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**Integration von Unternehmens-EDV und Leitsystemen –
Teil 3: Aktivitätsmodelle für das operative Produktionsmanagement
(IEC 62264-3:2007);
Deutsche Fassung EN 62264-3:2007, Text Englisch**

Enterprise-control system integration –
Part 3: Activity models of manufacturing operations management (IEC 62264-3:2007);
German version EN 62264-3:2007, text in English

Intégration du système de commande d'entreprise –
Partie 3: Modèles d'activités pour la gestion des opérations de fabrication
(CEI 62264-3:2007);
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Nationales Vorwort

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Für diese Norm ist das nationale Arbeitsgremium K 931 „Systemaspekte“ der DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE (<http://www.dke.de>) zuständig.

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Diese Norm legt, in Verbindung mit Teil 1 dieser Normenreihe, den Inhalt der Schnittstellen zwischen der Herstellung und anderen Unternehmensfunktionen fest. Es handelt sich dabei um die Schnittstellen zwischen Ebene 3 und Ebene 4 des hierarchischen Modells aus Teil 1.

Integration von Unternehmens-EDV und Leitsystemen –
Teil 3: Aktivitätsmodelle für das operative Produktionsmanagement
(IEC 62264-3:2007)

Enterprise-control system integration –
Part 3: Activity models of manufacturing
operations management
(IEC 62264-3:2007)

Intégration du système de commande
d'entreprise –
Partie 3: Modèles d'activités pour la gestion des
opérations de fabrication
(CEI 62264-3:2007)

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CENELEC

Europäisches Komitee für Elektrotechnische Normung
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique

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Vorwort

Der Text des Schriftstücks 65A/476/CDV, zukünftige 1. Ausgabe von IEC 62264-3, ausgearbeitet von dem SC 65A „System aspects“ des IEC TC 65 „Industrial-process measurement and control“, und dem SC 5, JWG 15, des ISO TC 184 „Enterprise-control system integration“, wurde der IEC-CENELEC Parallelen Einstufigen Annahmeverfahren unterworfen und von CENELEC am 2007-07-01 als EN 62264-3 angenommen.

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Anerkennungsnotiz

Der Text der Internationalen Norm IEC 62264-3:2007 wurde von CENELEC ohne irgendeine Abänderung als Europäische Norm angenommen.

In der offiziellen Fassung ist unter „Literaturhinweise“ zu der aufgelisteten Norm die nachstehende Anmerkung einzutragen:

IEC 61131-3 ANMERKUNG Harmonisiert als EN 61131-3:2003 (nicht modifiziert).

CONTENTS

INTRODUCTION	7
1 Scope	8
2 Normative references	8
3 Terms, definitions and abbreviations.....	8
3.1 Terms and definitions	8
3.2 Abbreviations	10
4 Structuring models	11
4.1 Manufacturing operations management.....	11
4.2 Functional hierarchy	12
4.3 Manufacturing operations management elements.....	14
4.4 Criterion for defining activities below Level 4	14
4.5 Categories of production information	14
4.6 Manufacturing operations information	15
5 Structuring models	16
5.1 Generic template for categories of manufacturing operations management.....	16
5.2 Interaction among generic activity models.....	17
5.3 Expanded equipment hierarchy model	19
5.4 Expanded decision hierarchy model.....	21
5.5 Hierarchy of planning and scheduling	24
5.6 Resource definition for scheduling activities.....	25
6 Production operations management.....	26
6.1 General activities in production operations management.....	26
6.2 Production operations management activity model	26
6.3 Information exchange in production operations management.....	27
6.4 Product definition management.....	28
6.5 Production resource management.....	30
6.6 Detailed production scheduling	33
6.7 Production dispatching	36
6.8 Production execution management	40
6.9 Production data collection.....	41
6.10 Production tracking.....	42
6.11 Production performance analysis	44
7 Maintenance operations management.....	49
7.1 General activities in maintenance operations management.....	49
7.2 Maintenance operations management activity model	49
7.3 Information exchanged in maintenance operations management	50
7.4 Maintenance definition management.....	52
7.5 Maintenance resource management	53
7.6 Detailed maintenance scheduling.....	53
7.7 Maintenance dispatching	54
7.8 Maintenance execution management	54

7.9	Maintenance data collection	54
7.10	Maintenance tracking	54
7.11	Maintenance analysis	55
8	Quality operations management	56
8.1	General activities in quality operations management	56
8.2	Quality test operations activity model	58
8.3	Information exchanged in quality test operations management	59
8.4	Quality test definition management	60
8.5	Quality test resource management	61
8.6	Detailed quality test scheduling	62
8.7	Quality test dispatching	62
8.8	Quality test execution management	62
8.9	Quality test data collection	63
8.10	Quality test tracking	64
8.11	Quality performance analysis	64
8.12	Supported activities	65
9	Inventory operations management	65
9.1	General activities in inventory operations management	65
9.2	Inventory operations management activity model	66
9.3	Information exchanged in inventory operations management	67
9.4	Inventory definition management	69
9.5	Inventory resource management	69
9.6	Detailed inventory scheduling	70
9.7	Inventory dispatching	70
9.8	Inventory execution management	71
9.9	Inventory data collection	71
9.10	Inventory tracking	72
9.11	Inventory analysis	72
10	Completeness, compliance and conformance	73
10.1	Completeness	73
10.2	Compliance	73
10.3	Conformance	73
	Annex A (informative) Other enterprise activities affecting manufacturing operations	75
	Annex B (informative) Technical and responsibility boundaries	81
	Annex C (informative) Scheduling hierarchy	86
	Annex D (informative) Associated standards	88
	Annex E (informative) Frequently asked questions	92
	Annex F (informative) Applying the decision hierarchy model to manufacturing operations management	95
	Annex G (informative) Mapping PSLX ontology to manufacturing operations management	100
	Annex H (informative) Advanced planning and scheduling concepts for manufacturing operations management	105
	Annex ZA (normative) Normative references to international publications with their corresponding European publications	109
	Bibliography	108

Figure 1 – Manufacturing operations management model	12
Figure 2 – Multi-level functional hierarchy of activities	13
Figure 3 – Activity relationships	13
Figure 4 – Categories of information exchange	15
Figure 5 – Manufacturing operations information	16
Figure 6 – Generic activity model of manufacturing operations management	17
Figure 7 – Detailed scheduling interactions	19
Figure 8 – Typical expanded equipment hierarchy	20
Figure 9 – Work centres and work units	21
Figure 10 – Decision hierarchy model framework for Level 3	22
Figure 11 – Decision-making with two variables	23
Figure 12 – Schematic relationship of planning and scheduling	24
Figure 13 – Projected inventory for a consumable resource	25
Figure 14 – Activity model of production operations management	27
Figure 15 – Product definition management activity model interfaces	28
Figure 16 – Production resource management activity model interfaces	30
Figure 17 – Resource management capacity reporting	32
Figure 18 – Detailed production scheduling activity model interfaces	34
Figure 19 – Splitting and merging production schedules to detailed production schedules	35
Figure 20 – Detailed production schedule	36
Figure 21 – Production dispatching activity model interfaces	37
Figure 22 – Sample production dispatch list	38
Figure 23 – Work dispatching for mixed process facility	39
Figure 24 – Production execution management activity model interfaces	40
Figure 25 – Production data collection activity model interfaces	42
Figure 26 – Production tracking activity model interfaces	43
Figure 27 – Merging and splitting production tracking information	44
Figure 28 – Production performance analysis activity model interfaces	45
Figure 29 – Activity model of maintenance operations management	50
Figure 30 – Activity model of quality test operations management	58
Figure 31 – Activity model of inventory operations management	67
Figure 32 – Inventory data collection activity model	72
Figure A.1 – Other enterprise activities affecting manufacturing operations	75
Figure A.2 – Functions in management of regulatory compliance	78
Figure B.1 – Different boundaries of responsibility	82
Figure B.2 – Lines of technical integration	84
Figure C.1 – Sample hierarchy of schedules and scheduling activities	87
Figure E.1 – PRM scope and standard focus	93
Figure F.1 – Decision hierarchy within an operational category	96
Figure F.2 – Decision hierarchy within an activity	96
Figure F.3 – Examples of decision hierarchies for resource management	97
Figure G.1 – PSLX ontology, part 1	103
Figure G.2 – PSLX ontology, part 2	103
Figure G.3 – PSLX ontology, part 3	104
Figure H.1 – Levels of decision-making for production	106

Table 1 – Storage zone and storage unit examples 20

Table G.1 – IEC 62264 relationship to PSLX..... 101

INTRODUCTION

This part of IEC 62264 shows activity models and data flows for manufacturing information that enables enterprise-control system integration. The modelled activities operate between Level 4 logistics and planning functions and Level 2 manual and automated process control functions. The models are consistent with the object models given in IEC 62264-1 and the Level 3 (manufacturing operations and control) definitions.

The goal of the standard is to reduce the risk, cost and errors associated with implementing enterprise systems and manufacturing operations systems in such a way that they inter-operate and easily integrate. The standard may also be used to reduce the effort associated with implementing new product offerings.

This standard provides models and terminology for defining the activities of manufacturing operations management. The models and terminology defined in this standard are:

- to emphasize the good practices of manufacturing operations;
- to be used to improve existing manufacturing operations systems;
- to be applied regardless of the degree of automation.

Some potential benefits produced when applying the standard may include

- reducing the time to reach full production levels for new products;
- enabling vendors to supply appropriate tools for manufacturing operations;
- enabling more uniform and consistent identification of manufacturing needs;
- reducing the cost of automating manufacturing processes;
- optimizing supply chains;
- improving efficiency in life-cycle engineering efforts.

It is not the intent of this part of the standard to

- suggest that there is only one way of implementing manufacturing operations;
- force users to abandon their current way of handling manufacturing operations;
- restrict development in the area of manufacturing operations;
- restrict use only to manufacturing industries.

