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# Manufacturing operations management — Key performance indicators — Part 2: Definitions and descriptions of KPIs



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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 22400-2 was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration and architectures of automation systems and applications*.

ISO 22400 consists of the following parts, under the general title *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management*

— Part 1: Overview, concepts and terminology

— Part 2: Definitions and descriptions

— Part 3: Templates and categories

— Part 4: Exchange and use

# Introduction

The management of manufacturing operations is normally associated with some intermediate level within the functional hierarchy of a manufacturing enterprise. Following the definitions in IEC 62264, the international standard on enterprise-control system integration, the intermediate level is referred to as the Manufacturing Operations Management (MOM) domain. This level includes a manufacturing execution system (MES) along with other operations management systems whose functional areas involve activities, such as, detailed operations scheduling, operations resources management, operations procedure management, and operations data collection, performance tracking, analyses and reporting.

A Manufacturing Execution System (MES) is closely linked to the manufacturing automation and control systems at Level 2, per the IEC 62264 definitions. Compared to similar systems for production planning, such as ERP (Enterprise Resource Planning), the MES more has a direct connection to the automation level and allows timely monitoring and control of production. The main activities include process data acquisition and evaluation, in particular, the handling of production data, equipment data, product quality data, logistical data (for traceability), measurements to support the continuous improvement process (CIP), personnel deployment, but also all other processes that have an immediate impact on the manufacturing and production process.

This International Standard is intended to establish guidance regarding KPI and associated metrics in the following areas:

- Definition
- Usage and application
- Benefits
- Collaboration

Definition – concepts and representations of categories, classifications, and instances of KPIs, including the procedures for their computation.

Usage and application - guidelines on the use of KPIs at different levels within an organization, especially in their use for decision support.

Benefits – descriptions of relationships between KPIs and other business indicators to show benefits (e.g. hard vs. soft, alignment to functional capability, alignment to role/title etc).

Collaboration – alignment with other industry frameworks on KPI, such as, MESA, WERC, SCOR, APICS and similar organizations to minimize overlap and duplication of effort.

Following IEC 62264, Figure 1 illustrates the kinds of data that are presented in the Key Performance Indicators generated at Level 3. The direct connection to the automation and control domains (Levels 2, 1, and 0) is through the acquisition of data related to production, process, equipment and related resources.

To allow for alignment with other manufacturing domain frameworks, a manufacturing execution system can be viewed as a set of resources for those applications of the Level 3 domain the closely interact with the resources of the automation and control applications at the Level 2 domain. The virtual boundary between the levels is not fixed and the notion of an MES provides a distinction between the resources that perform the actual physical manufacturing processes and those resources that are used to schedule, dispatch and coordinate the Level 2 activities.

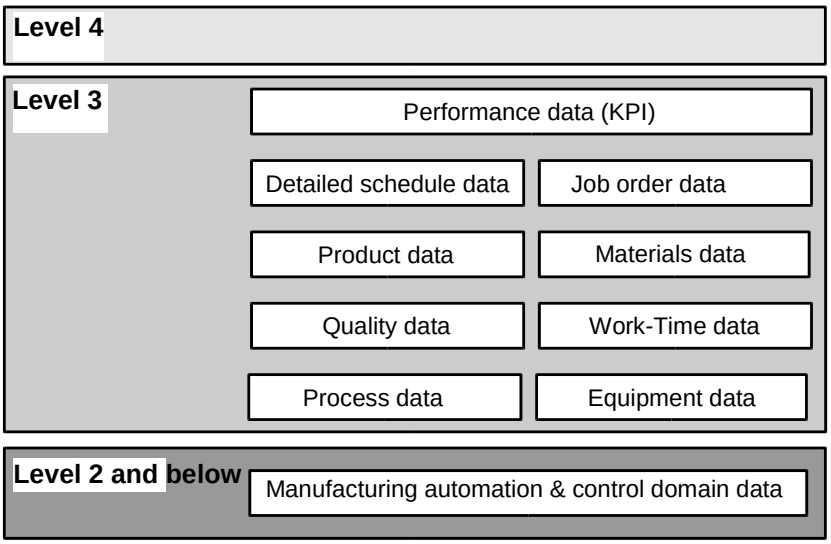


**Figure 1 — KPIs associated with Manufacturing Execution System (MES)**

Key Performance Indicators may also be considered as economic indicators used to assess the progress or degree of compliance with regard to important objectives or critical success factors within an organization. An economic indicator serves as a basis for decisions (problem identification, presentation, information extraction), for control (target / actual comparison), for documentation and/or for coordination (behavior management) of important facts and relationships within the company.

KPIs alone are not sufficient factors to perform the necessary management and execution operations for an enterprise. For many of the indicators, the actual threshold may have to be defined as company-specific. If the value of the indicator exceeds or falls below the limit, actions are intended to be initiated to improve efficiency. It is necessary to define warning and action limits. Warning limits help to detect the trends in process and equipment changes before enterprise-defined thresholds are violated.

Level 3 KPIs refer to data that are directly related to production and related manufacturing operations. These KPIs, typically forwarded to Level 4 applications, are generated and exchanged within Level 3. These KPIs may be evaluated using current data at the time of demand or as a "drill-down" computation using an integrated database capable of providing root analysis.

The KPIs gathered in this part of the International Standard have been used in various industry sectors for some time. Although these definitions were collected in a simple and readily understandable form; however, different interpretations of these terms may exist. The descriptions provided in this document are intended as recommendations.

In addition to ISO 9000 further ISO and IEC standards for the modeling of processes, information, and the integration of business and manufacturing operations management have been considered in the effort.

The intended users of this International Standard are developers of industrial automation applications, especially, those that design, implement, deploy, commission, and operate the required systems. ISO 9000 definitions have been referenced to foster alignment.

**Advantages using a common set of KPIs for a specific industry**

To realize the intended benefits, the information about the process, equipment, operator and material provided by many industrial automation systems and control devices can be more effectively used in providing critical feedback to improve the productivity of the manufacturing resources.

A standardized schema to express these KPIs could:

- Facilitate the specification and procurement of open, integrated systems, in particular, interoperability requirements among MES applications;

- Provide a means to categorize productivity tools that can be used across applications.

These KPI schemas can provide system integrators and application designers a means to assess the productivity of manufacturing applications.

**Relationship among the parts**

Part 1 provides an overview of the concepts, the terminology, and the methods to describe and to exchange key performance indicators (KPIs) for the purpose of managing manufacturing operations.

Part 2 provides the detailed definitions of domain-specific KPIs, including the elements, the structure, the rules for deriving and presenting the values for use by an application. The definitions are based on a data model that consists of items measured or computed at level 2 or level 3.

Part 3 provides the formal templates for KPIs and categories with specific instances.

Part 4 provides the procedures for exchange and use of the KPIs. The linkage to ISO 9000 process definitions for the KPI examination background, definition of processes and interfaces to other IT systems are discussed.

**Approach**

In particular, applicable concepts and definitions provided in IEC 62264 are referenced. Input from various industry groups and national organizations are listed in the Bibliography in Annex F.

