

# Maintenance — Maintenance Key Performance Indicators

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## National foreword

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English Version

## Maintenance - Maintenance Key Performance Indicators

Maintenance - Indicateurs-clés de performances en matière  
de maintenanceInstandhaltung - Wesentliche Leistungskennzahlen für die  
Instandhaltung

This European Standard was approved by CEN on 10 February 2007.

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## Foreword

This document (EN 15341:2007) 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of an identical text or by endorsement, at the latest by September 2007, and conflicting national standards shall be withdrawn at the latest by September 2007.

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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

## **Introduction**

This European Standard provides Maintenance Key Performance Indicators to support management in achieving maintenance excellence and utilize technical assets in a competitive manner. The majority of these indicators apply to all industrial and supporting facilities (buildings, infrastructure, transport, distribution, networks, 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) continuously measure changes over time.

## 1 Scope

This European standard describes a system for managing Key Performance Indicators to measure maintenance performance in the framework of the influencing factors such as economical, technical and organisational aspects, to appraise and to improve efficiency and effectiveness to achieve excellence in maintaining Technical Assets.

## 2 Normative references

The following referenced documents are indispensable for the application 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 13306:2001, *Maintenance Terminology*

IEC 60050-191:1990 *International electrotechnical vocabulary; chapter 191: dependability and quality of service*

## 3 Terms and definitions

For the purposes of this document the terms and definitions given in EN 13306:2001, IEC 60050-191:1990 and Annex A of this document, together with the following apply.

### 3.1 indicator

measured characteristic (or a set of characteristics) of a phenomenon, according to a given formula, which assess the evolution

NOTE Indicators are related to objectives.

### 3.2 scorecard

set of associated, consistent and complementary indicators providing synthetic and global information

NOTE It is a tool for the development and implementation of a strategy and for monitoring progress towards the goals outlined in the strategy.

## 4 Maintenance Performance

Maintenance Performance is the result of actively using resources to retain an item, or restore it to a state in which it can perform its required function. It can be expressed as an achieved or expected result.

Maintenance Performance depends on both external and internal factors such as: location, culture, transformation and service processes, size, utilization rate and age and is achieved by implementing corrective, preventive and improvement maintenance, using labour, information, materials, organisational methodologies, tools and operating techniques.

Maintenance Performance is an outcome of complex activities which can be evaluated by appropriate indicators to measure both the actual and expected results.

## 5 System of indicators

### 5.1 General

To cover this aspect of maintenance, this system of key performance indicators is structured into three groups: economic, technical and organisational.

These proposed indicators can be evaluated as a ratio between factors (numerator and denominator) measuring activities, resources or events, according to a given formula.

These indicators are used to measure any quantitative aspect or characteristic of an indenture level and homogeneous comparison.

Whenever a factor is defined using the words "internal" or "external", the derived indicator, should also be used only for "internal" or "external" influences.

### 5.2 Objectives

When the actual or expected performance is not satisfactory, it encourages management to define objectives and strategies to improve from an economic, technical or organisational point of view using the following system of indicators, allowing the organisation to:

- a) measure the status;
- b) evaluate the performance;
- c) compare performance;
- d) identify strengths and weaknesses;
- e) control progress and changes over time.

Measurement and analysis of these indicators can help management to:

- f) set objectives;
- g) plan strategies and actions;
- h) share the results in order to inform and motivate people.

These indicators can be used:

- i) on a periodic basis, for instance by preparing and following-up a budget, and during performance assessment;
- j) 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 company policy and management approach.

### 5.3 Architecture of key indicators

Figure 1 illustrates the external and internal factors that influence maintenance performance and consequently the three groups of key indicators.

External factors are variable conditions outside company management control.

Internal factors are referred to the group, company, factory, plant outside of the maintenance management control, but inside of the company management control.



When using the key maintenance performance indicators, it is important to consider these influencing factors as prerequisites to avoid misleading evaluations and comparisons due to not having homogeneous conditions.