ENTERPRISE-CONTROL SYSTEM INTEGRATION –

Part 3: Activity models of manufacturing operations management

1 Scope

This part of IEC 62264 defines activity models of manufacturing operations management that enable enterprise system to control system integration. The activities defined in this standard are consistent with the object models definitions given in IEC 62264-1. The modelled activities operate between business planning and logistics functions, defined as the Level 4 functions and the process control functions, defined as the Level 2 functions of IEC 62264-1. The scope of this standard is limited to

- a model of the activities associated with manufacturing operations management, Level 3 functions;
- an identification of some of the data exchanged between Level 3 activities.

2 Normative references

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

IEC 61512-1:1997, *Batch control – Part 1: Models and terminology*

IEC 62264-1, *Enterprise-control system integration – Part 1: Models and terminology*

IEC 62264-2, *Enterprise-control system integration – Part 2: Object model attributes*

ISO 15704:2000, *Industrial automation systems – Requirements for enterprise-reference architecture and methodologies*

3 Terms, definitions and abbreviations

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

3.1 Terms and definitions

3.1.1

detailed production schedule

organized and structured collection of production work orders and sequencing involved in the production of one or more products

3.1.2

finite capacity scheduling

scheduling methodology where work is scheduled for production equipment, in such a way that no production equipment capacity requirement exceeds the capacity available to the production equipment

3.1.3

inventory operations management

activities within Level 3 of a manufacturing facility which coordinate, direct, manage and track inventory and material movement within manufacturing operations

3.1.4

Level 0

actual physical process

3.1.5

Level 1

functions involved in sensing and manipulating the physical process

3.1.6

Level 2

functions involved in monitoring and controlling of the physical process

3.1.7

Level 3

functions involved in managing the work flows to produce the desired end-products

3.1.8

Level 4

functions involved in the business-related activities needed to manage a manufacturing organization

3.1.9

maintenance operations management

activities within Level 3 of a manufacturing facility which coordinate, direct and track the functions that maintain the equipment, tools and related assets to ensure their availability for manufacturing and ensure scheduling for reactive, periodic, preventive, or proactive maintenance

3.1.10

manufacturing facility

site, or area within a site, that includes the resources within the site or area and includes the activities associated with the use of the resources

3.1.11

manufacturing operations management

activities within Level 3 of a manufacturing facility that coordinate the personnel, equipment and material in manufacturing

NOTE 1 This standard details manufacturing operations management in terms of four categories (production operations management, maintenance operations management, quality operations management and inventory operations management) and provides references for other enterprise activities affecting manufacturing operations.

NOTE 2 In the PERA model, the concept of manufacturing defines the physical resources used in production. The manufacturing operations management activities defined in this standard pertain to the information-handling functions of the PERA model.

3.1.12

production dispatch list

set of specific production work orders to be performed on or by a particular set of resources, at a given location and the time or event to start or stop the activity

NOTE 1 This may take the form of set-up instructions for machines, operating conditions for continuous processes, material movement instructions, or batches to be started in a batch system.

NOTE 2 Dispatch lists are applicable to other operations management areas, such as maintenance dispatch lists, quality test dispatch lists and inventory dispatch lists.

3.1.13

production operations management

activities within Level 3 of a manufacturing facility which coordinate, direct, manage and track the functions that use raw materials, energy, equipment, personnel and information to produce products, with the required costs, qualities, quantities, safety and timeliness

3.1.14

production work order

unit of scheduled work that may be dispatched to a work center and which consists of lower-level elements

3.1.15

quality operations management

activities within Level 3 of a manufacturing facility which coordinate, direct and track the functions that measure and report on quality

3.1.16

storage unit

subordinate entity within a storage zone that consists of equipment and information required to contain, move, condition and handle material

NOTE A storage unit is an element of the equipment hierarchy.

3.1.17

storage zone

logical grouping of resources that defines a span of logistical control and includes the equipment and information required for containing, moving, conditioning and handling of one or more material items

NOTE A storage zone is an element of the equipment hierarchy.

3.1.18

tracing

activity that provides an organized record of resource and product use from any point, forward or backward, using tracking information

3.1.19

tracking

activity of recording attributes of resources and products through all steps of instantiation, use, change and disposition

3.1.20

work center

process cell, production unit, production line, storage zone, or any other equivalent level equipment element defined as an extension to the equipment hierarchy model

NOTE For compatibility with existing schema implementations the defined term "work center" is used in place of the UK English spelling "work centre".

3.2 Abbreviations

For the purposes of this standard, the following abbreviations apply.

AGV	Automated guided vehicles
AMS	Asset management system
ASRS	Automated storage and retrieval system
CAPE	Computer-aided process engineering

CAD	Computer-aided design
CAE	Computer-aided engineering
CASE	Computer-aided software engineering
CIM	Computer integrated manufacturing
CNC	Computerized numerical control
DCS	Distributed control system
ERP	Enterprise resource planning
EWI	Electronic work instructions
HR	Human resources
KPI	Key performance indicator
LIMS	Laboratory information management system
MES	Manufacturing execution system
MPS	Master production schedule
MRP	Material resource planning
OEE	Overall equipment effectiveness
PAT	Process analytical technology
PERA	Purdue enterprise reference architecture
PDM	Product data management
PLC	Programmable logic controller
PLM	Product life-cycle management
PRM	Purdue reference model for computer-integrated manufacturing
QA	Quality assurance
R&D	Research and development
RFQ	Request for quote
ROA	Return on assets
SCADA	Supervisory control and data acquisition
SOC	Standard operating conditions
SOP	Standard operating procedure
SQC	Statistical quality control
SPC	Statistical process control
WIP	Work in process
WMS	Warehouse management system

4 Structuring concepts

4.1 Manufacturing operations management

The activities of manufacturing operations management are those activities of a manufacturing facility that coordinate the personnel, equipment, material and energy in the conversion of raw materials and/or parts into products. Manufacturing operations management includes activities that may be performed by physical equipment, human effort and information systems.

Manufacturing operations management shall encompass the activities of managing information about the schedules, use, capability, definition, history and status of all of the resources (personnel, equipment and material) within, and associated with, the manufacturing facility.

NOTE 1 Resources associated with the manufacturing facility but not within it may include, among others, government inspectors, regulatory certifications, resource coordination with other entities, outsourced activities and processes.

The manufacturing operations management activities correspond to the activity set defined in IEC 62264-1. These are the activities contained within the heavy dotted line shown in Figure 1. The heavy dotted line is equivalent to the Level 3/Level 4 interface defined in IEC 62264-1. Manufacturing operations management shall be subdivided into four categories: production operations management, maintenance operations management, quality operations management and inventory operations management, as shown in shaded areas in Figure 1.

NOTE 2 There are also other activities of a manufacturing facility, not shown in Figure 1, but described in Annex A.

NOTE 3 The model structure does not reflect a business organizational structure within a company but is a model of activities. Different companies assign responsibilities for activities or sub-activities to different business organizational groups.