# Manufacturing operations management — Key performance indicators — Part 2: Definitions and descriptions of KPIs

## 1 Scope

This part of ISO 22400 defines a class of key performance indicators (KPIs) for a set of manufacturing operations management domains. In particular, the domains of production, product quality assurance testing, materials handling and inventory, and maintenance are considered.

Benchmarks, comparisons, estimations and forecasts of KPIs are described in terms of data pertaining to the process, the machinery and equipment, the product manufactured and its quality, the manufacturing personnel and other related manufacturing resources.

## 2 Conformance

The conformity assessment of implementations based on ISO 22400 will be described in a separate specification.

## 3 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.

ISO 15745-1, Industrial automation systems and integration – Open systems application integration framework – Part 1: Generic reference description

IEC 62264-3, Industrial-process measurement and control—Enterprise-control system integration – Part 3: Activity models of manufacturing operations

REC-xml-20001006, Extensible Mark-up Language (XML) 1.0 Second Edition – W3C Recommendation 6 October 2000

REC-xmlschema-1-20010502, XML Schema Part 1: Structures – W3C Recommendation 02 May 2001

REC-xmlschema-2-20010502, XML Schema Part 2: Data types – W3C Recommendation 02 May 2001

ISO/IEC 19501:2005 Information technology -- Open Distributed Processing -- Unified Modeling Language (UML) Version 1.4.2

## 4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**4.1**
**drill down**
examine the source of the data used to calculate a performance indicator

EXAMPLE Within the OEE index the quality rate is to be analyzed. The drill down presents a direct indicator with reference to workplace, product and time period as well as possible errors. This is a quick analysis which supports a most rapid efficiency improvement by corrective actions, and thus reduces errors.

**4.2**
**Enterprise Resource Planning**
**ERP**
business process of a company involving the enterprise-wide planning and business support functions, such as, procurement, human resource management, customer support, finance and accounting, master data management, etc.

**4.3**
**Work in Process inventory**
**WIP**
material being used to complete a production order and typically located in the production area

**4.4**
**time behavior**
property of a KPI that shows how often an application can examine the value of the KPI

EXAMPLE Categories include: Demand-oriented – determined by an operator; Periodically – calculated by system per specified time intervals; Event-driven – updated whenever data changes and displayed immediately

## 5 Symbols (and abbreviated terms)

BT Busy time (BLZ)

CI Consumables inventory

DeT Delay time (SU)

DoT Down time (SZ)

ESUT Real set up time / effective set up time (TRZ)

FGI Finished goods inventory

GP Good pieces (GT)

GQ Good quantity (GM)

IP Inspected parts (PT)

LLV Lower limit value (UGW)

LT Labor time (PZt)

MA Machine

OS Operation sequence (AFO)

| | |
|---|---|
| OP | Operation process (AG) |
| OT | Operation time (BZ) |
| PBT | Planned busy time (PBZ) |
| PCT | Process time (BAZ) |
| PDT | Production time (HNZ) |
| PO | Production order (FA) |
| POQ | Production order quantity (FAM) |
| POT | Production order time (AZ) |
| PQ | Produced quantity / output quantity (PM) |
| PSQ | Planned scrap quantity (GAM) |
| PSUT | Planned set up time (PRZ) |
| PTU | Production time per unit (PEZ) |
| PU | Production unit (PE) |
| RMI | Raw material inventory |
| RQ | Rework quantity (NM) |
| s | Standard deviation |
| SQ | Scrap quantity (AM) |
| TAT | Total attendance time (GAZ) |
| TPT | Lead time / throughput time (DLZ) |
| TT | Transportation time (TZ) |
| ULV | Upper limit value (OGW) |
| WT | Wait time (LZ) |
| WG | Working group (AGR) |
| WIP | Work in process inventory (WPI) |
| WP | Work place (AP) |
| WOT | Working time (PAZ) |
| $\sigma$ | Variance |
| $\hat{\sigma}$ | Estimated deviation (sigma roof) |
| $\bar{x}$ | Average |

$\bar{\bar{x}}$ Average of average values

# 6 Component elements of KPIs

## 6.1 Time Descriptions

### 6.1.1 Notations

Many time models for data on performance indicators are complete and conclusive only for manually performed production, but cannot always be used for automated production processes. To avoid potential misunderstanding, the time model used here is independently defined and the used times are explained.

In the following remarks made on times, the name of the time is extended with a simple abbreviation in round brackets, which is used further below in the formulas. An abbreviation typically used in manufacturing environment is shown in curly brackets.

### 6.1.2 Planned periods

#### 6.1.2.1 Order duration (POT) {T}

The order duration is the scheduled time for executing a production task based on the work plan data. It is calculated from the production time per unit multiplied by the order quantity plus the planned set-up time.

#### 6.1.2.2 Operation Time (OT)

The operation time is that time in which a production unit can be used operational and personnel for production and maintenance. The operation time is a scheduled time.

#### 6.1.2.3 Planned set-up time (PSUT) {$t_r$}

The planned set-up time is the scheduled time for the set-up of a production unit for an order.

#### 6.1.2.4 Calendar day

The calendar day (24 h) is the maximum daily available time for production.

#### 6.1.2.5 Planned allocation time (PBT)

The planned allocation time is the operating time minus the planned standstill (planned downtime). The planned standstill may be used for planned maintenance work. The planned allocation period is available for the detailed planning of machine usage with production orders.

#### 6.1.2.6 Production time per unit (PTU) {$t_e$}

The production time per unit is the scheduled time for producing one unit.

### 6.1.3 Actual times

#### 6.1.3.1 Work time (WOT)

The work time is the time that a production worker needs for the execution of a manufacturing order.

#### 6.1.3.2 Processing time (PCT)

The processing time is the time needed for set-up and for the main usage.

#### 6.1.3.3 Busy time (BT) {$T_{BB}$}

The busy time is the time that a production unit is used for the execution of a manufacturing order.

#### 6.1.3.4 Execution time (TPT) {$T_D$}

The execution time is the time difference between start time and end time of a manufacturing order. It includes the busy time as well as the drop and transportation time.

#### 6.1.3.5 Total attendance time (TAT)

The total attendance is the time that a production employee is present for working in the company. It is the difference between "Come" and "Go" but without breaks.

#### 6.1.3.6 Main usage time (PDT) {$t_h$}

The main usage time is the producing time of the machine. It includes only the value-adding functions.

#### 6.1.3.7 Set aside time (LZ)

The set aside time is the time in which the material is not in progress of the manufacturing process and also is not on transport.

#### 6.1.3.8 Staff time (PZ)

The staff time is the total time consumed by the production staff to execute a manufacturing order.

#### 6.1.3.9 Downtime (DOT)

The down time is the time when the machine is not running with orders, although they are available.

#### 6.1.3.10 Malfunction-caused interrupts (SU) {$T_{BS}$, $T_{MS}$}

The malfunction-caused interrupts are times, which occur unplanned during the order processing and thus lead to an unwanted extension of busy times.

#### 6.1.3.11 Actual set-up time (ESUT)

The actual set-up time is the time that was consumed for the preparation of an order at a production unit.

#### 6.1.3.12 Transport time (TT)

The transport time is the time required for transport between production units, or to and from the warehouse of the used material.

### 6.2 Time model for production units

This model applies to time considerations for the use of production units. Figure 2 shows the relationship of the defined periods. It is important to note that the different times are linked to each other by specific losses.

