |
| | Total down time due to maintenance reasons | See maintenance reports |
| E10 Down time due to condition based maintenance (%) | Down time due to condition based maintenance | See maintenance reports |
| | Total down time due to maintenance reasons | See maintenance reports |
| E11 Down time due to predetermined maintenance (%) | Down time due to predetermined maintenance | See maintenance reports |
| | Total down time due to maintenance reasons | See maintenance reports |
| E12 Down time due to preventive maintenance (%) | Down time due to preventive maintenance | See maintenance records |
| | Total down time related to maintenance reasons | See maintenance records |
| E13 Use of predictive maintenance technologies (%) | Number of predictive technologies used | See maintenance reports |
| | Number of predictive technologies that can be used | See kind of diagnostic tool offered by the market |
| E14 Intensity of RCA analysis (%) | Number of root causes analysis performed | See maintenance reports on RCA |
| | Number of failures | See maintenance records |
| E15 Standardization of maintenance procedure (%) | Maintenance procedures standardized | See list approved standards |
| | Maintenance procedures required | See list of required standards |
| E16 Reliability improvements (N°/year) | Number of technical actions implemented to improve reliability | See reports of engineering (include inherent and operational reliability) |
| | Year | Year as period of reference |
| E17 Maintainability improvements (N°/year) | Number of technical actions implemented to improve maintainability | See reports of engineering (include inherent and operational reliability) |
| | Year | Year as period of reference |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| E18<br>Maintenance actions to improve energy conservation<br>(N°/year) | Number of maintenance actions implemented to improve energy conservation | See engineering reports |
| | Year | Year as reference period |
| E19<br>Improvements<br>(N°/year) | Number of actions for improvements | Combination of all technical, administrative and managerial actions, intended to ameliorate the intrinsic reliability and/or maintainability and/or safety of an item, without changing the original function |
| | Year | See year of reference |

## 12 KPIs of Sub-function "Organization and Support"

It is a combination of the maintenance resources internal and external as people, spare parts, tools, equipment, information, methods, processes, procedures, standards, best practices, ICT, etc. to provide the requested maintenance services achieving the best performances in term of safety, productivity, effectiveness, quality, costs, service level.

The main tasks are:

1) To establish the rules of criticality and priority.

2) To define a procedure for planning-scheduling-performing and controlling the required works.

3) To design the work orders including the necessary information: safety, technical data, accounting, timing, etc.

4) To use a computerized standard procedure to achieve the best integrated work order flow according to the organizational structure, responsibility, processes, etc.

5) To schedule all the resources, crafts, supports, according to the Specifications and Good Maintenance Practices that are the best technical practice to repair or restore an item based on knowledge and competence available.

6) To prepare preventive cost, time and other implications and schedule the work according to the needs of the end-user.

7) To assign the work to internal operatives and external maintenance and control the advancement.

8) To close the work order adding technical comments and reporting it in the database.

9) To measure quality, efficiency and effectiveness of the works done.

10) To evaluate and provide the necessary support and auxiliary activity to improve quality and productivity.

The main aim is to organize and support the maintenance field activities in the framework of the strategy and physical asset management stated objectives, in order to achieve the best optimization of maintenance resources.

The main driven areas of Organization and Support and related KPIs, named O&S are:

— Structure and Support: O&S1, O&S2, O&S3, O&S4, O&S5, O&S6, O&S7, O&S8;

— Planning and Control: O&S9, O&S10, O&S11; O&S12, O&S13, O&S14, O&S15, O&S16; O&S17, O&S18, O&S19, O&S20, O&S21;

— Productivity and effectiveness: O&S22, O&S23, O&S24, O&S25, O&S26, O&S27, O&S28;

— Quality of the works: O&S29, O&S30.