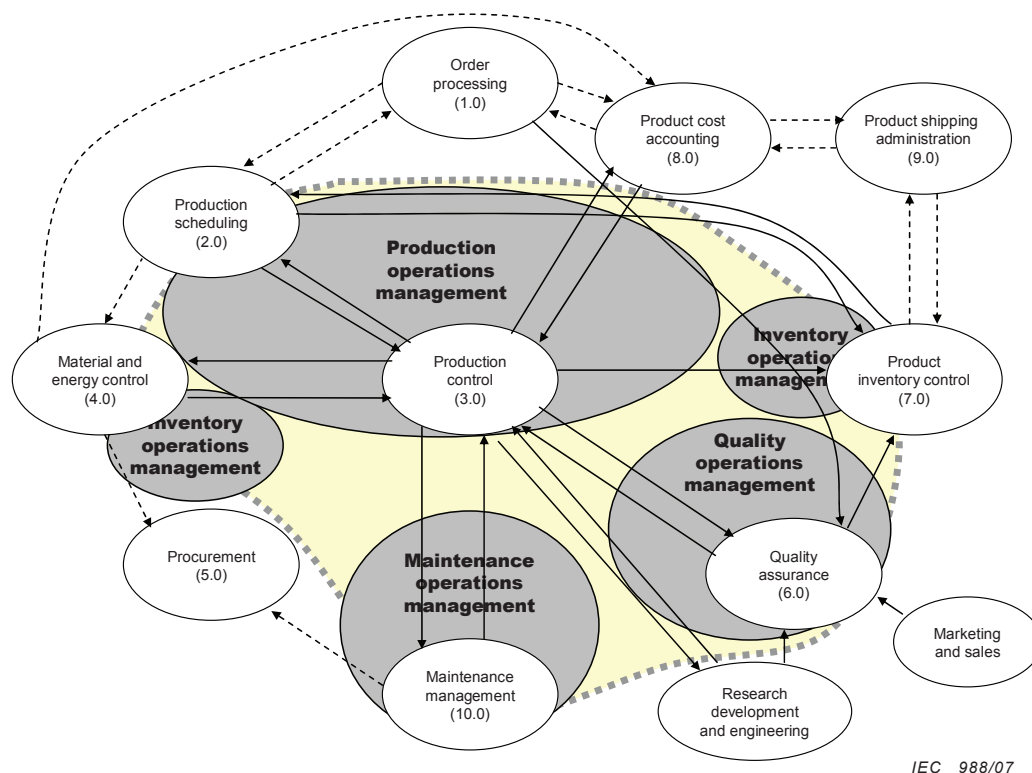


Figure 1 – Manufacturing operations management model

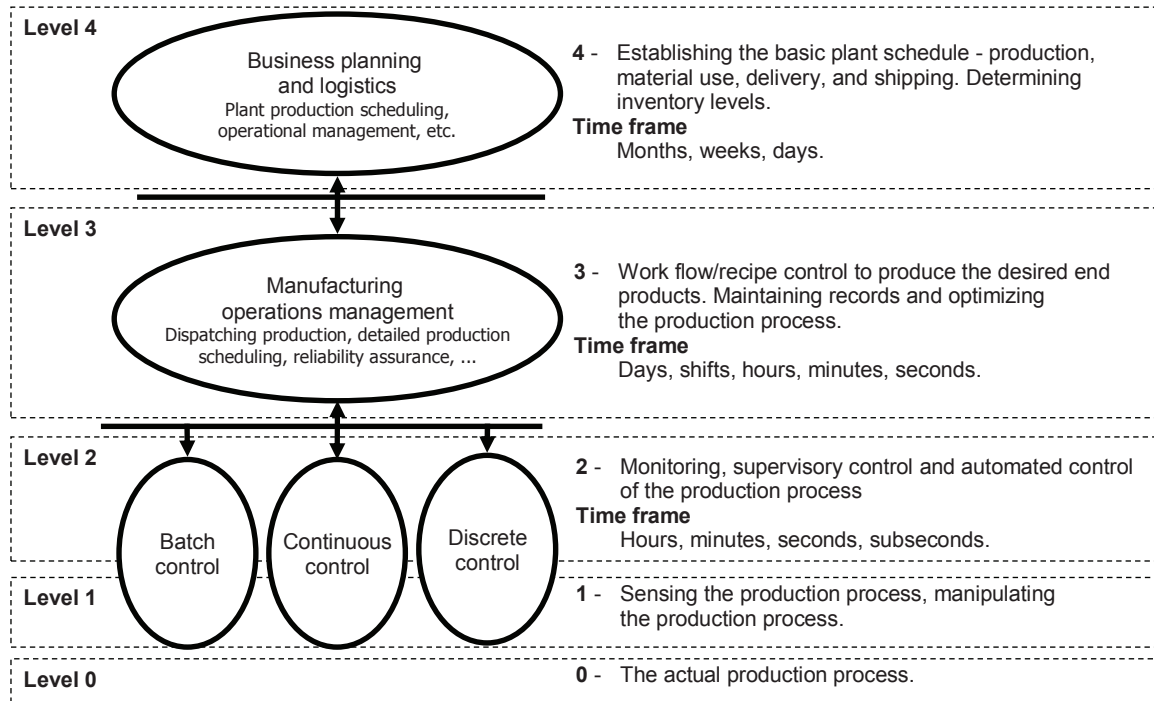
4.2 Functional hierarchy

IEC 62264-1 defines a functional hierarchy model. This standard specifies that each level shall provide the functions listed below and illustrated in Figure 2.

- Level 0 defines the actual physical processes.
- Level 1 defines the activities involved in sensing and manipulating the physical processes. Level 1 typically operates on time frames of seconds and faster.
- Level 2 defines the activities of monitoring and controlling the physical processes. Level 2 typically operates on time frames of hours, minutes, seconds and sub-seconds.
- Level 3 defines the activities of the work flow to produce the desired end-products. It includes the activities of maintaining records and coordinating the processes. Level 3 typically operates on time frames of days, shifts, hours, minutes and seconds.
- Level 4 defines the business-related activities needed to manage a manufacturing organization. Manufacturing-related activities include establishing the basic plant schedule (such as

material use, delivery and shipping), determining inventory levels and making sure that materials are delivered on time to the right place for production. Level 3 information is critical to Level 4 activities. Level 4 typically operates on time frames of months, weeks and days.

NOTE 1 There are other business-related activities that may be in Level 4 or higher levels, but these are not defined in this standard.



IEC 989/07

Figure 2 – Multi-level functional hierarchy of activities

NOTE

Figure 3 illustrates the activity models of this standard in relationship to IEC 62246-1 and IEC 62264-2. The activities in this standard exchange information with activities defined as Level 4 and Level 2 activities. The grey circles indicate the activities detailed in this standard. The information flows between the activities of this standard, indicated as heavy dashed lines, are described in general in this standard. In addition, the information flows between the activities of this standard and dependent Level 2 activities are identified.

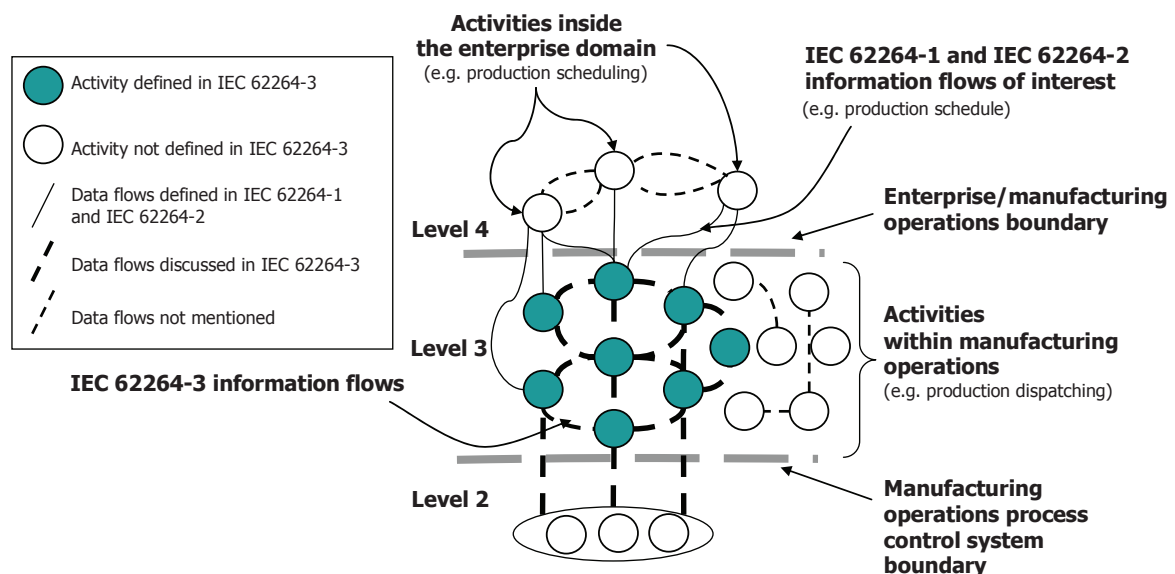


Figure 3 – Activity relationships

IEC 990/07

4.3 Manufacturing operations management elements

The shaded areas in Figure 1 represent the manufacturing operations management activities modelled in this standard. Manufacturing operations management is the collection of production operations management, maintenance operations management, quality operations management, inventory operations management and other activities of a manufacturing facility.

This standard defines four formal models: production operations management, maintenance operations management, quality operations management and inventory operations management. These are detailed in Clauses 6, 7, 8 and 9 and are listed below.

- a) The production operations management model, which shall include the activities of production control (3.0) that operate as Level 3 functions and the subset of the production scheduling (2.0) that operate as Level 3 functions and as shown in Figure 1.
- b) The maintenance operations management model, which shall include the activities of maintenance management (10.0) that operate as Level 3 functions.
- c) The quality operations management model, which shall include the activities of quality assurance (6.0) that operate as Level 3 functions.
- d) The inventory operations management model, which shall include the activities of management of inventory and material including product inventory control (7.0) and material and energy control activities (4.0) defined as operating as Level 3 functions and as shown in Figure 1.

NOTE Other categories of operation management may exist depending on company policy or organization. They are not formally modelled in this standard but they can make use of the generic standard model.

4.4 Criterion for defining activities below Level 4

The criterion for defining the activities to be included as a Level 3, 2, or 1 activity shall be that the activity is directly involved in manufacturing and includes information about personnel, equipment, or material and meets any of the following conditions.

- a) The activity is critical to plant safety.
- b) The activity is critical to plant reliability.
- c) The activity is critical to plant efficiency.
- d) The activity is critical to product quality.
- e) The activity is critical to maintaining regulatory compliance.

NOTE 1 This includes such factors as safety, environmental and cGMP (current good manufacturing practices) compliance.

EXAMPLE: Maintaining regional, government and other agency compliance.

NOTE 2 This list is a clarification of the criteria for inclusion of an activity in Level 3, 2, or 1 domain defined in IEC 62264-1. This list supersedes the criteria defined in IEC 62264-1.

NOTE 3 There are other criteria such as company policy and organizational structure, or the nature of the operations that could expand the scope of manufacturing operations management. See Annex B.

NOTE 4 Such activities as personnel management of salaries and job titles may be important for running a manufacturing business, but they are not considered part of manufacturing operations management.

NOTE 5 Absolute plant efficiencies may be dependent upon factors that are outside the control of a facility (MRP schedules, product mixes, etc.). These activities are not part of Level 3, 2, or 1.

4.5 Categories of production information

IEC 62264-1 defines the models and terminology to be used for enterprise-control system integration. It contains a definition of three general categories of information that should be exchanged between the business planning system (Level 4) and the manufacturing operations system (Level 3). The result of IEC 62264-1 includes object models for the three categories.

Production information shall have four categories of information as follows and as illustrated in Figure 4.

- a) Product definition information – what must be defined to make a product.
- b) Production capability information – what resources are available.
- c) Production schedule information – what actual production will be executed.
- d) Production performance information – what actual production was achieved.

