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Enterprise-control system integration –

Part 1: Models and terminology

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ENTERPRISE-CONTROL SYSTEM INTEGRATION –

Part 1: Models and terminology

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
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International Standard IEC 62264-1 has been developed by subcommittee 65A: System aspects, of IEC technical committee 65: Industrial-process measurement and control, and by ISO technical committee 184/SC5: Architecture, communication and integration frameworks.

This standard is based upon ANSI/ISA-95.00.01-2000, Enterprise-Control System Integration, Part 1: Models and Terminology. It is used with permission of the copyright holder, the Instrumentation, Systems and Automation Society (ISA)*. ISA encourages the use and application of its industry standards on a global basis.

This standard was submitted to the National Committees for voting under the Fast Track Procedure as the following documents:

FDIS	Report on voting
65A/369/FDIS	65A/373/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table. In ISO, the standard has been approved by 10 P members out of 10 having cast a vote.

* For information on ISA standards, contact ISA at: ISA – The Instrumentation, Systems and Automation Society, PO Box 12277, Research Triangle Park, NC 27709, USA, Tel. 1+919.549.8411, URL: standards.isa.org.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC 62264 consists of the following parts under the general title *Enterprise-control system integration:*

– Part 1: Models and terminology
– Part 2: Object models and attributes
– Part 3: Models of manufacturing operations

The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this standard may be issued at a later date.

INTRODUCTION

IEC 62264 is a multi-part standard that defines the interfaces between enterprise activities and control activities. This standard provides standard models and terminology for describing the interfaces between the business systems of an entreprise and its manufacturing-control systems. The models and terminology presented in this standard

a) emphasize good integration practices of control systems with enterprise systems during the entire life cycle of the systems;
b) can be used to improve existing integration capabilities of manufacturing control systems with enterprise systems; and
c) can be applied regardless of the degree of automation.

Specifically, this standard provides a standard terminology and a consistent set of concepts and models for integrating control systems with enterprise systems that will improve communications between all parties involved. Some of the benefits produced will

a) reduce users' times to reach full production levels for new products;
b) enable vendors to supply appropriate tools for implementing integration of control systems to enterprise systems;
c) enable users to better identify their needs;
d) reduce the costs of automating manufacturing processes;
e) optimize supply chains; and
f) reduce life-cycle engineering efforts.

It is not the intent of this standard to

– suggest that there is only one way of implementing integration of control systems to enterprise systems;
– force users to abandon their current methods of handling integration; or
– restrict development in the area of integration of control systems to enterprise systems.

This standard discusses the interface content between manufacturing-control functions and other enterprise functions, based upon the Purdue Reference Model for CIM (hierarchical form) as published by ISA. This standard presents a partial model or reference model as defined in ISO 15704.

The scope of this standard is limited to describing the relevant functions in the enterprise and the control domain and which objects are normally exchanged between these domains. Subsequent parts will address how these objects can be exchanged in a robust, secure, and cost-effective manner preserving the integrity of the complete system.

The intent of Clause 4 is to describe the context of the models in Clause 5 and Clause 6. It gives the criteria used to determine the scope of the manufacturing control system domain. Clause 4 does not contain the formal definitions of the models and terminology but describes the context to understand the other clauses.

The intent of Clause 5 is to describe hierarchy models of the activities involved in manufacturing-control enterprises. It presents in general terms the activities that are associated with manufacturing control and the activities that occur at the business logistics level. It also gives an equipment hierarchy model of equipment associated with manufacturing control.

The intent of Clause 6 is to describe a general model of the functions within an enterprise which are concerned with the integration of business and control. It presents, in detail, an abstract model of control functions and, in less detail, the business functions that interface to control. The purpose is to establish a common terminology for functions involved in information exchange.

The intent of Clause 7 is to state in detail the objects that make up the information streams defined in Clause 6. The purpose is to establish a common terminology for the elements of information exchanged.

Annex A defines the relationship of this standard with other related standardization work in the manufacturing area.

The intent of Annex B is to present the business reasons for the information exchange between business and control functions. The purpose is to establish a common terminology for the reason for information exchange.

Annex C discusses the rationale for multiple models.

Annex D contains selected elements from the Purdue Reference Model that may be used to place the functions described in Clauses 5 and 6 in context with the entire model.

Annex E is informative. It correlates the Purdue Reference Model to the MESA International Model.

This standard is intended for those who are

– involved in designing, building, or operating manufacturing facilities;
– responsible for specifying interfaces between manufacturing and process control systems and other systems of the business enterprise; or
– involved in designing, creating, marketing, and integrating automation products used to interface manufacturing operations and business systems.

Annex F is a discussion of systems, resources, capability, capacity, and time as used in this standard.

ENTERPRISE-CONTROL SYSTEM INTEGRATION –

Part 1: Models and terminology

1 Scope

This standard describes the interface content between manufacturing control functions and other enterprise functions. The interfaces considered are the interfaces between Levels 3 and 4 of the hierarchical model defined by this standard. The goal is to reduce the risk, cost, and errors associated with implementing these interfaces.

The standard can be used to reduce the effort associated with implementing new product offerings. The goal is to have enterprise systems and control systems that inter-operate and easily integrate.

The scope of this standard is limited to

a) a presentation of the scope of the manufacturing operations and control domain;

b) a discussion of the organization of physical assets of an enterprise involved in manufacturing;

c) a listing of the functions associated with the interface between control functions and enterprise functions; and

d) a description of the information that is shared between control functions and enterprise functions.

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*

ISO/IEC 19501-1, *Information technology – Unified Modeling Language (UML) – Part 1: Specification* [1]

ISO 10303-1:1994, *Industrial automation systems and integration – Product data representation and exchange – Part 1: Overview and fundamental principles*

ISO 15531-1, *Industrial automation systems and integration – Industrial manufacturing management data – Part 1: General overview* [2]

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

[1] To be published.

[2] To be published.

3 Terms and definitions

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

3.1
area
physical, geographical or logical grouping determined by the site

NOTE It can contain process cells, production units, and production lines.

3.2
available capacity
portion of the production capacity that can be attained but is not committed to current or future production

3.3
bill of lading
BOL
contract or receipt for goods that a carrier agrees to transport from one place to another and to deliver to a designated person or that it assigns for compensation upon the conditions stated therein

3.4
bill of material
BOM
listing of all the subassemblies, parts, and/or materials that are used in the production of a product including the quantity of each material required to make a product

3.5
bill of resources
listing of all resources and when in the production process they are needed to produce a product

NOTE It is also a listing of the key resources required to manufacture a product, organized as segments of production and is often used to predict the impact of activity changes in the master production schedule on the supply of resources.

3.6
capability
ability to perform actions, including attributes on qualifications and measures of the ability as capacity

NOTE See Annex F for additional background on this concept.

3.7
capacity
measure of the ability to take action, a subset of a capability

NOTE See Annex F for additional background on this concept.

EXAMPLE Measures of the production rates, flow rates, mass or volume.

3.8
certificate of analysis
COA
certification of conformance to quality standards or specifications for products or materials

NOTE It can include a list or reference of analysis results and process information. It is often required for custody transfer of materials.

3.9
committed capacity
portion of the production capacity that is currently in use or is scheduled for use

3.10
consumables
resources that are not normally included in bills of material or are not individually accounted for in specific production requests

3.11
control domain
in this standard, control domain is synonymous with the manufacturing operations and control domain

3.12
enterprise
one or more organizations sharing a definite mission, goals and objectives to offer an output such as a product or service

3.13
equipment class
means to describe a grouping of equipment with similar characteristics for purposes of scheduling and planning

3.14
finished goods
final materials on which all processing and production is completed

3.15
finished good waivers
approvals for deviation from normal product specifications

3.16
in-process waiver requests
requests for waivers on normal production procedures due to deviations in materials, equipment, or quality metrics, where normal product specifications are maintained

3.17
manufacturing operations and control domain
MO&C
domain that includes all the activities in Level 3 and information flows to and from levels 0, 1, and 2 across the boundary to Level 4

3.18
material class
means to describe a grouping of materials with similar characteristics for purposes of scheduling and planning

3.19
material lot
uniquely identifiable amount of a material

NOTE It describes the actual total quantity or amount of material available, its current state, and its specific property values.

3.20
material definition
definition of the properties and characteristics for a substance

3.21
material sublot
uniquely identifiable subset of a material lot, containing quantity and location

NOTE This may be a single item.

3.22
personnel class
means to describe a grouping of persons with similar characteristics for purposes of scheduling and planning

3.23
process segment
view of a collection of resources needed for a segment of production, independent of any particular product at the level of detail required to support business processes that may also be independent of any particular product

NOTE This may include material, energy, personnel, or equipment.

3.24
production capacity
ability of resources to perform production in the enterprise. The production capacity includes the capacity of those resources and represents

a) the collection of personnel, equipment, material, and process segment capabilities;

b) the total of the current committed, available, and unattainable capacity of the production facility;

c) the highest sustainable output rate that could be achieved for a given product mix, raw materials, worker effort, plant, and equipment

3.25
production control
collection of functions that manages all production within a site or area

3.26
production line
series of pieces of equipment dedicated to the manufacture of a specific number of products or families

3.27
production rules
information used to instruct a manufacturing operation how to produce a product

3.28
production unit
set of production equipment that converts, separates, or reacts one or more feedstocks to produce intermediate or final products

3.29
product segments
shared information between a bill of resources and a production rule for a specific product

NOTE A logical grouping of personnel resources, equipment resources, and material specifications required to carry out the production step.

3.30
resource
enterprise entity that provides some or all of the capabilities required by the execution of an enterprise activity and/or business process (in the context of this standard, a collection of personnel, equipment, and/or material)

3.31
unattainable capacity
portion of the production capacity that cannot be attained

NOTE Typically due to factors such as equipment unavailability, sub-optimal scheduling, or resource limitations.

3.32
work cell
dissimilar machines grouped together to produce a family of parts having similar manufacturing requirements

4 Enterprise-control system integration overview

4.1 Introduction

Successfully addressing the issue of enterprise-control system integration requires identifying the boundary between the enterprise and the manufacturing operations and control domains (MO&C). The boundary is identified using relevant models that represent functions, physical equipment, information within the MO&C domain, and information flows between the domains.

Multiple models show the functions and integration associated with control and enterprise systems.

a) Hierarchy models that describe the levels of functions and domains of control associated within manufacturing organizations are presented in Clause 5. These models are based on *The Purdue Reference Model for CIM*, referenced as PRM; the MESA International Functional Model; and the equipment hierarchy model from IEC 61512-1.

NOTE 1 Selected elements of the *Purdue Reference Model for CIM* are included in Annex D.

NOTE 2 See the Bibliography for reference to the MESA white paper defining MES functionality.

b) A data flow model that describes the functional and data flows within manufacturing organizations is given in Clause 6. This model is also based on The Purdue Reference Model for CIM.

c) An object model that describes the information that may cross the enterprise and control system boundary is given in Clause 7.

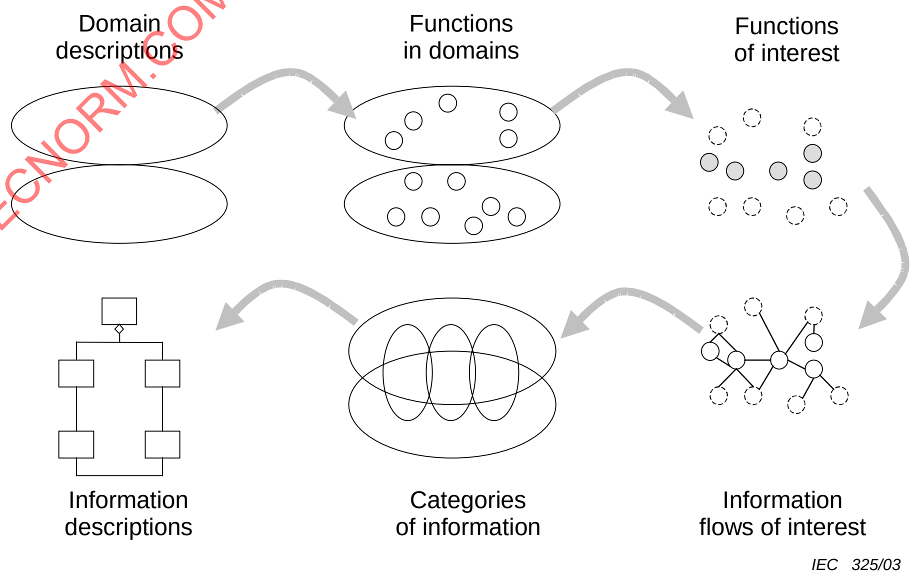


Figure 1 – Outline of models in the standard

This standard provides models and information in multiple levels of detail and abstraction. These levels are illustrated in Figure 1, which serves as a map to the rest of the document. Each model and diagram increases the level of detail presented in the previous model.

The models start with a description of the domain of control systems and the domain of enterprise systems. The domain discussion is contained in Clause 5.

Functions within the domains are presented in Clauses 5 and 6. Functions of interest that are relevant to the standard are also given a detailed description in Clause 6. The information flows of interest between the relevant functions are listed in 6.5.

The categories of information are given in 7.2. The formal object model of the information of interest is presented in 7.5, 7.6, 7.7, and 7.8.

4.2 Criteria for inclusion in manufacturing operations and control domain

The hierarchy and data flow models describe most of the functions within a manufacturing enterprise. Only some of those functions are associated with manufacturing control and manufacturing control systems. The following list shows the criteria used to determine which functions and which information flows are included in this standard.

a) The function is critical to maintaining regulatory compliance. This includes such factors as safety, and compliance to environmental and current good manufacturing practices.

b) The function is critical to plant reliability

c) The life impacts the operation phase of the life of a facility, as opposed to the design, construction, and disposal phases of the life of a facility.

d) The information is needed by facility operators in order to perform their jobs.

The information that flows between functions identified as being within the control domain and those outside the control domain describe the enterprise-control system boundary. Information exchanged between functions within the control domain and information exchanged between functions outside the control domain are outside the scope of this document. Figure 2 illustrates the enterprise-control system interface, as depicted in the data flow model, between control and non-control functions; the blue circles indicate functions that exchange information and are described in the data flow model. Functions depicted as white circles and data flows depicted as dashed lines are those considered as outside the scope of this standard.

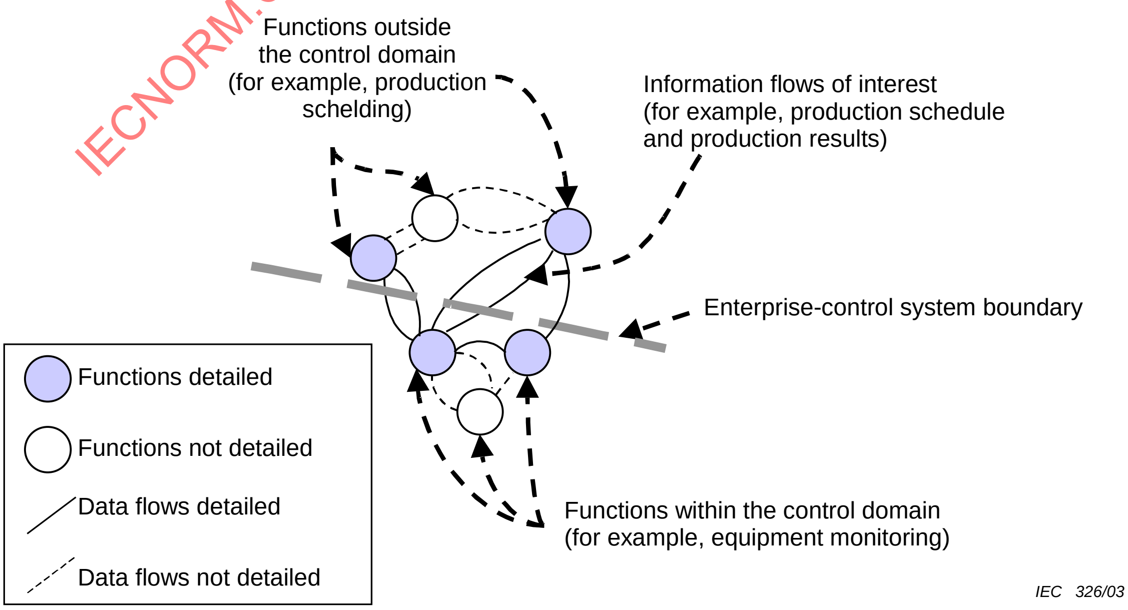


Figure 2 – Enterprise-control system interface

5 Hierarchy models

5.1 Hierarchy model introduction

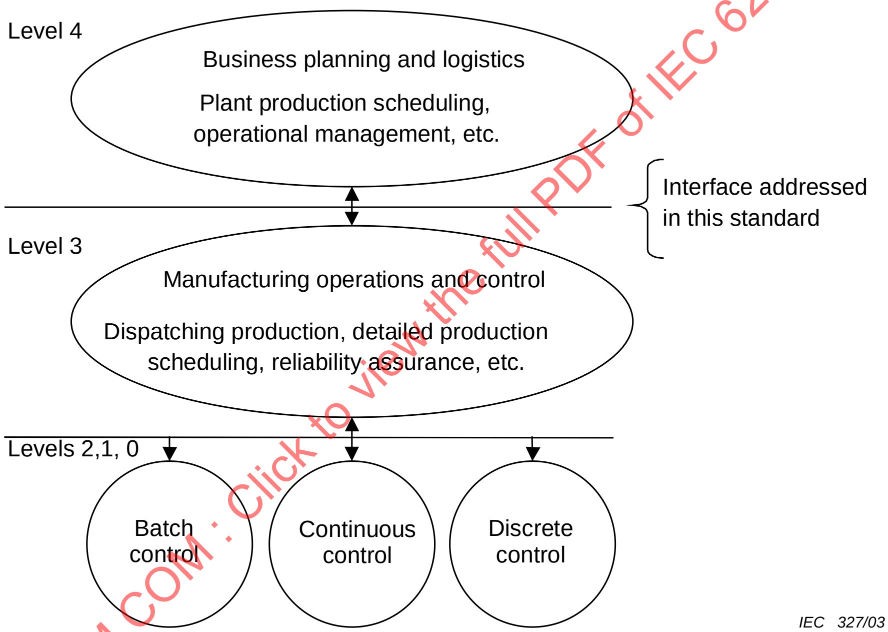
Clause 5 presents the hierarchy models associated with manufacturing control systems and other business systems.

5.2 Scheduling and control hierarchy

5.2.1 Hierarchy levels

Figure 3 depicts the different levels of a functional hierarchy model: business planning and logistics, manufacturing operations and control, and batch, continuous, or discrete control. The model shows the hierarchical levels at which decisions are made. The interface addressed in this standard is between Level 4 and Level 3 of the hierarchy model. This is generally the interface between plant production scheduling and operation management and plant floor coordination.

NOTE The figure is a simplified version of the Purdue Hierarchy Model, as shown in Figures D.1, D.2, D.3 and D.4 of Annex D.



IEC 327/03

Figure 3 – Functional hierarchy

Levels 2, 1, and 0 present the cell or line supervision functions, operations functions, and process control functions and are not addressed in this standard. The discussion and labelling of levels is based on a historical description, further described in Annex D. Level 0 indicates the process, usually the manufacturing or production process. Level 1 indicates manual sensing, sensors, and actuators used to monitor and manipulate the process. Level 2 indicates the control activities, either manual or automated, that keeps the process stable or under control. There are several different models for the functions at these levels based on the actual production strategy used.

5.2.2 Level 4 activities

Level 4 activities typically include

a) collecting and maintaining raw material and spare parts usage and available inventory, and providing data for purchase of raw material and spare parts;

b) collecting and maintaining overall energy use and available inventory and providing data for purchase of energy source;

c) collecting and maintaining overall goods in process and production inventory files;

d) collecting and maintaining quality control files as they relate to customer requirements;

e) collecting and maintaining machinery and equipment use and life history files necessary for preventive and predictive maintenance planning;

f) collecting and maintaining manpower use data for transmittal to personnel and accounting;

g) establishing the basic plant production schedule;

h) modifying the basic plant production schedule for orders received, based on resource availability changes, energy sources available, power demand levels, and maintenance requirements;

i) developing optimum preventive maintenance and equipment renovation schedules in coordination with the basic plant production schedule;

j) determining the optimum inventory levels of raw materials, energy sources, spare parts, and goods in process at each storage point. These functions also include materials requirements planning (MRP) and spare parts procurement;

k) modifying the basic plant production schedule as necessary whenever major production interruptions occur;

l) capacity planning, based on all of the above activities.

5.2.3 Level 3

5.2.3.1 Level 3 activities

Level 3 activities typically include

a) reporting on area production including variable manufacturing costs;

b) collecting and maintaining area data on production, inventory, manpower, raw materials, spare parts and energy usage;

c) the performance of data collection and off-line analysis as required by engineering functions. This may include statistical quality analysis and related control functions;

d) carrying out 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 including maintenance, transportation and other production-related needs;

f) locally optimizing the costs for its individual production area while carrying out the production schedule established by the Level 4 functions;

g) modification of production schedules to compensate for plant production interruptions that may occur in its area of responsibility.

Descriptions of the major functionalities associated with these various activities are given in 5.2.3.2 through 5.2.3.12. The standard assumes all activities not explicitly presented as part of the Level 3 control domain to be part of the enterprise domain. See Annex E for a correlation of the activities to the MESA International Model.