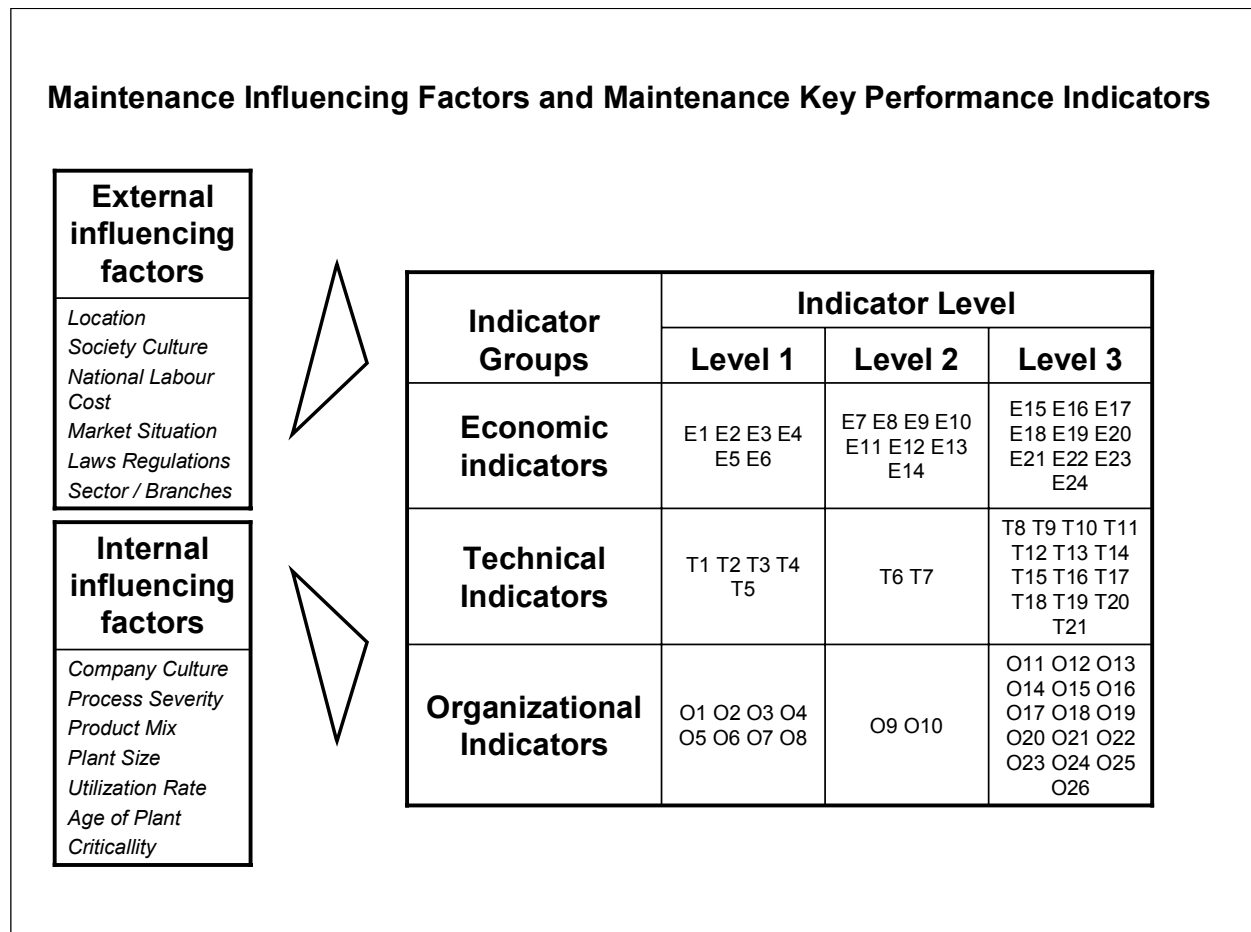


Figure 1 —Maintenance influencing factors and Maintenance Key Performance Indicators

## 6 Indicators

### 6.1 General

When calculating the indicators, denominator and numerator, factors shall be referred to the same activity/item and to the same period of time (year, quarter, month, etc.). These factors are defined and explained in Annex A of this document.

Most indicators can be used at different levels depending on whether they are used to measure the performance of plant production, one production line, or a given equipment or item, etc.

The indicators in this standard are structured in levels that represent their breakdown structure. Indicators below level one are a detailed description of indicators at a higher level. The magnitude and number of levels may be established by each company.

The indicators in this standard are numbered by level as a means of identification, not to indicate importance.

These indicators refer to internal maintenance, external maintenance or both.

The term “Time” is generally used to describe time units related to equipment and its performance.

The terms “Hours” or “Man-hours” describes the hours delivered to maintenance activities.

**6.2 Economical Key Indicators**

**6.2.1 LEVEL 1**

|    |  |       |
|----|--|-------|
| E1 | $\frac{\text{Total Maintenance Cost}}{\text{Assets Replacement Value}}$  | x 100 |
| E2 | $\frac{\text{Total Maintenance Cost}}{\text{Added value plus external costs for maintenance}}$                         | x 100 |
| E3 | $\frac{\text{Total Maintenance Cost}}{\text{Quantity of output}}$  |       |
| E4 | $\frac{\text{Total Maintenance Cost}}{\text{Production transformation cost}}$  | x 100 |
| E5 | $\frac{\text{Total Maintenance Cost} + \text{unavailability costs related to maintenance}}{\text{Quantity of output}}$ |       |
| E6 | $\frac{\text{Availability related to maintenance}}{\text{Total Maintenance Cost}}$                                     |       |

**6.2.2 LEVEL 2**

|    |   |       |
|----|---|-------|
| E7 | $\frac{\text{Average inventory value of maintenance materials}}{\text{Asset Replacement Value}}$  | x 100 |
| E8 | $\frac{\text{Total internal personnel cost spent in maintenance}}{\text{Total Maintenance Cost}}$ | x 100 |

|                      |  |                      |
|----------------------|--|----------------------|
| E9                   | $\frac{\text{Total external personnel cost spent in maintenance}}{\text{Total Maintenance Cost}}$            | x 100                |
| E10                  | $\frac{\text{Total contractor cost}}{\text{Total maintenance cost}}$   | x 100                |
| E11                  | $\frac{\text{Total cost of maintenance materials}}{\text{Total maintenance cost}}$                           | x 100                |
| E12                  | $\frac{\text{Total cost of maintenance materials}}{\text{Average inventory value of Maintenance materials}}$ | = Warehouse turnover |
| E13                  | $\frac{\text{Cost for indirect maintenance personnel}}{\text{Total Maintenance Cost}}$                       | x 100                |
| E14                  | $\frac{\text{Total Maintenance Cost}}{\text{Total Energy Used}}$   |                      |
| <b>6.2.3 LEVEL 3</b> |  |                      |
| E15                  | $\frac{\text{Corrective maintenance cost}}{\text{Total Maintenance Cost}}$                                   | x 100                |
| E16                  | $\frac{\text{Preventive maintenance cost}}{\text{Total Maintenance Cost}}$                                   | x 100                |
| E17                  | $\frac{\text{Condition based maintenance cost}}{\text{Total Maintenance Cost}}$                              | x 100                |
| E18                  | $\frac{\text{Predetermined maintenance cost}}{\text{Total Maintenance Cost}}$                                | x 100                |
| E19                  | $\frac{\text{Improvement maintenance cost}}{\text{Total Maintenance Cost}}$                                  | x 100                |
| E20                  | $\frac{\text{Maintenance shutdown cost}}{\text{Total Maintenance Cost}}$                                     | x 100                |