**Table 7 — Key Performance Indicators of sub function organization and support**

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| O&S1<br>Maintenance personnel vs site personnel<br>(%) | Number of internal maintenance personnel | Total number of people reported in the payroll of maintenance function of the site |
| | Total site personnel | Total number of people reported in the payroll of the site |
| O&S2<br>Rate of indirect vs direct personnel<br>(%) | Number of indirect maintenance personnel | Indirect personnel are managers, staff and clerk, maintenance engineering, planning and scheduling, tools store personnel, warehouse and store workers |
| | Total maintenance personnel | Total number of people reported in the maintenance manning |
| O&S3<br>Maintenance contribution by manufacturing operators<br>(%) | Maintenance man-hours performed by manufacturing operators | Maintenance activities performed by the manufacturing technicians and operators or users, in line with the methodology total productive maintenance |
| | Total direct maintenance man-hours | Direct personnel are technicians or operatives working on the field or workshops performing directly maintenance activities |
| O&S4<br>Maintenance activity carried out by operators<br>(%) | Maintenance activity performed by operators | The indicator shows the degree of application of autonomous maintenance, indicating the potential activities to be carried out by operators. A used attribute can be man-hours |
| | Total maintenance activity to be done | |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| O&S5<br>Maintenance people on shifts<br>(%) | Maintenance people on shift | Maintenance people working permanently on shift |
| | Total maintenance personnel | See O&S3 |
| O&S6<br>Ratio of<br>mechanical personnel<br>(%) | Internal mechanical man-hours | Man-hours worked by internal mechanical people reported in the payroll of the organization |
| | Total internal maintenance man-hours | Total man-hours worked by the internal people reported in the maintenance pay roll |
| O&S7<br>Electrical-instrument-automation<br>(%) | Internal electrical-instrument-automation man-hours | Man-hours worked by internal electrical instrument automation people reported in the pay roll |
| | Total internal maintenance man-hours | Total man-hours worked by internal people reported in the maintenance pay roll |
| O&S8<br>Intensity of works by external maintenance (%) | Man-hours of external maintenance works | Man-hours worked by external maintenance to provide supporting service as scaffoldings, handling, transport, etc. |
| | Internal + external maintenance man-hours | Total man-hours worked by internal and external personnel |
| O&S9<br>Proportion of corrective maintenance<br>(%) | Corrective maintenance man-hours | Man-hours spent on corrective maintenance activities internal and external |
| | Total maintenance man-hours | Total maintenance man-hours spent in the maintenance internal and external |
| O&S10<br>Proportion of immediate corrective maintenance<br>(%) | Total immediate corrective man-hours | Total man-hours spent in immediate corrective actions or works internal and external |
| | Total maintenance man-hours | Total maintenance man–hours spent in maintenance internal and external |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| O&S11<br>Proportion of preventive maintenance<br>(%) | Preventive maintenance man-hours | Total man-hours spent in preventive maintenance internal and external |
| | Total maintenance man-hours | Total maintenance man-hours spent in maintenance internal and external |
| O&S12<br>Proportion of predictive maintenance<br>(%) | Predictive maintenance man-hours | Total man-hours spent in predictive maintenance internal and external |
| | Total maintenance man-hours | Total maintenance man-hours spent in maintenance internal and external |
| O&S13<br>Proportion of condition based maintenance<br>(%) | On condition based maintenance man-hours | Total maintenance man-hours spent in condition based maintenance internal and external |
| | Total maintenance man-hours | Total maintenance man-hours spent in maintenance internal and external |
| O&S14<br>Proportion of predetermined maintenance<br>(%) | Predetermined man-hours | Total man-hours spent in predetermined maintenance internal and external |
| | Total maintenance man-hours | Total maintenance man-hours spent in maintenance internal and external |
| O&S15<br>Proportion of improvements (%) | Man-hours spent on improvements | Total maintenance man-hours spent on improvements |