5.2.3.2 Resource allocation and control

The control domain includes the functionality of managing resources directly associated with control and manufacturing. The resources include machines, tools, labour skills, materials, other equipment, documents, and other entities that are required for work to start and to be completed. The management of these resources may include local resource reservation to meet production-scheduling objectives.

The control domain also ensures that equipment is properly set up for processing, including any allocation needed for set-up. The control domain is also responsible for providing real-time statuses of the resources and a detailed history of resource use.

5.2.3.3 Dispatching production

The control domain includes the functionality of managing the flow of production in the form of jobs, orders, batches, lots, and work orders, by dispatching production to specific equipment and personnel. Dispatch information is typically presented in the sequence in which the work needs to be done and may change in real time as events occur on the factory floor.

The control domain may alter the prescribed schedules, within agreed limits, based on local availability and current conditions. Dispatching of production includes the ability to control the amount of work in process at any point through buffer management and management of rework and salvage processes.

5.2.3.4 Data collection and acquisition

The control domain includes the functionality of obtaining the operational production and parametric data that are associated with the production equipment and production processes.

The control domain also is responsible for providing real-time statuses of the production equipment and production processes and a history of production and parametric data.

5.2.3.5 Quality management

The control domain includes the functionality of providing real-time measurements collected from manufacturing and analysis in order to assure proper product quality control and to identify problems requiring attention. It may recommend actions to correct the problem, including correlating the symptoms, actions and results to determine the cause.

It includes statistical process control/statistical quality control (SPC/SQC), tracking and management of off-line inspection operations, and analysis in laboratory information management systems.

5.2.3.6 Process management

The control domain includes the functionality of monitoring production and either automatically corrects or provides decision support to operators for correcting and improving in-process functions. These functions may be intra-operational and focus specifically on machines or equipment being monitored and controlled, as well as inter-operational, tracking the process from one operation to the next.

It may include alarm management to make sure factory persons are aware of process changes that are outside acceptable tolerances.

5.2.3.7 Production tracking

The control domain includes the functionality of providing the status of production and the disposition of work. Status information may include personnel assigned to the work; component materials used in production; current production conditions; and any alarms, rework, or other exceptions related to the product. The functionality includes the capability of recording the production information to allow forward and backward traceability of components and their use within each end product.

5.2.3.8 Performance analysis

The control domain includes the functionality of providing up-to-the-minute reporting of actual manufacturing operations results along with comparisons to past history and expected results. Performance results include such measurements as resource utilization, resource availability, product unit cycle time, conformance to schedule, and performance to standards.

Performance analysis may include SPC/SQC analysis and may draw from information gathered by different control functions that measure operating parameters.

5.2.3.9 Operations and detailed scheduling

The control domain includes the functionality of providing sequencing based on priorities, attributes, characteristics, and production rules associated with specific production equipment and specific product characteristics, such as shape, colour sequencing or other characteristics that, when scheduled in sequence properly, minimize set-up. Operations and detailed scheduling takes into account finite capacity of resources and recognizes alternative and overlapping/parallel operations in order to calculate in detail the exact time of equipment loading and adjustment to shift patterns.

5.2.3.10 Document control

The control domain includes some of the functionality of controlling records and forms that are maintained with the production unit. The records and forms include work instructions, recipes, drawings, standard operation procedures, part programmes, batch records, engineering change notices, shift-to-shift communication, as well as the ability to edit "as planned" and "as built" information. It sends instructions down to the operations, including providing data to operators or recipes to device controls. It would also include the control and integrity of regulatory documentation, environmental, health and safety regulations, and SOP information such as corrective action procedures.

5.2.3.11 Labour management

The control domain includes some of the functionality of providing status of personnel in an up-to-the minute time frame. The functions include time and attendance reporting, certification tracking, as well as the ability to track indirect functions such as material preparation or tool room work as a basis for activity-based costing. Labour management may interact with resource allocation to determine optimal assignments.

5.2.3.12 Maintenance management

The control domain includes some of the functionality of maintaining equipment and tools. The functions ensure the equipment and tools availability for manufacturing. They also may include scheduling for periodic or preventive maintenance as well as responding to immediate problems. Maintenance management maintains a history of past events or problems to aid in diagnosing problems.

5.3 Equipment hierarchy

5.3.1 Equipment model

The physical assets of an enterprise involved in manufacturing are usually organized in a hierarchical fashion as described in Figure 4. This is an expansion of the model described in IEC 61512-1 and includes the definition of assets for discrete and continuous manufacturing. 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.

This model shows the areas of responsibility for the different function levels defined in the scheduling and control hierarchical model of Figure 3. The equipment hierarchy model additionally gives some of the objects utilized in information exchange between functions. This corresponds to a resource model for equipment, as defined in ISO 15704 and ISO 15531-1.

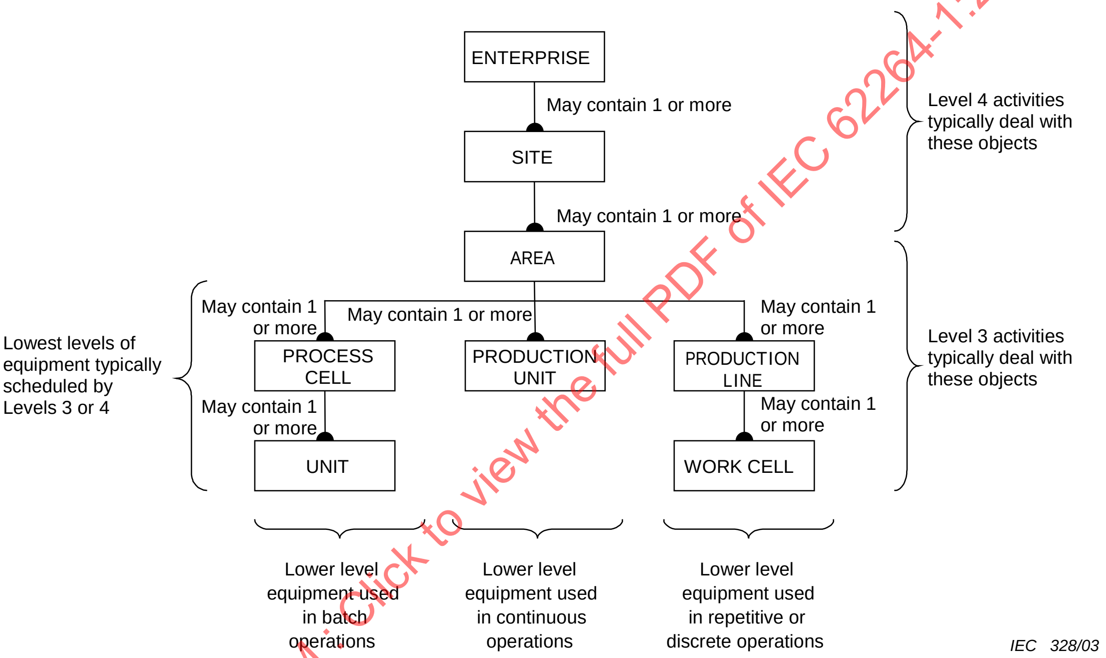


Figure 4 – Equipment hierarchy

5.3.2 Enterprise

An enterprise is a collection of one or more sites and may contain sites and areas. The enterprise is responsible for determining what products will be manufactured, at which sites they will be manufactured, and in general how they will be manufactured.

Level 4 functions are generally concerned with the enterprise and site levels. However, enterprise planning and scheduling may involve areas, cells, lines, or units within an area.

5.3.3 Site

A site is a physical, geographical, or logical grouping determined by the enterprise. It may contain areas, production lines, process cells, and production units. The Level 4 functions at a site are involved in local site management and optimization. Site planning and scheduling may involve cells, lines, or units within the areas.

A geographical location and main production capability usually identifies a site. Sites generally have well-defined manufacturing capabilities.

NOTE For example, site identifiers from various industries are Dallas Expressway Plant, Deer Park Olefins Plant and Johnson City Manufacturing Facility. Sites are often used for rough-cut planning and scheduling.

5.3.4 Area

An area is a physical, geographical, or logical grouping determined by the site. It may contain process cells, production units, and production lines. Most Level 3 functions occur within the area. The main production capability and geographical location within a site usually identify areas.

NOTE For example, area identifiers from various industries are CMOS Facility, North End Tank Farm and Building 2 Electronic Assembly.

Areas generally have well-defined manufacturing capabilities and capacities. The capabilities and capacities are used for Level 3 and Level 4 planning and scheduling.

An area is made up of lower-level elements that perform the manufacturing functions. There are three types of elements defined that correspond to continuous manufacturing models, discrete (repetitive and non-repetitive) manufacturing models, and batch manufacturing models. An area may have one or more of any of the lower-level elements depending upon the manufacturing requirements. Many areas will have a combination of production lines for the discrete operations, production units for the continuous processes, and process cells for batch processes. For example, a beverage manufacturer may have an area with continuous mixing in a production unit, which feeds a batch process cell for batch processing, feeding a bottling line for a discrete bottling process.

Depending on the planning and scheduling strategy selected, the Level 4 functions may stop at the area level, or they may schedule the functions of the lower-level elements within the areas.

5.3.5 Production unit

Production units are the lowest level of equipment typically scheduled by the Level 4 or Level 3 functions for continuous manufacturing processes. Production units are composed of lower level elements, such as equipment modules, sensors, and actuators, but definitions of these are outside the scope of this standard. A production unit generally encompasses all of the equipment required for a segment of continuous production that operates in a relatively autonomous manner. It generally converts, separates, or reacts one or more feed stocks to produce intermediate or final products.

The major processing activity or product generated often identifies the production unit.

NOTE For example, production unit identifiers from various industries are Catalytic Cracker #1, Steam Cracker #59 and Alkylation Unit 2.

Production units have well-defined processing capabilities and throughput capacities and these are used for Level 3 functions. The capacities and capabilities are also often used as input to Level 4 scheduling, even if the production units are not scheduled by the Level 4 functions.

5.3.6 Production line and work cell

Production lines and work cells are the lowest levels of equipment typically scheduled by the Level 4 or Level 3 functions for discrete manufacturing processes. Work cells are usually only identified when there is flexibility in the routing of work within a production line. Production lines and work cells may be composed of lower-level elements, but definitions of these are outside the scope of this document.

The major processing activity often identifies the production line.

NOTE For example, production line identifiers from various industries are Bottling Line #1, Capping Line #15, CMOS Line #2 and Water Pump Assembly Line #4.

Production line and work cells have well-defined manufacturing capabilities and throughput capacities and these are used for Level 3 functions. The capacities and capabilities are also often used as input to Level 4 scheduling, even if the production lines and work cells are not scheduled by the Level 4 functions.

5.3.7 Process cell and unit

Process cells and units are the lowest level of equipment typically scheduled by the Level 4 and Level 3 functions for batch manufacturing processes. Units are usually only identified at Level 3 and 4 if there is flexibility in the routing of the product within a process cell. The definitions for process cells and units are contained in IEC 61512-1.

The major processing capability or family of products produced often identifies the process cell.

NOTE For example, process cell identifiers from various industries are Mixing Line #5, West Side Glue Line and Detergent Line 13.

Process cells and units have well-defined manufacturing capabilities and batch capacities and these are used for Level 3 functions. The capacities and capabilities may also be used as input data for Level 4 scheduling, even if the process cells or units are not scheduled by the Level 4 functions.

5.4 Decision hierarchy

5.4.1 Introduction

In addition to the hierarchy of activities, there is also a hierarchy of decision-making and associated scheduling involved in enterprise-to-control integration. The following subclauses cover the rationale for such a hierarchy, and the categories and time horizons of such decisions. This hierarchy of decision-making and a mapping to manufacturing operations will be discussed in a later part of this standard.

5.4.2 Integrated decision making

An enterprise is organized by functions and in levels, and decisions are made within multiple functions and multiple levels. Integrated decision-making means that the (different categories of) decisions made within various functions are consistent in the sense that they contribute to the achievement of the global objectives of the enterprise. This also means that the time horizons in which various decisions are made are coordinated. In relationship to production, this means that the correct raw materials and products are available at the correct time, on the correct machine and processed by the correct personnel. Decisions to execute the production are made in multiple time horizons.

5.4.3 Categories of decision-making

Decision-making activities deal with products, resources and time. The different combinations of these lead to a categorization into three basic types of decisions.

– Manage products: This is concerned with the management of products and time without regard to resources. Major decisions are concerned with what products, what quantity, and when those products are to be produced or procured.
– Manage resources: This is concerned with the management of resources and time. Major decisions of this category are concerned with the management of capacity of the resources.
– Plan production: This is concerned with the production planning that synchronizes the flow of products, resources, and time.

5.4.4 Time horizons

Decisions can be classified into three general basic time horizons.

– Long term and broad scope: These are long-term decisions that are concerned with the presentation of the objectives consistent with the global objectives of the enterprise.
– Medium term and intermediate scope: These are medium-term decisions that deal with the allocation of resources to meet the objectives defined in the long-term time horizon.
– Short term and limited scope: This is a short-term time horizon associated with the planning and execution of actions, using the means presented at the medium-term time horizon, to reach the objectives of the long-term time horizon.

6 Functional data flow model

6.1 Functional data flow model contents

This clause presents

a) the functions of an enterprise involved with manufacturing;
b) the information flows between the functions that cross the enterprise-control interface.

6.2 Functional data flow model notation

The enterprise-control interface is described using a data flow model. The model uses the Yourdon-DeMarco notational methodology (see Bibliography).

Table 1 shows the Yourdon notation used in the functional model.

Table 1 – Yourdon notation used

Symbol	Definition
Function (4.0)	A function is represented as a labelled ellipse. A function is a group of tasks that are classified as having a common objective. Functions are organized in a hierarchical manner and are identified with a name and a number. The number represents an identification of the data model hierarchy level.
External entity	An external entity is represented as a labelled rectangle. An external entity is a component outside the model boundaries that sends data to, and/or receives data from, the functions.
Data flow name	A solid line with an arrow represents a grouping of data that flows between functions, data stores, or external entities. The data are defined in the enterprise-control integration model. All solid lines have a name for the data flows. A data flow at one level of the functional hierarchy may be represented by one or more flows at the lower level of the hierarchy.
- - - - - - - - ▶	A dashed line with an arrow represents a grouping of data that flows between functions, data stores, or external entities. The data are not pertinent to the enterprise-control integration model but are shown to illustrate the context of functions. Dashed-line data flows without names are not identified in this model but are defined in Annex D.
Data Store	A persistent data storage is represented as the name of the data store with a line above and a line below the name. A persistent data store maintains information defined in a data flow, so that it is usable in a potentially non-synchronous manner with the original data source.

6.3 Functional enterprise-control model

The functional model is depicted in Figure 5. The wide dotted line illustrates the boundary of the enterprise-control interface. The line is equivalent to the Level 3/Level 4 interface presented in 5.1. The manufacturing control side of the interface includes most of the functions in production control and some of the activities in the other major functions. The labelled lines indicate information flows of importance to manufacturing control. The wide dotted line intersects functions that have sub-functions that may fall into the control domain or the enterprise domain depending on organizational policies. This is a combination of a function view and an information view of the enterprise, as defined in ISO 15704.

The model structure does not reflect an organizational structure within a company but an organizational structure of functions. Different companies will place the functions in different organizational groups.

The detailed information in the information flows is presented in Clause 7.

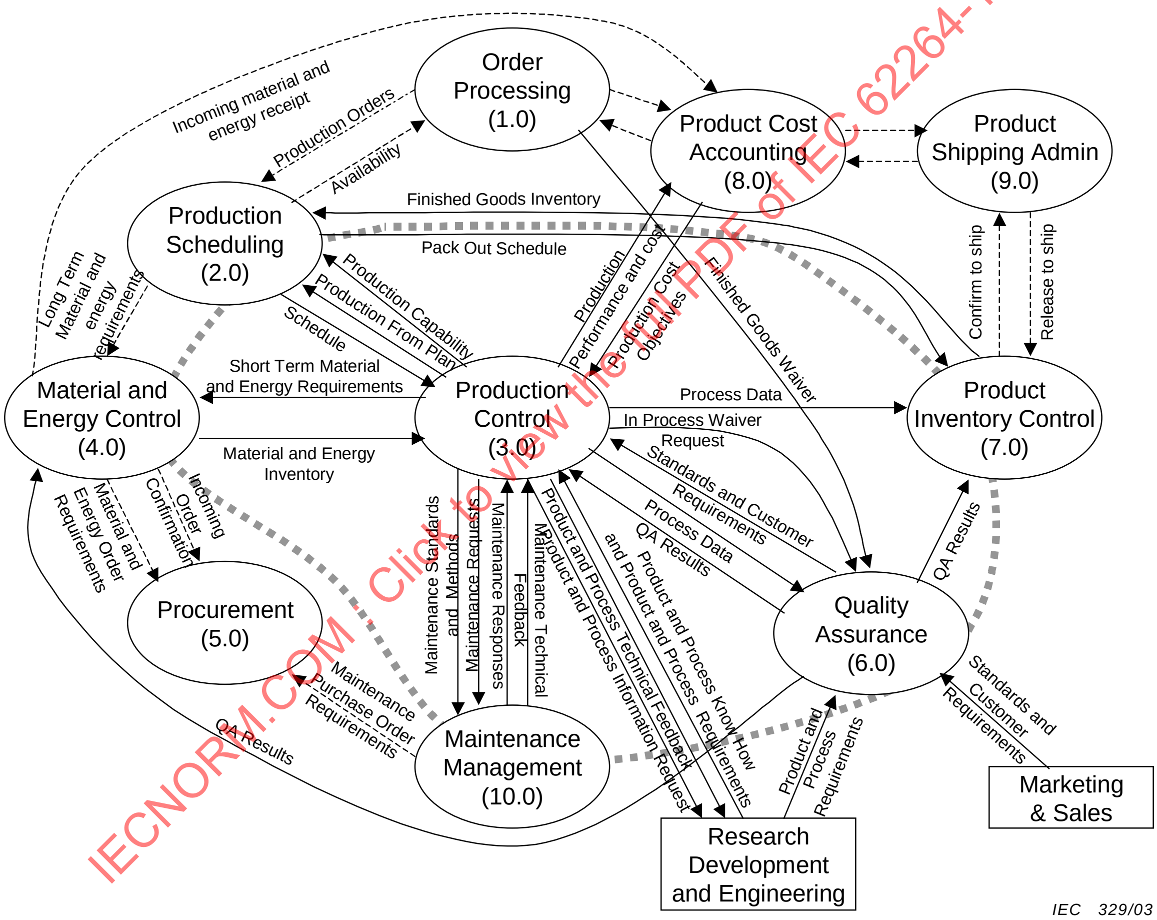


Figure 5 – Functional enterprise/control model

6.4 Functions

6.4.1 Order processing (1.0)

The general functions of order processing typically include

a) customer order handling, acceptance and confirmation;

b) sales forecasting;

c) waiver and reservation handling;

d) gross margin reporting;

e) determining production orders.

There is generally no direct interface between the functions of order processing and the manufacturing control functions.

6.4.2 Production scheduling (2.0)

Production scheduling functions interface to the manufacturing control system functions through a production schedule, actual production information, and production capability information. This information exchange is presented in the production control functions.

Detailed scheduling, within an area, is considered to be a control function.

The general functions of production scheduling typically include

a) the determination of production schedule;
b) the identification of long-term raw material requirements;
c) the determination of the pack-out schedule for end-products;
d) the determination of the available product for sales.

The information generated or modified by the production scheduling functions includes

1) the production schedule;
2) the actual production versus the planned production;
3) the production capacity and resource availability;
4) the current order status.

6.4.3 Production control (3.0)

6.4.3.1 Production control main functions

The production control functions encompass most of the functions associated with manufacturing control. The functions of production control typically include

a) controlling the transformation of raw materials into the end-product in accordance with the production schedule and production standards;
b) performing plant engineering activities and updating of process plans;
c) issuing requirements for raw materials;
d) producing reports of performance and costs;
e) evaluating constraints to capacity and quality;
f) self-testing and diagnosis of production and control equipment;
g) creating production standards and instructions for SOPs (standard operating procedures), recipes, and equipment handling for specific processing equipment.

The main functions in production control include process support engineering, operations control, and operations planning.

6.4.3.2 Process support engineering

The functions of process support engineering typically include

a) issuing requests for modification or maintenance;
b) coordinating maintenance and engineering functions;
c) providing technical standards and methods to operations and maintenance functions;
d) following up on equipment and process performance;
e) providing technical support to operators;

f) following up on technological developments.

The functions of process support engineering generate or modify the following information for use in other control functions.

1) Minor equipment and process modifications; this may include new design drawings.
2) Instructions on how to handle equipment; this may include standard operating procedures.
3) Instructions on how to make products; this includes production rules and the standard materials, equipment, and other resources used.
4) Material safety data sheets (MSDS).
5) Instructions on how to install equipment; this may include vendor equipment.
6) Environmental and safety operating limits and constraints.
7) Engineering standards for process equipment design techniques and process operational methods, and online operating instructions.

6.4.3.3 Operations control

Operations control is the collection of functions that manages all production within a site or area.