|     |   |                        |
|-----|---|------------------------|
| E21 | $\frac{\text{Cost of training for maintenance}}{\text{Number of maintenance personnel}}$                      | unit of value / person |
| E22 | $\frac{\text{Total Mechanical maintenance contractor costs}}{\text{Total maintenance contractor costs}}$      | x 100                  |
| E23 | $\frac{\text{Total Electrical maintenance contractor costs}}{\text{Total maintenance contractor costs}}$      | x 100                  |
| E24 | $\frac{\text{Total Instrumentation maintenance contractor costs}}{\text{Total maintenance contractor costs}}$ | x 100                  |

### 6.3 Technical key indicators

#### 6.3.1 LEVEL 1

|    |   |   |
|----|---|---|
| T1 | $\frac{\text{Total Operating time}}{\text{Total Operating time} + \text{Downtime due to maintenance}}$    | x 100 (availability related to maintenance) |
| T2 | $\frac{\text{Achieved up time during required time}}{\text{Required time}}$                               | x 100 (operational availability)            |
| T3 | $\frac{\text{Number of failures due to maintenance creating environmental damage}}{\text{Calendar time}}$ |   |
| T4 | $\frac{\text{Annual volume of wastes or harmful effects related to maintenance}}{\text{Calendar time}}$   |   |
| T5 | $\frac{\text{Number of injuries for people due to maintenance}}{\text{Working time}}$                     |   |

#### 6.3.2 LEVEL 2

|    |  |       |
|----|--|-------|
| T6 | $\frac{\text{Total operating time}}{\text{(Total operating time} + \text{Downtime related to failures)}}$                          | x 100 |
| T7 | $\frac{\text{Total operating time}}{\text{(Total operating time} + \text{Downtime related to planned and scheduled maintenance)}}$ | x 100 |

## 6.3.3 LEVEL 3

|     |  |        |
|-----|--|--------|
| T8  | $\frac{\text{Preventive maintenance time causing downtime}}{\text{Total downtime related to maintenance}}$   | x 100  |
| T9  | $\frac{\text{Predetermined maintenance time causing downtime}}{\text{Total downtime related to maintenance}}$  | x 100  |
| T10 | $\frac{\text{Condition based maintenance time causing downtime}}{\text{Total downtime related to maintenance}}$  | x 100  |
| T11 | $\frac{\text{Number of failures causing injury to people}}{\text{Total number of failures}}$   | x 100  |
| T12 | $\frac{\text{Number of failures causing potential injury to people}}{\text{Total number of failures}}$   | x 100  |
| T13 | $\frac{\text{Number of failures causing damage to the environment}}{\text{Total number of failures}}$  | x 100  |
| T14 | $\frac{\text{Number of failures causing potential damage to the environment}}{\text{Total number of failures}}$  | x 100  |
| T15 | $\frac{\text{Total Operating time}}{\text{Number of maintenance work-orders causing downtime}}$  |        |
| T16 | $\frac{\text{Total Operating time}}{\text{Number of maintenance work-orders}}$   |        |
| T17 | $\frac{\text{Total operating time}}{\text{Number of failures}}$  | = MTBF |
| T18 | $\frac{\text{Number of systems covered by a critical analysis}}{\text{Total number of systems}}$   | x 100  |
| T19 | $\frac{\text{Man-hours used for planning in a systematic maintenance planning process}}{\text{Total internal maintenance personnel man-hours}}$            | x 100  |
| T20 | $\frac{\text{Planned and scheduled maintenance time causing production downtime}}{\text{Planned and scheduled total maintenance time requiring downtime}}$ | x 100  |
| T21 | $\frac{\text{Total time to restoration}}{\text{Number of failures}}$   | = MTTR |

**6.4 Organisational indicators**

**6.4.1 LEVEL 1**

|    |  |                          |
|----|--|--------------------------|
| O1 | $\frac{\text{Number of internal maintenance personnel}}{\text{Total internal employees}}$  | x 100                    |
| O2 | $\frac{\text{Number of indirect maintenance personnel}}{\text{Number of internal maintenance personnel}}$                        | x 100                    |
| O3 | $\frac{\text{Number of indirect maintenance personnel}}{\text{Number of direct maintenance personnel}}$                          | x 100                    |
| O4 | $\frac{\text{Production operator maintenance man-hours}}{\text{Total direct maintenance personnel man-hours}}$                   | x 100                    |
| O5 | $\frac{\text{Planned and scheduled maintenance man-hours}}{\text{Total maintenance man-hours available}}$                        | x 100                    |
| O6 | $\frac{\text{Number of injuries to maintenance personnel}}{\text{Total maintenance personnel}}$                                  | x 10000 (frequency rate) |
| O7 | $\frac{\text{Man-hours lost due to injuries for maintenance personnel}}{\text{Total man-hours worked by maintenance personnel}}$ | x 10000 (severity rate)  |
| O8 | $\frac{\text{Man-hours used for continuous improvement}}{\text{Total maintenance personnel man-hours}}$                          | x 100                    |

