



BSI Standards Publication

Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management

Part 2: Definitions and descriptions

National foreword

This British Standard is the UK implementation of ISO 22400-2:2014+A1:2017. It supersedes BS ISO 22400-2:2014, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to ISO text carry the number of the ISO amendment. For example, text altered by ISO amendment 1 is indicated by A1 A1.

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Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management —

Part 2: Definitions and descriptions

*Systèmes d'automatisation et intégration — Indicateurs de
la performance clé pour le management des opérations de
fabrication —*

Partie 2: Définitions et descriptions



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is 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*

The following parts are under preparation:

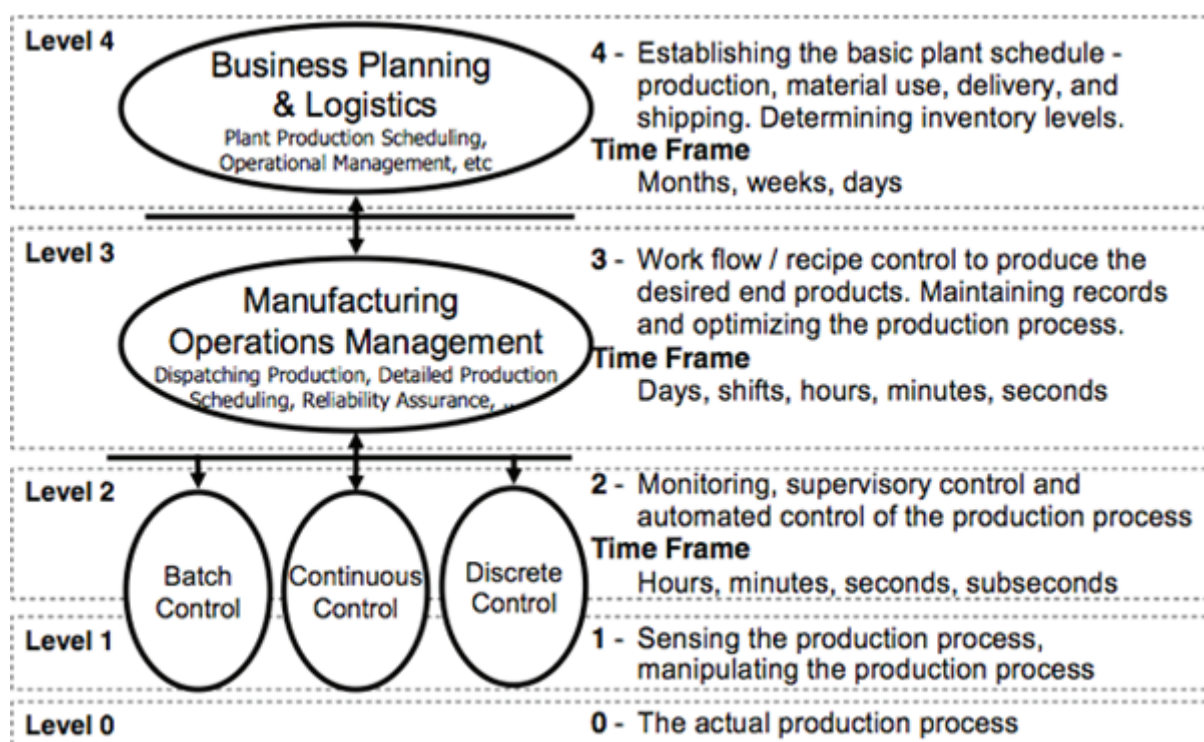
- *Part 3: Exchange and use*
- *Part 4: Relationships and dependencies*

Introduction

This part of ISO 22400 focuses on key performance indicators (KPIs) for manufacturing operations management.

KPIs are defined as quantifiable and strategic measurements that reflect an enterprise's critical success factors. KPIs are very important for understanding and improving manufacturing performance, both from the lean manufacturing perspective of eliminating waste and from the corporate perspective of achieving strategic goals.