The functions of production control typically include

a) producing the product according to the schedule and specifications;
b) reporting production, process, and resource information;
c) monitoring equipment, validating operational measurements, and determining the need for maintenance;
d) preparing equipment for maintenance and returning it to service after maintenance;
e) performing diagnostics and self-check of production and control equipment;
f) balancing and optimizing production within the site or area;
g) possible local site or area labour management and document management.

The functions of production control typically generate or modify the following information for use in other control functions.

1) Status of production requests.
2) Selected production data, such as data to calculate production cost and performance.
3) Selected process data, such as equipment performance feedback.
4) Status of resources.
5) Status of maintenance work order requests.
6) Requests for maintenance.
7) Diagnostic and self-test results.
8) Process history.
9) Requests for process support engineering support.
10) Requests for analysis of material.

6.4.3.4 Operations planning

The functions of operations planning typically include

a) setting up a short-term production plan based on the production schedule;
b) checking the schedule against raw material availability and product storage capacity;
c) checking the schedule against equipment and personnel availability;

d) determining the per cent of capacity status;

e) modifying the production plan hourly to account for equipment outage, manpower and raw materials availability.

The functions of operations planning typically generate or modify the following information for use in other control functions.

1) Material and energy inventory report.
2) Material and energy requirements required to meet the production plan.
3) Site or area production plan for operations control.
4) Available capability of the production resources.

6.4.4 Material and energy control (4.0)

The functions of materials and energy control typically include

a) managing inventory, transfers, and quality of material and energy;

b) generating requests for purchasing of materials and energy based on short- and long-term requirements;

c) calculating and reporting inventory balance and losses of raw material and energy utilization;

d) receiving incoming material and energy supplies and requesting quality assurance tests;

e) notifying purchasing of accepted material and energy supplies.

The functions of materials and energy control typically generate or modify the following information for use in other control functions.

1) Material and energy order requests.
2) Incoming confirmation of received materials and energy.
3) Material and energy inventory report.
4) Manual and automated transfer instructions for operations control.

Some of the functions within material and energy control may be inside the control domain, based on local organizational structures. Therefore, selected data flows into and out of material and energy control are presented because they may cross the enterprise-control system boundary.

6.4.5 Procurement (5.0)

The functions of procuring resources typically include

a) placing orders with suppliers for raw materials, supplies, spare parts, tools, equipment and other required materials;

b) monitoring progress of purchases and reporting to requisitioners;

c) releasing incoming invoices for payment after arrival and approval of goods;

d) collecting and processing of unit requests for raw materials, spare parts, etc., for order placement to vendors.

The functions of procurement typically generate or modify the expected material and energy delivery schedules for use in other control functions.

6.4.6 Quality assurance (6.0)

The functions of quality assurance typically include

a) testing and classification of materials;

b) setting standards for material quality;

c) issuing standards to manufacturing and testing laboratories in accordance with requirements from technology, marketing and customer services;

d) collecting and maintaining material quality data;

e) releasing material for further use (delivery or further processing);

f) certifying that the product was produced according to standard process conditions;

g) checking of product data versus customer's requirements and statistical quality control routines to assure adequate quality before shipment.

h) relaying material deviations to process engineering for re-evaluation to upgrade processes.

The functions of quality assurance typically generate or modify the following information for use in other control functions.

1) Quality assurance test results.
2) Approval to release materials or waivers on compliance.
3) Applicable standards and customer requirements for material quality.

Some of the functions within quality assurance may be inside the control domain, based on local organizational structures; for example, quality assurance requests. Therefore, selected data flows into and out of quality assurance are addressed because they may cross the enterprise-control system boundary.

6.4.7 Product inventory control (7.0)

The functions of product inventory control typically include

a) managing the inventory of finished products;

b) making reservations for specific product in accordance with product selling directives;

c) generating the pack-out end product in accordance with delivery schedule;

d) reporting on inventory to production scheduling;

e) reporting on balance and losses to product cost accounting;

f) arranging physical loading/shipment of goods in coordination with product shipping administration.

The functions of product inventory control typically generate or modify the following information for use in other control functions.

1) Finished goods inventory.
2) Inventory balances.
3) Pack-out schedule.
4) Release to ship.
5) Confirm to ship.
6) Requirements.

Some of the functions within product inventory control may be inside the control domain, based on local organizational structures. Therefore, selected data flows into and out of product inventory control are used because they may cross the enterprise-control system boundary.

6.4.8 Product cost accounting (8.0)

The functions of cost accounting typically include

a) calculating and reporting on total product cost;
b) reporting cost results to production for adjustment;
c) setting cost objectives for production;
d) collecting raw material, labour, energy and other costs for transmission to accounting;
e) calculating and reporting on total production cost, reporting cost results to production for adjustment;
f) setting cost objectives for materials and energy supply and distribution.

The functions of cost accounting typically generate or modify the following information for use in other control functions.

1) Cost objectives to production.
2) Performance and costs from production.
3) Parts and energy incoming to accounting from material and energy control.

6.4.9 Product shipping administration (9.0)

The functions of product shipping administration typically include

a) organizing transport for product shipment in accordance with accepted orders requirements;
b) negotiating and placing orders with transport companies;
c) accepting freight items on site and releasing material for shipment;
d) preparing accompanying documents for shipment (BOL, customs clearance);
e) confirming shipment and releasing for invoicing to general accounting;
f) reporting on shipping costs to product cost accounting.

6.4.10 Maintenance management (10.0)

The functions of maintenance management typically include

a) providing maintenance for existing installations;
b) providing a preventative maintenance programme;
c) providing equipment monitoring to anticipate failure, including self-check and diagnostic programmes;
d) placing purchase order requests for materials and spare parts;
e) developing maintenance cost reports, and coordinating outside contract work effort;
f) providing status and technical feedback on performance and reliability to process support engineering.

The functions of maintenance management typically generate or modify the following information for use in other control functions.

1) Maintenance schedules that specify the plan for future work orders.
2) Maintenance work orders that specify specific equipment to be taken out of service and made available for maintenance functions.
3) Diagnostic and self-test requests to be performed on the equipment.

Some of the functions within maintenance management may be inside the control domain, based on local organizational structures. Therefore, selected data flows into and out of maintenance management are shown because they may cross the enterprise-control system boundary.

6.4.11 Research, development, and engineering

The general functions of research, development and engineering typically include

a) development of new products;
b) definition of process requirements;
c) definition of product requirements, as related to the production of the products.

6.4.12 Marketing and sales

The general functions of marketing and sales typically include

a) generating sales plans;
b) generating marketing plans;
c) determining customer requirements for products;
d) determining requirements and standards for products;
e) interacting with customers.

6.5 Information flows

6.5.1 Information flow descriptions

The information flows between the functions that are labelled in Figure 5 are listed below.

6.5.2 Schedule

The schedule information flows from the production scheduling (2.0) functions to the production control (3.0) functions.

This typically contains the information, to production, on what product is to be made, how much is to be made, and when it is to be made. Elements of the schedule information are presented in 7.8 and are shown in Figure 22.

6.5.3 Production from plan

The production-from-plan information flows from the production control (3.0) functions to the production scheduling (2.0) functions.

This contains information about the current and completed production results from execution of the plan. It typically contains what was made, how much was made, how it was made, and when it was made. Elements of the production-from-plan information are presented in 7.8 and shown in Figure 23.

6.5.4 Production capability

The production capability information flows from the production control (3.0) functions to the production scheduling (2.0) functions.

Production capability information is the current committed, available, and unattainable capacity of the production facility. This typically includes materials, equipment, labour, and energy. Elements of the production capability information are listed in 7.6 and shown in Figure 18.

6.5.5 Material and energy order requirements

The material and energy order requirement information flows from the material and energy control (4.0) functions to the procurement (5.0) functions.

Material and energy order requirements define future requirements for materials and energy required to meet short-term and long-term requirements based on the current availability.

There are no object models for the material and energy order requirements, but the information may use the definitions relating to material and energy detailed in the Clause 7 object model.

6.5.6 Incoming order confirmation

The incoming order confirmation information flows from the material and energy control (4.0) functions to the procurement (5.0) functions.

Incoming order confirmations are the notification that the material or energy has been received.

This information is not detailed in the Clause 7 object model because it does not cross the interface between the enterprise and control domains.

6.5.7 Long-term material and energy requirements

The long-term material and energy requirements information flows from the production scheduling (2.0) functions to the material and energy control (4.0) functions.

The long-term material and energy requirements are typically time-sequenced definitions of material and energy resources that will be needed for planned production.

There are no object models for the long-term material and energy requirements, but the information may use the definitions relating to material and energy detailed in the Clause 7 object model.

6.5.8 Short-term material and energy requirements

The short-term material and energy requirements information flows from the production control (3.0) functions to the material and energy control (4.0) functions.

The short-term material and energy requirements are requirements for resources that are needed for currently scheduled or executing production. These typically include

a) requests for materials that may include deadlines;
b) reservations for materials;
c) indications of actual consumption;
d) release of reservations;
e) adjustments to consumption.

Material is represented in Figure 16 in 7.5 and the material and energy requirements are represented in Figure 22 in 7.8.

6.5.9 Material and energy inventory

The material and energy inventory information flows from the material and energy control (4.0) functions to the production control (3.0) functions.

The material and energy inventory information flows are the currently available material and energy that is used for short-term planning and for production. This information typically deals with raw materials. Material and energy inventory information is given in 7.5.

6.5.10 Production cost objectives

The production cost objectives information flows from the product cost accounting (8.0) functions to the production control (3.0) functions.

Production cost objectives are the production performance targets in terms of resources. This could be related to a product or to a process. This typically includes materials, labour hours, energy, equipment usage, or actual costs. Elements of the production cost objectives are presented in 7.7 and shown in Figure 21.

6.5.11 Production performance and costs

The production performance and costs information flows from the production control (3.0) functions to the product cost accounting (8.0) functions.

Production performance and costs are the actual use and results associated with specific production activities. This typically includes materials, labour hours, energy, and equipment usage. Results are typically identified by products, by-products, co-products, and scrap. This information would be in sufficient detail to identify all costs by product, co-products, and scrap.

6.5.12 Incoming material and energy receipt

The incoming material and energy receipt information flows from the material and energy control (4.0) functions to the product cost accounting (8.0) functions.

Incoming material and energy receipt is the notification that the material or energy has been received and additional information needed for cost accounting. This may include the BOL, material safety data sheet (MSDS), and COA. This information is coordinated with the incoming order confirmation (6.5.6) information flow.

This information is not detailed in the Clause 7 object model because it generally does not cross the interface between the enterprise and control domains.

6.5.13 Quality assurance results

The quality assurance (QA) results information flows from the quality assurance (6.0) functions to the product inventory control (7.0) functions, material and energy control (4.0) functions, and the production control, operations control (3.2) functions.

Quality assurance results are typically the results from QA tests performed on raw materials, in-process materials, or products. Quality assurance results may concern tests performed in the product or in-process tests performed in a particular segment of production. Quality assurance results may include granting of in-process waivers.

A positive QA result may be required before product inventory management may ship a product. A positive QA result may be required before production control transfers product-to-product inventory control.

6.5.14 Standards and customer requirements

The standards and customer requirements information flows from the marketing and sales functions to the quality assurance (6.0) functions, and from quality assurance to production control (3.0).

Standards and customer requirements are the specific values for attributes of the product that satisfy the customer needs. This typically includes specific processing specifications as well as material properties. This information may result in changes in or additions to material, equipment, and personnel properties and associated tests (see 7.7).

6.5.15 Product and process requirements

The product and process requirements information flows from the research, development and engineering (RD&E) functions to the production control (3.0) functions and the quality assurance (6.0) functions.

The product and process requirements define how to make a product. This typically corresponds to general or site recipes in batch manufacturing, assembly instructions and drawings in discrete manufacturing, and process descriptions in continuous manufacturing. Information about specific equipment, personnel, and material requirements may be specified according to the models in 7.7.

6.5.16 Finished goods waiver

Finished goods waiver information flows from the order processing (1.0) functions to the quality assurance (6.0) functions.

Finished goods waivers are approvals for deviation from normal product specifications. Finished goods waivers may be negotiated customer deviations from specifications defined in the standards and customer requirements (6.5.14).

6.5.17 In-process waiver request

In-process waiver request information flows from production control (3.0) to the quality assurance (6.0) functions.

In-process waiver requests are requests for waivers on normal production procedures due to deviations in materials, equipment, or quality metrics, where normal product specifications are maintained. The response to the request is in the quality assurance results.

6.5.18 Finished goods inventory

The finished goods inventory information flows from the product inventory control (7.0) functions to the production scheduling (2.0) functions.

The finished goods inventory is information on the current inventory of finished goods that is maintained by product inventory control. This typically includes quantity, quality, and location information that is used for the scheduling of new production, and as feedback on previously scheduled production. This is the total finished product available for distribution or shipment. This information is described in 7.8.

6.5.19 Process data

The process data information flows from the production control (3.0) functions to the product inventory control (7.0) functions and the quality assurance (6.0) functions.

Process data is information about production processes, as related to specific products and production requests, and is described in 7.8. Typical uses of process data are by quality assurance as part of the QA functions, and by product inventory control where this information is needed as part of the finished product deliverables.

6.5.20 Pack-out schedule

The pack-out schedule information flows from the production scheduling (2.0) functions to the product inventory control (7.0) functions.

A pack-out schedule is the consolidation of produced items of one or more stock-keeping unit for delivery to customers, inventory, or others.

6.5.21 Product and process know-how

The product and process know-how information flows from the research, development and engineering (RD&E) functions to the production control (3.0) functions.

Product and process know-how typically includes standard operating procedures, recipes, critical safety limits, and analytical methods. This may be generated in response to operations requests or originated by RD&E for new products and processes.

Elements of the product and process know-how information are presented in 7.6 and 7.7 and in Figures 20 and 21.

6.5.22 Product and process information request

The product and process information request flows from the production control (3.0) functions to the RD&E functions.

A product and process information request is a request for new or modified product definitions and process definitions.

6.5.23 Maintenance requests

The maintenance request information flows from the production control (3.0) functions to the maintenance management (10.0) functions.

Maintenance requests are requests for a maintenance function. This may be a planned request or an unplanned request due to an unplanned event, such as a lightning strike on a transformer.

6.5.24 Maintenance responses

The maintenance response information flows from the maintenance management (10.0) functions to the production control (3.0) functions.

Maintenance responses are the logged status or completion of routine, scheduled, or unplanned maintenance.

6.5.25 Maintenance standards and methods

Maintenance standards and methods information flows from the production control (3.0) functions to the maintenance management (10.0) functions.

Maintenance standards and methods are typically accepted practices and procedures that maintenance uses in performing its functions.

6.5.26 Maintenance technical feedback

Maintenance technical feedback information flows from the maintenance management (10.0) functions to the production control (3.0) functions.

Maintenance technical feedback is typically information about the performance and reliability of production equipment and may include reporting on performed maintenance. Reports on maintenance may include scheduled, preventive, or predictive.

6.5.27 Product and process technical feedback

Product and process technical feedback information flows from the production control (3.0) functions to the RD&E functions.

Product and process technical feedback is information about the performance of production equipment and product. This information generally results from performance tests and study requests to operations control.

6.5.28 Maintenance purchase order requirements

Maintenance purchase order requirements information flows from the maintenance management (10.0) functions to the procurement (5.0) functions.

Maintenance purchase order requirements are information about materials and supplies required to perform maintenance tasks.

6.5.29 Production order

Production order information flows from order processing (1.0) functions to production scheduling (2.0) functions.

Production order is information about accepted customer orders that defines work for the plant.

6.5.30 Availability

Availability information flows from the production scheduling (2.0) functions to the order processing (1.0) functions.

Availability is information about the plant's ability to fulfil the order.

6.5.31 Release to ship

Release to ship information flows from the product shipping administration (9.0) functions to the product inventory control (7.0) functions.

Release to ship is information about the permission to ship the product.

6.5.32 Confirm to ship

Confirm to ship information flows from the product inventory control (7.0) functions to the product shipping administration (9.0).

Confirm to ship is information about the actual shipment of product.

7 Object model

7.1 Model explanation

Subclause 7.2.1 is an overview of the information contained in the object model and provides a context for the object models. It includes the general categories of information given in extra detail in 7.2.2, 7.2.3, and 7.2.4.

7.2 Categories of information

7.2.1 Information areas

Most of the information described in the Clause 6 model falls into the following three main areas.

a) Information about the capability to produce a product.

b) Information required to produce a product.

c) Information about actual production of the product.

Some information in each of these three areas is shared between the manufacturing control systems and the other business systems, as illustrated in Figure 6. Venn diagrams are used to illustrate the overlap of information. This standard is only concerned with the overlapping information in the Venn diagrams, and with presenting a model and common terminology for that information.

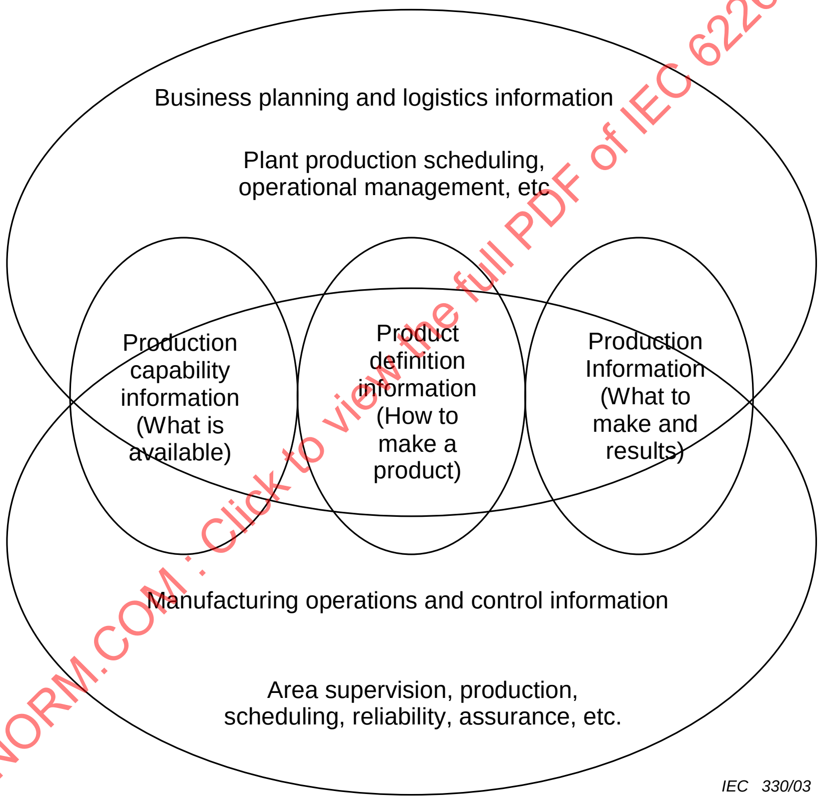


Figure 6 – Areas of information exchange

7.2.2 Production capability information

7.2.2.1 Production capability information categories

There are three main areas of information about the production capability that have significant overlap. The three areas of information are production capability information, maintenance information, and capacity scheduling information. Figure 7 illustrates the overlapping information.

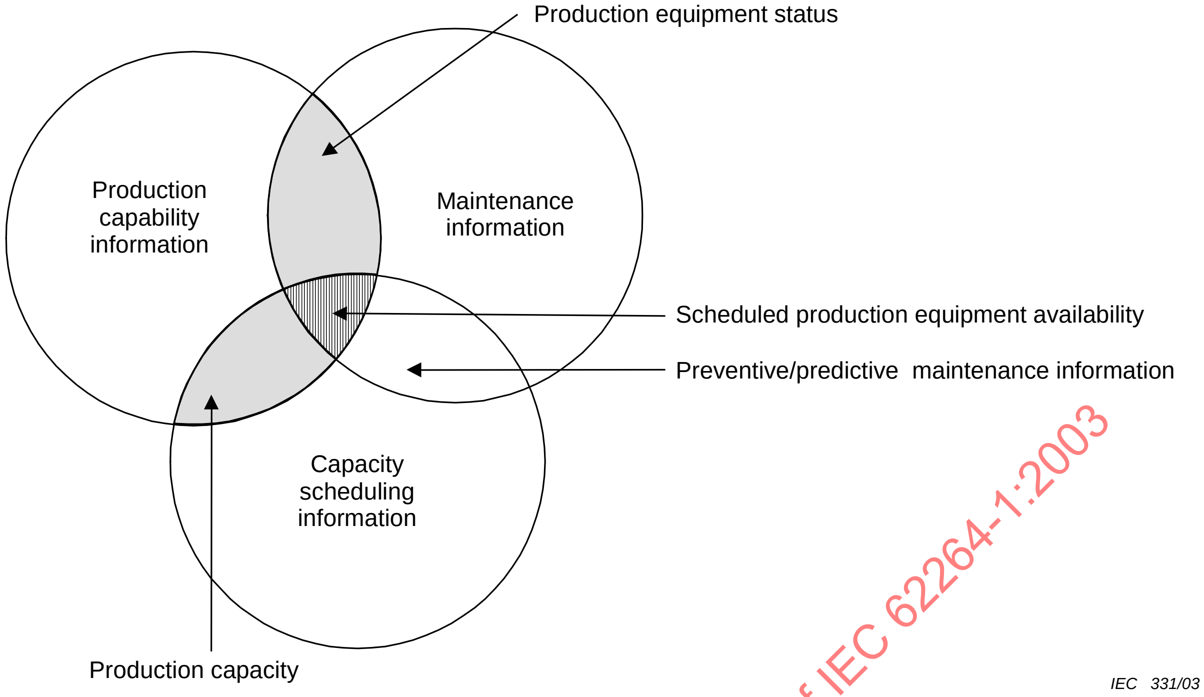


Figure 7 – Production capability information

7.2.2.2 Production capability information

For each site, area, and element within the area there is a presentation of the production capability of the personnel, equipment, and materials.