**6.4.2 LEVEL 2**

|     |  |       |
|-----|--|-------|
| O9  | $\frac{\text{Production operator maintenance man-hours}}{\text{Total production operators man-hours}}$ | x 100 |
| O10 | $\frac{\text{Direct maintenance personnel on shift}}{\text{Total direct maintenance personnel}}$       | x 100 |

**6.4.3 LEVEL 3**

|     |   |       |
|-----|---|-------|
| O11 | $\frac{\text{Immediate corrective maintenance time}}{\text{Total downtime related to maintenance}}$         | x 100 |
| O12 | $\frac{\text{Internal mechanical man-hours}}{\text{Total internal direct maintenance personnel man-hours}}$ | x 100 |

|     |   |       |  |
|-----|---|-------|--|
| O13 | <u>Internal electrical man-hours</u><br>Total internal direct maintenance personnel man-hours   | x 100 |  |
| O14 | <u>Internal instrumentation man-hours</u><br>Total internal direct maintenance personnel man-hours  | x 100 |  |
| O15 | <u>Number of internal Multi-skilled maintenance personnel</u><br>Number of internal maintenance personnel   | x 100 |  |
| O16 | <u>Corrective maintenance man-hours</u><br>Total maintenance man-hours  | x 100 |  |
| O17 | <u>Immediate Corrective maintenance man-hours</u><br>Total maintenance man-hours  | x 100 |  |
| O18 | <u>Preventive maintenance man-hours</u><br>Total maintenance man-hours  | x 100 |  |
| O19 | <u>Condition based maintenance man-hours</u><br>Total maintenance man-hours   | x 100 |  |
| O20 | <u>Predetermined maintenance man-hours</u><br>Total maintenance man-hours   | x 100 |  |
| O21 | <u>Overtime internal maintenance man-hours</u><br>Total internal maintenance man-hours  | x 100 |  |
| O22 | <u>Number of work orders performed as scheduled</u><br>Total number of scheduled work orders  | x 100 |  |
| O23 | <u>Number of maintenance internal personnel man-hours for training</u><br>Total internal maintenance man-hours                                    | x 100 |  |
| O24 | <u>Number of internal direct maintenance people using software</u><br>Number of internal direct maintenance personnel                             | x 100 |  |
| O25 | <u>Total man-hours spent by direct personnel on planned and scheduled activities</u><br>Total man-hours planned and scheduled to direct personnel | x 100 |  |
| O26 | <u>Number of the spare parts supplied by the warehouse as requested</u><br>Total number of spare parts required by maintenance                    | x 100 |  |

## 7 Methodology for the selection and use of key performance indicators for maintenance

### 7.1 Defining the objectives which characterise the maintenance management process

To select relevant indicators, the first step is to define the objectives to be reached at each level of the enterprise.

At the company level, the requirement is to identify how maintenance can be managed in order to improve global performance (profits, market shares, competitiveness etc). In this case, the most efficient means of maintenance improvement shall be determined.

At the systems level and production lines, the maintenance objectives can address some particular performance factors, which have been identified through previous analysis, such as:

- improvement of availability;
- improvement on cost-effective maintenance;
- retaining health, safety and environment preservation;
- improvement in cost-effective management of the value of the maintenance inventory;
- control of contracted services;
- etc.

At the equipment level, machines or types of machines, better control of the following may be desirable:

- reliability;
- costs;
- maintainability and maintenance supportability;
- etc.

The objectives may also consist of giving advice for decisions concerning:

- investments;
- duration of utilisation;
- choice of a strategy such as the recourse to contractors;
- etc.

### 7.2 Selecting the relevant indicators

When the objectives have been defined, and the performance parameters to be measured have been identified, the next step is to find the indicators that allow measuring these parameters. When selecting the indicators for maintenance management, the system could for example include:

- capacity of maintaining the equipment which includes:
  - maintainability of the equipment;
  - logistic support (spare parts, tools, documentation, etc.);



- work organisation;
- reliability of the equipment;
- efficiency of the maintenance activities;
- health, safety and the environment;
- etc.

An indicator is relevant when its value or its evaluation is correlated with the evaluation of the performance parameter to be measured. A relevant indicator shall be one element of decision making. This means that the data that constitute this indicator shall have a relation to the defined objective. This link can be proved by analysis or through interviewing experts. Statistical techniques can also be utilised to ascertain correlations between indicators.

In the search for relevant indicators, two approaches are possible:

- first: consists of choosing from amongst lists of existing indicators, which after analysis, fulfil the requirements;
- second: starts from the following methods which begin with the evaluation of the various processes of maintenance which can be obtained through functional analysis.

In practice, both approaches can be used.

### **7.3 Defining and collecting the necessary basic data**

It is necessary to precisely define:

- data to be collected to determine the values required for the indicator;
- measurement method (operating mode);
- tools required for the measurement (documents, counters, sensors, analysers, computerized maintenance management system, etc.).

To make the possible evaluation and comparisons easier, it is necessary that the collected data are in conformity with the standardised definitions when they exist (see EN 13306 and IEC 60050-191). If the definition does not exist, it will be necessary to derive such a definition.

### **7.4 Calculating the indicators and selecting the type of representation**

#### **7.4.1 Frequency of calculating the indicators**

Independently from collecting data, the frequency of the calculation could be predetermined (for instance, it is possible to evaluate a quarterly indicator with monthly collected data).