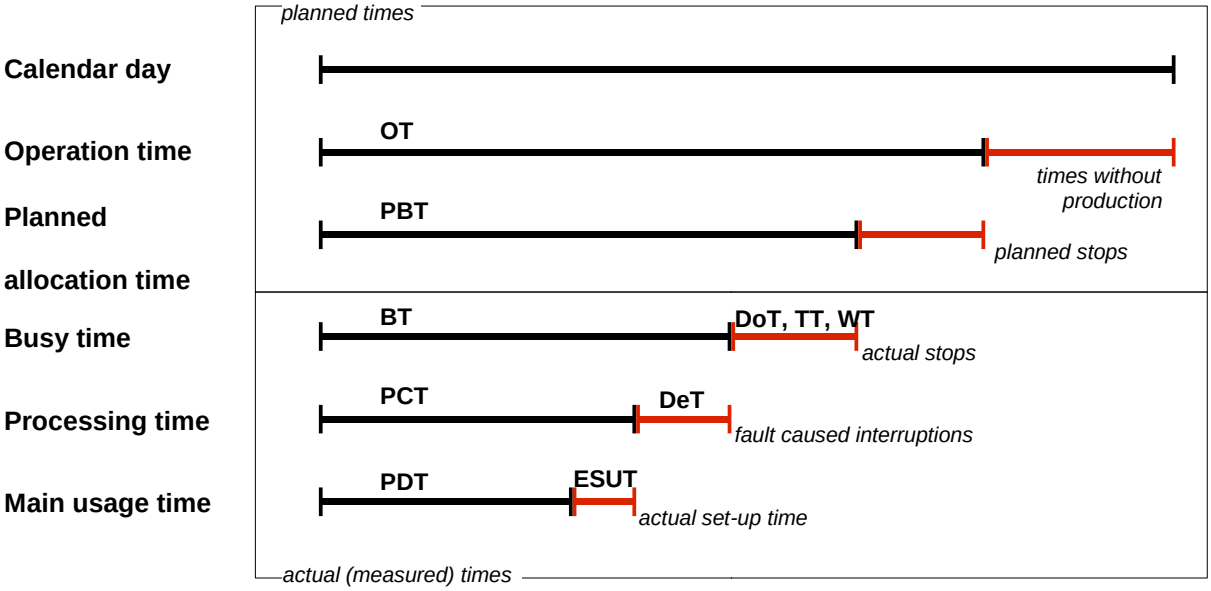


**Figure 2 – Time lines for production units**

## 6.3 Time model for manufacturing order

This time model is valid for executing the order. Figure 3 shows the manufacturing order processing time line consisting of multiple occurrences of production unit time lines (see Figure 2). It should be noted that the production unit time lines for a production order may be carried out in separate operations at several production units.

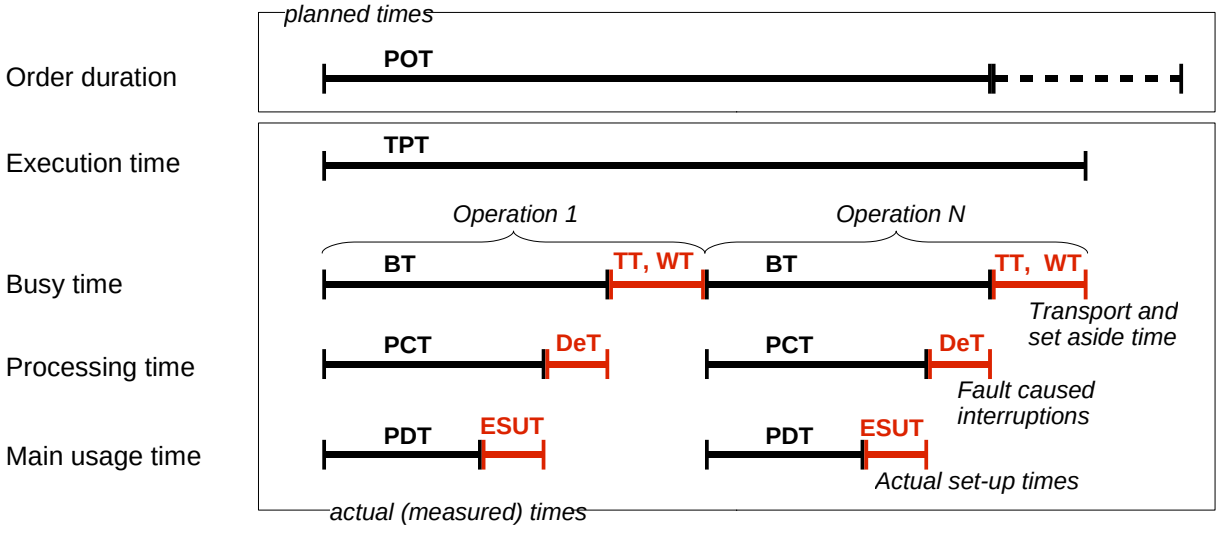


**Figure 3 – Time lines for manufacturing order processing**

## 6.4 Time model for employment

This model applies to time considerations for the employment of staff.

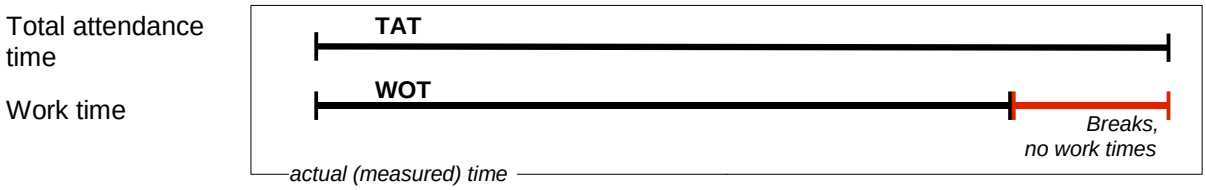


**Figure 4 – Time lines for employment**

## 6.5 Logistical quantities

### 6.5.1 Order quantity (POQ)

The order quantity is the planned quantity for a production order (lot size, production order quantity).

### 6.5.2 Wastage quantity (SQ)

The wastage quantity is the produced quantity that did not meet quality requirements and either has to be scrapped or recycled.

### 6.5.3 Planned wastage quantity (PSQ)

The planned wastage quantity is the amount of process-related wastage that is expected when manufacturing the product (e.g. at the start or ramp-up phases of the manufacturing systems).

### 6.5.4 Good quantity (GQ)

The good quantity is the produced quantity that meets quality requirements (see also 6.7.1).

### 6.5.5 Rework quantity (RQ)

The rework quantity is the produced quantity that missed the quality requirements. However, these requirements can be met by subsequent work.

### 6.5.6 Produced quantity (PQ)

The produced quantity is the quantity that a production unit has produced in relation to a production order.

## 6.6 Organizational quantities

### 6.6.1 Work sequence (OS)

The work sequence (also called work process or manufacturing order position) defines a subsequent manufacturing step within a manufacturing order, which is numbered subsequently (usually in steps of ten).

### 6.6.2 Operation (AG)

The operation defines a method of manufacturing (e.g. turning, hardening, etc.). The operation is assigned to the work sequences of the work orders by the work plan.