The production capability information includes the current state of what is available as updated by the production capability model in Figure 18.

7.2.2.3 Maintenance information

For each site, area, and element within the area there is a listing of the equipment as required for maintenance. This includes maintenance records and other information that is not part of the production capability model.

The maintenance information includes the current maintenance state of the equipment, as shown by information in the production capability model shown in Figure 18.

7.2.2.4 Capacity scheduling information

The capacity scheduling information contains the process segments available for the product unit, process cell, or production line.

For each site, area, and equipment element within the area there is a presentation of the production capacity of the personnel, equipment, and materials needed for scheduling of production.

7.2.2.5 Production equipment status

Production equipment status is information shared between the capability model of the equipment and the maintenance model. This includes the listing of the equipment, the current status of the equipment, and the usage history of the equipment.

7.2.2.6 Production capacity

Production capacity is defined as the information shared between the production capability model and the capacity scheduling model. This includes the listing of the capacity and current status of the personnel, equipment, and materials.

7.2.2.7 Scheduled production equipment availability

Scheduled production equipment availability is a dynamic interaction of production capability information, maintenance information, and capacity scheduling information that allows forecasting of scheduled production equipment availability.

7.2.2.8 Preventive/predictive maintenance information

Preventive/predictive maintenance information is the correlation of equipment health and maintenance requirements with capacity scheduling information so as to align maintenance processes and adjust the capacity scheduling information during the maintenance processes.

7.2.2.9 Process segment capability

A capability may be given in terms of a process segment. Process segments show the business view of a part of the manufacturing process. The capabilities may specify specific capabilities or the class of capability (such as class of equipment) needed for the process segment. Figure 8 illustrates how capabilities relate to process segments.

– A manual process segment may define the class of materials and class of personnel needed for production.
– A semi-automated process segment may define the class of materials, personnel, and equipment needed.
– A non-material process segment, such as an equipment set-up segment, may define the class of equipment and personnel used.
– An automated process segment may only define the material and equipment classes needed.

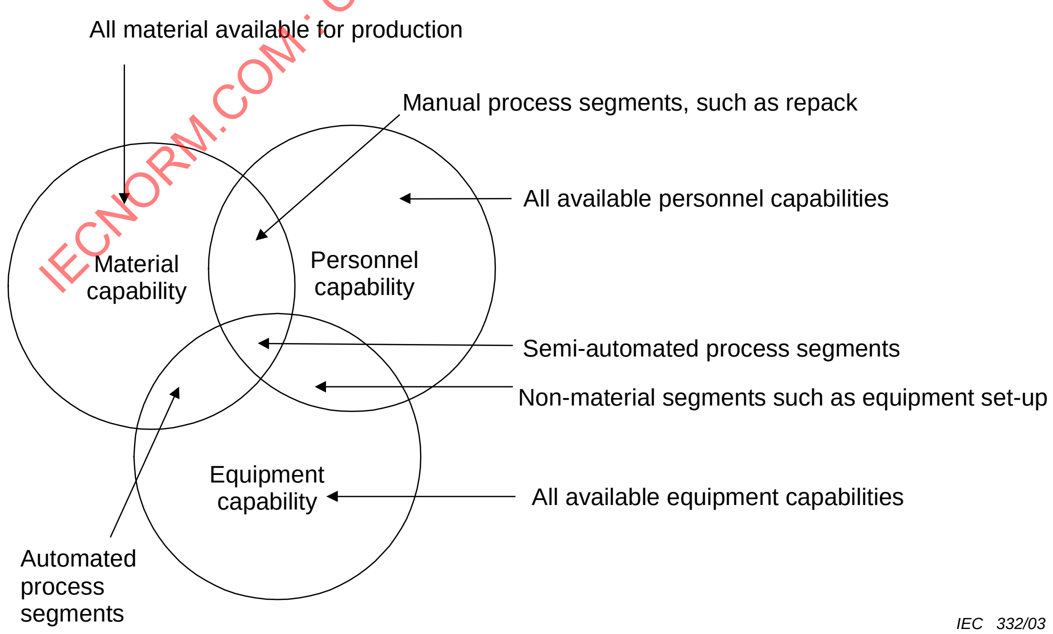


Figure 8 – Process segment capabilities

7.2.3 Product definition information

7.2.3.1 Product definition information categories

There are three main areas of information required for the production of a specific product that have significant overlap. The three areas are information for scheduling, material information, and production rules. Figure 9 illustrates the overlapping information.

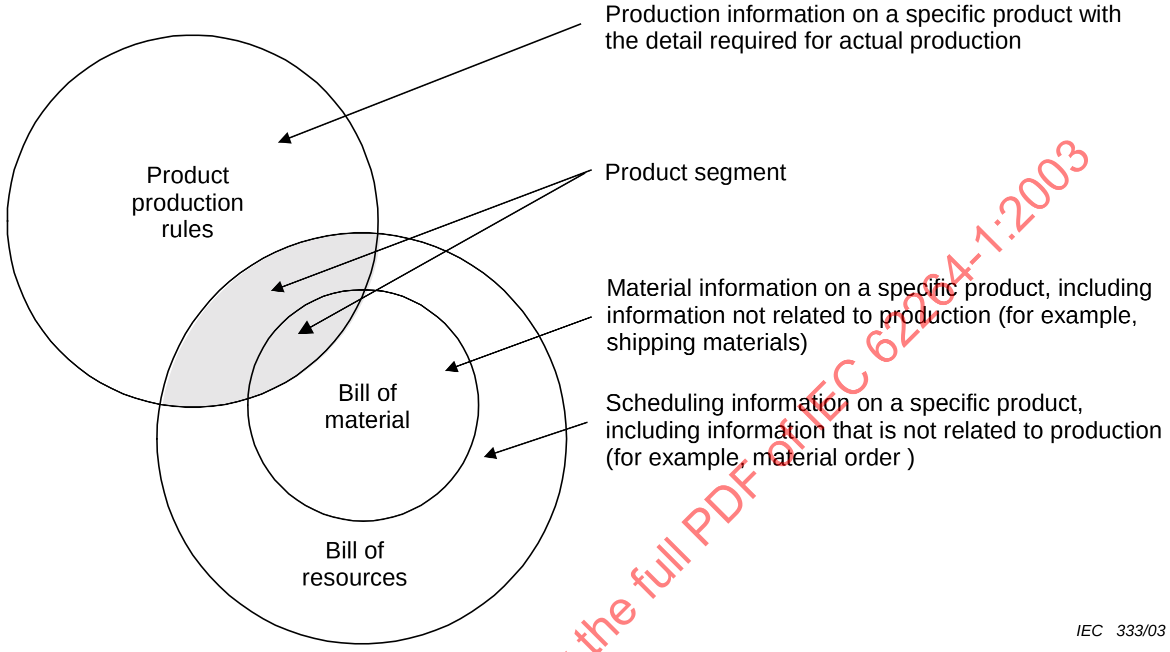


Figure 9 – Production information definition

7.2.3.2 Product production rules

Product production rules are 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 definitions), product data AP (application protocol) as defined in ISO 10303-1, standard operating procedure (SOP), standard operating conditions (SOC), routing, or assembly steps based on the production strategy used.

7.2.3.3 Bill of material

The bill of material is a list of all materials required to produce a product showing the quantity of each required. These may be raw materials, intermediate materials, subassemblies, parts, and consumables. This list does not contain the breakdown of where the materials are used or when they are needed, but it may be organized in a hierarchical manner that maps to some of the production steps. The bill of material often includes material that is not related to production of the product, such as shipping materials or included documentation. The bill of material is a subset of the bill of resources.

The manufacturing bill is the subset of the bill of material that is related to production.

7.2.3.4 Bill of resources

The bill of resources is the list of all resources required to produce a product. Resources may include materials, personnel, equipment, energy, and consumables. The bill of resources does not contain the specific production steps, but it may be organized in a hierarchical manner that maps to some of the production steps.

7.2.3.5 Product segment

Product segment is the overlap of information between product production rules and the bill of resources. It describes a job or task consisting of one of more work elements, usually carried out essentially in one location. A product segment is the most detailed process view for the business system to control material, labour, resource usage, cost, and quality in order to control the production.

Product segments may correspond to

a) IEC 61512-1 process stages, process operations, unit procedures, or operations for batch manufacturing;
b) production unit operations for continuous manufacturing;
c) assembly steps and assembly actions for discrete manufacturing;
d) other types of identifiable time spans for other types of manufacturing.

The example in Figure 10 illustrates product segments in a Gantt-type chart with time on the horizontal axis and each box corresponding to a different product segment.

Production routing is the overlap of information between the product production rule information and bill of resources information without the bill of material information. It represents all of the non-material aspects of production such as equipment, labour, and energy. Production routings include an ordered sequence of product segments.

Material routing is the overlap of information between the production rule information and the bill of material information. It represents both the production material inputs and where they are used in product segments.

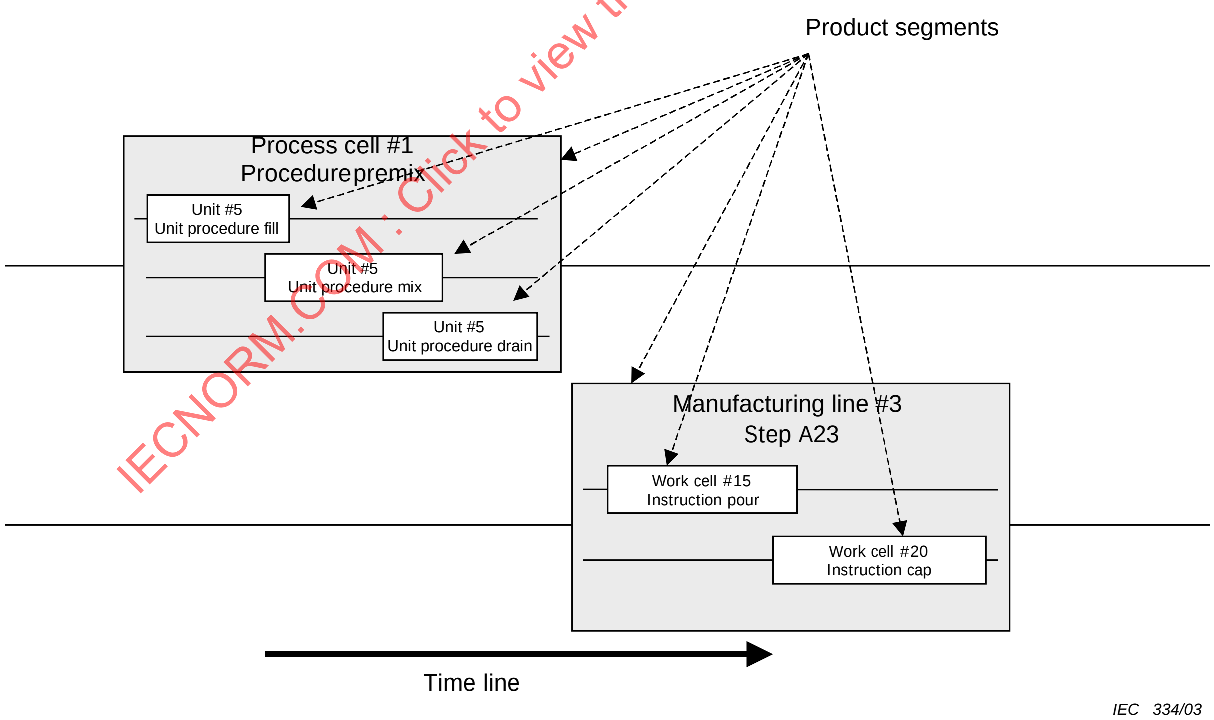


Figure 10 – Example of process segments

7.2.3.6 Overlapping areas

Figure 9 illustrates the overlap of information between different areas but is not meant to represent the amount or importance of the information. Different manufacturing and business strategies will have different amounts of information shared between the different areas. Figure 11 illustrates the amount of information in two examples. The left side of the figure shows an example where the manufacturing systems maintain most of the information required for a product. The right side of the figure shows an example where the business systems maintain most of the information.

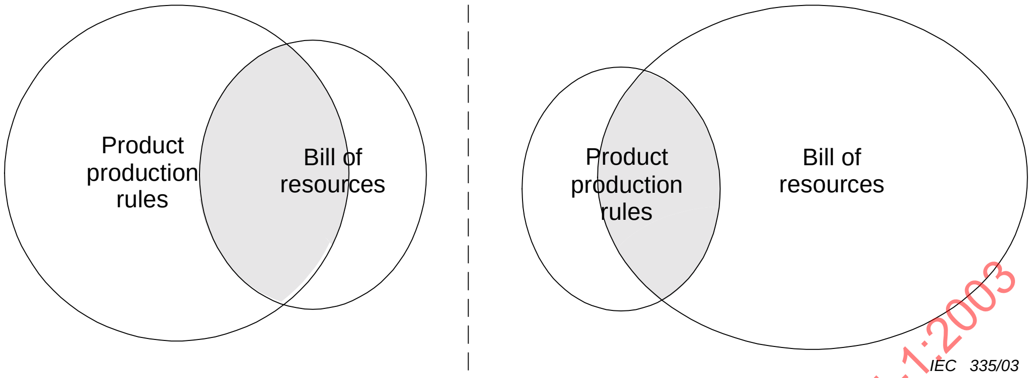


Figure 11 – Possible information overlaps

7.2.4 Production information

7.2.4.1 Production information categories

There are three main areas of information about actual production that have significant overlap. These three areas are production information, inventory information, and the production scheduling information. Figure 12 shows the overlap between the areas of information.

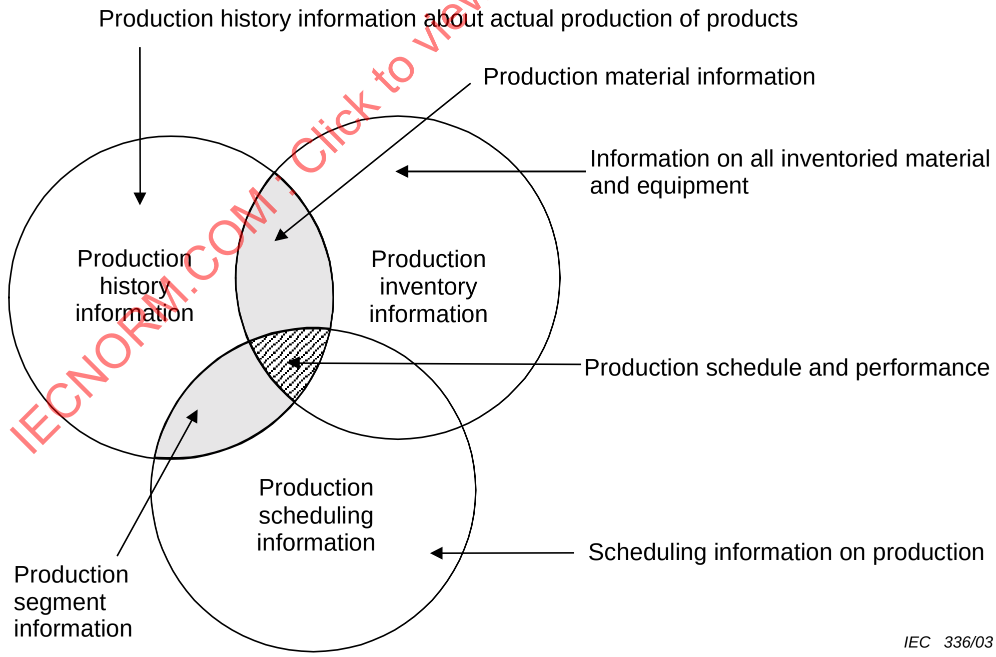


Figure 12 – Production information

7.2.4.2 Production history information

Production history information is all of the information recorded about production of a product. This may be called by many names, such as the batch journal, product log, or traveller.

7.2.4.3 Production inventory information

Production inventory information is all of the information about inventoried materials, including the current status of the materials. Typically all consumed and produced materials are maintained in the production inventory information, and sometimes intermediates are maintained if they are needed for financial evaluation. In some industries this may include energy information.

7.2.4.4 Production scheduling information

The scheduling model contains all of the information about the execution of scheduled production runs.

7.2.4.5 Production segment information

The production segment information is the part of the production history information that contains information on the segments of production and is used for scheduling.

7.2.4.6 Production material information

The production material information is the part of the production history information that contains information on material that is used by inventory.

7.2.4.7 Production schedule and performance

Production schedule and performance information is shared among production information, inventory information, and scheduling information. This includes the listing of the raw materials consumed, materials produced, and materials scrapped. It also includes the discussion of how long segments of production actually took and how much material was produced and consumed by specific segments of production. This information is generally used to track actual production against production requests and as feedback to the scheduling cycle.

7.2.5 Process segment

Given the previous definitions, a process segment is the collection of capabilities needed for a segment of production, independent of any particular product. This may include material, energy, personnel, or equipment capabilities as presented in 7.6.1.

There is a relationship among the collection of process segments, the product segment listings for each product, and the segment requirements for any specific production request. This concept is illustrated in Figure 13. A product segment references a process segment known to production, and a segment requirement references a known product segment of the product being manufactured.

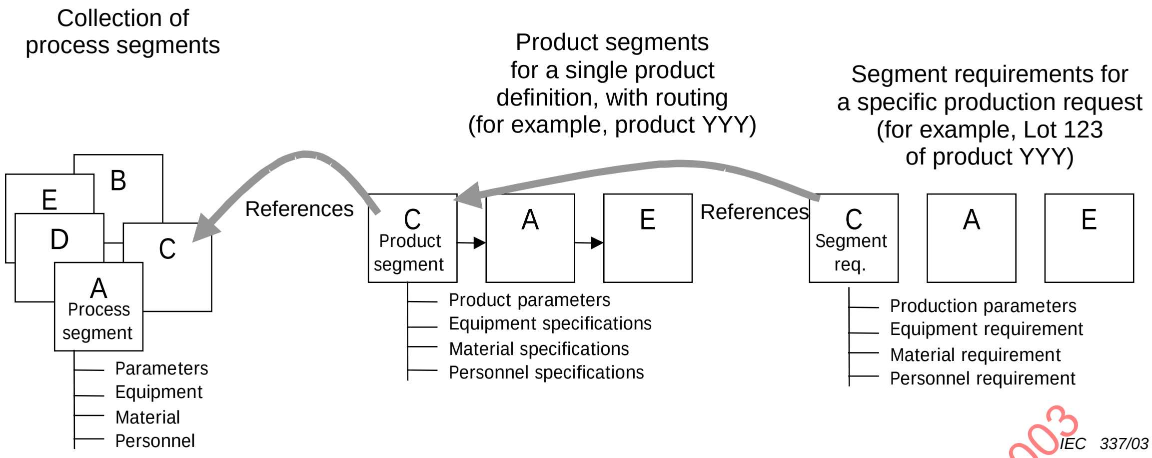


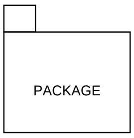
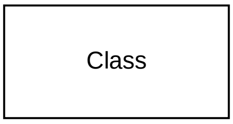
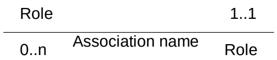
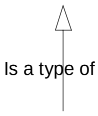
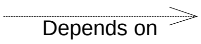
Figure 13 – Segment relationships

7.3 Object model structure

The object models are depicted using the unified modelling language (UML) notational methodology, as defined in ISO/IEC 19501-1. The diagrams have been kept simple and as a result a single object may appear on multiple diagrams.

Table 2 defines the UML notations used in the object diagrams.

Table 2 – UML notation used

Symbol	Definition
	Defines a package, a collection of object models, state models, use classes, and other UML models. In this document a package is used to specify an external model, such as a production rule model or a reference to another part of the model.
	Defines a class of objects, each with the same types of attributes. Each object is uniquely identifiable or enumerable. No operations or methods are listed for the classes. Attributes with a " - " before their name indicate attributes that are generally optional in any use of the class.
	An association between elements of a class and elements of another or the same class. Each association is identified. May have the expected number or range of members of the subclass, when 'n' indicates an indeterminate number. For example, 0,n means that zero or more members of the subclass may exist.
	Generalization (arrow points to the super class) shows that an element of the class is a specialized type of the super class.
	Dependence (tightly bound relationship between the items) shows that an element of the class depends on an element of another class.
	Aggregation (made up of) shows that an element of the class is made up of elements of other classes.
	Composite shows a strong form of aggregation, which requires that a part instance be included in at most one composite at a time and that the composite object has sole responsibility for disposition of its parts.

7.4 Object model extensibility

The general model for allowing extensibility to the information exchange is through the addition of properties to the objects. There may be sets of extensions that are business specific; for example, the food and beverage business may have commonly understood extensions that relate to nutritional content and caloric content.

7.5 Resources and views

7.5.1 Personnel information

7.5.1.1 Personnel model

The personnel model contains the information about specific personnel, classes of personnel, and qualifications of personnel. Figure 14 illustrates the personnel model. This corresponds to a resource model for personnel, as given in ISO 15704 and ISO 15531-1.