The frequency of data collection shall be adapted to:

- availability and time delay of the relevant data;
- changes over time (gradient, seasonality, etc.) of the measured performance;
- reactivity of the system to the actions undertaken.

#### **7.4.2 Type of presentation**

The utilisation of indicators generally requires a graphical presentation according to the required utilisation and to the importance of the series of data.

#### **7.4.3 Test and validation**

Before the calculation is used as a routine, each indicator will be calculated by using a representative sample during a significant period which will allow for validation of:

- methods of collecting and processing the data;
- methods of calculation and making graphical presentation;
- analysis and utilisation of these indicators.

#### **7.4.4 Analysis of the results**

One of the next steps, outside the scope of this standard, is to develop scorecards to analyse and to take the required actions.

## Annex A (normative)

### Key Indicators Factors List

**Table A.1 – Key indicators factors list**

| Indicators | Factors  | Definitions and comments   |
|------------|--|--|
| <b>E1</b>  | Total Maintenance Cost                               | <p>Total Maintenance Cost (often based annually related only to the Maintenance activities performed on the asset/item). Includes costs referred to:</p> <ul style="list-style-type: none"> <li>• Wages, salaries and overtimes for managerial, supervision, support staff and direct staff;</li> <li>• Payroll added costs for the above mentioned persons (Taxes, Insurance, Legislative contributions);</li> <li>• Spares and material consumables charged to maintenance (including freight costs);</li> <li>• Tools and equipment (not capitalized or rented);</li> <li>• Contractors, rented facilities;</li> <li>• Consultancy services;</li> <li>• Administration costs for maintenance;</li> <li>• Education and training;</li> <li>• Costs for maintenance activities carried out by production people;</li> <li>• Costs for transportation, hotels, etc;</li> <li>• Documentation;</li> <li>• CMMS (computerized maintenance management software) and Planning Systems;</li> <li>• Energy and utilities;</li> <li>• Depreciation of maintenance capitalized equipments and workshops, warehouse for spare-parts.</li> </ul> <p>Exclusions:</p> <ul style="list-style-type: none"> <li>— Costs for product changeover or transaction time (e.g. Exchange of dies);</li> <li>— Depreciation of strategic spare parts;</li> <li>— Downtime costs.</li> </ul> |
|            | Asset Replacement Value<br>(Plant Replacement Value) | <p>The Asset Replacement Value (ARV) is defined as the estimated amount of capital that would be required to build the Asset.</p> <p>ARV is an estimate of the current costs to replace in kind what now exists.</p> <p>NOTE 1 In industry ARV is usually the Plant Replacement Value.</p> <p>NOTE 2 ARV can be equivalent to the insurance value.</p>   |

| Indicators | Factors  | Definitions and comments   |
|------------|--|--|
| <b>E2</b>  | Total Maintenance Cost   | (see E1)   |
|            | Added value plus external costs for maintenance                      | Production value less the value of raw materials-utilities-services purchased plus external cost of maintenance.   |
| <b>E3</b>  | Total Maintenance Cost   | (see E1)   |
|            | Quantity of output   | Production or service quantity issued by an asset/item (tons, litres, etc.).   |
| <b>E4</b>  | Total Maintenance Cost   | (see E1)   |
|            | Production transformation cost                                       | Total cost required by an asset/item to transform an incoming material into a product/service, excluding raw materials and packaging auxiliary materials.  |
| <b>E5</b>  | Total Maintenance Cost + unavailability costs related to maintenance | <p>(see E1) for Total Maintenance Cost</p> <p>The unavailability costs related to maintenance is downtime due to maintenance multiplied with the average value of a time unit of lost production/service of the asset/item.</p> <p>The unit value of time of lost production can be extra production cost for production at a later stage/time, or/and the value or the lost income from production during the asset/item's down state due to maintenance.</p> <p>NOTE Value of the "hidden plant" due to downtime for maintenance.</p>  |
|            | Quantity of output   | (See E3)   |
| <b>E6</b>  | Availability related to maintenance                                  | <p>The time an item has been able to be in a state to perform a required function under given conditions at a given instant of time or during a given time interval, assuming that the required external resources are provided.</p> <p>NOTE 1 This ability depends on the combined aspects of the reliability, the maintainability and the maintenance supportability.</p> <p>NOTE 2 Required external resources, other than maintenance resources, do not affect the availability of the time.</p> <p>NOTE 3 In this standard availability is based on actual performance.</p> |
|            | Total Maintenance Cost   | (See E1)   |
| <b>E7</b>  | Average inventory value of Maintenance materials                     | Average inventory value of maintenance materials (spare parts, consumables, materials) on the respective period.   |