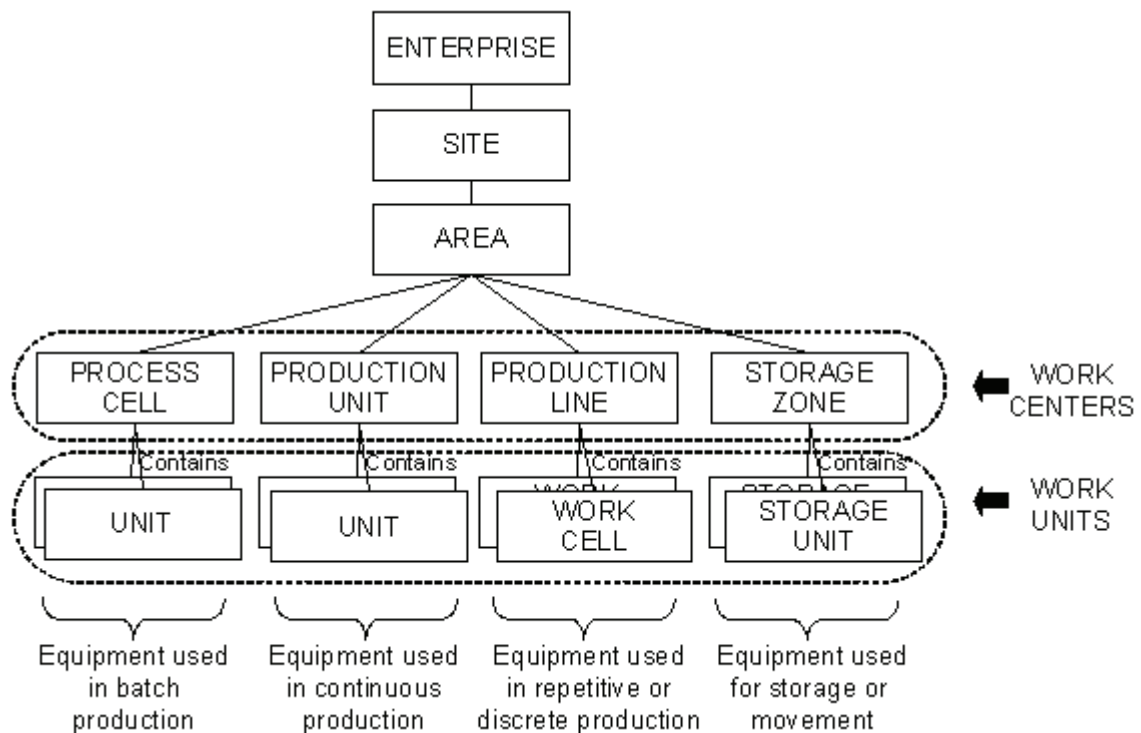
Manufacturing operations management (MOM) is a term used in IEC 62264 to specify a portion of the functional hierarchy model of a manufacturing enterprise. [Figure 1](#) depicts the different levels of the functional hierarchy model: business planning and logistics (Level 4), manufacturing operations and control (Level 3), and batch, continuous, or discrete control (Level 1-2). The levels provide different functions and work in different timeframes.



NOTE Adapted from IEC 62264-3.

Figure 1 — Functional hierarchy

IEC 62264 also specifies a hierarchical structure for the physical equipment (see [Figure 2](#)). Enterprise, site and areas are generic terms, whereas there are specific terms for work centres and work units that apply to batch production, continuous production, discrete or repetitive production, and for storage and movement of materials and equipment.



NOTE Adapted from IEC 62264-3.

Figure 2 — Role based equipment hierarchy

This part of ISO 22400 specifies the KPIs “residing” at Level 3, i.e. related to MOM. These KPIs are generated/calculated within Level 3. Some of these KPIs are forwarded to Level 4 for further usage. In order to generate these KPIs, parameters from Levels 2 and 1 might be needed.

The KPIs in this part of ISO 22400 use the most generic terms possible (e.g. work centres and work units), instead of industry specific terms.

MOM, sometimes referred to as manufacturing execution systems (MES), models four major categories of operations management:

- production operations management;
- maintenance operations management;
- quality operations management;
- inventory operations management.

An activity model further details each category. Each activity model includes eight activities:

- detailed scheduling;
- dispatching;
- execution management;
- resource management;
- definition management;
- tracking;

- data collection;
- analysis.

These activities apply to production operations, quality operations, inventory operations and maintenance operations.

Analysis is the performance of calculating KPIs using information from other activities. Workflows can be used to illustrate the important events and steps needed in the calculation process for KPIs.

KPIs alone are not sufficient factors to perform the necessary management and execution operations for an enterprise. For many of the indicators, a company specific threshold is defined. When the value of the indicator exceeds or falls below the threshold, actions are initiated (e.g. to improve efficiency or quality). Often it is necessary to define warning and action limits. Warning limits help to detect the trends in process and equipment changes before company-specific thresholds are violated.

To improve the productivity of the manufacturing resources, information provided by industrial automation systems and control devices about process, equipment, operator, and material can be useful for providing critical feedback through KPIs.

A standardized schema for the expression of these KPIs is intended to:

- a) facilitate the specification and procurement of integrated systems, in particular, the interoperability requirements among MES applications;
- b) provide a means to categorize productivity tools that can be used across applications.

ISO 22400 provides an overview of the concepts, the terminology and the methods to describe and to exchange KPIs for the purpose of managing manufacturing operations. The audience is factory managers responsible for production performance, software suppliers developing KPIs for factory management, engineers engaged in process planning of products, planners and designers of manufacturing systems, and equipment and device suppliers.

KPIs also reside at Level 4, i.e. KPIs related to business planning and logistics, which are outside the scope of this part of ISO 22400. Level 4 KPIs are often related to economic, business, logistic and financial factors. These KPIs are used to assess the progress or extent of compliance with regard to important objectives or critical success factors within a company. Economic KPIs serve as a basis for decisions (problem identification, presentation, information extraction), for economic control (target/actual comparison), for financial documentation and for coordination (behaviour management) of important facts and relationships within the company.