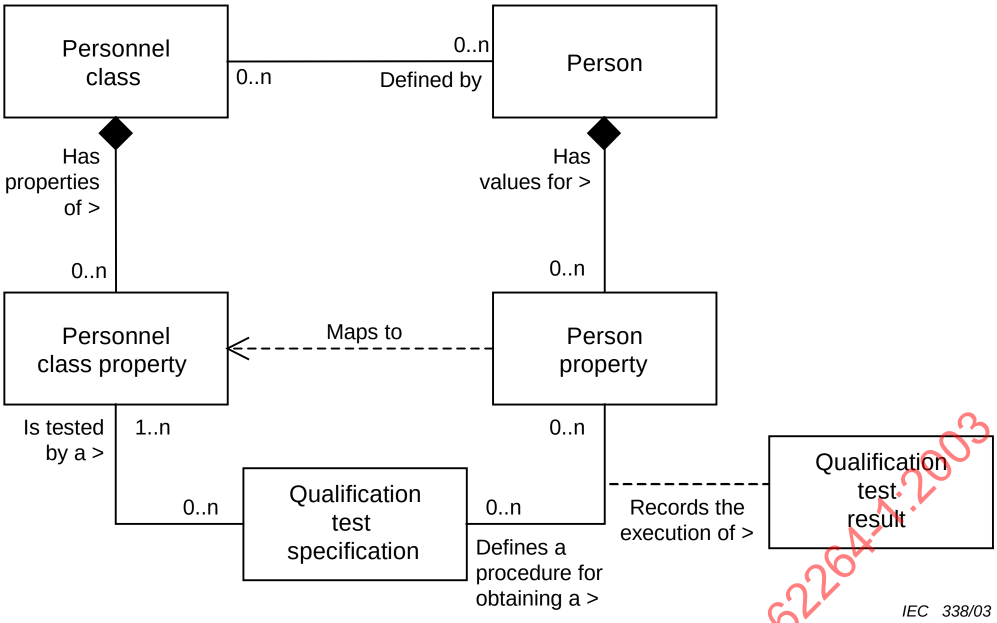


Figure 14 – Personnel model

7.5.1.2 Personnel class

A representation of a grouping of persons with similar characteristics for purposes of scheduling and planning shall be known as a personnel class. Any person may be a member of zero or more personnel classes.

NOTE Examples of personnel classes are cook machine mechanics, slicing machine operators, cat-cracker operator, and zipper line inspectors.

7.5.1.3 Personnel class property

Properties of a personnel class shall be shown as personnel class properties. Each personnel class shall have zero or more recognized properties.

NOTE Examples of personnel class properties for the personnel class operators are class 1 certified, class 2 certified, night shift, and exposure hours.

Production requests may specify required personnel class property requirements for a product segment.

7.5.1.4 Person

A representation of a specifically identified individual shall be presented as a person. A person may be a member of zero or more personnel classes.

Person shall include a unique identification of the individual

7.5.1.5 Person property

Properties of a person shall be listed as person properties. Each person shall have zero or more person properties. These specify the current property values of the person for the associated personnel property.

NOTE For example, a person property may be night shift and its value would be available, and a person property may be exposure hours available and its value would be 4.

Person properties may include the current availability of a person and other current information, such as location and assigned activity, and the unit of measure of the current information.

7.5.1.6 Qualification test specification

A representation of a qualification test shall be presented as a qualification test specification. A qualification test specification may be associated with either or both a personnel class property or person property. This is typically used where a qualification test is required to ensure that a person has the correct training and/or experience for specific operations. A qualification test specification may test for one or more properties.

A qualification test specification shall include

a) an identification of the test;
b) a version of the test;
c) a description of the test.

7.5.1.7 Qualification test result

The results from a qualification test for a specific person shall be given as a qualification test result.

A qualification test result shall include

d) the date of the test;
e) the result of the test (for example, passed or failed);
f) the expiration date of the qualification.

7.5.2 Equipment information

7.5.2.1 Equipment model

The equipment model contains the information about specific equipment, the classes of equipment, equipment capability tests, and maintenance information associated with equipment. Figure 15 illustrates the equipment model. This corresponds to a resource model for equipment, as given in ISO 15704 and ISO 15531-1.

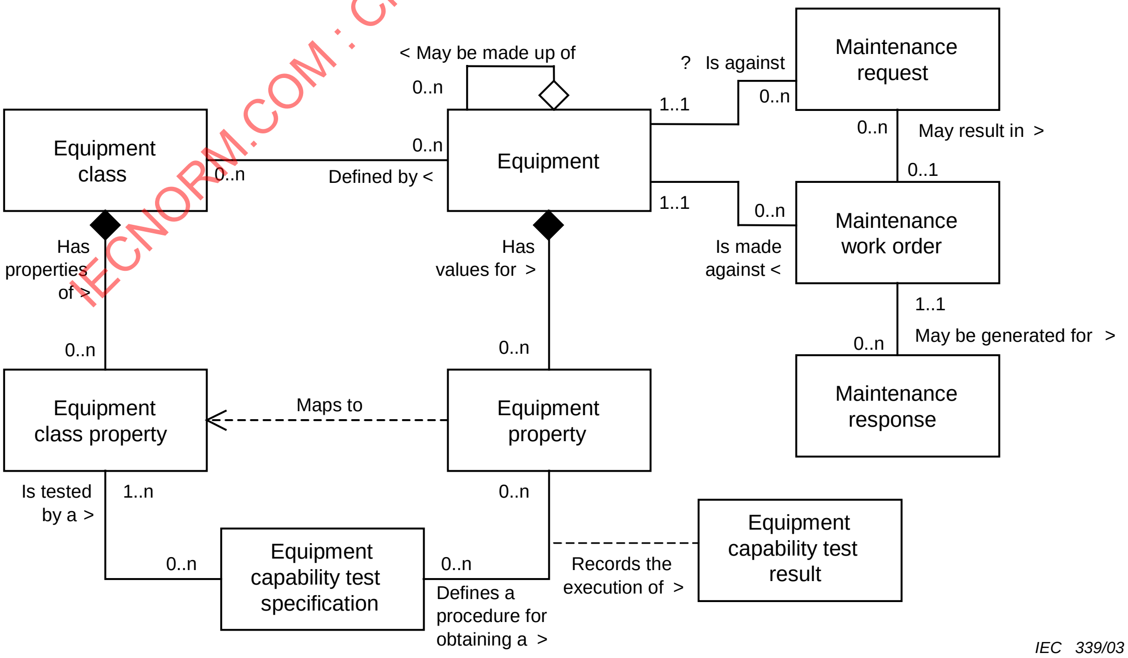


Figure 15 – Equipment model

7.5.2.2 Equipment class

A representation of a grouping of equipment with similar characteristics for purposes of scheduling and planning shall be used as an equipment class. Any piece of equipment may be a member of zero or more equipment classes.

NOTE Examples of equipment classes are reactor unit, bottling line and horizontal drill press.

7.5.2.3 Equipment class property

Properties of an equipment class shall be listed as equipment class properties. Each may have zero or more recognized properties.

NOTE Examples of equipment class properties for the equipment class reactor unit may be lining material, BTU extraction rate and volume.

Production requests may specify equipment property requirements for a product segment.

7.5.2.4 Equipment

A representation of the elements of the equipment hierarchy model shown in 5.3 shall be known as equipment. Equipment may be a listing of sites, areas, production units, production lines, work cells, process cells, or units.

Equipment may be made up of other equipment, as presented in the equipment hierarchy model. For example, a production line may be made up of work cells.

NOTE Examples of equipment are reactor unit #1, bottling line #1 and horizontal drill press #4.

7.5.2.5 Equipment property

Properties of equipment shall be listed as equipment properties. An equipment shall have zero or more equipment properties. These specify the current property values of the equipment for the associated equipment class property. Equipment properties may include a unit of measure.

NOTE 1 For example, an equipment class property may be volume with a value of 50 000 with a unit of measure of litres, an equipment property may be lining material with a value of glass.

NOTE 2 Examples of equipment properties are

- the current availability of equipment;
- other current information, such as when calibration is needed;
- maintenance status;
- the current state of the equipment;
- performance values.

7.5.2.6 Equipment capability test specification

A representation of a capability test shall be presented as an equipment capability test specification. An equipment capability test specification may be associated with an equipment property. This is typically used where a test is required to ensure that the equipment has the rated capability. An equipment capability test specification may test for one or more equipment properties.

An equipment capability test specification shall include

a) an identification of the test;

b) a version of the test;

c) a description of the test.

7.5.2.7 Equipment capability test result

The results from a qualification test for a specific piece of equipment shall be shown as an equipment capability test result.

An equipment capability test result shall include

a) the date of the test;

b) the result of the test (passed-failed or quantitative result);

c) the expiration date of the test.

7.5.2.8 Maintenance information

The overlap of information between manufacturing control and maintenance is in the equipment area. This is represented as maintenance requests, maintenance responses, and work orders associated to specific equipment.

7.5.2.9 Maintenance request

A request for maintenance shall be presented as a maintenance request. A maintenance request shall be made against specific equipment. There may be many outstanding maintenance requests against a piece of equipment.

Maintenance requests shall include

a) the person who made the request;

b) the date and time of the request;

c) the data and time of resolution needed;

d) the equipment associated with the request;

e) a description of the request;

f) a priority.

7.5.2.10 Maintenance work order

Work done against a maintenance request shall be presented as a maintenance work order. Zero or more maintenance work orders may be generated from a maintenance request.

Maintenance work orders shall include

a) the associated person or personnel class assigned;

b) the assigned priority of the work order;

c) the status of the work order (for example, pending, in process).

7.5.2.11 Maintenance response.

A response to a maintenance request shall be presented as a maintenance response. A maintenance response shall be made against a maintenance work order.

Maintenance responses shall include

a) the date and time of the response;

b) the person who responded to the work order;

c) a description of the response;

d) the result of the work order.

7.5.3 Material information

7.5.3.1 Material model

The material model lists the actual materials, material definitions, and information about classes of material definitions. Material information includes the inventory of raw, finished, and intermediate materials. The current material information is contained in the material lot and material sublot information. Material classes are used to organize materials. Figure 16 illustrates the material model. This corresponds to a resource model for material, as defined in ISO 10303-1.

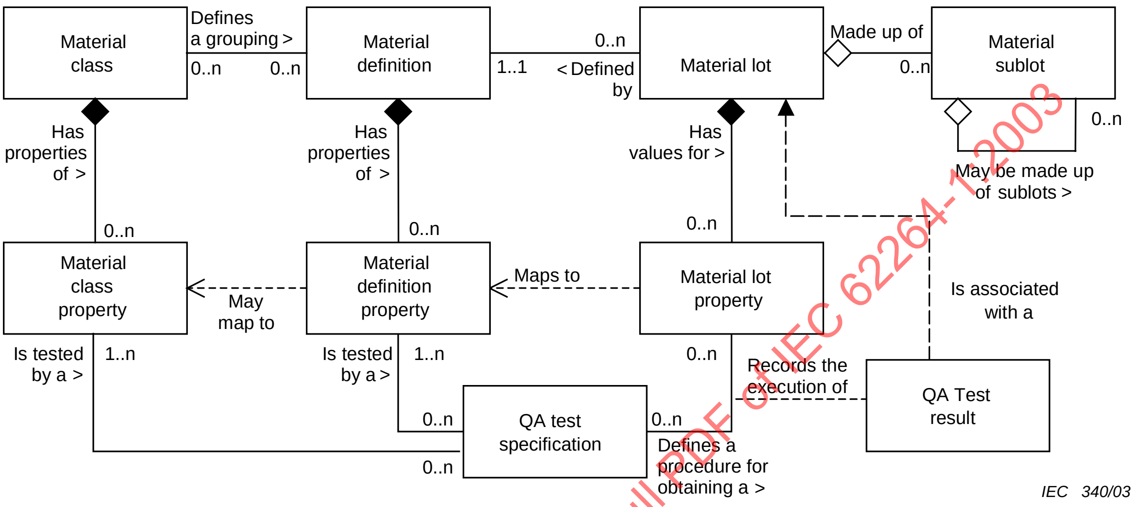


Figure 16 – Material model

7.5.3.2 Material definition

A representation of goods with similar characteristics for scheduling and planning purposes shall be shown as a material definition.

NOTE Examples of these may be city water, hydrochloric acid and grade B aluminium.

The materials may be identified as raw, intermediate, or final and may have other state information, such as availability of safety information.

Any material lot shall be associated with one material definition.

Material definitions may also be related to a production request. The same material may have different representations for different production requests, depending on specific customer requirements.

7.5.3.3 Material definition property

Properties of a material definition shall be defined as material definition properties. A material definition shall be further characterized through zero or more material definition properties.

NOTE Examples of material definition property include density, pH factor or material strength.

Properties may present the nominal or standard values for the material.

7.5.3.4 Material class

A representation of groupings of material definitions for use in production scheduling or processing shall be defined as a material class.

NOTE An example of a material class may be sweetener, with members of fructose, corn syrup and sugar cane syrup. Another example of a material class may be water, with members of city water, recycled water and spring water.

A material definition shall belong to zero or more material classes.

7.5.3.5 Material class property

Properties of a material class shall be presented as material class properties. A material class shall be further characterized through zero or more material class properties.

NOTE Examples of material class properties include density, pH factor, and material strength.

The material class properties often list the nominal, or standard, values for the material. A material property does not have to match a material class property.

7.5.3.6 Material lot

A representation of a uniquely identified specific amount of material, either countable or weighable shall be named as a material lot. A material lot describes the actual total quantity or amount of material available, its current state, and its specific property values.

Materials may be made up of other materials but that association is not described in this model.

A material lot shall include

a) a unique identification of the lot;
b) the amount of material (count or weight);
c) the unit of measure of the material (for example, parts, kg, tons);
d) a location for the material;
e) any status of the lot.

A material lot may be made up of material sublots. Material lots and material sublots may be used for traceability when they contain unique identifications.

7.5.3.7 Material lot property

Each material can have unique values for zero or more material lot properties, such as a specific pH value for the specific lot of material, or a specific density for the lot of material.

7.5.3.8 Material sublot

A material lot may be stored in separately identifiable quantities. Each separately identifiable quantity of the same material lot shall be presented as a material sublot. All material sublots contain the same material lot, so they use the material lot element's property values. A material sublot may be just a single item.

Each material sublot shall contain the location of the sublot and the quantity or amount of material available in the sublot.

Material sublots may contain other sublots.

NOTE For example, a sublot may be a pallet, each box on the pallet may also be a sublot, and each material blister pack in the box may also be a sublot.

A material sublot shall include

a) a unique identification of the sublot;
b) the location of the sublot;
c) the unit of measure of the material (for example, parts, kg, tons);
d) any status of the sublot.

7.5.3.9 QA test specification

A representation of a quality assurance (QA) test shall be shown as a QA test specification. A QA test specification shall be associated with one or more material definition properties. This is typically used where a test is required to ensure that the material has the required property value. A QA test specification may identify a test for one or more material definition properties. Not all properties need to have a defined QA test specification.

QA test specifications may also be related to a production request. The same material may have different specifications for different production requests, depending on specific customer requirements.

A QA test specification shall include

a) an identification of the test;

b) a version of the test;

c) a description of the test.

7.5.3.10 QA test results

A representation of the results from the execution of a quality assurance test shall be presented as a QA test result. A QA test result records the results from a QA test for a specific material lot. The following are some characteristics of QA test results.

a) They shall be related to a material lot.

b) They may be related to a production request.

c) They may be associated with a specific production response.

d) They may be related to a specific process segment.

e) They may include a pass/fail status of the test.

f) They may include quantitative information of the tests.

g) They may include the granting or refusing of an in-process or finished goods waiver request.

h) They may be related to a product characteristic.

QA test results may be associated with a specific production response.

7.5.4 Process segment information

7.5.4.1 Process segment model

The process segment model contains information about the commonly used process segments. Figure 17 illustrates the process segment model.

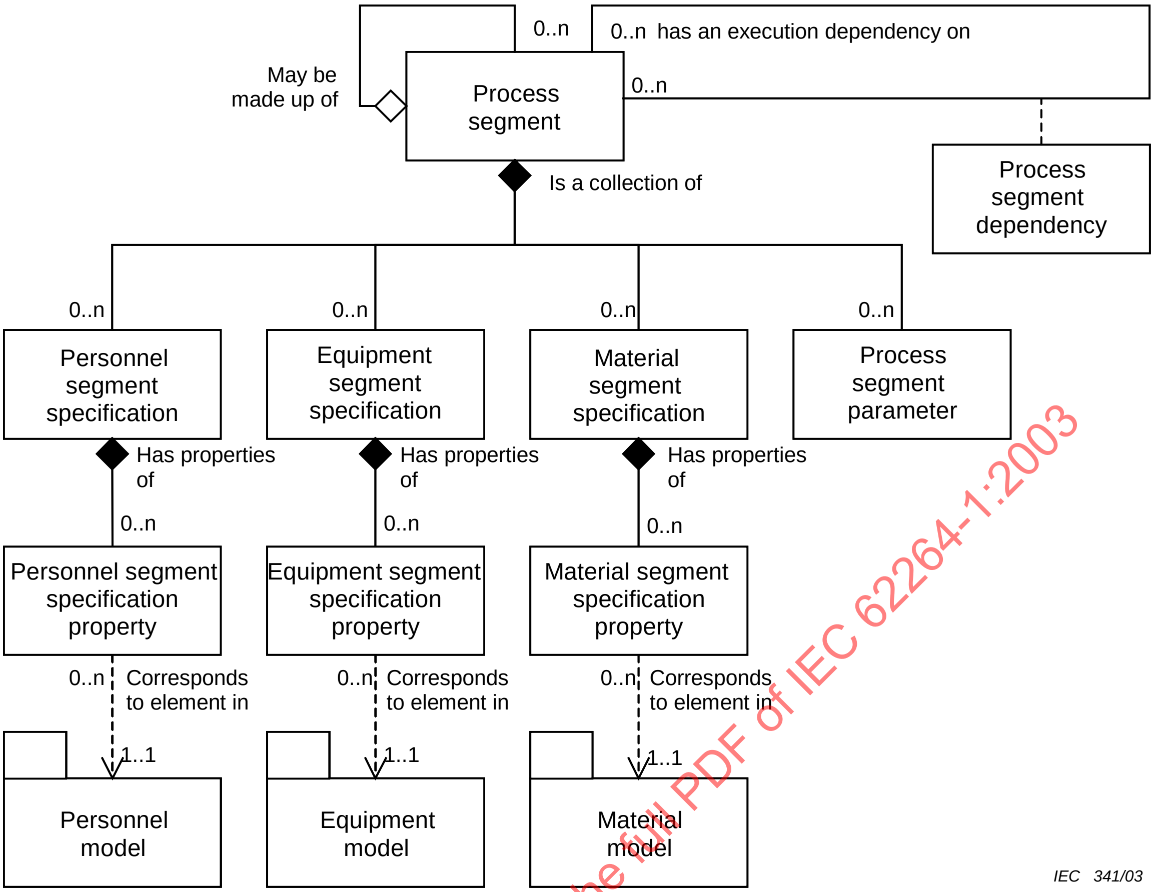


Figure 17 – Process segment model

7.5.4.2 Process segment

A process segment lists the classes of personnel, equipment, and material needed, and/or it may present specific resources, such as specific equipment needed. A process segment may list the quantity of the resource needed.

A process segment is related to a product segment that can occur during production, as presented in the product information model in 7.7. A process segment may relate to one or more products.

Process segment may identify

a) the time duration associated with the capability;

NOTE Five hours or 5 hours/100 kg.

b) constraint rules associated with ordering or sequencing of segments.

A process segment may be made up of other process segments, in a hierarchy of definitions. Figure 17 illustrates the elements of a process segment.

Process segments may contain specifications of specific resources required by the process segment. Process segments may contain parameters that can be listed in specific production requests.

7.5.4.3 Process segment parameter

Specific parameters required for a segment shall be shown as process segment parameters.

NOTE Examples of parameters are product colours, quality requirements, assembly options and packaging options.

7.5.4.4 Personnel segment specification

Personnel resources that are required for a process segment shall be presented as personnel segment specifications.

NOTE Examples include the requirement for three lathe machine operators or a certified inspector.

Specific properties that are required are specified in personnel segment specification properties.

7.5.4.5 Equipment segment specification

Equipment resources that are required for a process segment shall be presented as equipment segment specifications.

NOTE Examples include the requirement for three lathe machines or a certified test chamber.

Specific properties that are required are specified in equipment segment specification properties.

7.5.4.6 Material segment specification

Material resources that are required for a process segment shall be listed as material segment specifications.

NOTE Examples include the requirement for distilled water or hydrochloric acid.

Specific properties that are required are specified in material segment specification properties.

7.5.4.7 Process segment dependency

Process segment dependencies can be used to describe process dependencies that are independent of any particular product.

NOTE For example, a process segment dependency may define that an inspection segment must follow an assembly segment.

7.6 Production capability information

7.6.1 Production capability model

The production capability information is the collection of information about all resources for production for selected times. This information corresponds to the overlap of information depicted in Figure 7. This is made up of information about equipment, material, personnel, and process segments. It describes the names, terms, statuses, and quantities of which the manufacturing control system has knowledge. The production capability information contains the vocabulary for capacity scheduling and maintenance information.