| Indicators | Factors  | Definitions and comments   |
|------------|--|--|
|            | Replacement Value of respective Assets             | (See E1 for Asset Replacement Value definition)  |
| <b>E8</b>  | Total internal personnel cost spent in maintenance | <p>Cost of internal personnel engaged in maintenance.</p> <p>The internal personnel cost (including payroll added costs as shown in E1) spent on maintenance is composed of:</p> <p>a) Direct personnel are personnel working in the field, or workshops performing maintenance activities (usually referred to as “blue collar workers”);</p> <p>b) Indirect Personnel (Managers, Staff and clerks, Supervisors, Maintenance engineering personnel, Planning and scheduling personnel, Tools store men, Warehouse and store workers);</p> <p>c) Costs of maintenance activities carried out by production people.</p> |
|            | Total Maintenance Cost                             | (See E1)   |
| <b>E9</b>  | Total external personnel cost spent in maintenance | Cost of external personnel engaged in maintenance activities.  |
|            | Total Maintenance Cost                             | (See E1)   |
| <b>E10</b> | Total contractor cost                              | Sum of contractor invoices billed for their maintenance activities spent on the asset/item.  |
|            | Total Maintenance Cost                             | (See E1)   |
| <b>E11</b> | Total cost of maintenance materials                | Costs of the maintenance materials (spare parts, consumables, materials) consumed in a period.   |
|            | Total Maintenance Cost                             | (See E1)   |
| <b>E12</b> | Total cost of maintenance materials                | (See E11)  |
|            | Average inventory value of Maintenance materials   | (See E7)   |
| <b>E13</b> | Cost for indirect maintenance personnel            | Total cost related to indirect personnel (see E8 b) in this Table).  |
|            | Total Maintenance Cost                             | (See E1)   |
| <b>E14</b> | Total Maintenance Cost                             | (See E1)   |

| Indicators | Factors                                       | Definitions and comments  |
|------------|---|---|
|            | Total Energy Used                             | <p>Power + gas + fuel oil + any other energy</p> <p>NOTE Energies are measured either all in kcal or all in MJoule as preferred.</p>  |
| E15        | Corrective maintenance cost                   | Total cost for maintenance carried out after fault has occurred and intended to put an item into a state in which it can perform a required function.   |
|            | Total Maintenance Cost                        | (See E1)  |
| E16        | Preventive maintenance cost                   | Cost for maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or degradation of the functioning of an item. |
|            | Total Maintenance Cost                        | (See E1)  |
| E17        | Condition based maintenance cost              | The value of maintenance activities for condition based maintenance measured in terms of costs.   |
|            | Total Maintenance Cost                        | (See E1)  |
| E18        | Predetermined maintenance cost                | Cost of preventive maintenance carried out in accordance with established intervals of time or number of units of use but without previous condition investigation.                             |
|            | Total Maintenance Cost                        | (See E1)  |
| E19        | Improvement maintenance cost                  | Cost of maintenance carried out to improve the availability of the item, without changing the required function.  |
|            | Total Maintenance Cost                        | (See E1)  |
| E20        | Maintenance shut down cost                    | Cost of maintenance performed during shutdowns (outage scheduled for maintenance) of a plant or a factory (annual shutdown for example).  |
|            | Total Maintenance Cost                        | (See E1)  |
| E21        | Cost of training for maintenance              | Cost for training for direct and indirect maintenance personnel (direct and indirect: see E8).  |
|            | Number of maintenance personnel               | Number of Direct Personnel plus number of Indirect Personnel (see E8).  |
| E22        | Total Mechanical maintenance contractor costs | Sum of the costs for the mechanical contractors activities.   |
|            | Total maintenance contractor costs            | Sum of the costs by contractors for the mechanical, electrical and instrumental contractors activities.   |
| E23        | Total Electrical maintenance contractor costs | Sum of the costs for the electrical contractors activities.   |

| Indicators | Factors   | Definitions and comments   |
|------------|---|--|
|            | Total maintenance contractor costs                                  | (See E22)  |
| <b>E24</b> | Total Instrumentation maintenance contractor costs                  | Sum of the costs for the instrumentation contractors activities.   |
|            | Total maintenance contractor costs                                  | (See E22)  |
| <b>T1</b>  | Total operating time  | Time interval during which an item is performing its required function (see EN 13306:2001, 9.3).   |
|            | Downtime due to maintenance   | Time interval during which an item is in a down state (see EN 13306:2001, 9.2) due to maintenance.   |
| <b>T2</b>  | Achieved up time during required time                               | <p>Up time: time interval during which an item is in up state (see EN 13306:2001, 9.1).</p> <p>Up state: state of an item characterized by the fact that it can perform a required function, assuming that the external resources, if required, are provided (see EN 13306:2001, 6.7).</p> <p>NOTE To more easily understand this definition with the support of a figure, see EN 13306.</p> |
|            | Required time   | <p>Time interval during which the user requires the item to be in a condition to perform a required function (see EN 13306:2001, 9.4).</p> <p>NOTE To easily understand this definition with the support of a figure, see EN 13306.</p>  |
| <b>T3</b>  | Number of failures due to maintenance creating environmental damage | Numbers of failures caused by maintenance or lack of maintenance that have caused damage to the environment.   |
|            | Calendar time   | Time interval (years, months).   |
| <b>T4</b>  | Annual volume of wastes or harmful effects related to maintenance   | <p>Annual volume of wastes or harmful effects related to maintenance.</p> <p>These indicators should be measured per chemical item (i.e. CO<sup>2</sup>, ...) or harmful effect.</p>   |
|            | Calendar time   | Time interval (years, months).   |
| <b>T5</b>  | Number of injuries for people due to maintenance                    | Numbers of failures caused by maintenance or lack of maintenance that have caused injuries for people.   |
|            | Working time  | Time interval (years, months).   |
| <b>T6</b>  | Total operating time  | (See T1)   |
|            | Downtime related to failures  | Total downtime lost due to failures.   |