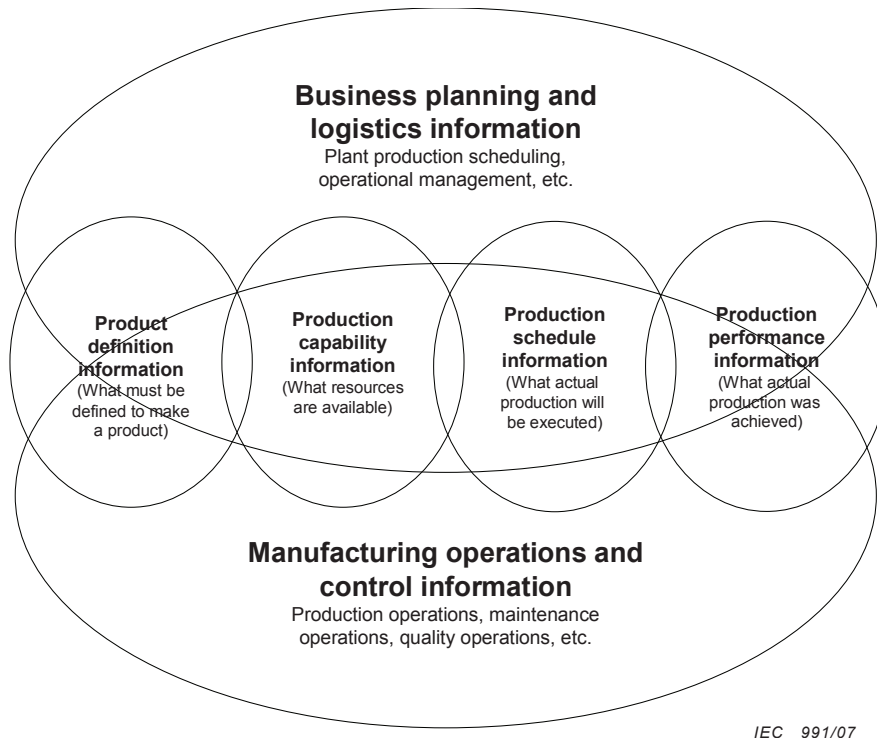


Figure 4 – Categories of information exchange

4.6 Manufacturing operations information

The structure of the production information defined in IEC 62264-1 and depicted in Figure 4 shall be applied to maintenance information, quality test information and inventory transfer information as depicted in Figure 5. The production schedule, production performance, product definition management, production capability, maintenance request and maintenance response, shown in Figure 5 as bold and underlined text, are defined in IEC 62264-1. There are equivalent information structures for maintenance, quality test and inventory management that are of importance for manufacturing operations that are also discussed in this standard.

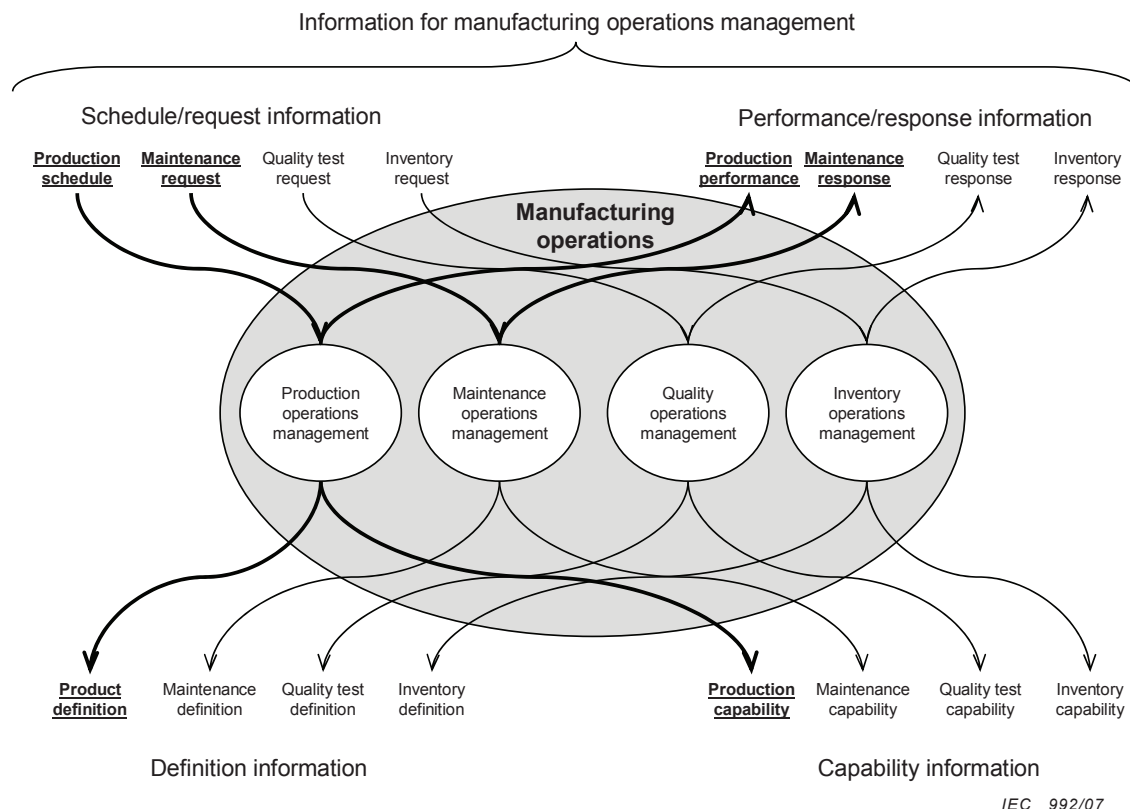


Figure 5 – Manufacturing operations information

5 Structuring models

5.1 Generic template for categories of manufacturing operations management

5.1.1 Template for management of operations

A generic model for management of operations shall be used as a template to define the production operations management, maintenance operations management, quality operations management and inventory operations management models. This model is shown in Figure 6. This generic model is extended for each specific area in later clauses.

NOTE The fine details of the generic model are different for each of the manufacturing operations management areas.

5.1.2 Use of the generic model

The generic model is instantiated for the four categories listed in 5.1.1. However, this same template may be instantiated for other possible manufacturing operations categories or for other operations areas within the enterprise.

EXAMPLE 1: A company could apply the model to receiving operations management and shipping operations management where these are separately managed.

EXAMPLE 2: A company could apply the model to cleaning and sterilization operations management, where these are separately managed.

EXAMPLE 3: A company could apply the model to independent logistics operations management categories for inbound logistics, outbound logistics, internal transfer and inventory control.

NOTE This clause is normative so that companies that apply the generic model to areas other than the four detailed in this standard can determine and document their degree of conformance to the model.

When the generic model is instantiated for a new category, the activities within a category shall include the definitions of resource management, definition management, dispatching, tracking, data collection, analysis, detailed scheduling, and execution management.

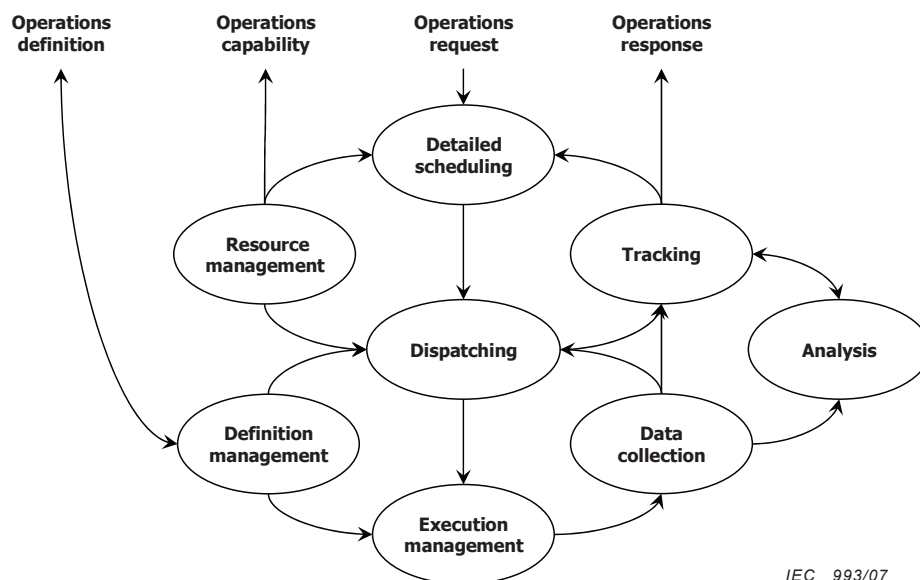
5.1.3 Generic activity model

There shall be a hierarchy used in this standard that starts at a category of operations management. Each category is composed of a collection of activities and each activity is composed of a set of tasks. The generic model applies to the sets of activities.

The generic activity model defines a general request-response cycle that starts with requests or schedules, converts them into a detailed schedule, dispatches work according to the detailed schedule, manages the execution of work, collects data and converts the collected data back into responses. This request-response cycle is supported with

- analysis of the work performed for improvements or corrections;
- management of the resources used in execution of the performed work;
- management of the definitions of the performed work.

The generic activity model and the detailed models are not intended to represent an actual implementation of a manufacturing information system. However, they do provide a consistent framework for such systems. Actual systems may use different structures supporting other task arrangements. The purpose of these models is to identify possible data flows within manufacturing operations. The ovals in the model indicate collections of tasks, identified as the main activities. Lines with arrowheads indicate a set of important information flows between the activities.



IEC 993/07

Figure 6 – Generic activity model of manufacturing operations management

NOTE Not all information flows are depicted in Figure 6. In any specific implementation, information from any activity may be required by any other activity. Where the model is expanded for specific activities, the lines indicating information flows are not intended to be exclusive lists of information exchanged.

5.2 Interaction among generic activity models

5.2.1 Information flows between generic activity models

In addition to the information flows within the activities of specific operations categories, there are also information flows between the different categories. Some of this information is defined in the following clauses, but not all information flows are explicitly defined in this standard.

NOTE Specific implementations of activity models may give prominence to one specific activity model over others.

EXAMPLE 1: In pharmaceutical industries, quality operations may provide the direction for other operations.

EXAMPLE 2: In distribution centres, inventory operations may provide the direction for other operations.

EXAMPLE 3: In consumer packaged goods, production operations may provide the direction for other operations.

EXAMPLE 4: In refining, inventory operations may provide the direction for production operations.

5.2.2 Handling resources within the generic activity models

Information about resources (materials, personnel and equipment) may be handled within any one of the four activity models of manufacturing operations (production, quality, maintenance and inventory) presented in this standard.

Although data for different resources may be found in different models, there are primary reporting paths through which information should be obtained.

- a) Personnel information specific to each activity model may be obtained from the specific activity model.
- b) Equipment information specific to each activity model may be obtained from the specific activity model.
- c) Material information specific to each activity model may be obtained from the specific activity model. However, material inventory information, including finished goods and raw materials, may be obtained from the inventory activity model. Material movement operations may be managed by activities in the production, quality, maintenance, or inventory activity models. A specific material movement instance only exists within one activity model at any given point in time.