### 6.6.3 Working group (AGR)

The working group serves as a superior indication for evaluations. Every employee in production can be assigned to a working group.

#### 6.6.4 Workplace (WP)

The workplace is a logical unit of production, which may be manual, semi-automatic or fully automatic.

#### 6.6.5 Manufacturing order (PO)

The manufacturing order includes the necessary work sequences and the order quantity for the manufacturing of a product.

#### 6.6.6 Machine (MA)

A machine is an assembly of linked parts or components, at least one of which moves, and appropriate actuators, control and power circuits, etc., used for a specific application, such as the processing, treatment, moving or packaging of a material.

#### 6.6.7 Production unit (PU)

A production unit can be a machine, a workstation or a group of it, or a line or a plant. The production units are hierarchically defined. A production unit is within a hierarchical level a configuration of one or more workplaces up to a production plant.

### 6.7 Quality figures

#### 6.7.1 Good parts (GP)

A good part is an individual identifiable part, e.g. by serialization, which meets the quality requirements.

#### 6.7.2 Inspected parts (IP)

A tested part is an individual identifiable part, e.g. by serialization, which was tested against the quality requirements.

#### 6.7.3 Arithmetic Average ( $\bar{x}$ )

If, in a series of n measurements, each measured value $x_1,\ldots,x_i,\ldots,x_n$ was measured independently based on repetition conditions, then $\bar{x}$ ("x-bar") represents the arithmetic average value from these n individual values.

#### 6.7.4 Average of average values ( $\bar{\bar{x}}$ )

$\bar{\bar{x}}$ is calculated from the average of single sample average values ( $\bar{x}$ ).

#### 6.7.5 Upper limit value (ULV)

The upper limit value corresponds to the upper specification border related to the characteristic of a product.

#### 6.7.6 Standard deviation (s)

The standard deviation is a measure for the dispersion of measured values around its average value and is determined from the square root of the variance.

#### 6.7.7 Estimated value ($\hat{\sigma}$)

The estimated value (“sigma roof”) is calculated by the average value of the standard deviation from a sequence of samples with constant random inspection size, multiplied by a confidence factor depending on the random inspection size of the standard deviations.

#### 6.7.8 Lower limit value (LLV)

The lower limit value corresponds to the lower specification border related to the characteristic of a product.

#### 6.7.9 Variance ($\sigma$)

The variance is a measure, which describes, how strongly a measured variable (characteristic) strews. It is calculated as the distances of the measured values from the average value are squared, summed up and divided by the number of measured values.

## 7 Specific KPIs

### 7.1 Worker productivity

| | |
|---|---|
| Name / Title of index: | Worker Productivity |
| Description | |
| Benefit / Application: | Provides information about the ratio of job-related working hours of employees in relation to the total attendance time of the employee. |
| Time behaviour | periodically |
| Definition and Calculation | |
| Formula: | Worker Productivity = WOT/TAT |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher the better |
| Analysis / Drill Down: | Based on working group |
| Remarks | |
| Notes / Explanation: | It has to be noted that the work time relating to orders of the worker is to be divided accordingly if the worker works on several workplaces at the same time. . |
| Corporate level | Master, Chief, Management |

### 7.2 Allocation degree

| | |
|---|---|
| Name / Title of index: | Allocation degree |
| Description | |
| Benefit / Application: | The allocation degree is the relationship of the holding time of all jobs involved to the entire cycle time of the orders. The allocation degree is an index for the process density and thus for the height of the rotating resources in the manufacturing (work in process, WIP inventory) as well as maintenance and downtimes. To high WIP of |

| | |
|---|---|
| | resources robs liquidity, causes subsequent costs by the downtimes (container, transport, search expenditure, etc.) and is extending the cycle time. |
| Time behaviour | periodically |
| Definition and Calculation | |
| Formula: | Allocation degree = BT/TPT |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher the better |
| Analysis / Drill Down: | Related to product<br>Related to production order<br>Related to plant |
| Remarks | |
| Notes / Explanation: | The smallest evaluation unit is the production order. The allocation time is the sum of allocation time of all jobs, which were involved in the selected orders. |
| Corporate level | Master, Chief, Management |

### 7.3 Throughput

| | |
|---|---|
| Name / Title of index: | Throughput |
| Description | |
| Benefit / Application: | The throughput is an index for the performance of a process, i.e. the quantity per unit time is produced. This performance indicator is an important index for the efficiency in production.. |
| Time behaviour | demand-oriented, periodically |
| Definition and Calculation | |
| Formula: | Throughput = PQ/TPT |
| Unit/Dimension: | Quantity unit / Time unit |
| Rating: | Min: 0<br>Max: depending on product<br>Trend: the higher the better |
| Analysis / Drill Down: | Related to product<br>Related to production order<br>Related to production unit |
| Remarks | |
| Notes / Explanation: | The performance indicator is calculated per job after job completion. The time unit may also be chosen in hours or days, specific for a product, to determine the efficiency. |
| Corporate level | Master, Chief, Management |

### 7.4 Allocation efficiency

| | |
|---|---|
| Name / Title of index: | Allocation efficiency |

| Description | |
|---|---|
| Benefit / Application: | The allocation efficiency is the ratio between the real allocation time of a machine and planned time for allocating the machine. |
| Time behaviour | demand-oriented |
| Definition and Calculation | |
| Formula: | Allocation efficiency = BT/PBT |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher the better |
| Analysis / Drill Down: | Related to product<br>Related to production order<br>Related to production unit |
| Remarks | |
| Notes / Explanation: | The allocation efficiency indicates how strongly the capacity of the machine is already used and how much capacity is still available. |
| Corporate level | Worker, Master, Chief, Management |

### 7.5 Efficiency

| Name / Title of index: | Efficiency |
|---|---|
| Description | |
| Benefit / Application: | The efficiency is the portion of the main usage time of the entire allocation time, thus it is a measure for the productivity of the machine. Since only the operating time is value-adding and is remunerated by the market, for an enterprise it must be the goal to increase this portion drastically . |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Efficiency = PDT/BT |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher the better |
| Analysis / Drill Down: | Related to production unit |
| Remarks | |
| Notes / Explanation: | This performance indicator is suitable as on-line characteristic number for the worker level. . |
| Corporate level | Master, Chief, Management |

### 7.6 OEE Index

| Name / Title of index: | OEE Index |
|---|---|
| Description | |

| | |
|---|---|
| Benefit / Application: | Overall Equipment Effectiveness (OEE) is a measure for the efficiency of machines and/or plants, manufacturing cells with several machines or an entire assembly line. The OEE Index forms the basis for improvements by better production information, identification of production losses, and improvement of the product quality by optimized processes.<br>The OEE Index represents the used availability, the effectiveness of the production unit, and their quality rate summarized in a characteristic number. |
| Time behaviour | demand-oriented, periodically |
| Definition and Calculation | |
| Formula: | OEE Index = Availability * Effectiveness * Quality rate |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | With the bench mark of manufacturing processes by means of the OEE Index the criteria for a comparability are to be examined before. |
| Corporate level | Master, Chief, Management |