Figure 18 illustrates the model for production capability. A production capability is the collection of personnel capabilities, equipment capabilities, material capabilities, and process segment capabilities, for a given segment of time (current or future), and listed as committed, available, and unattainable.

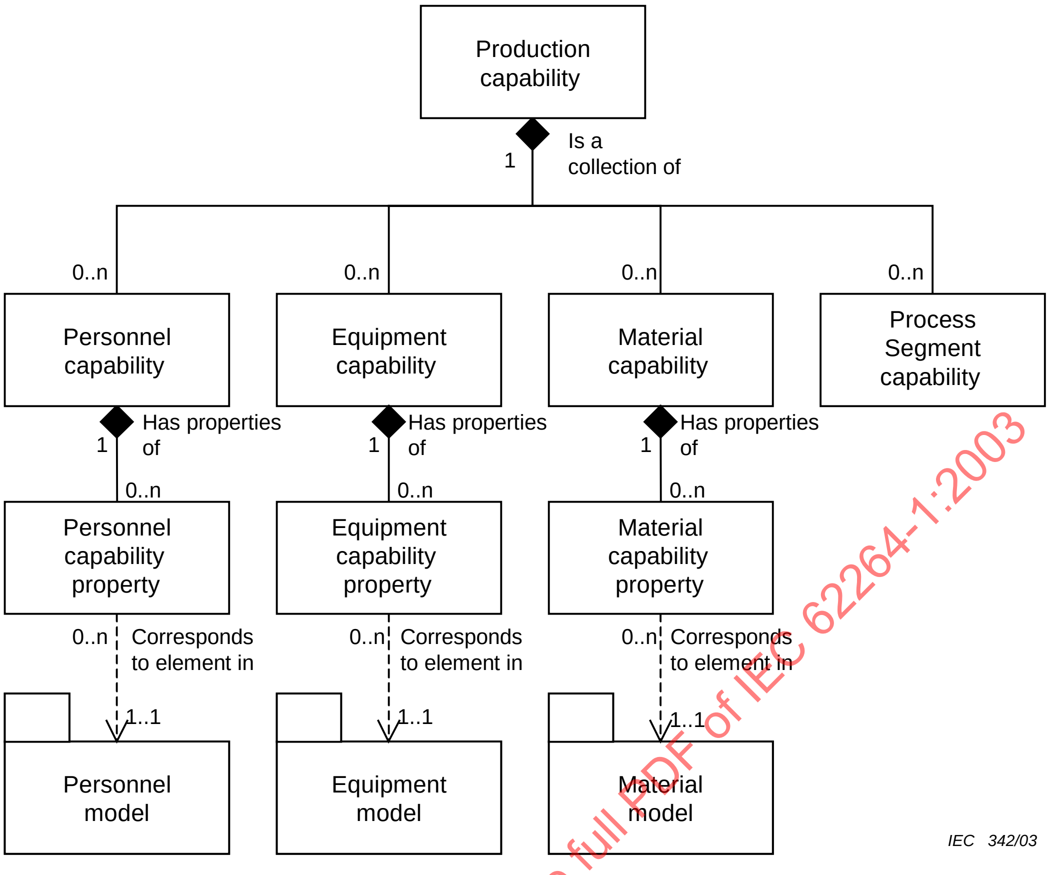


Figure 18 – Production capability model

7.6.2 Personnel capability

A representation of the capability of persons or personnel classes that is committed, available, or unattainable for a defined time shall be known as a personnel capability. Personnel capability may contain references to either persons or personnel classes. Persons and personnel classes are shown in the personnel model in 7.5.1.

Personnel capability shall identify

a) the availability (available, unattainable, committed);

b) the time associated with the availability (for example, third shift on a specific date).

Specific personnel capabilities shall be presented in personnel capability properties. The personnel capability property may include the quantity of the resource referenced.

NOTE For example, 3 horizontal drill press operators available for the third shift on 2000-02-29.

7.6.3 Equipment capability

A representation of the capability of equipment or equipment classes that is committed, available, or unattainable for a specific time shall be used as an equipment capability. Equipment capability may contain references to either equipment or equipment classes. Equipment and equipment classes are presented in the equipment model given in 7.5.2.

Equipment capability shall identify

a) the availability (available, unattainable, committed);

b) the time associated with the availability (for example, third shift on a specific date).

Specific equipment capabilities shall be used in equipment capability properties. The equipment capability properties may include the quantity of the resource referenced.

NOTE For example, 3 horizontal drill presses currently available.

7.6.4 Material capability

A representation of the capability of material that is committed, available, or unattainable for a specific time shall be used as a material capability. Material capability is used for material lots or sublots. This includes information that is associated with the functions of material and energy control (4.0) and product inventory control (7.0). The currently available and committed material capability is the inventory. WIP (work in progress) is a material capability currently under the control of production.

Material capability shall identify

a) the availability (available, unattainable, committed);

b) the time associated with the availability (for example, third shift on a specific date).

Specific material capabilities shall be listed in material capability properties. The material capability properties may include the quantity of the material referenced.

NOTE For example, 3 sublots in building 3 of material starch lot #12345 committed to production for 2000-02-29.

7.6.5 Process segment capability

A representation of a logical grouping of personnel resources, equipment resources, and material that is committed, available, or unavailable for a given process segment for a specific time (see Figure 19) shall be used as a process segment capability.

A process segment capability is related to a product segment that can occur during production, as presented in the product definition model given in 7.7. A process segment capability may relate to one or more products.

Process segment capability shall identify

a) the capability type (available, unattainable, committed);

b) the time associated with the capability (for example, third shift on a specific date).

Process segment capabilities shall be made up of

a) personnel segment capabilities, which lists specific properties required in personnel segment capability properties;

b) equipment segment capabilities, which lists specific properties required in equipment capability properties;

c) material segment capabilities, which lists specific properties required in material segment capability properties.

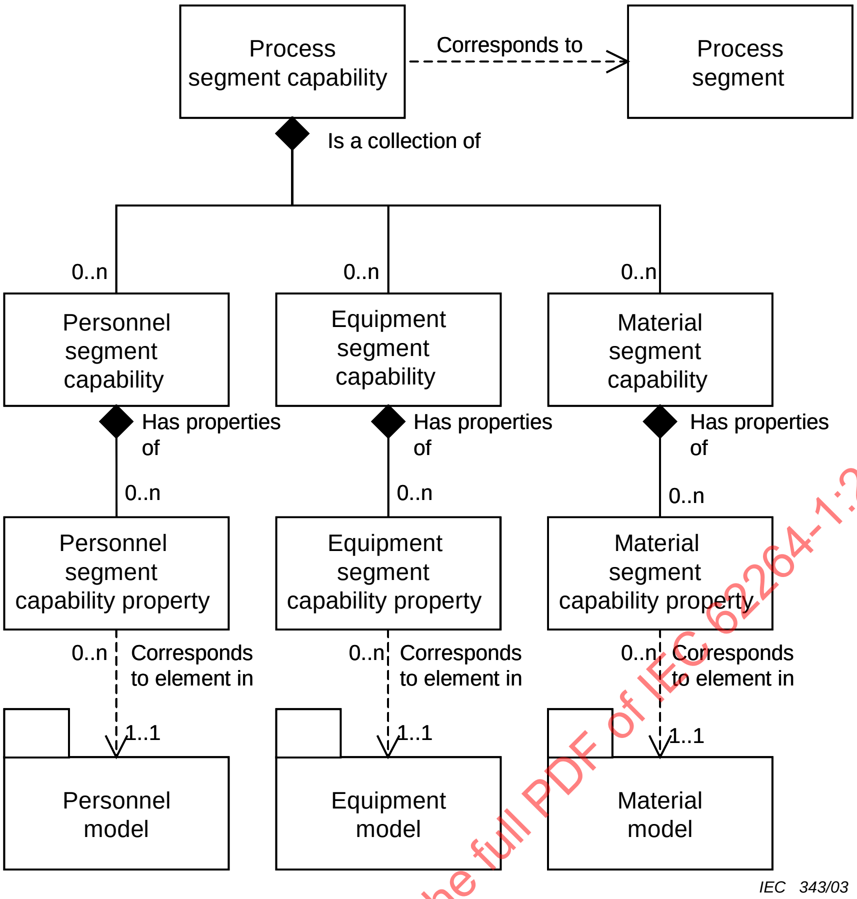


Figure 19 – Process segment capability model

7.6.6 Production capacity types

The collection of available capacity, committed capacity, and unattainable capacity shall be shown as production capacity, as depicted in Figure 20. The production capacity is the theoretical maximum capability available for use in production.

a) Committed capacity defines resources that are committed to future production, usually due to existing schedules and/or materials in production.

b) Unattainable capacity defines resources that are not attainable given the equipment condition (such as equipment out of service for maintenance), equipment utilization (such as 75 % of a vessel filled and the other 25 % not available for other products), personnel availability (such as vacations), and material availability.

c) Available capacity defines the resources that are available for additional production and not committed to production.

d) A capacity may be identified as current, or may be identified for future times, as depicted in Figure 20.

e) Production capacity may change over time as equipment, material, and personnel capability is added, modified, or removed.

f) The capability includes the capacity of the resource.

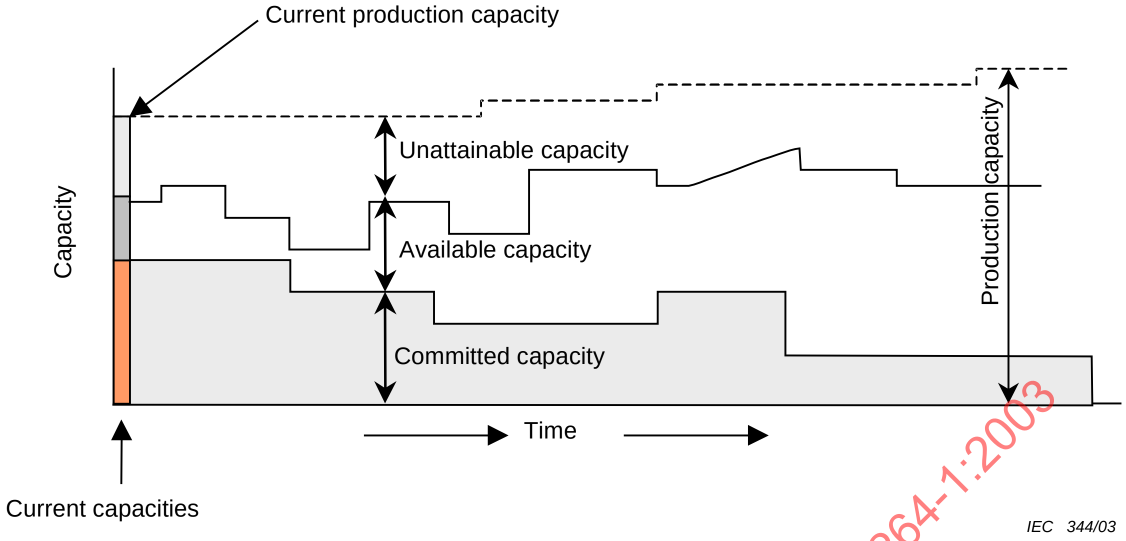


Figure 20 – Current and future capacities

7.7 Product definition information

7.7.1 Product definition model

The product definition information is information shared between production rules, bill of material, and bill of resources. These three external models are represented by packages in Figure 21; their definitions are outside the scope of this document. The model in this clause presents the information shown in the shaded areas of Figure 9.

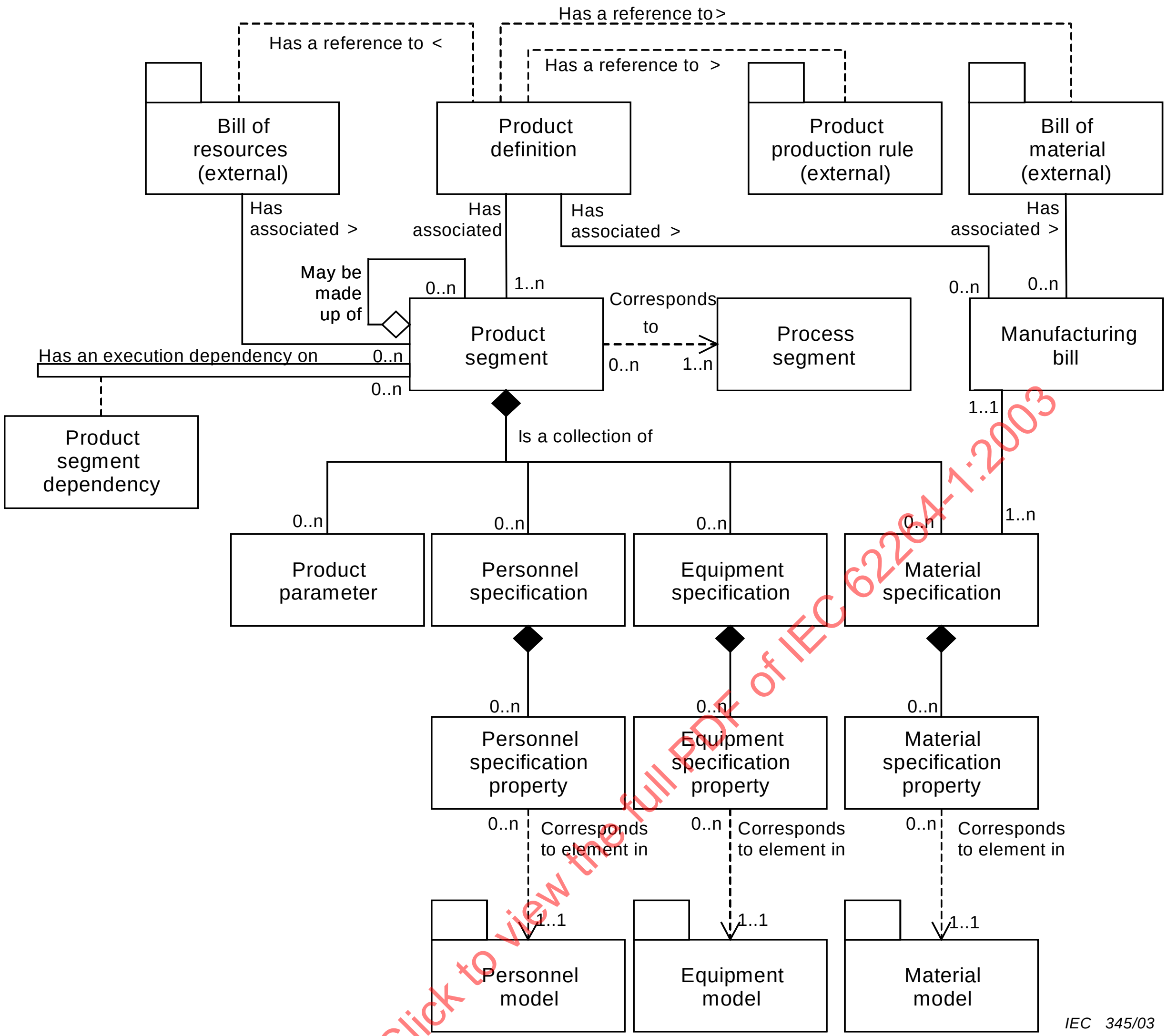


Figure 21 – Product definition model

7.7.2 Product definition

A product definition contains a listing of the exchanged information about a product. The information is used in a set of product segments. A product definition has a reference to a bill of materials, a product production rule, and a bill of resources.

7.7.3 Product segment

The values needed to quantify a segment for a specific product shall be used as a product segment. A product segment identifies, references, or corresponds to a process segment. A product segment is related to a specific product, while a process segment is product independent.

NOTE Examples include the requirement of a specific number of operators with specific qualifications.

The collection of product segments for a product gives the sequence and ordering of segments required to manufacture a product in sufficient detail for production planning and scheduling. The corresponding production rule presents the additional detail required for actual production.

A product segment shall use zero or more resources, which correspond to an equipment specification, a personnel specification or a material specification. A product segment may have parameter values for parameters specified in the corresponding process segment.

7.7.4 Product parameter

The production rule definition is outside the scope of this document, but a production rule may have an associated set of zero or more product parameters per product segment for each product presented. The product parameters present the names and types of the values that may be sent to the control system to parameterize the product.

NOTE Examples of product parameter specifications are pH of 3,5, pressure limit of 35 psi, and flange colour = orange.

Product parameters shall include

a) an identification of the parameter;
b) the units of measure of the parameter value.

Product parameters should include

1) a default value for the parameter;
2) possible ranges of the parameter value – may include alarm or quality ranges;
3) tolerances for acceptable parameter values.

7.7.5 Personnel specification

An identification, reference, or correspondence to a personnel capability shall be presented as a personnel specification. A personnel specification usually specifies personnel class but may specify a person. This identifies the specific personnel capability that is associated with the identified product segment.

A personnel specification shall include

a) an identification of the personnel capability needed;
b) the quantity of the personnel capability needed;
c) the unit of measure of the quantity.

Specific elements associated with a personnel specification may be included in one or more personnel specification properties.

NOTE Examples of personnel specification properties are training level required, specific skill required, and exposure availability.

7.7.6 Equipment specification

An identification, reference, or correspondence to an equipment capability shall be used as an equipment specification. An equipment specification may specify either an equipment class or a piece of equipment. This identifies the specific equipment capability that is associated with the identified product segment.

An equipment specification shall include

a) an identification of the equipment capability needed either as the equipment class needed or specific equipment;
b) the quantity of the equipment capability needed;
c) the unit of measure of the quantity.

Specific elements associated with an equipment specification may be included in one or more equipment specification properties.

NOTE Examples of equipment specification properties are material of construction, maximum material capacity, and minimum heat extraction amount.

7.7.7 Material specification

An identification or correspondence to a material capability shall be presented as a material specification. A material specification specifies a material or a material class. This identifies the specific material specification that is associated with the identified product segment.

A material specification shall include

a) an identification of the material needed;
b) the quantity of the material needed;
c) the unit of measure of the quantity.

Specific elements associated with a material specification may be included in one or more material specification properties.

NOTE Examples of material specification properties are colour range, density tolerance, and maximum scrap content.

7.7.8 Manufacturing bill

The identification of the material or material classes that are needed for production of the product shall be known as a manufacturing bill.

The manufacturing bill includes all uses of the material in production of the product, while the product segment material specification gives just the amount used in a segment of production.

NOTE For example, a manufacturing bill may identify 55 Type C left-threaded screws, where 20 are used in one product segment, 20 in another product segment, and 15 in a third product segment.

7.7.9 Product segment dependency

Product segment dependencies can be used to describe dependencies that are product specific.

NOTE For example, a product segment dependency may define that a wheel assembly and a frame assembly are able to run in parallel.

7.8 Production information

7.8.1 Production information models

Production information is presented in two models, shown in Figure 22 and Figure 23. These correspond to requests for production and responses to the requests, a request for production becomes the schedule and the response becomes the production performance.

7.8.2 Production schedule information

7.8.2.1 Production schedule model

The production schedule shown in Figure 22 represents the hashed information shown in Figure 12.

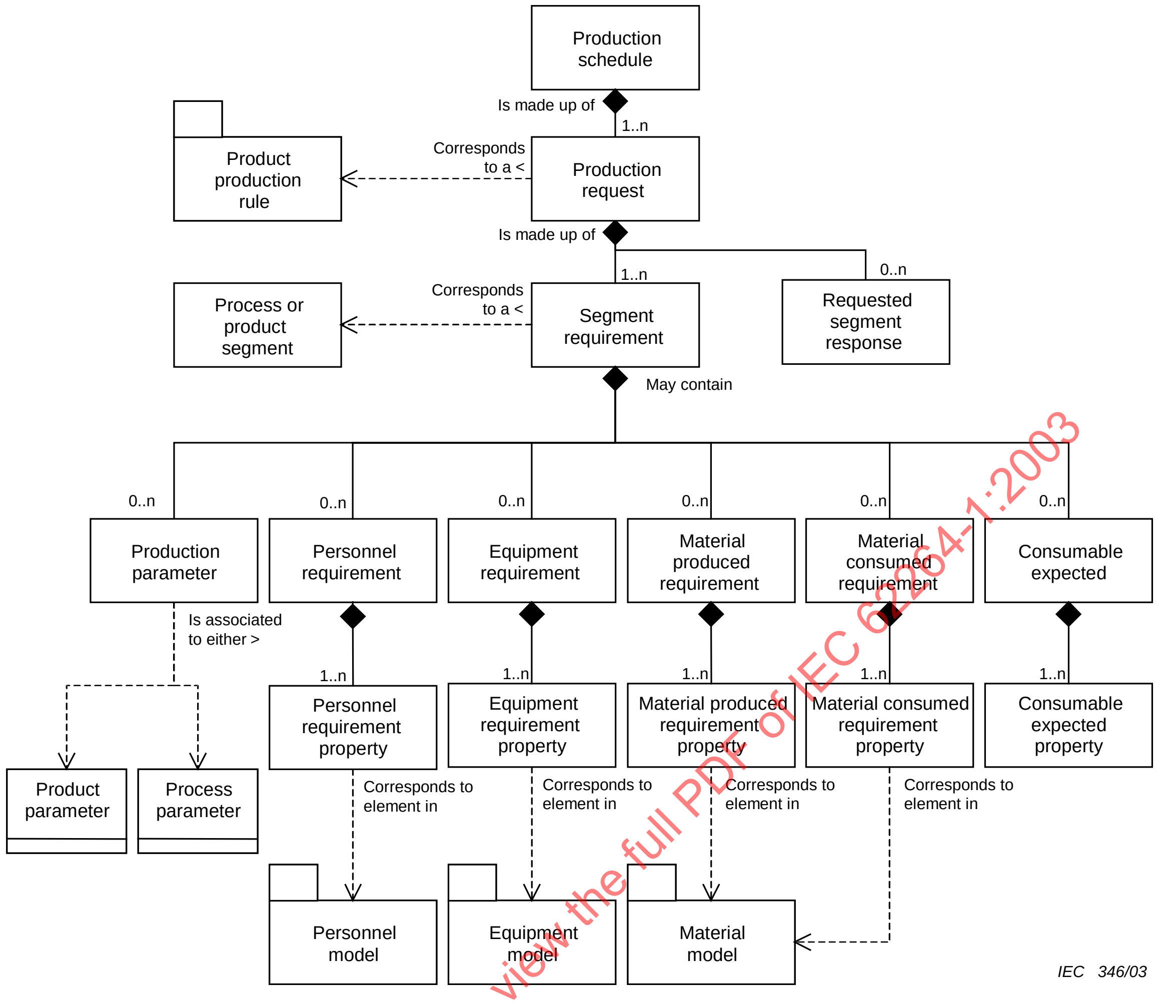


Figure 22 – Production schedule model

7.8.2.2 Production schedule

A request for production shall be listed as a production schedule. A production schedule shall be made up of one or more production requests.