5.2.3 Scheduling interactions

An activity in a detailed activity model has interactions with other activities in the same model and interactions with equivalent activities in other activity models. Interactions within each activity model are described in Clauses 6, 7, 8 and 9.

There are many interactions associated with detailed scheduling between activity models because of the need to coordinate between many work tasks assigned to a same resource on a given time interval. Also, the definitions of work tasks in the different types of operations management are closely related.

Clear definition of interactions between detailed production scheduling, detailed inventory scheduling, detailed maintenance scheduling and detailed quality-test scheduling should be specified. For interactions with production the following three interactions shall be defined, as illustrated in Figure 7.

- 1) Interaction between detailed production scheduling and detailed inventory scheduling. This is defined as coordination of information, at the start or completion of production, of the quantity of materials that is consumed or produced during production and stored or moved by inventory operations.

EXAMPLE 1: Production not scheduled to start before the scheduled issuing of the corresponding inventory of materials.

EXAMPLE 2: Completion of scheduled production triggers a scheduled inventory operation.

NOTE 1 Scheduling of transportation can be defined in either detailed production scheduling or detailed inventory scheduling.

- 2) Interaction between detailed production scheduling and detailed maintenance scheduling. This is defined as coordination of information about equipment that provides capability and capacity during production and needs to be reserved for maintenance depending on the equipment condition.

EXAMPLE 3: Not scheduling corrective maintenance and production on equipment simultaneously.

EXAMPLE 4: Scheduling maintenance based on scheduled use of equipment for production.

- 3) Interaction between detailed production scheduling and detailed quality-test scheduling. This is defined as coordination of information about the quality of produced and consumed materials,

which need to be quality-tested depending on the required level of quality and the latest production performance.

EXAMPLE 5: Detailed inspection schedule embedded in the detailed production schedule.

EXAMPLE 6: Inspection operations requests production operations to schedule rework of the product.

Figure 7 shows an integrated scheduling framework across Level 3.

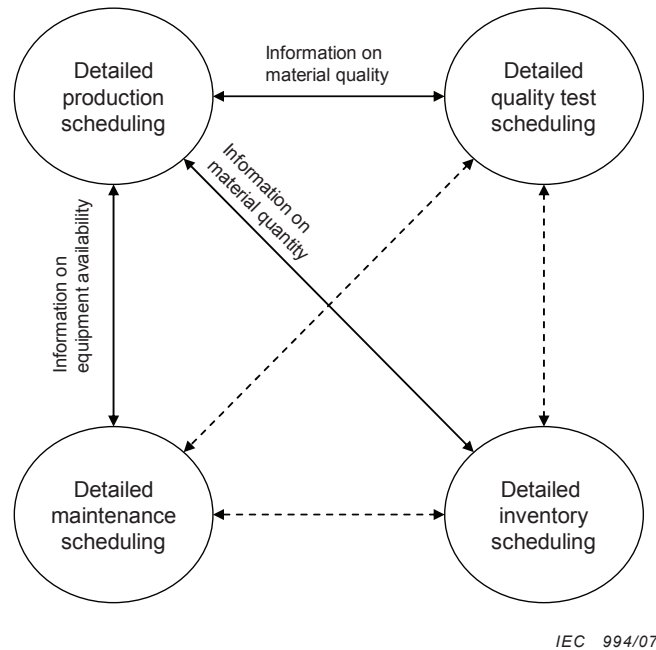


Figure 7 – Detailed scheduling interactions

5.3 Expanded equipment hierarchy model

5.3.1 Equipment hierarchy model

The equipment hierarchy model, defined in IEC 62264-1, is extended in this standard to the model shown in Figure 8. Additional items are included for inventory operations management and management of material. Lower-level groupings are combined to form higher levels in the hierarchy. In some cases, a grouping within one level may be incorporated into another grouping at that same level as a recursive structure. The models may be collapsed or expanded as required for specific applications.

There shall be at least one site within the enterprise, at least one work center in an area (or site if the area is collapsed out) and at least one work unit within a work center.

NOTE 1 Specific rules for collapsing and expanding these models are not defined in this standard. The following guidelines should be considered for collapsing and expanding the models.

- Collapsing – Elements in the models may be omitted as long as the models remain consistent and the functions of the element removed are taken into account.
- Expanding – Elements may be added to the models. When they are added between related elements, the integrity of the original relationship should be maintained.

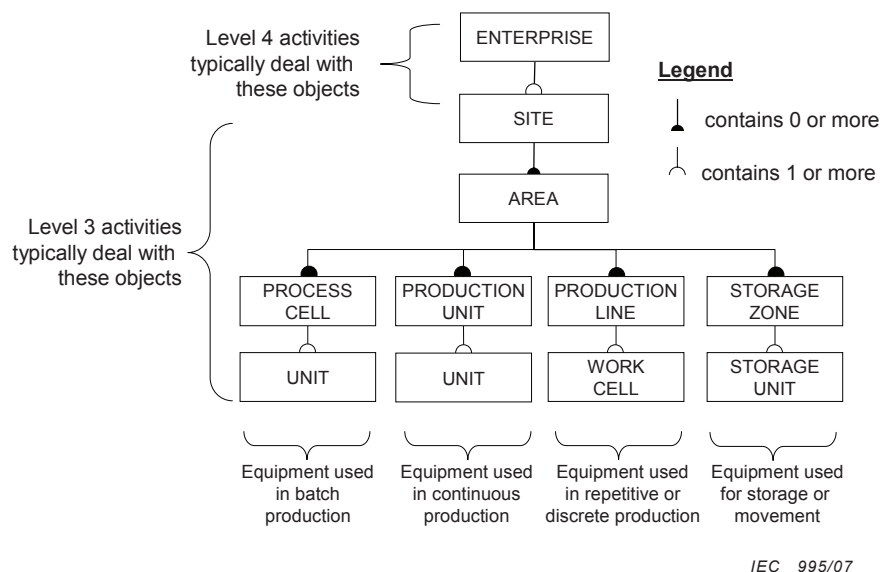


Figure 8 – Typical expanded equipment hierarchy

Storage zones and storage units shall be elements under an area. These are the lower-level elements used in material storage.

NOTE 2 Material is also temporarily stored in process cells, production units and production lines. This material is typically considered WIP and is usually distinct from inventory managed materials.

5.3.2 Storage zone

A storage zone typically has the capability needed for the receipt, storage, retrieval, movement and shipment of materials. This may include the movement of materials from one work center to another work center within or between enterprises.

5.3.3 Storage unit

Storage units are typically of interest to business systems only when business functions maintain inventory to a finer level of detail than a storage zone. The physical location of a storage unit may change over time; for example, for goods in transit.

Storage units may be dedicated to a given material, group of materials, or method of storage.

5.3.4 Storage zone and storage unit examples

Table 1 lists examples of a hierarchy of storage zones and the associated storage units.

Table 1 – Storage zone and storage unit examples

Storage zone	Storage unit
Warehouse	Rack/Bin/Slot
Trailer yard	Trailer, container
Tank farm	Tank, pipe section
Silo farm	Silo, pipe section
Ship terminal	Ship, ship's hold, container, barrel, tank
Rail yard	Railcar
Holding area	Pallet, barrel

NOTE Some storage zones and storage units could also be identified as equipment used in a transport request.

5.3.5 Work center

A work center shall be any element of the equipment hierarchy under an area. Work centers may be used when the specific type of the equipment element is not significant for the purpose of the discussion. A work center may be a process cell, production unit, production line, storage zone, or any other equipment element subordinate to an area that may be defined by the user in an extension to the equipment hierarchy model. See Figure 9.

5.3.6 Work unit

A work unit shall be any element of the equipment hierarchy under a work center. Work units are typically the most elemental schedulable item by Level 3 functions. See Figure 9.

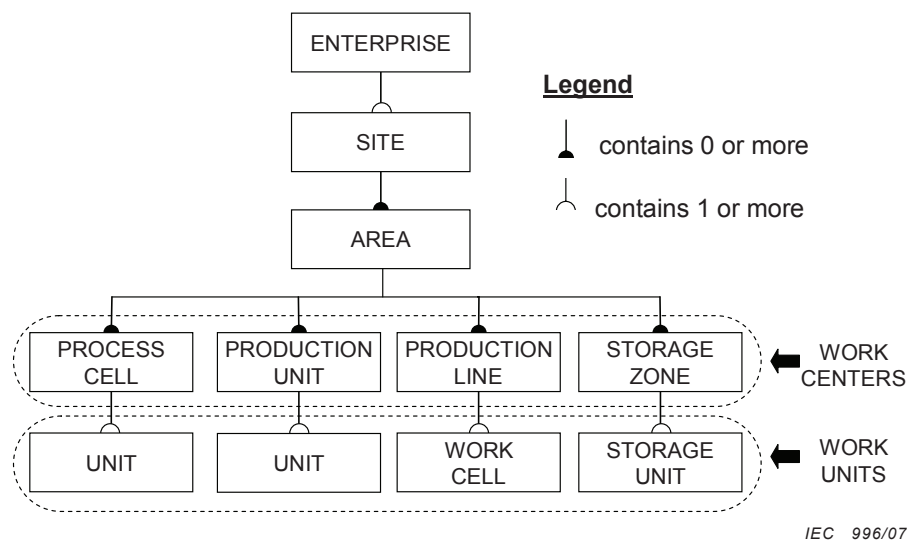


Figure 9 – Work centers and work units

Work centers are typically the grouping of equipment scheduled by the Level 4 or Level 3 functions for continuous, batch and discrete manufacturing. Work centers have well-defined capabilities and capacities and these are used for Level 3 functions. The capacities and capabilities are also often used as input to Level 4 business processes. Scheduling functions may identify specific work units.