[A1] KPIs for energy management within MOM are in accordance with ISO 50001 and ISO 20140, and they complement MOM indicators regarding energy consumption. KPIs for energy management support the evaluation of direct energy consumption per work unit or per order, and per manufactured product item. [Figure 3](#) illustrates the approach and the focus in the determination of energy consumption. **[A1]**

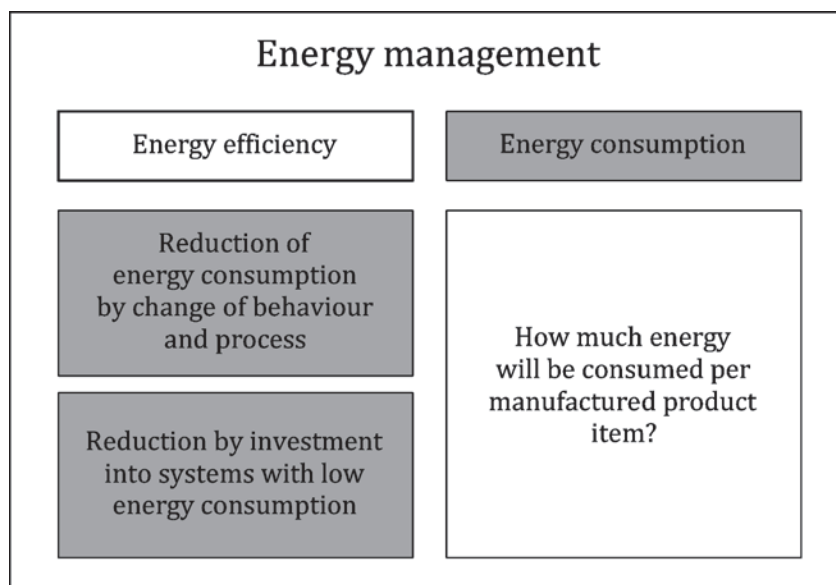


Figure 3 — Approach and focus in the determination of energy consumption

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Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management —

Part 2: Definitions and descriptions

1 Scope

ISO 22400 specifies key performance indicators (KPIs) used in manufacturing operations management (MOM).

This part of ISO 22400 specifies a selected number of KPIs in current practice. The KPIs are presented by means of their formula and corresponding elements, their time behaviour, their unit/dimension and other characteristics. This part of ISO 22400 also indicates the user group where the KPIs are used, and the production methodology to which they correspond.

With reference to equipment, the KPIs in this part of ISO 22400 relate to work units, as specified in IEC 62264.

2 Terms and definitions

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

2.1

reference time

base timeline used for time models, corresponding to the planned maximum time interval available for production and maintenance tasks

EXAMPLE A calendar day with 24 hours; a week.

2.2

planned time

planned duration of a specific time period

EXAMPLE The intended duration of an operation or a resource state according to the planning.

2.3

actual time

realized duration of a specific time period

EXAMPLE The actual duration of an operation or a resource state.

Note 1 to entry: Actual time may be less than, equal to, or greater than corresponding planned time.

2.4

time model

partition of the reference time

A1 2.5

energy consumed by the work unit during the actual unit busy time direct energy consumption

Note 1 to entry: The concept of “direct energy consumption” in ISO 20140-1 represents the energy consumed by a work unit for a direct operation (as defined in ISO 20140-1:2013, 3.4). ISO 20140 enables an energy efficiency evaluation quantified by KPIs with a granularity that itemizes the energy consumption per equipment part of the work unit. The granularity of this part of ISO 22400 does not itemize the work unit energy consumption per equipment part of the work unit. The difference in the granularity of the KPI and scope between ISO 22400 and ISO 20140 leads to different, though not contradictory, definitions of the term “direct energy consumption” in the two standards.

Note 2 to entry: If a work centre fulfils the same requirements as a work unit, it can be considered as a work unit.

Note 3 to entry: fThe attribute direct is used for the purpose of consistency with the concept direct cost. **A1**

3 Symbols and abbreviated terms

A1 ADEC actual direct energy consumption **A1**

ADET actual unit delay time

ADOT actual unit downtime

AOET actual order execution time

APAT actual personnel attendance time

APT actual production time

APWT actual personnel work time

AQT actual queuing time

AUST actual unit setup time

ATT actual transport time

AUBT actual unit busy time

AUPT actual unit processing time

CI consumables inventory

C_m machine capability index

CM consumed material

C_{mk} critical machine capability index

CMT corrective maintenance time

C_p process capability index

C_{pk} critical process capability index

EPC equipment production capacity

FE failure event

FGI finished goods inventory

GP	good part
GQ	good quantity
IGQ	integrated good quantity
IP	inspected part
LSL	lower specification limit
LT	loading time
MOM	manufacturing operations management
NEE	net overall equipment effectiveness index
NOT	net operating time
OC	operation cluster
OEE	overall equipment effectiveness
OL	other loss
OPT	operating time
PBT	planned busy time
 PDEI	planned direct energy consumption per item 
PL	production loss
PMT	preventive maintenance time
PO	production order
POET	planned order execution time
POQ	planned order quantity
POS	production order sequence
POT	planned operation time
PQ	produced quantity
PRI	planned run time per item
PSQ	planned scrap quantity
PUST	planned unit setup time
RMI	raw material inventory
RQ	rework quantity
σ	standard deviation
SQ	scrap quantity
STL	storage and transportation loss
TBF	operating time between failure