| | Total maintenance man-hours | Total maintenance man-hours spent in maintenance internal or external |
| O&S16<br>MTTR (mean time to restoration)<br>(Hours) | Total time to restoration | Time interval, from the instant of failure, until restoration (it includes delays and repair time) |
| | Number of failures | Total failure restored using internal or external resources |
| O&S17<br>MRT (mean repair time)<br>(%) | Total repair time | Total repair time spent to adapt or repair components or groups internal or external |
| | Number of failures | See O&S16 |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| O&S18<br>Proportion of total delay time<br>(%) | Total delay time | Total delay time includes: logistic delay, technical delay, internal and external administrative delays |
| | Total time to restoration | Total work supported |
| O&S19<br>Proportion of repair time on total time to restoration<br>(%) | Total repair time | Total repair time in order to restore the required function (EN 13306:2017) of item |
| | Total time to restoration | |
| O&S20<br>Number of weeks of workload to be performed | Total man-hours of works approved to be done | This indicator can be calculated considering the average number of maintenance personnel budgeted, internal and or external |
| | Weekly available man-hours budgeted | |
| O&S21<br>Level of planning<br>(%) | Planned maintenance man-hours | Internal and external man–hours planned to perform the works |
| | Total available maintenance man-hours | Total maintenance man-hours available internal and external |
| O&S22<br>Proportion of scheduled available man hours<br>(%) | Scheduled maintenance man-hours | Maintenance carried out in accordance with a specified time schedule or specified number of units of use |
| | Total maintenance man-hours available | Total maintenance man-hours available internal and/or external |
| OS&22 a)<br>Proportion of planned and scheduled man-hours | Planned and scheduled man-hours | See OS&21 and OS&22 |
| | Total maintenance man-hours available | See OS&21 and OS&22 |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| O&S23<br>Works covered by good maintenance practices<br>(%) | Number of maintenance works covered by G.M.P.[a] | The G.M.P. of a single work technical standard specification recognized as "best standard practice" to perform the internal maintenance work with the best quality, efficiency and service level |
| | Total maintenance works requiring G.M.P. | The main maintenance works and repetitive failures shall be covered by technical standard and consequently by G.M.P. |
| O&S24<br>Effectiveness of maintenance work<br>(%) | Actual man- hours spent to do the work | Actual man-hours spent for each work or as average of many works |
| | Planned man-hours assigned to do the work | Standard planned man-hours required by G.M.P. or by technical estimation or by work analysis.<br>This indicator can be calculated for single work order or many work orders or the total maintenance department.<br>The result of the indicator should be analysed |
| O&S25<br>Overtime<br>(%) | Over time of internal personnel | See records |
| | Total internal man-hours worked | See records |
| O&S26<br>External maintenance effectiveness<br>(%) | Actual man–hours spent by external maintenance | See records |
| | Assigned man–hours to the external maintenance | See records<br>The result of the indicator should be analysed |
| O&S27<br>Effectiveness of shutdown works<br>(%) | Man–hours spent for works during shutdown | See actual man–hours reported in maintenance works orders performed in shutdown |
| | Man-hours planned to be spent for the works | See man-hours planned and scheduled in the maintenance works orders |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| O&S28<br>Work orders effectiveness<br>(%) | Works orders effectively delivered on time | See records |
| | Total required work orders to be delivered | See records |
| O&S29<br>Quality complaints<br>(%) | Number of quality complaints | See records |
| | Total number of works orders performed | See report of work order delivered |
| O&S30<br>Rework<br>(%) | Number of work orders reworked | Due to the maintenance activities done not in line with expectations: work not complete, defects or tests not approved. See work orders report and users complaints |
| | Total number of work orders performed | See records of work orders performed |
| [a] Good Maintenance Practice | | |