5.4 Expanded decision hierarchy model

The decision hierarchy model defines a hierarchical structure for documenting how decisions are made and is defined in IEC 62264-1. It is extended and detailed in this standard to deal with the decisions that are taken within the manufacturing operations of Level 3. The decisions considered in this clause are only those considered having a significant value for manufacturing operations management.

Decisions taken at Level 3 are most often related to the medium-term and intermediate-scope time-horizons, as defined in IEC 62264-1. Within any time-horizon, there can be one or more decisions. Each decision is characterized by a horizon (H), period (P) and event (E). The horizon (H) is the time interval for which the decision is valid. The period (P) is the time interval after which the decision is reviewed. The event (E) is an occurrence of such significance as to trigger a review. A decision at a given time-horizon sets targets, environments and/or constraints for the next shorter time-horizon decision.

NOTE 1 A horizon is the part of the future taken into account by a decision, i.e. the horizon is six months when a decision is taken on a time interval of six months. The notion of period is closely related to the concept of control and adjustment. For example, a three-month plan may be re-evaluated and decided upon every two weeks, for example, the horizon is three months and the period is two weeks.

These decisions can be further categorized into several sub-time-horizons.

The three basic types of decisions defined in IEC 62264-1 (manage products, manage resources and plan production) are extended and mapped to the categories of manufacturing operations. For each category, appropriate sub-time-horizons of decisions should be identified and recorded. As an example, Figure 10 presents two identified decisions. Specific rules for decision-model consistency checking can be found in Annex F.

Sub-time horizon \	Maintenance operations management	Inventory operations management	Production operations management	Quality operations management	Other operations management	Event
H = P/E =						
H = P/E =			Periodic decision ← Event based decision			●
H = P/E =						
H = P/E =						

IEC 997/07

Figure 10 – Decision hierarchy model framework for Level 3

In this standard, the scope of the decision model as defined in ISO 15704 is expanded to also cover event-driven decisions, as shown in the right-hand column of Figure 10.

NOTE 2 For long-term horizons, the majority of decisions are usually periodic whereas for short-term horizons, the majority of decisions are usually event-driven.

EXAMPLE 1: Example of events include machine break-down, raw material shortage, unplanned maintenance request, urgent customer order. These events trigger decision-making process/activities.

The main items influencing decision-making as shown in Figure 11 (Figure C.3 in ISO 15704) are:

- the decision objective or set of objectives that the decision has to meet;
- the decision variables that are the parameters that the decision-maker can change;
- the decision constraints that are the bounds of the decision variables;
- the decision criteria that guide the choice in decision-making.

Decision-making is the selection of values for decision variables. A decision-space is a collection of decision variables and decision constraints. A decision is a result of decision-making and is a point in the decision-space.

A decision frame is a combination of a decision space and decision objectives.

NOTE 3 The decision criteria are outside the decision frame since they are not specific to a particular decision.

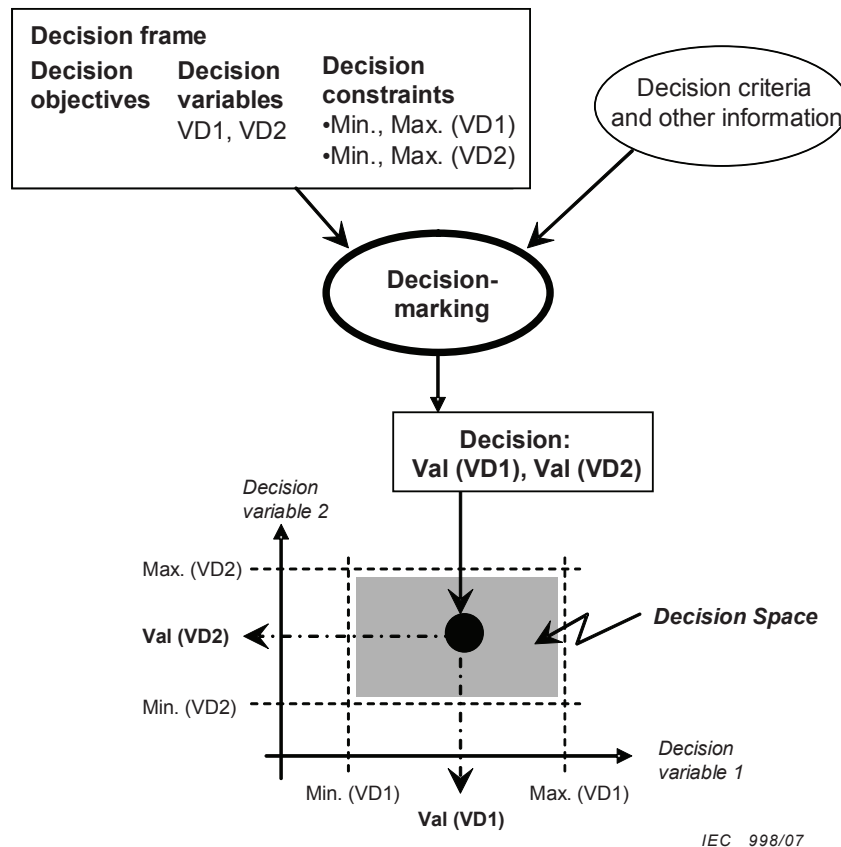


Figure 11 – Decision-making with two variables

NOTE 4 The decision hierarchy model does not define how decisions are made within various manufacturing operations. Instead the decision model helps with identifying

- significant decisions that are taken either periodically or triggered by events within the manufacturing operations;
- decision objectives, decision variables and decision constraints associated to those decisions;
- horizon and period of the decisions so that decisions can be properly linked in a hierarchy for possible consistency analysis.

EXAMPLE 2: Considering an example of generating a detailed production schedule as part of production operations management. The example shows decision-making on how to address an over-demand for future available capacity. (The decision has a horizon of 1 month and a period of 1 week). If the production load is 250 man hours higher than available production capacity for the coming week, a decision is needed.

Possible decision variables are: (1) extra man hours, (2) subcontracting man hours and (3) re-scheduling.

Constraints are, for example,

- a) min. and max. extra man hours: $50 < h < 100$ per week;
- b) min. and max. subcontracting man hours: $100 < h < 500$.

The objective of the company is to give priority to internal extra hours whenever possible and to re-schedule as infrequently as possible.

The decision would be: 100 extra hours by company personnel and 150 hours of subcontracting. This decision is an acceptable one because it is consistent with decision objectives and satisfies the constraints.

EXAMPLE 3: Considering an example of event-driven decision-making triggered by an unplanned maintenance request due to machine breakdown. This event triggers a decision-making activity.

Two decision variables defined are:

- a) delay on-going preventive maintenance activities to repair the machine;
- b) overtime work to repair the machine.

The decision constraints are:

- a) on-going preventive maintenance activities can only be delayed if no impact to planned manufacturing schedule;
- b) overtime maintenance hours can be kept to less than 5 % of total maintenance hours.

The decision objective is to give priority to reactive maintenance.

The decision would be to delay on-going preventive maintenance activity (1/2 day delay with no impact on current production schedule) to repair the machine.

5.5 Hierarchy of planning and scheduling

In this subclause, planning is defined as an activity for clarifying actions or operations to achieve a given goal and reserving enough amount of resource capacity to hit minimum targets. Scheduling is defined as an activity for allocating actions and operations to particular resources at particular times, taking into account various actual constraints and optimization of several evaluation parameters.

Figure 12 illustrates that in terms of the hierarchy, planning ranks higher than scheduling because a schedule is made using the results of a plan. Planning determines the goals for scheduling. Some constraints and sub-goals for objective functions in scheduling problems are determined in advance by planning activities. The results of scheduling show whether or not the result of planning is feasible and efficient. If it is not feasible, planning usually generates another result for scheduling. Feasibility and efficiency of scheduling are types of constraints of planning.

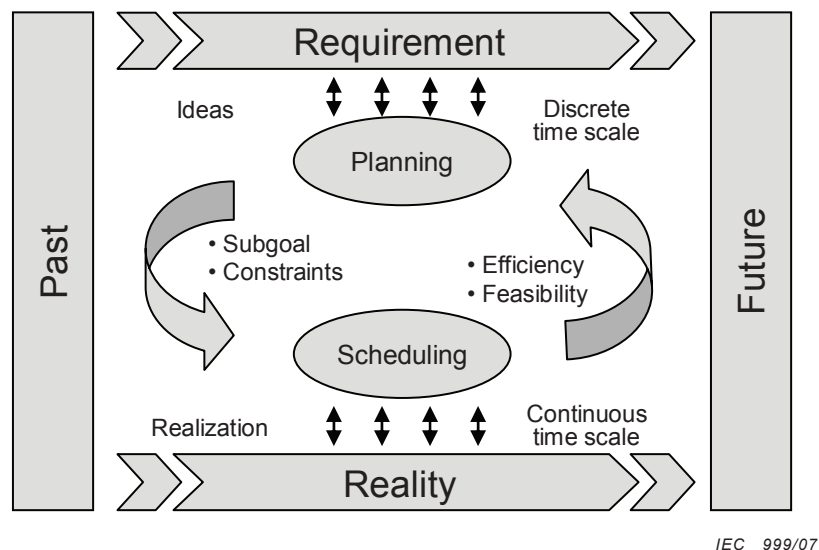


Figure 12 – Schematic relationship of planning and scheduling

The differences between planning and scheduling are the kinds of results which are related to different aspects of time concepts. Figure 12 also illustrates these two concepts.

In planning, the main results will be target quantities that apply over certain periods of time. The results of planning are represented on a discrete time scale as periodic times.

EXAMPLE 1: Results of planning might be “50,000 widgets this month”, “divisional sales of \$480,000 next month”, “summary of overtime hours for next week”, etc.

Results in scheduling represent the specific timing of actions, for example, start time and completion time of operation, inventory issue time, shipping time, etc. The results of sequence information for operations are represented on a continuous time scale as relative or absolute times.

EXAMPLE 2: Results of scheduling might be “9:00 Monday run Work Order 2345 for 6 shifts at 100 % utilization”, “9:00 Wednesday perform preventative maintenance on E887e”.