TTF	time to failure
TTR	time to repair
USL	upper specification limit
WG	working group
WIP	work in process inventory
WOP	work process
WP	work place
$\bar{x}$	arithmetic average
$\bar{\bar{x}}$	average of average values
$\hat{\sigma}$	estimated deviation
σ^2	variance

4 Structure of KPI description

KPI specifications are expressed using the structure in [Table 1](#) and are in accordance with ISO 22400-1. The structure in [Table 1](#) identifies KPI descriptive elements in the left column and gives a description of each element in the right column.

Table 1 — Structure of KPI description

KPI description	
Content:	
Name	Name of the KPI
ID	A user defined unique identification of the KPI in the user environment
Description	A brief description of the KPI
Scope	Identification of the element that the KPI is relevant for, which can be a work unit, work centre or production order, product or personnel
Formula	The mathematical formula of the KPI specified in terms of elements
Unit of measure	The basic unit or dimension in which the KPI is expressed
Range	Specifies the upper and lower logical limits of the KPI
Trend	Is the information about the improvement direction, higher is better or lower is better
Context:	
Timing	A KPI can be calculated either in • real-time - after each new data acquisition event • on demand - after a specific data selection request • periodically - done at a certain interval, e.g. once per day
Audience	Audience is the user group typically using this KPI. The user groups used in this part of ISO 22400 are • Operators – personnel responsible for the direct operation of the equipment • Supervisors – personnel responsible for directing the activities of the operators • Management – personnel responsible for the overall execution of production

Production methodology	Specifies the production methodology that the KPI is generally applicable for • Discrete • Batch • Continuous
Effect model diagram	The effect model diagram is a graphical representation of the dependencies of the KPI elements that can be used to drill down and understand the source of the element values. NOTE This is a quick analysis which supports rapid efficiency improvement by corrective actions, and thus reduces errors
Notes	Can contain additional information related to the KPI. Typical examples are • Constraints • Usage • Other information

5 Elements used in KPI description

5.1 Time elements

5.1.1 Notations

In the time model of this part of ISO 22400, in order to process and complete a production order, one or more tasks are performed using a set of production resources, e.g. production personnel, equipment and materials.

NOTE 1 Since many continuous operations (e.g. refineries and other petrochemical facilities) define “throughput” using an arbitrary time period (e.g. a day or a shift), rather than a production order based time interval, KPIs derived using this production order time model need to be adjusted for those industries.

NOTE 2 The identifying element name abbreviations indicated in round brackets in this clause are used in KPI calculations in [Clause 6](#).

NOTE 3 Definitions of maintenance elements have been taken from IEC 60050-191.

NOTE 4 The term “time” in the element specifications refers to a duration of time.

5.1.2 Planned times

5.1.2.1 Planned order execution time (POET)

The planned order execution time shall be the planned time for executing an order.

NOTE It is often calculated from the planned run time per item multiplied by the order quantity plus the planned setup time.

5.1.2.2 Planned operation time (POT)

The planned operation time shall be the planned time in which a work unit can be used. The operation time is a scheduled time.

5.1.2.3 Planned unit setup time (PUST)

The planned unit setup time shall be the planned time for the setup of a work unit for an order.

5.1.2.4 Planned busy time (PBT)

The planned busy time shall be the planned operation time minus the planned downtime.

NOTE The planned down time can be used for planned maintenance work. The planned busy period is available for the detailed planning of the work unit for expected production orders.

5.1.2.5 Planned run time per item (PRI)

The planned run time per item shall be the planned time for producing one quantity unit.

5.1.3 Actual times

5.1.3.1 Actual personnel work time (APWT)

The actual personnel work time shall be the time that a worker needs for the execution of a production order.

5.1.3.2 Actual unit processing time (AUPT)

The actual unit processing time shall be the time needed for setup and for the production.

5.1.3.3 Actual unit busy time (AUBT)

The actual unit busy time shall be the actual time that a work unit is used for the execution of a production order.

5.1.3.4 Actual order execution time (AOET)

The actual order execution time shall be the time difference between start time and end time of a production order. It includes the actual busy time, the actual transport and the actual queuing time.

5.1.3.5 Actual personnel attendance time (APAT)

The actual personnel attendance time shall be the actual time that a worker is available to work on production orders. It does not include actual time for company authorized break periods (e.g. lunch). It shall be the difference between login and logout excluding breaks.

5.1.3.6 Actual production time (APT)

The actual production time shall be the actual time during which a work unit is producing. It includes only the value-adding functions.