| Indicators | Factors  | Definitions and comments   |
|------------|--|--|
| <b>T7</b>  | Total operating time   | (See T1)   |
|            | Downtime related to planned and scheduled maintenance downtime | The total time of planned and scheduled maintenance works, which requires downtime.  |
| <b>T8</b>  | Preventive maintenance time causing downtime                   | Time interval during which an item is in a down state due to preventive maintenance.   |
|            | Total downtime related to maintenance                          | Time interval during which an item is in a down state due to maintenance.  |
| <b>T9</b>  | Predetermined maintenance time causing downtime                | Time interval during which an item is in a down state due to predetermined maintenance.  |
|            | Total downtime related to maintenance                          | (See T8)   |
| <b>T10</b> | Condition based maintenance time causing downtime              | Time interval during which an item is in a down state due to condition based maintenance.  |
|            | Total downtime related to maintenance                          | (See T8)   |
| <b>T11</b> | Number of failures causing injury for people                   | Number of failures that cause injuries which will result in one or more lost working days.   |
|            | Total number of failures                                       | Total number of failures.<br>Failure: termination of the ability of an item to perform a required function (see EN 13306:2001, 5.1).<br><br>NOTE 1 After failure the item has a fault, which may be complete or partial.<br><br>NOTE 2 "Failure" is an event, as distinguished from "fault", which is a state. |
| <b>T12</b> | Number of failures causing potential injury for people         | Number of failures that could cause injuries.  |
|            | Total number of failures                                       | (See T11)  |
| <b>T13</b> | Number of failures causing damage for the environment          | Number of failures that cause damage for the environment.  |
|            | Total number of failures                                       | (See T11)  |



| Indicators | Factors  | Definitions and comments  |
|------------|--|---|
| <b>T14</b> | Number of failures causing potential damage for the environment          | Number of failures that could cause damage for the environment.   |
|            | Total number of failures   | (See T11)   |
| <b>T15</b> | Total operating time   | (See T1)  |
|            | Number of maintenance work-orders causing downtime                       | Number of all corrective and preventive maintenance work-orders, as well as all improvement work-orders, causing downtime.  |
| <b>T16</b> | Total operating time   | (See T1)  |
|            | Number of maintenance work-orders  | Number of all corrective and preventive maintenance work-orders, as well as improving work-orders.  |
| <b>T17</b> | Total operating time   | (See T1)  |
|            | Total number of failures   | (See T11)   |
| <b>T18</b> | Number of systems covered by a critical analysis                         | Number of systems analyzed and covered by a methodology with the purpose to assess and reduce risk.<br><br>NOTE For the definition of "system", please refer to the specific methodology used.  |
|            | Total number of systems  | Total number of systems.<br><br>NOTE For the definition of "system", please refer to the specific methodology used.   |
| <b>T19</b> | Man-hours used for planning in a systematic maintenance planning process | Man-hours used to plan maintenance.<br><br>NOTE The planning process is performed according to a predefined procedure.<br><br>Planning includes safety considerations, labour, materials, tools and equipment, an estimate of the downtime and man-hours required to complete the work, etc...<br><br>All this information is available to the first line maintenance staff performing the work before it starts. |
|            | Total internal maintenance personnel man-hours                           | Number of hours carried out by internal maintenance personnel.  |
| <b>T20</b> | Planned and scheduled maintenance time causing production downtime       | This is the total calendar time spent on planned and scheduled maintenance works causing production downtime.   |

| Indicators | Factors   | Definitions and comments   |
|------------|---|--|
|            | Planned and scheduled total maintenance time requiring downtime | The total time of planned and scheduled maintenance works which requires downtime.   |
| <b>T21</b> | Total time to restoration                                       | Sum of the times to restoration.<br>Time to restoration: time interval during which an item is in downstate due to a failure (see IEC 60050-191)<br><br>It includes administrative and logistics delays. |
|            | Total number of failures  | (See T11)  |
| <b>O1</b>  | Number of internal maintenance personnel                        | Internal (direct and indirect: see E8) maintenance personnel.  |
|            | Total internal employees  | Total internal personnel in the asset.   |
| <b>O2</b>  | Number of indirect maintenance personnel                        | Number of internal indirect (see E8) maintenance personnel.  |
|            | Number of internal maintenance personnel                        | (See O1)   |
| <b>O3</b>  | Number of indirect maintenance personnel                        | (See O2)   |
|            | Number of direct maintenance personnel                          | Number of direct (see E8) maintenance personnel.   |
| <b>O4</b>  | Production operator maintenance man-hours                       | Maintenance man-hours carried out by a user or operator.   |
|            | Total direct maintenance personnel man-hours                    | Number of hours carried out by direct (see E8) maintenance personnel.  |

| Indicators | Factors  | Definitions and comments  |
|------------|--|---|
| O5         | Planned and scheduled maintenance man-hours              | <p>Man-hours by direct (see E8) maintenance personnel to be used on planned and scheduled activities (internal and external).</p> <p>NOTE 1 In the planning activities:</p> <ul style="list-style-type: none"> <li>- safety considerations,</li> <li>- special tools or procedures,</li> <li>- tolerance standards,</li> <li>- required replacement parts or material,</li> </ul> <p>are defined with an estimate of the downtime and man-hours required to complete the work before it starts.</p> <p>NOTE 2 In the scheduling activities a time schedule, or the number of units of use, indicating when maintenance should be performed, is established.</p> <p>NOTE 3 Planned and scheduled man-hours could be man-hours used for corrective maintenance, conditioned-based maintenance, performed maintenance and improvement maintenance.</p> |
|            | Total maintenance man-hours available                    | Number of maintenance man-hours (internal and external) available for maintenance activities (excluding holidays, training, etc...).  |
| O6         | Number of injuries for maintenance personnel             | Number of injuries occurred to internal maintenance personnel, preventing them to further work for a day or more.   |
|            | Number of internal maintenance personnel                 | (See O1)  |
| O7         | Man-hours lost due to injuries for maintenance personnel | Internal maintenance man-hours lost due to injuries for internal maintenance personnel.   |
|            | Total man-hours worked by maintenance personnel          | Number of internal maintenance man-hours actually produced.   |
| O8         | Man-hours used for continuous improvements               | <p>The man-hours used on improvement processes intended to improve the current level of availability, reliability, maintainability, quality, safety, environment and costs.</p> <p>NOTE Examples are hours used for systematic critical analysis, for identification of improvement, for participation in projects and their preparations, as instructor for training and education internally and externally, or, finally, for safety, quality or environmental audit or schemes.</p>  |
|            | Total maintenance personnel man-hours                    | Number of hours carried out by maintenance personnel.   |