5.6 Resource definition for scheduling activities

5.6.1 Consumable resources and non-consumable resources

A resource is defined in IEC 62264-1 as personnel, equipment and/or material. In this standard, particularly from the viewpoint of detailed scheduling activities, resources can be divided into two different groups: consumable resources generally corresponding to materials and non-consumable resources generally corresponding to personnel and equipment.

A consumable resource is produced or consumed by production processes. This type of resource usually includes raw materials, WIP inventories and final products. The quantity of the resource typically changes before or after production.

A non-consumable resource is not used up by production processes but is scheduled on the basis of capacity. The quantity of the resource typically does not change before or after production.

5.6.2 Resource capacity and availability

Consumable resources and non-consumable resources are typically handled differently in scheduling activities. In IEC 62264-1 and IEC 62264-2, production scheduling depends on the availability of both consumable and non-consumable resources. Available capacity in this standard is a portion of production capacity that can be attained but is not committed to current or future production and may be defined as a rate. Available capacity for consumable resources is not the inventory of the resource and does not mean the availability of the consumable resource. The expected future availability of inventory is defined as projected inventory and may be defined for specific resources for specific future times.

Example 1: For a bicycle factory, the available capacity for production is 10 bicycle seats per hour of operation, during first shift, Monday through Friday.

Example 2: For a bicycle factory, the available capacity for consumption is 30 bicycle seats per hour of operation, during first shift, Monday through Friday.

Example 3: Projected inventory for bicycle seats within a bicycle factory is 380 seats at the start of the first shift on Monday and 360 seats at the end of the first shift. Sixty seats would have been consumed (2 h of consumption) and 40 seats would have been produced (4 h of production).

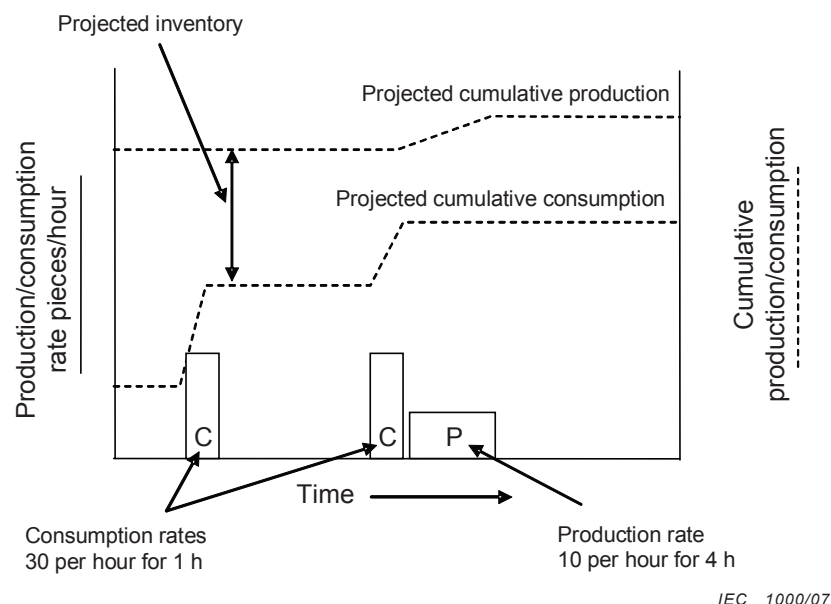


Figure 13 – Projected inventory for a consumable resource

NOTE Consumable resources and non-consumable resources are typically handled differently in scheduling activities. In IEC 62264-1 and IEC 62264-2, production scheduling depends on the availability of both consumable and non-consumable resources. Production capacity is determined by both the availability of consumable resources (inputs such as raw

material, components) and the availability and capacity of non-consumable resources (the physical system such as equipment, facilities and people).

6 Production operations management

6.1 General activities in production operations management

Production operations management shall be defined as the collection of activities that coordinate, direct, manage and track the functions that use raw materials, energy, equipment, personnel and information to produce products, with the required costs, qualities, quantities, safety and timeliness. The general activities in production operations management are listed in IEC 62264-1 and include

- a) reporting on production including variable manufacturing costs;
- b) collecting and maintaining data on production, inventory, manpower, raw materials, spare parts and energy usage;
- c) performing data collection and off-line analysis as required by engineering functions. This may include statistical quality analysis and related control functions;
- d) performing needed personnel functions, such as work period statistics (for example, time, task), vacation schedule, work force schedules, union line of progression and in-house training and personnel qualification;
- e) establishing the immediate detailed production schedule for its own area accounting for maintenance, transportation and other production-related requests;
- f) locally optimizing the costs for individual production areas while carrying out the production schedule established by the Level 4 functions;
- g) modifying production schedules to compensate for plant production interruptions that may occur in its area of responsibility.

6.2 Production operations management activity model

The production operations management model illustrated by the shaded area in Figure 1 is expanded to a more detailed activity model of production operations shown in Figure 14. The four elements of information (product definition, production capability, production schedule and production performance) correspond to the exchanged information defined in IEC 62264-1 and illustrated in Figure 4. The oval-labelled production Level 1-2 functions represent the Level 1 and Level 2 sensing and control functions. The other ovals (with solid outlines) represent the activities of production operations.

The activities defined here are not intended to imply an organizational structure of systems, software, or personnel. The model is provided to help in the identification of activities that may be performed and in the identification of roles associated with the activities. It defines what is done, not how it should be organized. Different organizations may have a different arrangement of roles and assignment of roles to personnel or systems.



Not all information flows within production operations management are depicted in Figure 14. In any specific implementation, information from any activity may be required by any other activity. Where activities in the production operations management model are defined in detail in this clause, some additional information flows are identified. Not all data sources and data sinks are identified in the detailed models.

6.3.1 Equipment and process specific production rules

NOTE See IEC 61131-3 for examples of this type of data.

NOTE This information exchange corresponds to the recipe-equipment interface defined in IEC 61512-1.

6.3.3 Operational responses

Operational responses shall be defined as information received from Level 2 in response to commands. These typically correspond to the completion or status of elements of work orders.

NOTE This information exchange corresponds to the recipe-equipment interface defined in IEC 61512-1.

6.3.4 Equipment and process specific data

Equipment and process specific data shall be defined as information received as a result of monitoring Level 2. This is typically information about the process being performed and the resources involved.

6.4 Product definition management

6.4.1 Activity definition

Product definition management shall be defined as the collection of activities that manage all of the Level 3 information about the product required for manufacturing, including the product production rules.

Product definition information is shared between product production rules, bill of material and bill of resources. The product production rules contain the information used to instruct a manufacturing operation how to produce a product. This may be called a general, site, or master recipe (IEC 61512-1, definition 3.9), standard operating procedure (SOP), standard operating conditions (SOC), routing, or assembly steps based on the production strategy used. The product definition information is made available to other Level 3 functions and to Level 2 functions as required.

Product definition management includes management of the distribution of product production rules. Some of the product production rules may exist in Level 2 and Level 1 equipment. When that is the case, downloads of this information shall be coordinated with other manufacturing operations management functions to avoid affecting production. This information may be included as part of operational commands when the download is part of a production execution management activity.

6.4.2 Activity model

Figure 15 illustrates some of the interfaces to product definition management.

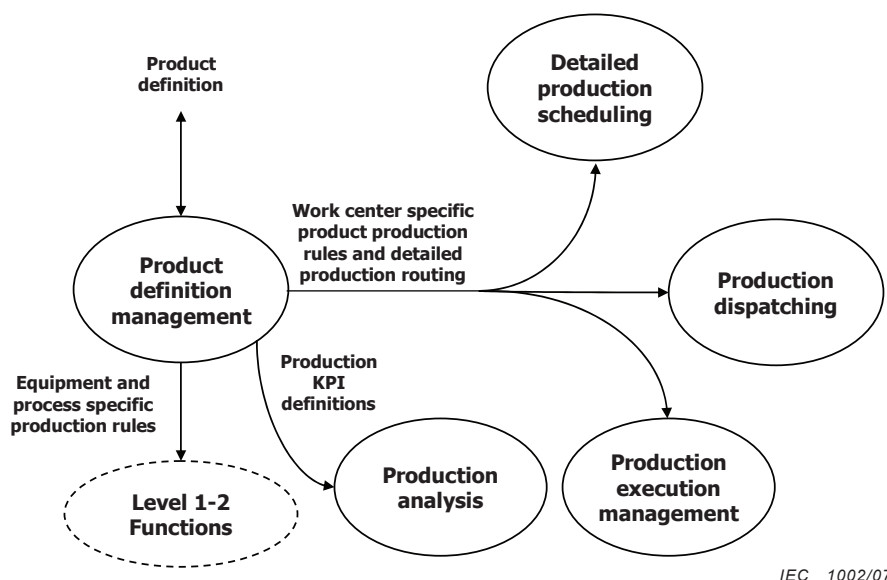


Figure 15 – Product definition management activity model interfaces

6.4.3 Tasks in product definition management

Product definition management tasks may include

- a) managing documents such as manufacturing instructions, recipes, product structure diagrams, manufacturing bills and product variant definitions;
- b) managing new product definitions;
- c) managing changes to product definitions. This may include the ability to route designs and manufacturing bill changes through an appropriate approval process, management of versions, tracking of modifications and security control of the information;
- d) providing product production rules to personnel or other activities;
- e) EXAMPLE: these may take the form of manufacturing steps, master recipes, machine set-up rules and process flow sheets;
- f) maintaining the feasible detailed production routings for products;
- g) providing the product segment route to manufacturing operations in the level of detail required by manufacturing operations;
- h) managing the exchange of product definition information with Level 4 functions at the level of detail required by the business operations;
- i) optimizing product production rules based on process analysis and production performance analysis;
- j) generating and maintaining local production rule sets indirectly related to products, such as for cleaning, start-up and shutdown;
- k) managing the key performance indicator (KPI) definitions associated with products and production.

NOTE 1 There are a number of tools to assist in the product definition management activity, including mechanical and electronic computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided software.