7.8.2.3 Production request

A request for production for a single product identified by a production rule shall be shown as a production request. A production request contains the information required by manufacturing to fulfil scheduled production. This may be a subset of the business production order information, or it may contain additional information not normally used by the business system.

A production request may identify or reference the associated production rule. A production request shall contain at least one segment requirement, even if it spans all production of the product. If not uniquely given by the production rule, then a segment requirement shall contain at least one material produced requirement with the identification, quantity, and units of measure of the material to be produced.

A production request may include

a) when to start production, typically used if a scheduling system controls the schedule;

b) when the production is to be finished, typically used if the manufacturing system controls its internal schedule to meet deadlines;

c) the priority of the request, typically used if exact ordering of production is not externally scheduled;

d) a pack-out schedule;

e) a pre-assigned lot identification for the produced material.

A production request may be reported on by one or more production responses. In some situations, the material identification, production rule identification, and material quantity may be all that is needed for the manufacturing. Other situations may require additional information. The additional information may be described in the production parameters, personnel requirements, equipment requirements, and material requirements.

7.8.2.4 Segment requirement

A production request shall be made up of one or more segment requirements. Each segment requirement shall correspond to, or reference, an identified process segment. The segment requirement identifies or references the segment capability to which the associated personnel, equipment, materials, and production parameters correspond.

The personnel requirement property, equipment requirement property and product parameter shall align with the personnel property, equipment property, and product parameters sent as part of a production request. If the scheduling function sends information that is not understood by the receiving control function, then that information cannot be used within the control function. Likewise the scheduling function has to be able to determine what information can be accepted by the control function.

7.8.2.5 Personnel requirement

The identification of the number, type, duration, and scheduling of specific certifications and job classifications needed to support the current production request shall be identified as a personnel requirement. Properties of the personnel requirement shall be identified as personnel requirement properties.

NOTE 1 Examples of job classification types include mechanics, operators, health and protection, and inspectors.

NOTE 2 For example, there may be a requirement for one operator with a specified level of certification available 2 h after production starts. There would be one personnel requirement for the requirement for the operator and two personnel requirement properties, one for the certification level and one for the time requirement.

A personnel requirement shall include

a) the identification of the personnel needed, such as milling machine operator;

b) the quantity of personnel needed.

Specific elements associated with each personnel requirement may be included in one or more personnel requirement properties.

NOTE Examples of personnel requirement property elements are training and certification, specific skill, physical location, seniority level, exposure level, training certification, security level, experience level, physical requirements, and overtime limitations and restrictions.

7.8.2.6 Equipment requirement

The identification of the number, type, duration, and scheduling of specific equipment and equipment classifications or equipment constraints needed to support the current production request shall be used as an equipment requirement. Properties of the equipment requirement shall be identified as equipment requirement properties. The production request may include one or more equipment requirements. Requirements can be as generic as materials of construction, or as specific as a particular piece of equipment. Each of these requirements shall be an instance of the equipment requirement class.

Each equipment requirement identifies a general class of equipment (such as reactor vessels), a specific class of equipment (such as isothermal reactors), or a specific piece or set of equipment (such as isothermal reactor #7). The specific requirements on the equipment, or equipment class are listed as equipment requirement property objects.

An equipment requirement shall include

a) the identification of the equipment needed, such as milling machine;

b) the quantity of equipment needed.

Specific elements associated with each equipment requirement may be included in one or more equipment requirement properties.

NOTE Examples of equipment requirement properties are material of construction and minimum equipment capacity.

7.8.2.7 Material produced requirement

An identification of a material to be produced from the production request shall be presented as a material produced requirement.

A material produced requirement shall include

a) the total quantity of the material to be produced;

b) the unit of measure of the quantity, such as 5 000 lbs.

Properties of the material produced requirement shall be identified as material produced requirement properties. Specific elements associated with each material produced requirement may be included in one or more material produced requirement properties.

NOTE Examples of material produced requirement properties are

- fat content;
- octane rating;
- delivery locations;
- material lot identification (such as starch lot #45663) to be assigned to the material;
- identification of sublots.

7.8.2.8 Material consumed requirement

An identification of a material to be used in the production request shall be listed as a material consumed requirement.

A material consumed requirement shall include

a) the total quantity of the material to be used;

b) the unit of measure of the quantity, such as 5 000 kg;

c) an acceptable range of the quantity of the material.

Properties of the material consumed requirement shall be identified as material consumed requirement properties. Specific elements associated with each material consumed requirement may be included in one or more material consumed requirement properties.

NOTE Examples of material produced requirement properties include

- material lot (such as starch lot #45663);
- a list of possible material lots that can be used in production, where the production system or operators may select the lot from the list;
- a material definition, such as starch, where the actual lot of material is not specified;
- a material class, such as starch alternates, so that any material lot of that class can be used for production.

7.8.2.9 Consumable expected

An identification of resources that are not normally included in bills of material or are not individually accounted for in specific production requests shall be listed as consumable expected. Depending on the industry these may include water, catalysts, common chemicals, and utilities, such as electricity and steam. These items will often result in direct charges that will usually be considered in costing the product segment. Consumables are often materials that do have an inventory balance.

In some industries consumable expected are not used and the information is included in material consumed requirement.

Consumables do not have lot identifications. Consumables with lot identifications are typically treated as material consumed requirements.

Consumable expected shall include the following information.

a) The identification of the resource expected to be consumed.
b) The total quantity of the resource expected to be consumed.
c) The unit of measure of the quantity.

Properties of the consumable expected shall be identified as consumable expected properties. Specific elements associated with each consumable expected may be included in one or more consumable expected properties.

NOTE Examples of consumable expected properties include

– a unique identification of the consumable, such as river water 01-01-2001;
– a definition of the consumable, such as rubber gloves or cotton balls.

7.8.2.10 Production parameter

Information contained in the enterprise system that is required by the operation system for correct production shall be known as production parameters.

A production parameter shall include

a) an identification of the parameter that matches the product parameter of the product's production rule, such as target acidity;
b) a value for the parameter, such as 3,4;
c) the unit of measure of the parameter, such as pH.

A production parameter should include a set of limits that apply to any change to the value, such as quality limits and safety limits.

Production parameters may be either product parameters that show some characteristics of the product (such as paint colour), or process parameters that present some characteristics of the production process (such as bake time).

NOTE Examples of production parameters are
– quality limits;
– set points;
– targets;
– specific customer requirements (such as purity = 99,95%);
– final disposition of the produced product;
– transportation information;
– other information not directly related to control (such as a customer order number required for labelling or language for labels).

7.8.2.11 Requested segment response

The identification of the information that shall be sent back as a result of the production request shall be used as a requested segment response. This information is of the same form as a segment response, but without actual values.

A requested segment response may include required information, which presents information that shall be reported on from production, such as the actual amount of material consumed.

A requested segment response may include optional information, which presents information that may be reported on from production, such as operator-entered comments.

7.8.3 Production performance information

7.8.3.1 Production performance model

Production performance shown in Figure 23 shows the hashed information shown in Figure 12. Information about production performance is presented in the production performance model (see Figure 23).

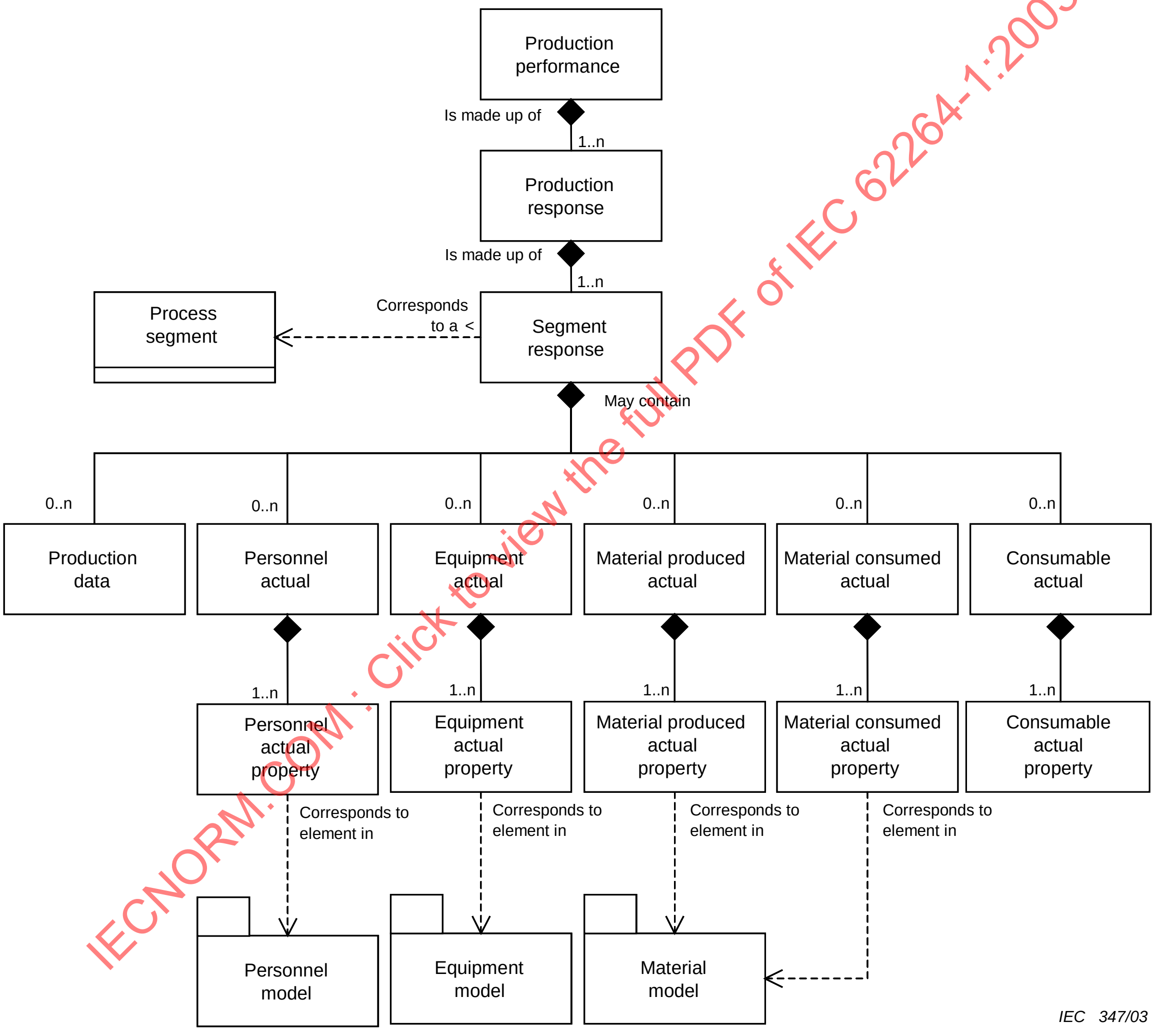


Figure 23 – Production performance model

7.8.3.2 Production performance

The performance of the requested manufacturing requests shall be listed as production performance. Production performance shall be a collection of production responses.

7.8.3.3 Production response

The responses from manufacturing that are associated with a production request shall be used as production responses. There may be one or more production responses for a single production request if the production facility needs to split the production request into smaller elements of work.

NOTE For example, a single production request for the production of 200 gears may be reported on by 10 production response objects of 20 gears each because of manufacturing restrictions.

A production result may include the status of the request, such as the percentage complete, a finished status, or an aborted status.

Production responses contain the items reported back to the business system, at the end of production or during production. The business system may need to know intermediate production response statuses, rather than waiting for the final production response status, because of cost accounting of material produced or intermediate materials.

7.8.3.4 Segment response

Information on a segment of production for a production response shall be used as a segment response. A segment response shall be made up of zero or more sets of information on production data, personnel actual, equipment actual, materials consumed actual, materials produced actual, and consumables actual.

A segment response shall include

a) an identification of the associated process segment;

b) the actual starting time of the segment;

c) the actual stopping time of the segment.

The response actuals may contain attributes that define if the response was required or optional.

7.8.3.5 Production data

Information related to the actual products made shall be presented as production data.

NOTE Examples of production data are

– a customer order number associated with the production request;
– specific commercial notes from operations related to the customer order, such as order complete, order incomplete, or an anticipated completion date and time;
– quality information;
– certification of analysis;
– procedural deviations, such as an identification of an event used in another system and alarm information;
– process behaviour, such as temperature profiles;
– operator behaviour, such as interventions, actions, and comments.

7.8.3.6 Personnel actual

An identification of a personnel capability used during a specified segment of production shall be used as personnel actual. Production functions often require people as a resource to carry out tasks.

Personnel actuals shall include the identification of each resource used, usually identifying a specific personnel capability or personnel class, such as end-point transmission assembly operators, or personnel IDs such as Jean Smith or SS# 999-123-4567.

Specific information about personnel actuals shall be listed in personnel actual properties.

NOTE Examples of personnel actual properties are

– the actual duration of use of the personnel during the product segment, such as 2 h; this information is often needed for actual costing analysis;
– actual monitored exposure times by the personnel during the product segment;

– the location of the personnel after use in the product segment, such as area 51; this information is often used for short-term scheduling of personnel resources.

7.8.3.7 Equipment actual

An identification of an equipment capability used during a specified segment of production shall be identified as an equipment actual. Production functions often require equipment as a resource to carry out tasks.

Equipment actual shall include the identification of the equipment used, usually identifying a specific piece of equipment.

Specific information about equipment actuals shall be listed in equipment actual properties.

NOTE Examples of equipment actual properties are

– the actual duration of use of the equipment during the product segment; this information is often needed for actual costing analysis;
– the equipment condition, after use in the product segment, such as a status of available, out-of-service, or cleaning; this information is often used for short-term scheduling of equipment resources;
– the equipment set-up procedures used for the product segment; this information is often needed for actual costing analysis and scheduling feedback;
– other equipment attributes, such as percentage of available capability used.

7.8.3.8 Material produced actual

An identification of a material produced during a defined segment of production shall be used as a material produced actual. The material may be the final product, an intermediate product that is identified for costing or scheduling purposes, or a scrapped product or material.

Material produced actual shall include

a) the identification of the material produced, usually identifying the material;

   NOTE Examples include resin-89-B, motherboard MP667a.

b) the quantity of the material produced;
c) the unit of measure of the quantity produced.

Specific information about material produced actuals shall be listed in material produced actual properties.

NOTE Examples of material produced actual properties are

– an identification of the material lot or material sublot produced;
– type of material, such as final, intermediate, or co-product.

7.8.3.9 Material consumed actual

An identification of a material used during a specified segment of production shall be listed as a material consumed actual. This material may be identified in the bill of material and can be a raw material or purchased material.

Material consumed shall include

a) the identification of the material consumed;
b) the quantity of the material consumed;
c) the unit of measure of the quantity;

Specific information about material consumed actuals shall be listed in material consumed actual properties.

NOTE Examples of material consumed actual properties are

– the material lot or material sublot consumed;
– comments about the use from operations.

7.8.3.10 Consumable actual

An identification of resources that are not normally included in bills of material or are not individually accounted for in specific production requests shall be used as consumable actual. These include water, catalysts, common chemicals, and utilities, such as electricity and steam. These items will often result in direct charges that will usually be considered in costing the product segment. Consumables are often materials that do have an inventory balance.

Consumable actual shall include

d) the identification of the resource consumed;
e) the quantity of the resource consumed;
f) the unit of measure of the quantity.

Specific information about consumable actuals shall be listed in consumable actual properties.

7.9 Model cross-reference

Figure 24 provides an informative illustration of how the object models inter-relate. The production information presents what was made and what was used. Its elements correspond to information in production scheduling that listed what to make and what to use. The production scheduling elements correspond to information in the product definition that shows what is specified to make a product. The product definition elements correspond to information in the process segment descriptions that present what can be done with the production resources.

The slanted rectangles in Figure 24 represent any of the resources (personnel, equipment, or material) or properties.

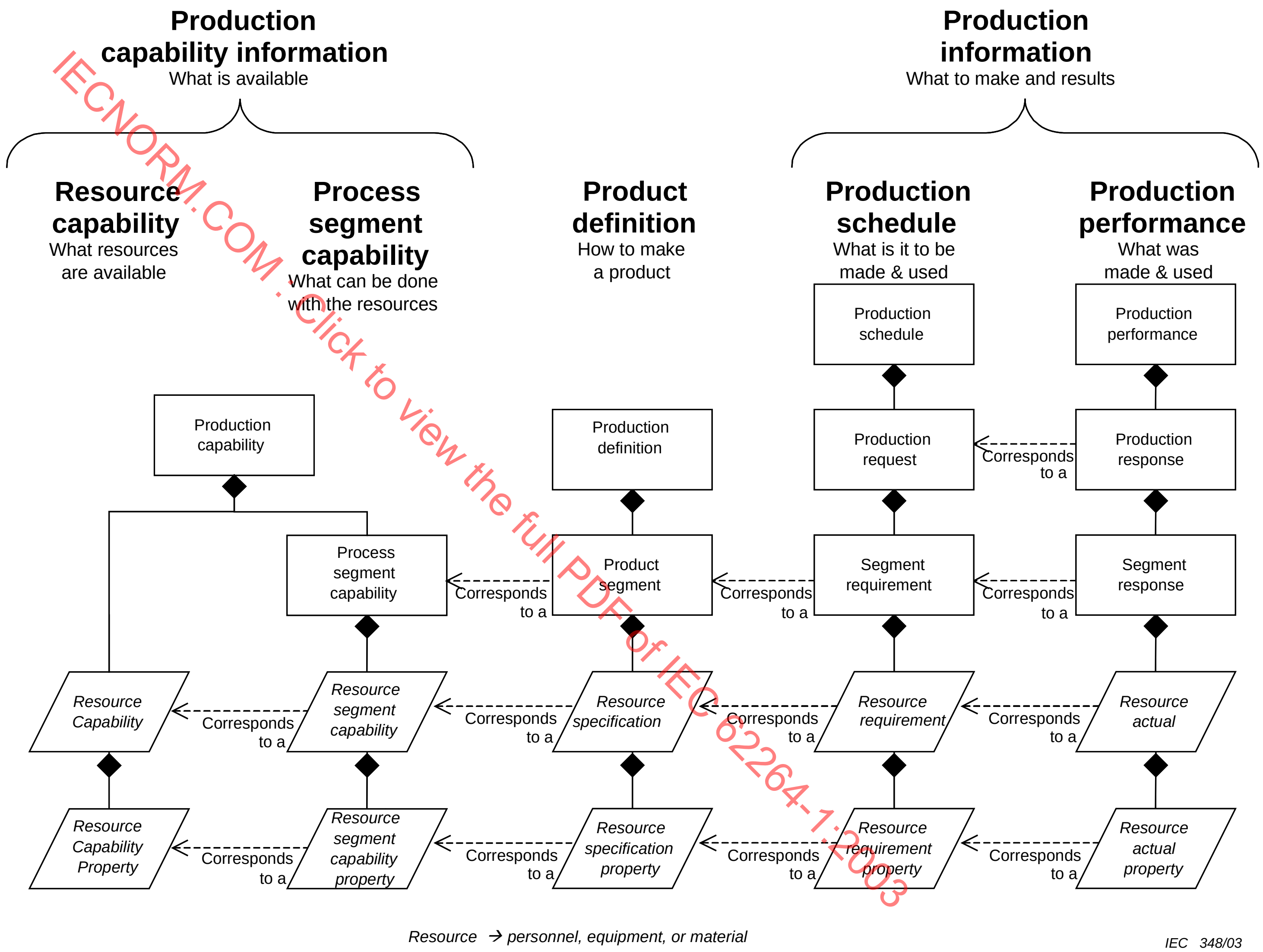


Figure 24 – Object model inter-relations

Table 3 provides a cross-reference between the elements of the information flows in the data flow model and the corresponding clause describing the object model.