## 13 KPIs of Sub-function "Administration and Supply"

This sub-function is covering three main areas:

1) The compliance of all the economic practices and procedures of maintenance with the financial and accounting rules of the country and the company.

2) Accounting activities and suitable procedures for all the maintenance resources and for budget and costs control.

3) The supply chain management to purchase and provide all the technical support as devices, tools, equipment, spare parts, materials and external maintenance, in line with the needs and programs of maintenance for execution of work.

The main contents are:

— to implement accounting principles, accounting activities for maintenance including work execution and projects and establish budgeting and control system,

— to support, with analysis and cost evaluations methods, the management and the supervision in each step of maintenance process,

— to set the annual economic maintenance plan and budget,

— to keep all the administrative documents, standards, good maintenance practices, budgets etc. up to date,

— to evaluate and define the standard costs of maintenance resources,

— to define and use the most useful economic, organizational, technical KPIs and carry out benchmarking activities to evaluate the competitiveness of maintenance,

— to define the contracts regarding maintenance outsourcing: e.g. contracted services, full services, global services,

— to provide external maintenance, spare parts and materials.

The main driven areas and related KPIs, named A&S, are the following:

— Economics: A&S1, A&S2, A&S3, A&S4, A&S5, A&S6,

— Budget and Cost Control A&S7, A&S8, A&S9, A&S10, A&S11, A&S12, A&S13, A&S14, A&S15, A&S16, A&S17, A&S18, A&S19,

— Outsourcing Services: A&S20, A&S21, A&S22, A&S23, A&S24, A&S25,

— Materials, Spare Parts: A&S26, A&S27, A&S28, A&S29.

**Table 8 — KPI of administration and supply on maintenance**

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| A&S1<br>Relative maintenance costs<br>(%) | Total maintenance costs | See M15 |
| | Asset replacement value | See economic records |
| A&S2<br>Maintenance contribution on production-service transformation cost<br>(%) | Total maintenance costs | See M15 |
| | Production transformation cost | Total cost required by an asset/item to transform the incoming materials in product/service, excluding cost of raw materials, packaging and auxiliary materials. See industrial accounting reports |
| A&S3<br>Maintenance contribution to investments<br>(%) | Tasks performed by maintenance for investments | This activity includes the modifications, revamping, extraordinary works, upgrade, retrofitting, etc. Sometime performed by maintenance department, classified investments |
| | Total maintenance costs | See M15 |
| A&S4<br>Maintenance contribution on added value<br>(%) | Total maintenance cost | See M15 |
| | Total added value | See economic records |
| A&S5<br>Hourly external maintenance cost<br>(Euro/Hour) | External maintenance cost (external maintenance total price + allocated fixed costs of internal organization on the price) | Total hourly cost including all the internal supervision and other unit fixed costs allocated. See industrial accounting books |
| | Man-hours worked by external maintenance | See annual contract agreements |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| A&S6<br>Contribution of maintenance on output<br>(COST/OUTPUT) | Total maintenance costs + unavailability cost due to maintenance | Unavailability costs due to maintenance is downtime due to maintenance multiplied with the average unit value of lost production/service of an item |
| | Quantity of output | Standard or effective output |
| A&S7<br>Contribution of internal personnel cost<br>(%) | Internal maintenance personnel cost | Cost of internal people engaged in maintenance, see M15.<br>Direct and indirect personnel and maintenance carried out by production operators |
| | Total maintenance cost | See M15 |
| A&S8<br>Contribution of spare parts and materials cost<br>(%) | Total costs of spare parts + materials used | Non-capitalized cost of spare parts, materials and consumables used in maintenance activities |
| | Total maintenance cost | See M15 |
| A&S9<br>Contribution of overhead costs<br>(%) | Total over heads costs | Total overhead costs of maintenance+general overheads allocated to maintenance |
| | Total maintenance cost | See M15 |
| A&S10<br>Contribution of total outsourcing cost<br>(%) | Cost of outsourced maintenance | Total cost of external maintenance activities.<br>See contracts and reports |
| | Total maintenance cost | See M15 |