### 7.7 NEE Index

| | |
|---|---|
| Name / Title of index: | NEE Index |
| Description | |
| Benefit / Application: | The NEE Index gives hints to losses by plant stop, cycle time losses and losses due to defective and to-be-reworked products. |
| Time behaviour | demand-oriented, periodically |
| Definition and Calculation | |
| Formula: | NEE Index = PCT/PBT * Effectiveness * Quality rate |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | Contrary to the OEE Index, the NEE index is used more rarely. The NEE does not regard the preparation and setting-up as losses, as OEE does. |
| Corporate level | Worker, Master, Chief, Management |

### 7.8 Availability

| | |
|---|---|
| Name / Title of index: | Availability |
| Description | |
| Benefit / Application: | The availability indicates, how strongly the capacity of the machine for the worth-drawing functions related to the planned availability is used. |
| Time behaviour | demand-oriented, periodically |
| Definition and Calculation | |
| Formula: | Availability = PDT/PBT |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to production unit |
| Remarks | |
| Notes / Explanation: | The term availability is also called usage grade. |
| Corporate level | Master, Chief, Management |

### 7.9 Effectiveness

| | |
|---|---|
| Name / Title of index: | Effectiveness |
| Description | |
| Benefit / Application: | The effectiveness is the measure for the power of a process. The relationship of the target cycle to the actual cycle is represented. The effectiveness is a characteristic number, which may be calculated and displayed in short periodic distances at run time of a machine. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Effectiveness = PTU * PQ / PDT |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better.<br>The 100% can be exceeded, if the planned production time for each production unit is larger than the actual production time. |
| Analysis / Drill Down: | Related to product, production unit and order |
| Remarks | |
| Notes / Explanation: | The effectiveness is called also efficiency factor or performance. This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level | Master, Chief, Management |

## 7.10 Quality Rate

| | |
|---|---|
| Name / Title of index: | Quality Rate |
| Description | |
| Benefit / Application: | The quality rate is the relationship of the proper quantity to the produced quantity. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Quality Rate = GQ / PQ |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level | Master, Chief, Management |

## 7.11 Preparation degree

| | |
|---|---|
| Name / Title of index: | Preparation Degree |
| Description | |
| Benefit / Application: | The preparation degree is an index for the preparation portion related to the operating time at a machine. The larger the value becomes, the higher the preparation part of the time that was announced with the production order at the machine. For an enterprise a high preparation degree means a consumption of valuable time, which is not worth drawing in the actual sense. |
| Time behaviour | demand-oriented, periodically |
| Definition and Calculation | |
| Formula: | Preparation Degree = ESUT/BRZ |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to production unit, to product and to order. |
| Remarks | |
| Notes / Explanation: | The preparation degree is to be considered in particular with the reduction from lot sizes and shall be minimized |
| Corporate level: | Setter, Master, Chief |

## 7.12 Technical Usage Level

| | |
|---|---|
| Name / Title of index: | Technical Usage Level |
| Description | |
| Benefit / Application: | The technical usage level is the efficiency of a machine.<br>It is the relationship between the main usage period and the main usage period including the fault caused interruptions. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Technical Usage Level = PDT / (PDT + DeT) |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better.<br>100% correspond to maximum attainable technical efficiency without fault-caused interruptions. |
| Analysis / Drill Down: | Related to production unit, to product and to order. |
| Remarks | |
| Notes / Explanation: | The technical usage level indicates, how much capacity is still available by reduction of the machine-conditioned disturbances. Contrary to the efficiency, here the set-up times are not considered. This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level: | Worker, Master, Chief, Management |

## 7.13 Wastage Degree

| | |
|---|---|
| Name / Title of index: | Wastage Degree |
| Description | |
| Benefit / Application: | Border definition for wastage and examination of the compliance. The wastage degree shall take into account process-conditioned wastage on one hand and on the other hand it should stay below one hundred percent. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Wastage Degree = SQ / PSQ |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to production unit, to product and to errors |
| Remarks | |

| | |
|---|---|
| Notes / Explanation: | The wastage degree supports the monitoring of the target demand. The planned wastage quantity (that which can be expected) is normally already defined in the ERP system in order to ensure also the necessary material allocation. This characteristic number is suitable as on-line characteristic number for the worker level. |
| Corporate level: | Worker, Master, Chief, Management |

### 7.14 First Pass Yield (FPY)

| | |
|---|---|
| Name / Title of index: | First Pass Yield (FPY) |
| Description | |
| Benefit / Application: | The FPY is a characteristic number for the direct process quality regarding work place and product. If the result of the characteristic number becomes larger, the so-called "yield" increases, error costs and material wastage are avoided, the yield quantities are increased. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | FPY = GP / PT |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to work place, to product, to order and to error types. |
| Remarks | |
| Notes / Explanation: | Serialization of the produced quantity or process-conditioned guaranteed "one time run" is a condition. The FPY designates the percentage at products, which already fulfill quality requirements fully in the first process run without reworking (proper parts). The FPY stands in reciprocal relationship to the errors or extra costs. If the FPY is increased, then the false achievement costs reduce. This characteristic number is suitable as on-line characteristic number for the worker level. |
| Corporate level: | Worker, Master, Chief, Management |

### 7.15 Wastage Ratio

| | |
|---|---|
| Name / Title of index: | Wastage Ratio |
| Description | |
| Benefit / Application: | The wastage ratio gives the percentage portion of the entire production, which is wastage. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Wastage Ratio = SQ / PQ |
| Unit/Dimension: | % |

| | |
|---|---|
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to order and to error types. |
| Remarks | |
| Notes / Explanation: | The wastage ratio gives a quality evaluation of the production and a balance evaluation. The smaller the value, the better is the productivity. This characteristic number is suitable as on-line characteristic number for the worker level. |
| Corporate level: | Worker, Master, Chief, Management |

### 7.16 Reworking Ratio

| | |
|---|---|
| Name / Title of index: | Reworking Ratio |
| Description | |
| Benefit / Application: | The reworking ratio gives the proportional portion of entire production which is reworking. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Reworking Ratio = RQ / PQ |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to order and to error types. |
| Remarks | |
| Notes / Explanation: | The reworking ratio gives a quality evaluation of the production and a balance evaluation. The smaller the value, the better the productivity. This characteristic number is suitable as an on-line characteristic number for the worker level. |
| Corporate level: | Worker, Master, Chief, Management |

### 7.17 Fall off Rate

| | |
|---|---|
| Name / Title of index: | Fall off Rate |
| Description | |
| Benefit / Application: | This indicator is applied with concatenated processes, on the basis of a mother product (e.g. basis building group or motherboard) which is produced in the first manufacturing step and leads to further wastages in the context of the following manufacturing steps. The mother products can be serialized in the first manufacturing step. The characteristic number has an influence on the planning quality (planned wastage) and on the production quality per manufacturing step as well as the material wastage. This characteristic number indicates, how big the wastage ratio is |

| | |
|---|---|
| | in relation to the produced amount of the first manufacturing step. |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Fall off Rate = SQ / $PQ_{\text{ of the first manufacturing step}}$ |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to product, to manufacturing order and to operation |
| Remarks | |
| Notes / Explanation: | This characteristic number is suitable as on-line characteristic number for the worker level. |
| Corporate level: | Worker, Master, Chief, Management |