5.1.3.7 Actual queuing time (AQT)

The actual queuing time shall be the actual time in which the material is either in transport or progressing through a manufacturing process, i.e. the material is waiting for the process to begin.

5.1.3.8 Actual unit down time (ADOT)

The actual unit down time shall be the actual time when the work unit is not executing order production although it is available.

5.1.3.9 Actual unit delay time (ADET)

The actual unit delay time shall be the actual time associated with malfunction-caused interruptions, minor stoppages, and other unplanned time intervals that occur while tasks are being completed that lead to unwanted extension of the order processing time.

5.1.3.10 Actual unit setup time (AUST)

The actual unit setup time shall be the time consumed for the preparation of an order at a work unit.

5.1.3.11 Actual transport time (ATT)

The actual transport time shall be the actual time required for transport between work units.

5.1.3.12 Actual unit processing time (AUPT)

The actual unit processing time shall be the actual production time plus the actual unit setup time.

5.1.3.13 Actual unit busy time (AUBT)

The actual unit busy time shall be the actual unit processing time plus the actual unit delay time.

5.1.3.14 Actual order execution time (AOET)

The actual order execution time shall be the time from the start of the order until the time of the completion of the order.

5.1.4 Maintenance times

5.1.4.1 Time between failures (TBF)

The time between failures shall be the actual unit busy time (AUBT) between two consecutive failures of a work unit including setup time, production time and repair time related to the orders being processed and without delay times.

5.1.4.2 Time to repair (TTR)

The time to repair shall be the actual time during which a work unit is unavailable due to a failure.

5.1.4.3 Time to failure (TTF)

The time to failure shall be the time between failures minus the time to repair.

5.1.4.4 Failure event count (FE)

The failure event count shall be the count over a specified time interval of the terminations of the ability for a work unit to perform a required operation.

5.1.4.5 Corrective maintenance time (CMT)

The corrective maintenance time shall be the part of the maintenance time during which corrective maintenance is performed on a work unit, including technical delays and logistic delays inherent in corrective maintenance (see IEC 60050-191).

5.1.4.6 Preventive maintenance time (PMT)

The preventive maintenance time shall be that part of the maintenance time during which preventive maintenance is performed on a work unit, including technical delays and logistic delays inherent in preventive maintenance (see IEC 60050-191).

5.2 Time model for work units

This time model applies to time considerations for the use of work units. [Figure 4](#) shows the relationship between specific periods. In [Figure 4](#), the difference between time elements constitutes a loss of operation time.

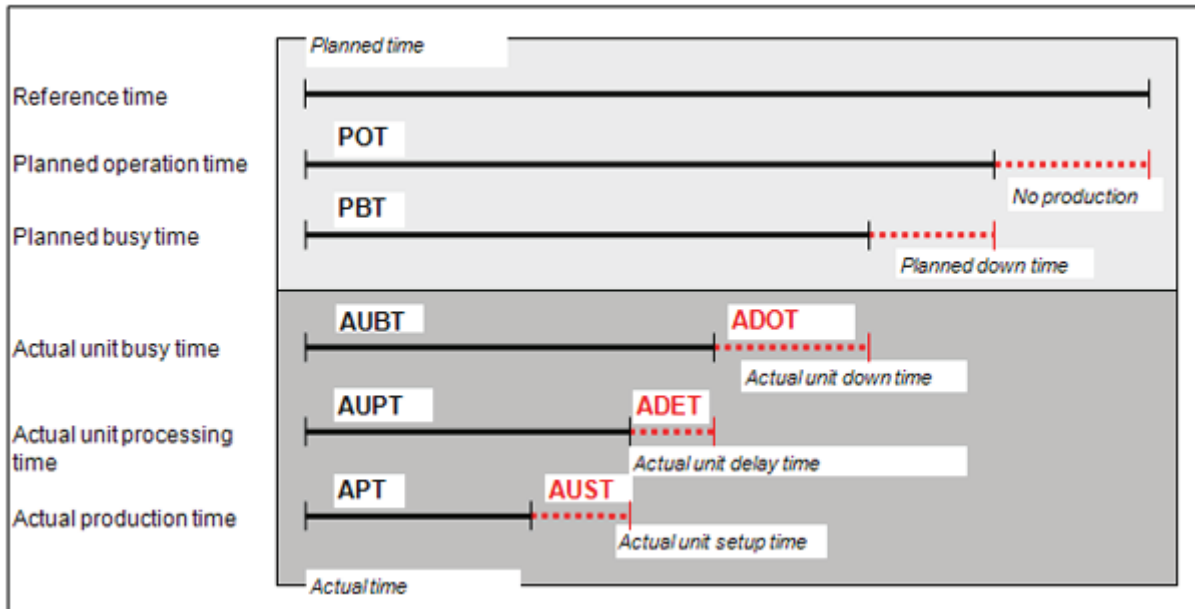


Figure 4 — Time lines for work units

NOTE [Annex B](#) provides a time model for work units with different time element partitions for which KPIs (e.g. OEE) generated using that model are different from those specified in [Clause 6](#).