| A&S11<br>Contribution of indirect personnel cost<br>(%) | Indirect personnel cost | Indirect personnel, managers, staff and clerks, maintenance engineers, planning and scheduling personnel, tooling, warehouse and store workers |
| | Total maintenance cost | See M15 |
| A&S12<br>Contribution of corrective maintenance<br>(%) | Corrective maintenance cost | See EN 13306:2017, 7.9 |
| | Total maintenance cost | See M15 |
| A&S13<br>Contribution of preventive maintenance<br>(%) | Preventive maintenance cost | See EN 13306:2017, 7.1 |
| | Total maintenance cost | See M15 |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| A&S14<br>Proportion of condition based Maintenance<br>(%) | Condition based maintenance costs | See EN 13306:2017, 7.3 |
| | Total maintenance cost | See M15 |
| A&S15<br>Proportion of predetermined maintenance<br>(%) | Predetermined maintenance cost | See EN 13306:2017, 7.3 |
| | Total maintenance cost | See M15 |
| A&S16<br>Cost of improvements<br>(%) | Cost of maintenance improvements | See maintenance records |
| | Total maintenance cost | See M15 |
| A&S17<br>Proportion of maintenance shutdown<br>(%) | Maintenance shutdown cost | Total maintenance cost due to the activities to be performed during the shutdown period |
| | Total maintenance cost | See M15 |
| A&S18<br>Proportion of internal maintenance in shutdown activities<br>(%) | Internal maintenance man-hours during shutdown | See records of maintenance |
| | Total man-hours internal + external spent in shutdown | See maintenance reports |
| A&S19<br>Proportion of global services on total external maintenance<br>(%) | Total global services cost | Global maintenance services is a contract that is delivering all direct and indirect maintenance activities to achieve the required performances of the physical assets during its life and it is paid based on actual measured results |
| | Total cost of external maintenance | See accounting reports |
| A&S20<br>Proportion of full services on total external maintenance<br>(%) | Total full services cost | Full maintenance services is a contract that is providing all the necessary resources to maintain or restore an item according to the request and technical requirements outlined in the contract.<br>It is paid based on the used resources |
| | Total cost of contract services | See accounting reports |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| A&S21<br>Contribution of mechanical external maintenance cost on total external maintenance cost<br>(%) | Mechanical external maintenance cost | See accounting reports |
| | Total external maintenance costs | See accounting reports |
| A&S22<br>Contribution of electrical external maintenance cost on total external maintenance cost<br>(%) | Electrical external maintenance cost | See accounting reports |
| | Total external maintenance costs | See accounting reports |
| A&S23<br>Contribution of instrumentation external maintenance cost on total external maintenance cost<br>(%) | Instrumentation external maintenance costs | See accounting reports |
| | Total external maintenance cost | See accounting reports |
| A&S24<br>Professionalism of outsourced services<br>(%) | Number of certified services | Certified services performed |
| | Total services | Total number of services performed |
| A&S25<br>Contribution of spare parts on physical asset replace value<br>(%) | Annual average inventory value of spare parts and materials | See warehouse records excluding spare parts capitalized |
| | Physical asset replacement value | It is the estimated amount of capital that would be required to replace the physical asset as it is now |
| A&S26<br>Spare parts inventory turnover<br>(Number) | Value of spare parts and material used | See annual or six months records excluding spare parts capitalized |
| | Average inventory value of spare parts and materials | See annual or six months records |
| A&S27<br>Service level of warehouse<br>(%) | Number of items immediately delivered to maintenance people | See records of warehouse |
| | Total number of items required by maintenance people | See records of maintenance |
| A&S28<br>Service level of spare parts supply<br>(%) | Number of spare parts delivered at committed date | See records of warehouse |
| | Total number of spare parts to be delivered at committed date | See purchase orders |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| A&S29<br>Reliability of spare parts supply<br>(%) | Number of annual complaints | See maintenance reports. Number of complaints includes:<br>• quality conformity,<br>• delivered quantity versus the ordered |
| | Number of spare parts yearly supplied | See purchase orders and warehouse |