| Indicators | Factors  | Definitions and comments  |
|------------|--|---|
| O9         | Production operator maintenance man-hours              | Maintenance man-hours carried out by a user or operator.<br><br>NOTE Thus it is maintenance carried out by people not under the maintenance department.   |
|            | Total production operators man-hours                   | Hours carried out for whatever activities by a user or production operator.   |
| O10        | Direct maintenance personnel on shift                  | Direct (see E8) maintenance personnel that “work on shift”, on plant and services (on operation).   |
|            | Total direct maintenance personnel                     | Number of direct maintenance personnel.   |
| O11        | Immediate corrective maintenance time                  | Maintenance, which is carried out without delay after a fault has been detected to avoid unacceptable consequences.   |
|            | Total downtime related to maintenance                  | (See T8)  |
| O12        | Internal direct mechanical man-hours                   | Man-hours from internal maintenance mechanical personnel.   |
|            | Total internal direct maintenance personnel man-hours  | Number of hours carried out by internal direct (see E8) maintenance personnel.  |
| O13        | Internal direct electrical man-hours                   | Man-hours from internal maintenance electrical personnel.   |
|            | Total internal direct maintenance personnel man-hours  | (See O12)   |
| O14        | Internal direct instrumentation man-hours              | Man-hours from internal maintenance instrumental personnel.   |
|            | Total internal direct maintenance personnel man-hours  | (See O12)   |
| O15        | Number of internal multi-skilled maintenance personnel | Number of internal direct (see E8) maintenance personnel that operate as multi skill (have the ability to perform more than one craft and have been formally trained in more than one craft) maintenance personnel. |
|            | Number of internal maintenance personnel               | (See O1)  |
| O16        | Corrective maintenance man-hours                       | Hours spent on corrective maintenance activities (internal and external).   |
|            | Total maintenance man-hours                            | Number of man-hours carried out by internal and external maintenance personnel.   |

| Indicators | Factors   | Definitions and comments   |
|------------|---|--|
| O17        | Immediate Corrective maintenance man-hours                      | Man-hours spent on immediate corrective maintenance activities (internal and external).  |
|            | Total maintenance man-hours                                     | (See O16)  |
| O18        | Preventive maintenance man-hours                                | Man-hours spent on preventive maintenance activities (internal and external).  |
|            | Total maintenance man-hours                                     | (See O16)  |
| O19        | Condition based maintenance man-hours                           | Man-hours spent on condition-based maintenance activities (internal and external).   |
|            | Total maintenance man-hours                                     | (See O16)  |
| O20        | Predetermined maintenance man-hours                             | Man-hours spent on preventive predetermined maintenance activities (internal and external).  |
|            | Total maintenance man-hours                                     | (See O16)  |
| O21        | Overtime internal maintenance man-hours                         | Number of man-hours carried out by internal maintenance personnel during overtime.   |
|            | Total internal maintenance personnel man-hours                  | (See T19)  |
| O22        | Number of work orders performed as scheduled                    | Number of work orders that are technically complete in a timeframe less than a given time after the estimate of its conclusion.  |
|            | Total number of scheduled work orders                           | Number of work orders scheduled.<br>(See O5, NOTE 2, for scheduling activities)  |
| O23        | Number of maintenance internal personnel man-hours for training | Number of hours used in training for all personnel (direct and indirect: see E8) of maintenance service.   |
|            | Total internal maintenance man-hours                            | (See O16)  |
| O24        | Number of internal direct maintenance personnel using software  | Number of direct (see E8) maintenance personnel using maintenance software (CMMS) for any maintenance or asset management means (work orders flow, bills of materials, planning, spare-parts warehousing, etc...). |
|            |   | NOTE In order to be qualified as a user of CMMS software, the user should use the software for at least 5 % of his working time.   |

| Indicators | Factors   | Definitions and comments  |
|------------|---|---|
|            | Number of internal direct maintenance personnel                               | Internal direct (see E8) maintenance personnel.   |
| <b>O25</b> | Total man-hours spent by direct personnel on planned and scheduled activities | Number of man-hours actually spent by direct (see E8) personnel on planned and scheduled activities.<br>(See O5, NOTE 1 and NOTE 2, for planning and scheduling activities)   |
|            | Total man-hours planned and scheduled to direct personnel                     | Number of planned and scheduled man-hours for direct (see E8) personnel.<br>(See O5, NOTE 1 and NOTE 2, for planning and scheduling activities)<br><br>NOTE This amount of man-hours are planned and scheduled and may differ from the actually spent man-hours due to organizational issues. |
| <b>O26</b> | Number of the spare parts supplied by the warehouse as requested              | No need for definition.   |
|            | Total number of spare parts required by maintenance                           | No need for definition.   |



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