## 7.18 Machine Capability Index (Cm)

| | |
|---|---|
| Name / Title of index: | Machine Capability Index ($C_m$) |
| Description | |
| Benefit / Application: | The machine capability index shows the ability of a machine or a work mechanism to produce the demanded quality. The evaluation should take place if possible under exclusion of further process influences. Application takes place mainly with the approval from plants/machines/products |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Cm = (ULV - LLV ) / (6 * s) |
| Unit/Dimension: | --- |
| Rating: | Min: → 0, if s is very big<br>Max: infinite, if s → 0<br>Trend: the higher, the better |
| Analysis / Drill Down: | Related to product, to machine, to characteristic and to measurement |
| Remarks | |
| Notes / Explanation: | $C_m$ = characteristic value of a short time capability investigation.<br>Usually for this the normal distribution is consulted. The machine capability value is usually defined with customer requirements. Typical value is $C_m$ > 1,66. The value can be used only with reciprocally tolerated characteristics. |
| Corporate level: | Worker, Master, Chief |

## 7.19 Critical Machine Capability Index (Cmk)

| | |
|---|---|
| Name / Title of index: | Critical Machine Capability Index |
| Description | |
| Benefit / Application: | The critical machine capability index shows the ability of a machine or a work mechanism to produce the demanded quality. The evaluation should take place if possible under exclusion of further process influences. Application takes place mainly with the approval from plants/machines/products |
| Time behaviour | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | $C_{mko} = (ULV - x_{qq}) / (3 * s)$ ; $C_{mku} = (X_{qq} - LLV) / (3 * s)$ |
| Unit/Dimension: | --- |
| Rating: | Min: < 0, if xqq is outside tolerance<br>Max: infinite, if s → 0<br>Trend: the higher, the better |
| Analysis / Drill Down: | Related to product, to machine, to characteristic and to measurement |
| Remarks | |
| Notes / Explanation: | $C_{mk}$ = critical characteristic value of a short time capability investigation. Usually for this the normal distribution is consulted. The machine capability value is usually defined with customer requirements. Typical value is $C_m$ > 1,66. The value can be used only with reciprocally tolerated characteristics.<br>The $C_{mk}$ is calculated as well for the lower ($C_{mku}$) as for the higher ($C_{mko}$) tolerance value. The relevant $C_{mk}$ is the smaller value of both calculations. |
| Corporate level: | Worker, Master, Chief |

## 7.20 Process Capability Index (Cp)

| | |
|---|---|
| Name / Title of index: | Process Capability Index |
| Description | |
| Benefit / Application: | The process capability shall prove as early as possible with statistic methods that the manufacturing process can surely manufacture the products with the demanded quality. The process capability index $C_p$ designates the relationship between the dispersion of a process and the specification borders. The range between the specification borders (tolerance width) is compared with the 6-times process dispersion. A process is usually called capable if the process capability index is > 1,33. |
| Time behaviour | demand-oriented, online |
| Definition and Calculation | |
| Formula: | $C_p = (ULV - LLV) / (6 * \hat{\sigma})$ |

| | |
|---|---|
| Unit/Dimension: | -- |
| Rating: | Min: → 0, if $\hat{\sigma}$ is very big<br>Max: infinite, if $\hat{\sigma}$ → 0<br>Trend: the higher, the better |
| Analysis / Drill Down: | Related to product, to machine, to characteristic and to measurement |
| Remarks | |
| Notes / Explanation: | The measurement is done in regular time steps or after defined amount intervals with small samples (1-25).<br>$\hat{\sigma}$ results with a confidence factor from the standard deviation, depending of the random inspection size. |
| Corporate level: | Worker, Master, Chief |

## 7.21 Critical Process Capability Index (Cpk)

| | |
|---|---|
| Name / Title of index: | Critical Process Capability Index |
| Description | |
| Benefit / Application: | The process capability shall prove as early as possible with statistic methods that the manufacturing process can surely manufacture the products with the demanded quality.<br>With the critical process capability $C_{pk}$ additionally the average value is considered, as the smallest distance between average value and specification border is compared with the triple dispersion.<br>A process is usually called capable if the critical process capability index is > 1,33. |
| Time behaviour | demand-oriented, online |
| Definition and Calculation | |
| Formula: | $C_{pko} = (ULV - x_{qq}) / (3 * \hat{\sigma})$ ; $C_{pku} = (x_{qq} - LLV) / (3 * \hat{\sigma})$ |
| Unit/Dimension: | --- |
| Rating: | |
| Analysis / Drill Down: | Related to product, to machine, to characteristic and to measurement |
| Remarks | |
| Notes / Explanation: | The measurement is done in regular time steps or after defined amount intervals with small samples (i.e. 1 to 25).<br>$x_{qq}$ is calculated from the averages of the samples. $\hat{\sigma}$ results in a confidence factor from the standard deviation, depending of the random inspection size.<br>The $C_{pk}$ is calculated as well for the lower ($C_{pku}$) as for the higher ($C_{pko}$) tolerance value. The relevant $C_{pk}$ is the smaller |

| | |
|---|---|
| | value of both calculations. |
| Corporate level: | Worker, Master, Chief |

## 7.22 Environmental compatibility KPIs

### 7.22.1 Selection of environmental KPIs

Environmental KPIs are selected according to their impact on the environment and not their direct effect on company earnings. The five identified KPIs are emission ratio, energy ratio, ratio of used material, harmful substances and hazardous waste..

### 7.22.2 Emission ratio

| | |
|---|---|
| Name / Title of index: | Emissions ratio |
| Description | |
| Benefit / Application: | The energy balance of the entire climate system is affected by changes in the atmospheric abundance of greenhouse gases.The most important anthropogenic greenhouse gas is carbon dioxide since $CO_2$ comprises 80 % of the total greenhouse gases. The concentration of carbon dioxide has increased from a pre-industrial value of 280 ppm to 379 ppm in 2005. This has resulted in a rise in global temperature of 0.76 °C and therefore a rise in sea levels of 0.17 m during the 20th century. Therefore the recommendation is that fossil $CO_2$ emissions are monitored as the total amount produced within the system borders earlier defined. |
| Time behaviour | demand-oriented |
| Definition and Calculation | |
| Formula: | Emission ratio = ($CO_{2energy}$ + $CO_{2transported\ goods}$ + $CO_{2travel}$ + $CO_{2internal}$) / VA |
| Unit/Dimension: | ton/kkr |
| Rating: | Min: infinite<br>Max: infinite<br>Trend: the lower, the better |
| Analysis / Drill Down: | Related to product, to production unit, to production plant |
| Remarks | |
| Notes / Explanation: | $CO_{2energy}$ = contribution from energy used in production<br>$CO_{2transported\ goods}$ = contribution from all transports paid for by the organization except internal transports<br>$CO_{2travel}$ = contribution from travels of staff employed in production<br>$CO_{2internal}$ = contribution from all internal sources in the production<br>VA = Value Added |
| Corporate level: | Worker, Master, Chief |