## 14 KPIs of Sub-function "Information and Communication Technology"

The Information and Communication technology (ICT) is a complex of interconnected sciences, criteria, methodologies, techniques and tools, designed to enhance activities relating to the collection, transmission and processing of data and information to create added value and support the management and maintenance people in achieving the best performance.

The Enabling Technologies can contribute significantly to the increase of competitiveness, optimizing strategies, decisions, actions and controls to achieve new excellent models of Maintenance Function opening new advanced frontiers.

This subsystem of information and communication technologies includes applications to develop and achieve the best maintenance performance in the framework of Internet of Things according to the vision, mission, values and stated organizational objectives

The main driven areas and related KPIs, named ICT, are the following:

— Management ICT1, ICT2, ICT3, ICT4, ICT5, ICT6;

— Administration and Supply ICT7, ICT8, ICT9, ICT10;

— Organization and Support ICT11, ICT12, ICT13;

— Maintenance Engineering ICT14, ICT15, ICT16,ICT17,ICT18, ICT19, ICT20.

The indicators related to the functionality and the degree of utilization and integration of ICT in the main maintenance areas cannot be measured by formulas. Consequently it is suitable to have a qualitative value using a Specific Questionnaire to appraise for each indicator the "Status Degree" of the subject to know the reality in order to improve.

**Table 9 — KPI of information communication technology**

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| ICT1<br>Functionalities of software installed | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See audits performed by experts |
| ICT2<br>Integration of maintenance related software in organization's ICT system | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | Maintenance as users and ICT experts as providers shall set reference points and then evaluate the effective positions and progress |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| ICT3<br>ICT intensity of utilization (%) | Number of ICT access or machines, lines, etc. connected | See ICT records |
| | Number of personnel working on maintenance | See organization structure |
| ICT4<br>Maintenance cockpit utilization | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See reports and management requests. Cockpit is a mix of significant KPIs to keep the activities under control on line<br>Co = continuos,C0 = control,KPI,T = timely |
| ICT5<br>Capability of *ICT t*o calculate total life cycle cost | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See management reports |
| ICT6<br>Usability of maintenance software | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See functionality, process and management required |
| ICT7<br>Utilization of application for spare parts and materials | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See planning and warehouse organization |
| ICT8<br>Utilization of application for budgeting and costs control | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See budgeting and controlling procedures |
| ICT9<br>Integration with HSE procedures | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See HSE laws and rules |
| ICT10<br>Utilization of application for purchasing online with warehouse | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See purchasing activities and warehouse organization |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| ICT11<br>Utilization of application to collect Big Data | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See records and maintenance reports |
| ICT12<br>Utilization of application for tasks planning<br>(%) | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See records and organization activities, planning and control |
| ICT13<br>Utilization of application for tasks control | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See planning and control |
| ICT14<br>Utilization of application for preventive maintenance | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See engineering reports and records |
| ICT15<br>Utilization of application for prognostic maintenance | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See management, engineering, organization and support records |
| ICT16<br>Utilization of mobile applications | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See management and engineering reports |
| ICT17<br>Utilization of maintenance engineering applications | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See criticality analysis, RCA, FMECA, redundancy configuration, etc. |
| ICT18<br>Utilization of condition based monitoring online | Very High<br>High<br>Medium<br>Low<br>Very low | See methodology machine to machine (Internet of Things) |
| ICT19<br>Utilization of TAG–RFID[a] | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See engineering reports |

| KPI | FACTORS | DEFINITIONS AND NOTES |
|---|---|---|
| ICT20<br>3D Digital Printing System<br>to supply spare parts | High<br>Medium<br>Sufficient<br>Insufficient<br>Poor | See engineering reports |
| a Radio frequency identification. | | |

# 15 Process to improve maintenance performance

## 15.1 Use of KPI

The maintenance process is a motor to provide high level of performances (safety availability, environment, cost effectiveness, quality, etc.) to a physical asset. This motor shall be adjusted periodically in order to evaluate and achieve the best trade-off between all the different and sometimes antagonistic criteria.

The improvement process is shown in Figure 3 which represents the Deming Cycle and it can be managed through the following steps:

1) to identify objectives, targets, weaknesses, strengths, etc. to select the reference KPIs and reference values defined by decided thresholds, benchmarking actions and their evolution,

2) to measure the actual values of KPIs using formulas or qualitative evaluation methods and models such as management questionnaires,

3) to compare the actual values of KPI with references in order to identify the gaps and to analyse them,

4) to define and implement continuous improvement actions on the existing status to achieve better values.

If one of these steps is missing there will be no improvement. In practice, such situation can sometimes happen when indicators have been determined and are used, but their actual values cannot be gathered or when no appropriate actions are done despite the detected gap.

Using the KPIs it is easy to design and to organize a tailored Performance Appraisal System, computerized or not, to supply all the maintenance information to the involved functions, as Organization Management, Site Management, Maintenance Management, Supervisory function, etc.