5.3 Time model for production order

This time model is valid for executing the production order. [Figure 5](#) shows the production order processing time line consisting of multiple occurrences of operations equipment time lines (see [Figure 4](#)). The work unit time lines for a production order may be carried out in separate operations at several work units.

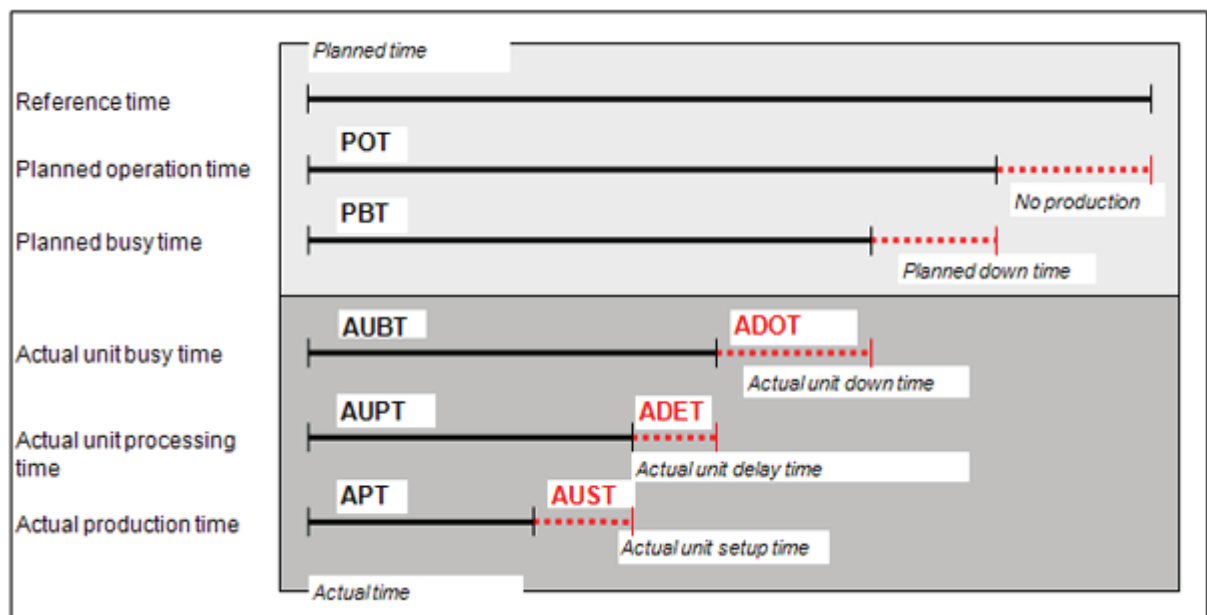


Figure 5 — Time lines for production order processing

5.4 Time model for personnel

This time model applies to time considerations for personnel.

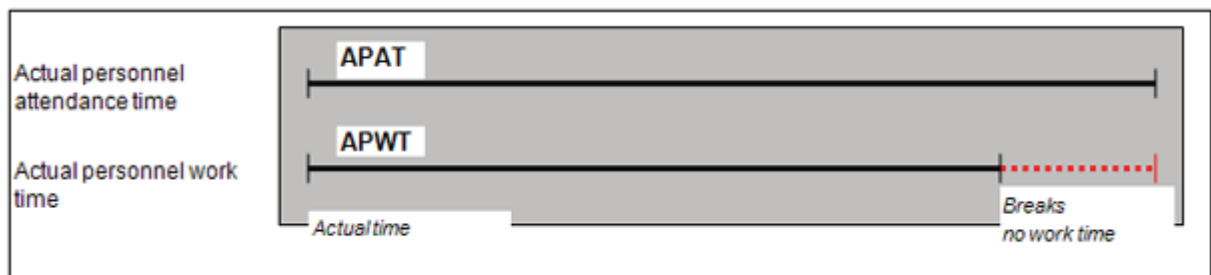


Figure 6 — Time lines for personnel

5.5 Logistical elements

5.5.1 Planned order quantity (POQ)

The planned order quantity shall be the planned quantity of products for a production order (lot size, production order quantity).

5.5.2 Scrap quantity (SQ)

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

5.5.3 Planned scrap quantity (PSQ)

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

5.5.4 Good quantity (GQ)

The good quantity shall be the produced quantity that meets quality requirements.

5.5.5 Rework quantity (RQ)

The rework quantity shall be the quantity that fails to meet the quality requirements, but where these requirements can be met by subsequent work.

5.5.6 Produced quantity (PQ)

The produced quantity shall be the quantity that a work unit has produced in relation to a production order.

5.5.7 Raw materials (RM)

The raw materials shall be the materials that are changed into finished goods through the production.

5.5.8 Raw materials inventory (RMI)

The raw materials inventory shall be the inventory of materials that are changed into intermediates or finished goods through production.

5.5.9 Finished goods inventory (FGI)

The finished goods inventory shall be the amount of acceptable quantity which can be delivered.