### 7.22.3 Energy ratio

| | |
|---|---|
| Name / Title of index: | Energy ratio |
| Description | |
| Benefit / Application: | The energy sector contributes a large amount of the pollution of greenhouse gases. Nuclear energy production partly effects the immediate surrounding environment and furthermost has an effect during mining of nuclear fuel. The final storage of used radioactive material has an impact on the environment under at least 100 000 years. Even renewable energy has an impact on the close surrounding environment as land is taken in use by the constructions. The measurement of $CO_2$ will be an initiative for lowering the dependence of fossil energy and therefore total energy consumption should be measured since lowered total energy consumption is desirable. |
| Time behaviour | demand-oriented |
| Definition and Calculation | |
| Formula: | Energy ratio = (energy bought + energy internally produced) / VA |
| Unit/Dimension: | MWh / kkr |
| Rating: | Min: infinite<br>Max: infinite<br>Trend: the lower, the better |
| Analysis / Drill Down: | Related to product, to production unit, to production plant |
| Remarks | |
| Notes / Explanation: | All forms of energy, both fossil and renewable, should be taken into account since lowered energy consumption, in general, is good for the environment. |
| Corporate level: | Worker, Master, Chief |

### 7.22.4 Ratio of used material

| | |
|---|---|
| Name / Title of index: | Ratio of used material |
| Description | |
| Benefit / Application: | Manufacturing that reduces the amount of used materials in the process will lessen its impact on the environment. A study indicates that if material reduction is fully utilized this will result in lowered carbon dioxide emission from transportation and energy production. |
| Time behaviour | demand-oriented |
| Definition and Calculation | |
| Formula: | Ratio of used material = total amount of material used / VA |
| Unit/Dimension: | ton / kkr |
| Rating: | |
| Analysis / Drill Down: | Related to product, to production unit, to production plant |
| Remarks | |
| Notes / Explanation: | All materials bought, excluding packaging, water and fuel |

| | |
|---|---|
| | according to the definition by the World Business Council for Sustainable Development. Wastage and wastage ratio already exists in this part of ISO 22400 and it is therefore necessary to focus on total amount of materials used. |
| Corporate level: | Worker, Master, Chief |

### 7.22.5 Harmful substances

| | |
|---|---|
| Name / Title of index: | Harmful substances |
| Description | |
| Benefit / Application: | Successful reduction of harmful substances in production will lead to lowered danger of hazardous accidents and therefore lowered risk of cost associated with sanitation for the producer and the society. The global restoration of environmental devastation has been estimated to $125 billion. Production of harmful substances in the European Union has unfortunately increased from 259 million tons in1996 to 317 million tons in 2007. |
| Time behaviour | demand-oriented |
| Definition and Calculation | |
| Formula: | Harmful substances = total used amount of harmful substances in tons / VA |
| Unit/Dimension: | ton / kkr |
| Rating: | |
| Analysis / Drill Down: | Related to product, to production unit, to production plant |
| Remarks | |
| Notes / Explanation: | Total weight of substances used defined by the KEMI classification list and REACH (European Union Directive for the registration, evaluation, authorization and limitation of chemicals). |
| Corporate level: | Worker, Master, Chief |

### 7.22.6 Hazardous waste

| | |
|---|---|
| Name / Title of index: | Hazardous waste |
| Description | |
| Benefit / Application: | The total amount of hazardous waste in the EU was 84.4 million tons in 2006, an increase by 14 % from 2004. In the US hazardous waste has increased with 54.7 % from 2003 to 2007. The manufacturing industry is responsible for the majority of total hazardous waste. Agenda 21 suggest several actions for governments in order to strengthen the international capacity of handling hazardous waste such as invest in R&D associated with waste management, increase information and education on the subject, improving waste handling infrastructure, establish legal frameworks etc. Actions incurring an estimated global cost of 18.5 billion dollars yearly. As the amount of hazardous waste is increasing and incurs great costs for the society, the authors find this indicator highly relevant. |
| Time behaviour | demand-oriented |
| Definition and Calculation | |

| | |
|---|---|
| Formula: | Ratio of hazardous waste= total amount of hazardous waste/ VA |
| Unit/Dimension: | ton / kkr |
| Rating: | Min: infinite<br>Max: infinite<br>Trend: the lower, the better |
| Analysis / Drill Down: | Related to product, to production unit, to production plant |
| Remarks | |
| Notes / Explanation: | The quantity of hazardous waste in comparison to total waste varies between the countries. |
| Corporate level: | Worker, Master, Chief |

## 7.23 KPIs for energy consumption

### 7.23.1 Comprehensive Energy Consumption

Indicators to measure the consumption of energy are used by enterprises for energy savings, environmental protection, and cost reduction. Though energy can be considered as a form of raw material, it helps to evaluate the consumption of energy using distinct indicators.

| | |
|---|---|
| Name / Title of index: | Comprehensive Energy Consumption |
| Description | |
| Benefit / Application: | Comprehensive Energy Consumption is the ratio between all the energy consumed in a production cycle and produced quantity. |
| Time behavior | demand-oriented, periodically |
| Definition and Calculation | |
| Formula: | e = E/PQ = （∑Mi*Ri + Q） / PQ<br>e: unit energy consumption of statistical object, standard quantity / ton<br>E: comprehensive energy consumption, standard quantity<br>Mi: actual consumption of certain kind of energy, ton (kilowatt hour)<br>Ri: conversion coefficient of certain kind of energy, standard quantity / ton<br>Q: algebraic sum of effective energy exchanges with environment, standard quantity<br>PQ is expressed in tons |
| Unit/Dimension: | standard quantity / ton |
| Rating: | Min: 0<br>Max: related to product<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to product, to statistics unit |
| Remarks | |
| Notes / Explanation: | Energy consumption is an important factor impacting the production costs and final profits. |
| Corporate level | Worker, Master, Chief, Management |

NOTE The conversion coefficient Ri is used to unify the measurement modes of different energy types, by which a certain kind of energy can be changed into standard quantity. (e.g. the unit of Ri for water is standard quantity / ton; for electricity the unit of Ri is standard quantity / kilowatt-hour.) The Comprehensive Energy Consumption indicator is used with a collection of standard quantity conversion tables, which are unique for different industries.

## 7.24 KPIs for inventory handling and management

### 7.24.1 Inventory turns

The definition of indicators for inventory is quite important in the process industry where production is organized based on inventory. How long the product is stored may affect the quality and cost.

The following are descriptions of the four types of inventory: raw material inventory (RMI), consumables inventory (CI), finished goods inventory (FGI), and work in process inventory (WIP).

a) Raw materials: The materials that are changed into finished goods though the production.

b) Consumables: The materials of which the quantity or quality is changed during the production, such as a catalyst. (Consumables have been defined in detail in IEC 62264-1.)

c) Crib and finished goods inventory (FGI): The stock point at the end of a routing is either a crib inventory location or finished goods inventory. Crib inventories are used to gather different parts within the plant before further processing or assembly. For instance, a routing to produce gear assemblies may be fed by several crib inventories containing gears, housings, crankshafts and so on. Finished goods inventory is where end items are held prior to shipping to the customer.

d) Work in process inventory (WIP): The inventory between the start and end points of a product routing is called Work in process (WIP). Since routing begin and end at stock points, WIP is the entire product between, but not including, the ending stock points. Although in colloquial use WIP often includes crib inventories, a distinction is made between crib inventory and WIP for clarification.