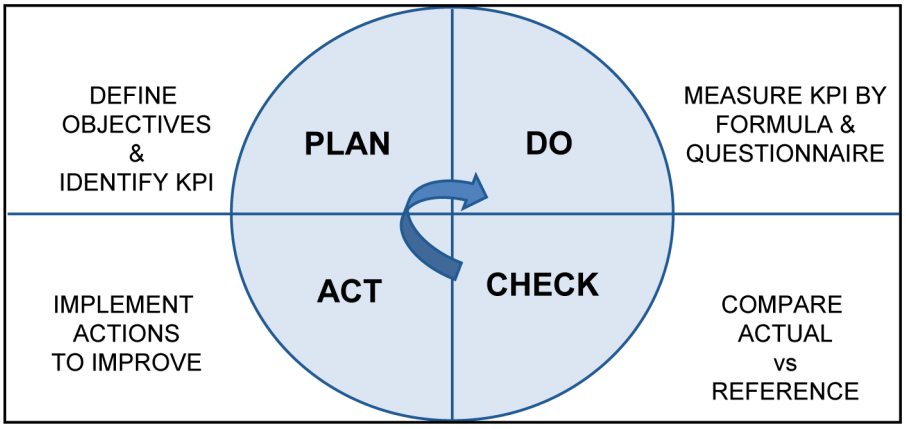



**Figure 3 — Application of KPI using the cycle of P.D.C.A (Deming)**

## 15.2 Classification of Maintenance Indicators

Some indicators measure the technical performances of the assets (e.g. safety, availability, reliability, maintainability, etc.) and can be considered at different levels (portfolio of plants, plant, system, subsystem, equipment, components). Other indicators measure directly the performances of the maintenance sub-processes (preventive maintenance process, corrective maintenance process, spare part provisioning process, human maintenance resources process, etc.). These processes provide activities and need resources which can be measured by specific indicators.

Finally other performances depend both on the maintenance process and the assets. The implementation of maintenance on assets provides efficiency, economical performances and reduction of risk levels.

A complete and coherent classification shall include indicators for the different level of organization's functions:

— plant;

— maintenance management;

— maintenance execution.

Depending on the position of the users in the organization it can be evaluated:

— the performance of relatively basic actions;

— the results of sub-processes, as for example the preventive maintenance process or the spare parts provisioning process;

— the overall results of the maintenance process to evaluate the strategy, to measure the performed activity, to analyse the resources, to evaluate the overall effectiveness.

## 15.3 Steps for an Improvement Process

Figure 4 shows the chronology in the development of an improvement process, based on the implementation of a system of indicators.

After having defined the objectives of the KPIs, the process starts with the breakdowns of:

— the items which are included in the evaluation;

— the involved maintenance processes.

Then two complementary approaches can be used to identify relevant indicators:

— choosing among lists of existing indicators those fulfilling the requirements;

— start from the actions done in each sub-processes, based on the knowledge of the inputs and outputs of these actions, which serve to measure their efficiency and to identify possible weak points.

The next step consists of checking the availability of data and in developing appropriate data visualization systems, that constitute the information system to handle the physical assets.

An operational phase is performed to collect data and to calculate values of indicators and design dashboards. Comparison of indicators with reference values, (benchmarks or previous values), makes it possible to detect possible gaps and, in that case, different situations can be distinguished:

a) Deviations are detected on indicators associated to processes and improvement actions shall be undertaken on the concerned processes.

b) Values of indicators related to assets are far from the expected ones.

This situation leads to consider different options:

1) Looking for the processes that could explain the poor results of the asset in order to determine the needed improvements of these processes. This action shall be based on the analysis of indicators related to the processes.

2) Consider the opportunity to perform modifications of the asset to overcome defects in design or manufacture that could affect reliability or maintainability.

3) Change operating conditions that could initiate or accelerate the kinetics of failure mechanisms or interfere with maintenance tasks.

It shall be underlined that benchmarking is also a way to identify best practices that can serve to define improvement actions to implement.