NOTE 2 Engineering (CASE), recipe management systems, computer-aided process engineering (CAPE) and electronic work instructions (EWIs).

6.4.4 Product definition rule information

Product definition is the information exchanged with engineering, R&D and others to develop the site-specific product production rules. This information may include R&D manufacturing definitions that are translated and extended by product definition management into site-specific definitions using local material, equipment and personnel. This may also involve translation to elements of a work order.

EXAMPLE: Translation to master recipes, machine set-up rules and process flow diagrams.

Product definition management may also include managing other product information in conjunction with manufacturing information. This may include

- customer requirements, product design and test specifications;
- process design and simulation;
- technical publications and service materials;
- regulatory filings requirement information.

The product definition management activity interacts with production dispatching and production execution management to get the work done and interacts with research development and engineering to obtain the product production rules for executing the work.

EXAMPLE: Production dispatching activities may need to refer to production dependencies to identify when a specific resource will be required.

The product production rule identifies elements of a work order and establishes relationships between them. Each element can contain information regarding personnel, equipment, material and

product parameters. To perform these functions, product definition management may need to exchange information with resource management.

6.4.5 Detailed production routing

The product definition information includes dependencies of work order elements. Detailed work order element routing may contain a finer granularity of definition than is visible to business systems, but is required for detailed routing of work between work centers (process cells, production lines and production units). Detailed work order element routing is organized by the physical production process.

NOTE A detailed production routing is sometimes called a production route, master business system route, master route, or business route.

6.5 Production resource management

6.5.1 Activity definition

Production resource management shall be defined as the collection of activities that manage the information about resources required by production operations. The resources include machines, tools, labour (with specific skill sets), materials and energy, as defined in the object models given in IEC 62264-1. Direct control of these resources in order to meet production requirements is performed in other activities, such as production dispatching and production execution management. Management of information about segments of production is also an activity in resource management.

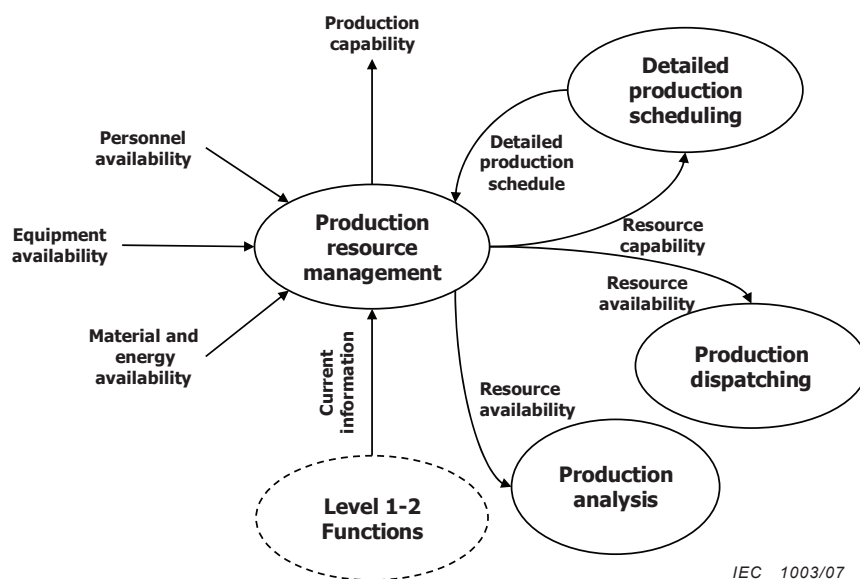
Management of the resource information may be handled by computer systems but it may be partly or entirely handled by manual processes.

Management of the resources may include local resource reservation systems to manage information about future availability. There may be separate reservation systems for each managed critical resource. There may be separate activities for each type of resource, or combined activities for sets of resources.

Information about resources needed for a segment of production must be maintained and provided on the available, committed and unattainable capacity for specific periods of time of specified resources as defined in IEC 62264-1.

6.5.2 Activity model

Figure 16 illustrates some of the interfaces to production resource management.



IEC 1003/07

Figure 16 – Production resource management activity model interfaces

6.5.3 Tasks in production resource management

Production resource management tasks may include

- a) providing personnel, material and equipment resource definitions. The information may be provided on demand or on a defined schedule and may be provided to people, to applications, or to other activities;
- b) providing information on resource (material, equipment, or personnel) capability (committed, available, or unattainable). The information is based on the current statuses, future reservations and future needs (as identified in the production plan and detailed production schedule) and is specific for resources, for defined time spans and process segments. It may include information on current balance and losses to product cost accounting and may be provided on demand or on a defined schedule and may be provided to people, to applications, or to other activities;
- c) ensuring that requests for acquisition of resources to meet future operational capabilities are initiated;
- d) ensuring that equipment is available for the assigned tasks and that job titles are correct and training is current for personnel assigned to tasks;
EXAMPLE 1: Checking that an equipment sterilization status is correct ("clean") before it is assigned to a production operation.
- e) providing information on the location of resources and assignment of resources to areas of production;
EXAMPLE 2: Providing a location for a mobile inspection machine that can be used in multiple locations.
- f) coordinating the management of resources with maintenance resource management and quality resource management;
- g) collecting information on the current state of personnel, equipment and material resources and on the capacity and capability of the resources. Information may be collected on the basis of events, on demand and/or on a defined schedule and may be collected from equipment, people and/or applications;
- h) collecting future needs such as from the production plan, current production, maintenance schedules, or vacation schedules;
- i) maintaining personnel qualification test result information;
- j) maintaining equipment capability test result information;
- k) managing reservations for future use of resources.

6.5.4 Resource availability

Resource availability provides time-specific definitions needed for scheduling and reporting on a resource. The resource availability must take into account elements such as working hours, labour regulations, holiday calendar, breaks, plant shutdowns and shift schedules.

EXAMPLE: The available time can be a fixed time or a flexible time. For example, in personnel resource management, the time for lunch may be flexible between 11:00 a.m. and 2:00 p.m., or a machine may be unavailable for 8 h within a 16-h period. Personnel availability may define working days and days off; Monday to Friday are available for work, Saturday and Sunday are unavailable for work, or available for 2 days early shift, 2 days late shift, 2 days night shift and 3 days off.

Figure 17 illustrates the types of information about the capacity of a single resource that may be provided by resource management.

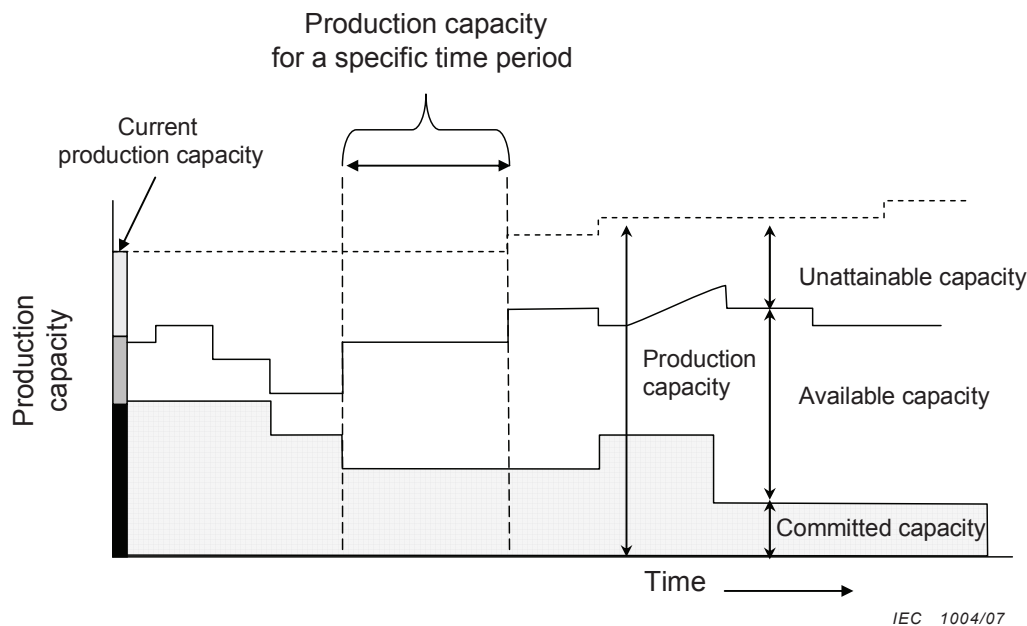


Figure 17 – Resource management capacity reporting

6.5.5 Collecting future committed resource information

Production resource management manages committed resource availability based on the detailed production schedule and product requirements. An assigned resource changes from available to committed for the period of time defined by the production plan, or until the completion of the scheduled task.

NOTE Once the schedule window requiring the resource is completed, the resource is typically taken back to the available state, unless it was already dispatched for a new assignment. In the most basic systems, the end of the planned schedule window triggers this ending of committed time window; but, for more sophisticated systems, it may be triggered by production tracking that relays the actual time the work is completed to production resource management.

6.5.6 Collecting resource definition changes

The production resource management activity includes collecting information about new, modified, or deleted resource definitions, classes and instances. This includes information on resource property definitions.

6.5.7 Personnel resource information management

Management of information about personnel resources and future personnel availability is part of resource management.

EXAMPLE: If an individual has vacation planned or is known to be sick for a certain period of time, then a business-level human resource (HR) function may report this situation to production resource management. This prevents production from assigning the resource within this period of time. As an extension, the whole working schedule of the personnel should be known by production in order to make the right allocation decisions.

This may include information such as levels of certification, tracking of time spent for specific tasks and managing availability of personnel resources. In some cases, this information is maintained and managed in corporate HR systems but shall be available to manufacturing. Often the level of detail required for manufacturing, such as certification expiration dates and union line of seniority, is not maintained in the HR systems. In these cases, labour management can be considered as part of the manufacturing operations activities.

The production resource management activity also has to address skill levels. Each member of the personnel may have recognized skills through qualification tests results. This defines a skill profile