5.5.10 Consumable inventory (CI)

The consumable inventory shall be material which is transformed in quantity or quality during the production process and which is no longer available for use in production operations.

EXAMPLE Fuel.

NOTE Consumables are specified in detail in IEC 62264-1.

5.5.11 Consumed material (CM)

The consumed material shall be the summed quantity of materials consumed by a process.

NOTE 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.

5.5.12 Integrated good quantity (IGQ)

The integrated good quantity shall be the summed product count or quantity resulting from a multi-product production process used in KPI calculations instead of GQ.

EXAMPLE If 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 ratio of products of level "B" raises as the ratio of products of level "A" declines. Therefore, KPIs are calculated from the view of all related products, e.g. the level "A" plus level "B" products.

NOTE Since IGQ represents the quantity of all products during production, all products need to be measured in the same unit of measure, or be converted to the same unit of measure. A list of conversion coefficients can be used to unify the measurement modes of different products.

5.5.13 Production loss (PL)

The production loss shall be the quantity lost during production, calculated as output minus input.

NOTE Used in batch and continuous manufacturing.

5.5.14 Storage and transportation loss (STL)

The storage and transportation loss shall be the quantity lost during storage and transportation, e.g. inventory lost during an inventory calculation or material lost during movement from one place to another.

NOTE Used in batch and continuous manufacturing.

5.5.15 Other loss (OL)

Other loss shall be the quantity lost due to extraordinary incidents, e.g. natural disasters.

NOTE Used in batch and continuous manufacturing.

5.5.16 Equipment production capacity (EPC)

Equipment production capacity is the maximum production quantity of production equipment.

NOTE Used in batch and continuous manufacturing.

5.6 Quality elements

5.6.1 Good part (GP)

A good part shall be the count of individual identifiable parts, e.g. by serialization, which meets the quality requirements.

NOTE In discrete manufacturing, a part is typically a single produced item. In batch manufacturing, a party refers to a specified material lot.

5.6.2 Inspected part (IP)

An inspected part shall be the count of individual identifiable parts, e.g. by serialization, which was tested against the quality requirements.

NOTE In discrete manufacturing, a part is typically a single produced item. In batch manufacturing, a party refers to a specified material lot.

5.6.3 Upper specification limit (USL)

An upper specification limit is a value below which performance of a product or process is acceptable. It represents the maximum acceptable value of a variable.

5.6.4 Lower specification limit (LSL)

A lower specification limit is a value above which performance of a product or process is acceptable. It represents the minimum acceptable value of a variable.

5.7 Quality elements

5.7.1 Arithmetic average ($\bar{x}$)

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

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

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

5.7.3 Estimated deviation ($\hat{\sigma}$)

The estimated deviation 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.

5.7.4 Standard deviation (σ)

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.

5.7.5 Variance (σ^2)

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.

5.8 Energy elements

5.8.1 Actual direct energy consumption (ADEC)

The actual direct energy consumption is the measured direct energy consumption per work unit and during actual unit busy time.

5.8.2 Planned direct energy consumption per item (PDEI)

The planned direct energy consumption shall be the planned energy consumption in average for producing one product item.

NOTE This factor is analogous to the planned run time per item.

5.8.3 Time period

A time period is the time during which a work unit is in a specific state. With each change of state a new time period always begins.

5.8.4 Fundamentals of energy types

5.8.4.1 Conversion to a unified energy unit

Energy measurements are commonly made in various units of energy and shall be converted to the industry standard, namely, kWh, as illustrated in [Figure 7](#). This conversion is necessary to obtain a valid

summation of the different expressions of energy usage for computing the direct energy consumption. For this purpose, conversion factors depending on the type of energy need to be determined.