NOTE WIP inventory as specified in VDMA 66412-1 is that material which is assigned to the production order and is not for the stock. This inventory is normally located in the production area.

| Name / Title of index: | Inventory Turns |
|---|---|
| Description | |
| Benefit / Application: | The Inventory Turns is defended as the ratio of the throughput (TH) to average inventory. It is commonly used to measure the efficiency of inventory, and represents the average number of times the inventory stock is replenished or turned over. |
| Time behavior | demand-oriented, periodically |
| Definition and Calculation | |
| Formula: | Inventory Turns = Throughput / average inventory |
| Unit/Dimension: | times |
| Rating: | Min: 0<br>Max: related to product<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to product, to order, to production unit, to inventory unit |
| Remarks | |
| Notes / Explanation: | Exactly which inventory is included depends on what is being measured. For instance, in a warehouse, all inventory is FGI, so turns are given by TH / FGI. In a plant, we generally consider both WIP and FGI, so turns are given by TH / (WIP+FGI). There are also other inventory turns to different departments, such as Raw Material Inventory Turns (TH/RMI), Consumables Inventory Turns (TH/CI), and so on.<br>Need to pay attention to the boundary of the inventory Turns in MES. Usually, Inventory Turns in MES only focuses on the inventory of WIP, while the Inventory Turns about RMI and FGI may be concerned in ERP.<br>It is essential to make sure that throughput and inventory are measured in the same unit. |

| | |
|---|---|
| Corporate level | Master, Chief, Management |

## 7.25 KPIs for input-output (quality of manufacturing process)

### 7.25.1 Finished Goods Rate

In the process industry (e.g. oil refining and chemicals), “consumed material” is usually used in the denominator to calculate the related KPIs. In some industrial processes, input can be less than the output. Many chemical and physical changes occur during production, and product yield has fluctuation and uncertainty. It is therefore difficult to calculate and measure the output.

NOTE The KPI of finished goods rate defined below is in contrast with the “Quality Rate” as defined in VDMA 66412-1.

| | |
|---|---|
| Name / Title of index: | Finished Goods Rate |
| Description | |
| Benefit / Application: | The Finished Goods Rate is the ratio of the good quantity produced (GQ) to the consumed material. |
| Time behavior | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Finished Goods Rate = GQ / consumed material |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level | Master, Chief, Management |

Additionally, products in the process industry are closely related with each other since partial amounts of a specific quantity of finished goods at a particular grade or quality can be converted to another product with a different grade or quality. Therefore, the Finished Goods Rate of a single product is not enough to reflect the production. For example, when the quality of a product has not reached a higher level “A”, it can be sold as a product with a lower quality level “B”. Then the rate of products in level “B” rises as the rate of products in level “A” declines. Therefore, KPIs are calculated from the view of all related products, such as the level “A” and level “B” products mentioned above. In this case, the term “Integrated Goods Rate” (see 7.25.2) is used instead of “Finished Goods Rate”.

### 7.25.2 Integrated Goods Rate

Integrated Goods represents the quantity of all products during production. It is important to make sure that all products are measured in the same unit, or can be converted to the same unit. A list of conversion coefficients can be used to unify the measurement modes of different products.

| | |
|---|---|
| Name / Title of index: | Integrated Goods Rate |
| Description | |
| Benefit / Application: | The integrated goods rate is the relationship of the proper quantity to the consumed material. |
| Time behavior | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Finished Goods Rate = $\frac{\text{Integrated Good quantity}}{\text{consumed material}}$ |
| Unit/Dimension: | % |

| | |
|---|---|
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the higher, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level | Master, Chief, Management |

### 7.25.3 Production Lost Rate

Wastage and reworking are not measured in the process industries. Instead, the focus is on loss, where:

Integrated Goods Rate + Lost Rate = 1

Lost Rate = production lost rate + storage and transportation lost rate + other lost rate

For these calculcations the following apply.

a) Production lost: the quantity of lost during the production, calculate as output minus input.

b) Storage and transportation lost: the quantity lost during storage and transportation, such as inventory lost during an inventory calculation or material lost during movement from one place to another.

c) Other lost: the quantity lost due to extraordinary incidents such as natural disasters.

| | |
|---|---|
| Name / Title of index: | Production Lost Rate |
| Description | |
| Benefit / Application: | The production lost rate is the relationship of the quantity of the lost during production to the consumed material. |
| Time behavior | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Production Lost Rate = production lost / consumed material |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level | Master, Chief, Management |

### 7.25.4 Storage and Transportation Lost Rate

| | |
|---|---|
| Name / Title of index: | Storage and Transportation Lost Rate |
| Description | |
| Benefit / Application: | The storage and transportation lost rate is the relationship of the quantity of the lost during storage and transportation to the consumed material. |
| Time behavior | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Storage and Transportation Lost Rate = storage and transportation |

| | |
|---|---|
| | lost consumed material |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level | Master, Chief, Management |

#### 7.25.5 Other Lost Rate

| | |
|---|---|
| Name / Title of index: | Other Lost Rate |
| Description | |
| Benefit / Application: | The other lost rate evaluates the lost that is not during production, storage, or transportation. |
| Time behavior | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Other Lost Rate = other lost / consumed material |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: the lower, the better. |
| Analysis / Drill Down: | Related to production unit, to product, to period (day) and to error types. |
| Remarks | |
| Notes / Explanation: | This indicator is suitable as on-line characteristic number for the worker level. |
| Corporate level | Master, Chief, Management |

### 7.26 KPIs of Load Rate

#### 7.26.1 Equipment Load Rate

Production capacity and the load rate of equipment are important indicators in a manufacturing enterprise. The load rate of equipment is calculated as:

Equipment Load Rate = Produced Quantity (PQ) / Equipment Production Capacity

As defined below, equipment production capacity is either “rated” or “maximum”.

a) Maximum Equipment Production Capacity: the upper limit value of production demarcated before the equipment delivery.

b) Rated Equipment Production Capacity: the upper limit value of production promised the stable operation of the equipment.

| | |
|---|---|
| Name / Title of index: | Equipment Load Rate |
| Description | |
| Benefit / Application: | Provides information about the ratio of produced quantity (PQ) in relation to the maximum equipment production capacity. It is an indicator to reflect the production state of equipment and production efficiency. It helps to reflect the technical performance and utilization of equipments and by researching the |

| | |
|---|---|
| | usage of equipment |
| Time behavior | demand-oriented, periodically, online |
| Definition and Calculation | |
| Formula: | Equipment Load Rate = PQ / maximum equipment production capacity |
| Unit/Dimension: | % |
| Rating: | Min: 0%<br>Max: 100%<br>Trend: If the produced quantity is below the Rated Equipment Production Capacity, the higher, the better. It is possible to impact the security and reliability of equipment when the produced quantity is above the Rated Equipment Production Capacity. There is also a lower limit of Equipment Load Rate to some equipment, below which it cannot be produced. |
| Analysis / Drill Down: | Related to production unit |
| Remarks | |
| Notes / Explanation: | The value of Equipment Load Rate impacts the production costs and, ultimately, profits. |
| Corporate level | Master, Chief, Management |

# Bibliography

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[4] ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units*