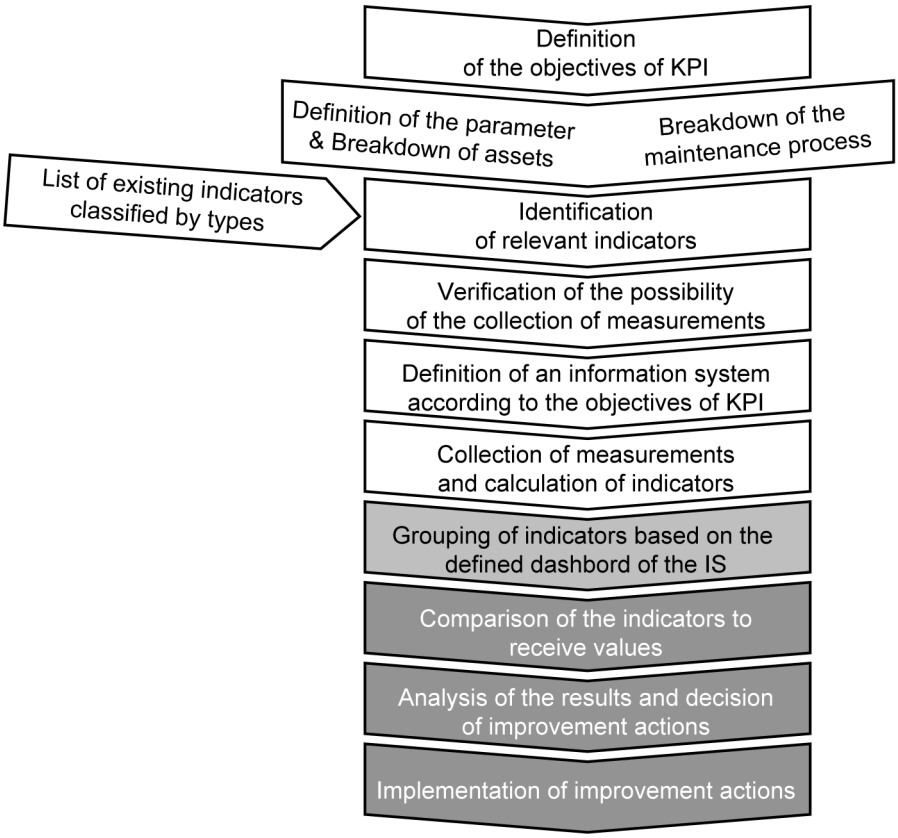



**Figure 4 — Steps of the improvement process base on KPIs**

This process shall itself be iterative and the relevance of the indicators used shall be periodically re-examined. It is also important to update the periods of data collection and calculation which shall be adapted to the kinetics of the measured variables to detect early changes.

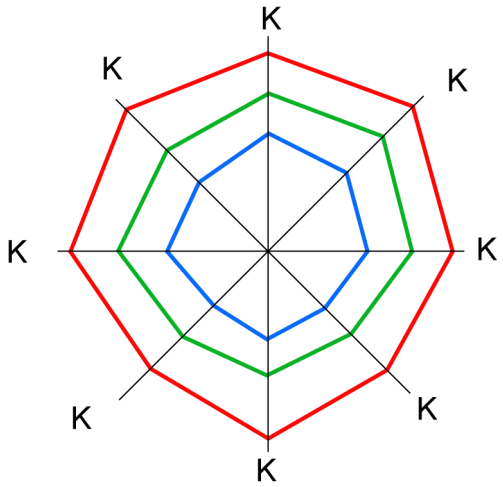
It is therefore important to develop a culture of continuous improvement based on quantified observations and resulting in implementation of improvement actions.

## 15.4 Maintenance assessment

The Matrix of KPIs in Table 1 provides a large set of KPIs, to be used to achieve an overall evaluation of the maintenance function and a specific evaluation of each sub-function and its components.

In this way it is possible to establish the existing status and the target for each technological sector and physical asset.

It is also enabling a comparison against the best in class (best of references) of each maintenance sub-function and to position their degree of maturity (see radar chart in Figure 5).




**Key**

= Reference value

= Objective

= Actual

**Figure 5 — Example of radar chart to show the assessment of a maintenance sub function from 8 relevant KPIs**

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