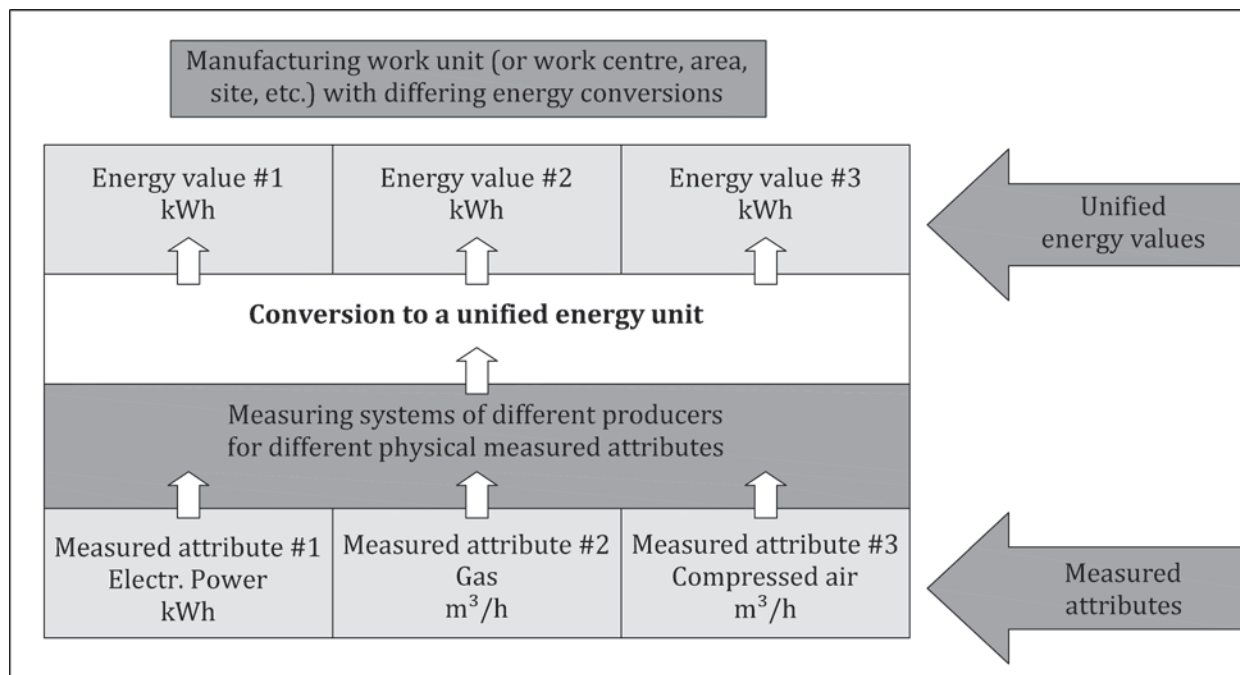


Figure 7 — Conversion to energy unit of measure from measured attributes

5.8.4.2 Conversion factors

Conversion factors provided by energy suppliers

Conversion factors for energy types are usually obtained directly from an energy supplier. These conversions introduce measurement uncertainties from a number of different sources, which should be understood and incorporated in calculations.

EXAMPLE

Natural gas	10 kWh/m ³	12,66 kWh/kg
Gas oil	9,93 kWh/l	11,68 kWh/kg
Bunker oil	10,27 kWh/l	11,17 kWh/kg
Hard coal		approx. 8,14 kWh/kg
Lignite		approx. 5,35 kWh/kg

5.8.4.2.2 Some conversion factors may not be constants that can be found in property tables, but may need to be calculated individually. For example, the conversion factors need to be calculated individually for compressed air, steam, and water.

EXAMPLE 1

The measured energy consumption for compressed air generation need to be allocated to actually measured compressed air consumption at the involved work units. The calculated conversion factor is used for the conversion of the measured energy type on the respective work unit to the collective energy unit kWh.

The conversion factor is calculated via the relation:

Σ (energy consumed [kWh] for compressed air generation) / Σ (compressed air [m³] generated)

The conversion factor in this case is the unit “kWh/m³”.

EXAMPLE 2

Calculation:

A compressor with 37 kW power generates at 600 kPa up to 7 m³/min compressed air. A direct air consumption of 6 m³/min will be measured as consumed by the work units.

The conversion factor would be at a total consumption of measured 6 m³/min and 37 kW power as follows:

Conversion factor = 37 kW/360 m³/h = 0,102 8 kWh/m³ ^(A1)

6 Description of KPIs

^(A1) Tables 2 to 39 describe the KPIs for MOM. ^(A1) [Annex A](#) specifies the logical relation among the KPI elements. [Annex A](#) is mandatory for any implementation of this part of ISO 22400, although not all elements of [Annex A](#) are required in all implementations.

Table 2 — Worker efficiency

KPI description	
Content	
Name	Worker efficiency
ID	
Description	The worker efficiency considers the relationship between the actual personnel work time (APWT) related to production orders and the actual personnel attendance time (APAT) of the employee.
Scope	Worker, workgroup, work unit
Formula	Worker efficiency = APWT / APAT
Unit of measure	%
Range	Min: 0% Max: 100%
Trend	The higher the better
Context	
Timing	Periodically
Audience	Supervisor, management
Production methodology	Discrete, batch, continuous
Effect model diagram	see Figure A.1
Notes	When calculating worker efficiency be careful of possible double counts if the worker is working on several work units or production orders simultaneously

Table 3 — Allocation ratio

KPI description	
Content	
Name	Allocation ratio
ID	
Description	The allocation ratio is the relationship of the complete actual busy time over all work units (AUBT) involved in a production order to the actual order execution time of a production order (AOET).
Scope	Product, production order, and plant
Formula	Allocation ratio = $\sum \text{AUBT} / \text{AOET}$ $\sum \text{AUBT}$ = sum of the AUBT of all work units involved in a production order.
Unit of measure	%
Range	Min: 0% Max: 100% >100% is possible in case of overlapping of production operations
Trend	The higher the better
Context	
Timing	Periodically
Audience	Supervisor, management
Production methodology	Discrete, batch, continuous
Effect model diagram	see Figure A.2
Notes	The allocation ratio is an index for the wait times and delay times. It shows how much of the throughput time of a production order is caused by actual processing. Too much wait and down time extend the throughput time.