Table 3 – Model cross-reference

Data flow model information	From function	To function	Object model clause
6.5.2 Schedule	Production scheduling (2.0)	Production control (3.0)	7.8.2
6.5.3 Production from plan	Production control (3.0)	Production scheduling (2.0)	7.8.3
6.5.4 Production capability	Production control (3.0)	Production scheduling (2.0)	7.6
6.5.5 Material and energy order requirements	Production control (3.0)		Described in terms of the material model, 7.5.3
6.5.6 Incoming order confirmation	Material and energy control (4.0)	Procurement (5.0)	Described in terms of the material model, 7.5.3
6.5.7 Long-term material and energy requirements	Production scheduling (2.0)	Material and energy control (4.0)	Described in terms of the material model, 7.5.3
6.5.8 Short-term material and energy requirements	Production control (3.0)	Material and energy control (4.0)	Described in terms of the material model, 7.5.3
6.5.9 Material and energy inventory	Material and energy control (4.0)	Production control (3.0)	7.5.3
6.5.10 Production cost objectives	Product cost accounting (8.0)	Production control (3.0)	7.7
6.5.11 Production performance and costs	Production control (3.0)	Product cost accounting (8.0)	7.8.3
6.5.12 Incoming material and energy receipt	Material and energy control (4.0)	Product inventory control (7.0)	<Not detailed in object model>
6.5.13 Quality assurance results	Quality assurance (6.0)	Production control (3.0)	7.5.3 and 7.8.3
6.5.14 Standards and customer requirements	Marketing and sales	Quality assurance (6.0)	7.5.3 and 7.7
	Quality assurance (6.0)	Production control (3.0)	
6.5.15 Product and process requirements	Research, development, and engineering	Quality assurance (6.0)	7.7
6.5.16 Finished goods waiver	Functions Order processing (1.0)	Quality assurance (6.0)	<Not detailed in object model> Typically unstructured information handled on an *ad hoc* basis
6.5.17 In-process waiver request	Production control (3.0)	Quality assurance (6.0)	Described in terms of the material model, 7.5.3
6.5.18 Finished goods inventory	Product inventory control (7.0)	Production scheduling (2.0)	7.5.3 and 7.8.3
6.5.19 Process data	Production control (3.0)	Quality assurance (6.0)	7.8.3
6.5.20 Pack-out schedule	Production scheduling (2.0)	Product inventory control (7.0)	7.8.2

Table 3 – Model cross-reference *(continued)*

Data flow model information	From function	To function	Object model clause
6.5.21 Product and process know-how	Research, development, and engineering	Production control (3.0)	7.5.4 and 7.7
6.5.22 Product and process information request	Production control (3.0)	Research, development, and engineering	<Not detailed in object model>
6.5.23 Maintenance requests	Production control (3.0)	Maintenance management (10.0)	7.5.2
6.5.24 Maintenance responses	Maintenance management (10.0)	Production control (3.0)	7.5.2
6.5.25 Maintenance standards and methods	Production control (3.0)	Maintenance management (10.0)	<Not detailed in object model>
6.5.26 Maintenance technical feedback	Maintenance management (10.0)	Production control (3.0)	7.5.2
6.5.27 Product and process technical feedback	Production control (3.0)	Research, development, and engineering	<Not detailed in object model>
6.5.28 Maintenance purchase order requirements	Maintenance management (10.0)	Procurement (5.0)	<Not detailed in object model>
6.5.29 Production order	Functions Order processing (1.0)	Production scheduling (2.0)	<Not detailed in object model>
6.5.30 Availability	Production scheduling (2.0)	Functions order processing (1.0)	<Not detailed in object model>
6.5.31 Release to ship	Product shipping administration (9.0)	Product inventory control (7.0)	<Not detailed in object model>
6.5.32 Confirm to ship	Product inventory control (7.0)	Product shipping administration (9.0)	<Not detailed in object model>

8 Completeness, compliance and conformance

8.1 Completeness

The number of object models and objects supported, as defined in Clause 7, shall determine the degree of completeness of a specification or application.

8.2 Compliance

Any assessment of the degree of compliance of a specification shall be qualified by the following.

a) The use of the terminology defined in Clause 7.

b) A statement of the degree to which they then conform partially or totally to definitions.

In the event of partial compliance, areas of non-compliance shall be explicitly identified.

8.3 Conformance

Any assessment of the degree of conformance of an application shall be qualified by the documentation to which the object models and objects conform.

In the event of partial conformance, areas of non-conformance shall be explicitly identified.

Annex A
(informative)

IEC 62264 relationship with some other standardization work in the manufacturing related area

A.1 Introduction

Very important standardization efforts are being made in various institutional standardization committees or consortia in the area of manufacturing integration or areas related to it. Many standards and standardization efforts are strongly related to IEC 62264.

It is therefore essential to identify the relationship between these standardization works and the similar entities and features they address, in order to review these similarities, the possible overlaps, the differences in context and purpose, and then to

- avoid duplication of work, as well as redundancy (unnecessary overlap);
- determine the needs in term of interfaces for further developments; and
- improve consistency and interoperability between standardization efforts in this area.

NOTE For example, data modelling of a drill:

– ISO 10303 model of a drill is a product model (designer or vendor point of view);
– ISO 15531 model of a drill is a resource model (user or manufacturer point of view);
– ISO 13584 model of a drill is an item belonging to a library (vendor or purchaser point of view).

Most of the features, entities or attributes of a drill are different in these three standards. Some are similar or even the same. The same manufacturing application may make use of the three representations (for example, in a shop-floor a drill may first be a product in a sharpening application and then become a resource when it is used to make a hole). The overlap between these three standards (identical or similar feature) is needed to provide interfaces between them.

Different standards that address the same area have to be consistent (as compatible and interoperable as possible); at least the similar features and concepts, differences, and relationships between them have to be clearly identified and treated.

That is why this annex, after a short presentation of manufacturing integration concerns, provides some rough indication of the relationships between IEC 62264 and a selection of closely related standards developed in ISO TC184, ISO/IEC JTC1, and IEC TC65.

A.2 Manufacturing, modelling and integration

Various approaches, principles, methodologies and tools may be used to achieve integration. Depending on the level, integration may be at one of the following levels (see Bibliography):

- physical;
- application; or
- business.

Depending on the approaches, the integration may be

- top down; or
- bottom up.

Depending on the principles, the integration may be

- full integration (like proprietary software); in that case, the standard is the software or system itself;
- integration by unification (like Windows or Office); in that case, possible standards are methods, architecture, constructs, partial models, and even commercial products; or
- integration by federation (like specific software built around various products); in that case, standards may be the interfaces.

Depending on the tools, integration may be

- data integration (through data modelling);
- organization integration (through enterprise, systems and processes modeling); or
- communication integration (through network and communication modeling and tool; or

  NOTE For example, the ISO seven-layer model.
- integration through interfaces and translations.

Other approaches may also be noted such as integration through enterprise modelling or integration through enterprise-wide decision-making (see Bibliography) that both may be envisioned as part of organization integration. Anyway, all these principles, methodologies and tools are complementary and very often research or standardization workbelongs to more then one type of integration even though one of them is more important.

According to the above, current manufacturing related standardization efforts or standards in ISO and IEC might roughly be classified as follows.

a) Organization integration (enterprises, systems and processes modelling)
   - ISO 15705;
   - ISO 14258;
   - ISO 19439;
   - ISO 19440;
   - ISO 10314;
   - IEC 62264;
   - IEC 61512;
   - ISO/IEC 10746 and ISO/IEC 15414;

   1) Data modelling
      - ISO 10303-1;
      - ISO 15531;
      - ISO 13584;
      - ISO 14649;
      - ISO 13399.
   2) Communications and exchanges
      - ISO/IEC 9506;
      - ISO 15745;
      - Most of the standardization effort of IEC TC65 and ISO TC184/SC5 WG2 and WG5.

3) Translation and interoperability tools
   - ISO 16668;
   - ISO 16100;
   - ISO 18629;
   - ISO 13281.

A.3 IEC 62264 relationship with European and TC184 SC5 WG1 standardization work

The European Standardization Committee, CEN TC310/WG1, has elaborated three European Standards: ENV 40003, ENV 12204 and ENV 13550 with respect to ENV 40003 (or ISO 19439), IEC 62264 can be considered as a reference model situated at partial level of the framework for modelling. Within this framework, IEC 62264 provides not only function and information but also resource descriptions of production planning and control system. With regard to ENV 12204 (or ISO 19440), the modelling languages used to represent the IEC 62264 models are different from the modelling constructs defined in ENV 12204 (or ISO 19440). There is no direct link between IEC 62264 and ENV 13550, because the IEC 62264 models are not required to be computer executable; they are conceptual descriptions of functions, information (including resource information) of the production planning and control system.

Concerning the standards developed in ISO TC184 SC5/WG1, the relationship with ISO 19440 and ISO are the same as those of IEC 62264 with ENV 40003 and ENV 12264.

IEC 62264 makes use of ISO 15704 as one of its main references and may, as a partial model of ISO 19439, be considered as included in an ISO 15704 partial model at the design specification phase of the modelling phase dimension (life cycle dimension) of ISO 15704, ISO 19439 and ISO 14258.

Furthermore, time does not seem to be treated in the same way in IEC 62264 and other ISO TC184 standards. No modelling view is clearly identified in IEC 62264, according to ISO 15704, ISO 14258 and ISO 19439 requests.

The constructs identified in ISO 10314 are very near to the IDEF0 approach, but are completely different from those identified by IEC 62264 (ISO 10314 was not designed for job scheduling).

Some interfaces and translation tools may have to be developed to ensure compatibility and interoperability of IEC 62264 and these standards, especially for view modelling, and possibly with models developed at the requirement phase and implementation phase of ISO 15704 and ISO 19439.

A.4 IEC 62264 relationship with ISO TC184 SC5 WG4 standard

There is no direct link between IEC 62264 and ISO 13281 (MAPLE) because MAPLE is an interoperability tool that gathers software in a MAPLE compliant database after development of appropriate interfaces. There is thus no MAPLE specific model, no MAPLE constructs.

ISO 16100-1 provides a very generic manufacturing model that makes use of ISO 15704 and IEC 62264 as normative references. In its Annex A, ISO 16100-1 provides a summary of IEC 62264. There is no consistency problem between these two standards, because they address two different areas of manufacturing integration (ISO 16100 is more an interoperability tool).

A.5 IEC 62264 relationship with ISO TC184 SC4 standard

Relations between ISO TC184/SC4 standards and IEC 62264 are numerous and important. First of all, IEC 62264 identifies features such as material, equipment, consumables, and finished goods, products that are very near to those described by ISO 10303 and ISO 13584 (and ISO 13399 from TC29/WG34), or features such as resources and capability that are very near to those of ISO 15531. In addition IEC 62264 address a scope (scheduling, process planning), which is very near to that of ISO 15531 and some application protocols of STEP (for example, ISO 10303-214 used in the automotive industry and ISO 10303-212 used in the electrotechnical industry) with a different approach (and probably a different usage) from these standards.

In ISO 10303 any kind of product is modelled; these may include some of the material, equipment, product, and finished goods identified in IEC 62264. The purpose of ISO 10303 is mainly product design; however, some applications of 10303 model inputs or outputs of manufacturing systems (for example, 10303-214). For ISO 13584, products are described as components in a parts library (catalogue) with a sale or purchasing purpose.

ISO 13399 models cutting tool data as machine resources with the support of ISO 13584.

ISO 15531 addresses modelling of resource usage management data with a manufacturing management purpose (including scheduling) at the shop-floor or plant level. For ISO 15531 resources modelled are part of the manufacturing system, thus they cannot include inputs (for example, raw material, consumables) or outputs (for example, product, components, finished goods) of the system. The resource model of ISO 15531 is very generic, including humans, devices, software and data sets that may contribute to the transformation of inputs (raw material component) into outputs (new components, products, finished goods). It excludes time, which is modelled independently in another part of ISO 15531; it also excludes facilities. ISO 15531 also identifies capability and capacity as two different features (see also Annex F).

ISO 18629 is a translation tool between applications. It is based on a manufacturing ontology and may help the translation between IEC 62264 applications and other applications based on ISO TC184 standards (for example, STEP, MANDATE, etc.).

Even where there are time-related entities in the STEP integrated resources they are more related to events than to time itself, which is modelled separately (in a scheduling purpose) in ISO 15531-42.

Most of the ISO TC184/SC4 standards make use of EXPRESS (ISO 10303-11) in their data modelling. That may not be a major concern due to the fact that OMG and ISO TC184/SC4 are working together on a mapping between UML and EXPRESS and the result may be integrated in the next version of UML. In addition, ISO TC184/SC4 is working on the mapping between EXPRESS and XML. A mapping between PSL and XML is also scheduled in a specific part of PSL.

A.6 IEC 62264 relationship with ISO/IEC 10746 and ISO/IEC 15414

The purpose of IEC 62264 is clearly different from the purpose and approach of ISO/IEC 10746 and ISO/IEC 15414. IEC 62264 addresses industrial processes, while the ODP Reference Model (RM-ODP) enables a modeller to specify any information system with 5 separate points of view to obtain rigorous and complete specification. RM-ODP addresses processes as one concept of the model of the enterprise view. RM-ODP identifies four levels of model. From that point of view, if the level M0 addresses the real-world, M1 the model of the real word and M2 a meta-model, IEC 62264 appears at the M1 level, while RM-ODP is at the M2 level.

In addition, while IEC 62264 makes use of model classes for its concepts and makes use of UML notation, RM-ODP uses models only to illustrate its purpose and the use of UML notation is only implicit.

A.7 IEC 62264 relationship with ISO 16668

The Basic Semantics Register (BSR) is a tool to capture the semantics of concepts independently of any naming using rules and guidelines gathered in ISO 16668. This standard is being developed in ISO TC154 WG1 (ISO TC154 is in charge of EDI standards such as TDED). The tool that gathers the Basic Semantic Concepts (BSCs) and Basic Semantic Units (BSUs) and records them is now operational and includes concepts definitions coming from various sources such as UN/EDIFACT, TC184/SC4 and other standardization committees.

This tool is helpful in interoperability by identifying semantic similarities (not based only on keyword matching) between basic concepts.

There is no compatibility or interoperability concern with ISO 16668. Nevertheless, it will be useful to check IEC 62264 concepts with those already collected in the BSR and to populate BSR with some key concepts of IEC 62264.

A.8 IEC 62264 relationship with IEC 61512

The IEC 61512 batch control standard includes a definition of product manufacturing instructions, as defined in recipes. The recipes in IEC 61512 are the equivalent of the production rules in ISO/IEC 62254. The IEC 61512 standard also discusses an interface to production scheduling, but only in general and not to the level of detail defined in IEC 62264. The concepts in IEC 62264 are consistent with the concepts in IEC 61512. In fact IEC 62264 builds on the definitions in IEC 61512 to include non-batch manufacturing and other production areas.

A.9 Reference documents

IEC 61512 (all parts), *Batch control*

IEC 62264 (all parts), *Enterprise-control system integration*

ISO 9506 (all parts), *Industrial automation systems – Manufacturing Message Specification*

ISO 10304 (all parts), *Water quality – Determination of dissolved fluoride, chloride, nitrate, orthophosphate, bromide, nitrate and sulfate ions, using liquid chromatography of ions*

ISO 13281 (all parts), *Industrial automation systems – Manufacturing Automation Programming Environment (MAPLE) – Functional architecture*

ISO 13399 (all parts), *Cutting tool data representation and exchange*

ISO 13584 (all parts), *Industrial automation systems and integration – Parts library*

ISO 14258 (all parts), *Industrial automation systems – Concepts and rules for enterprise models*

ISO 14649 (all parts), *Industrial automation systems and integration – Physical device control – Data model for computerized numerical controllers*

ISO 15531 (all parts), *Industrial automation systems and integration – Industrial manufacturing management data*

ISO 15705, *Water quality – Determination of the chemical oxygen demand index (ST-COD) – Small-scale sealed tube method*[3]

ISO 15745 (all parts), *Industrial automation systems and integration – Open systems application integration framework*

ISO 16100 (all parts), *Industrial automation systems and integration – Manufacturing software capability profiling*

ISO/TS 16668 (2000), *Basic Semantics Register (BSR)*

ISO 18629 (all parts), *Industrial automation systems and integration – Process specification language*

ISO 19439, *CIM systems architecture – Framework for enterprise modelling*[4]

ISO 19440, *CIM systems architecture – Constructs for enterprise modelling*[5]

ISO/IEC 10746 (all parts), *Information technology – Open Distribution Processing – Reference model*

ISO/IEC 15414, *Information technology – Open Distribution Processing – Reference model – Enterprise language* [6]

[3] To be published.

[4] To be published.

[5] To be published.

[6] To be published.

Annex B
(informative)

Business drivers and key performance indicators

B.1 Purpose

This annex contains a collection of business drivers and key performance indicators or issues that have been defined, and used as the potential touch points into the business processes of the users of the standard. These are also called Critical Success Factors. The drivers were used to test the informational content included within the standards. They determined if the communications model adequately addressed the business issue associated with integration.

These business drivers are identified as being critical to the success of the operations of manufacturing companies across a variety of industries. The drivers have been clarified and validated with operating companies and vendors companies. The drivers provide users with the basis from which to determine the usage of the standard based on their particular industry and information system needs.

B.2 History

Key business drivers are the areas of performance that are most critical to an organization's success. Key business driver is a term used in connection with strategic planning and related goal setting. Key business drivers refer to principal organization-level requirements (similar to Mission Essential Task List, or METL, in tactical units), derived from short- and long-term strategic planning. They include customer-driven quality requirements and operational requirements such as productivity, cycle time, deployment of new technology, strategic alliances, supplier development, and research and development. In simplest terms, key business drivers are those things the organization has to do well for its strategy to succeed (see Bibliography).

B.3 Drivers and issues

Business drivers, in a manufacturing facility, generate the need for information to flow between the executive offices and the process or manufacturing floor. Enterprises focus on these business drivers to meet competitive requirements in the marketplace. Business drivers subsequently influence information sent to the production floor or are influenced by information gathered from the production floor.

Business drivers and some information demands have been identified. Additional research and work may be required to clarify the scope and definition of the drivers and information demands for particular users requirements.

There is always some business process that needs information from production, or needs to exercise control of production that drives the need for integration. Integration requires that the production information can be mapped back to the business information.

B.4 Value of standard to business

Manufacturing enterprises are typically dynamic entities. There are continual changes in business processes to meet changing business and legal environments. There are also usually continual changes in production processes, as new technologies and advances in production capabilities emerge. The purpose of this standard is to aid in the separation of the business processes from the production processes. The standard describes information in a way that is business-process independent and production-process independent. Figure B.1 illustrates this concept of a common model that bridges the different business and production processes.

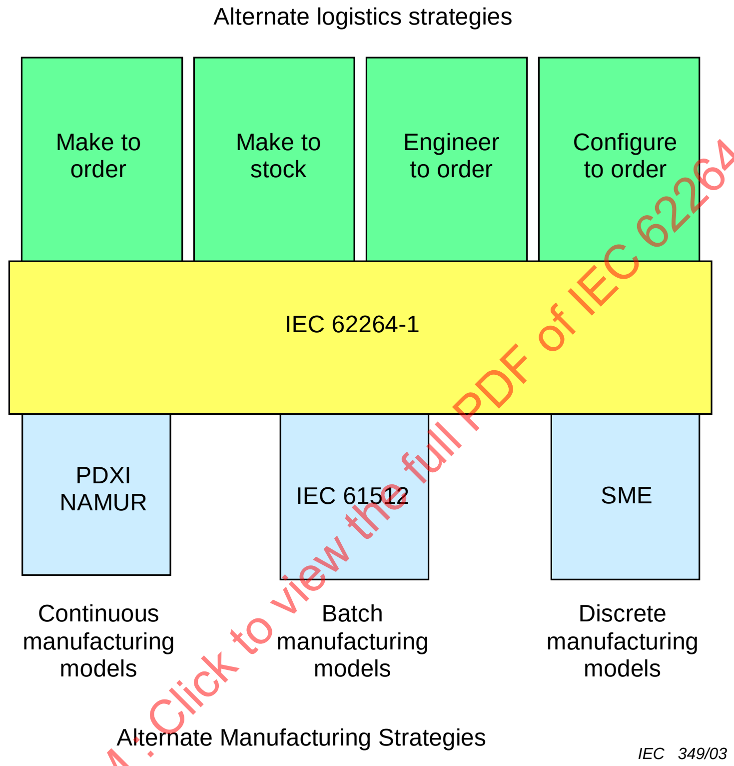


Figure B.1 – Multiple business and production processes

B.5 Vendor-independent exchange

Another value of the standard to business is the separation of exchanged information from specific implementations of manufacturing control systems and specific implementations of business management systems. Manufacturing control systems change when the production processes change, when factories are bought or sold, or when control equipment is updated or replaced. Likewise, business management systems change due to corporate mergers, sell-offs, technology changes, or business or legal changes.

This standard provides vendor-independent methods of describing the information exchanged that can be consistent across changes to manufacturing systems and IT business systems.

B.6 Business drivers

Some terms or labels that describe such business drivers include the following.

B.6.1 Available to promise

Automated available-to-promise is achieved by giving order takers access to inventory and capacity information, and in some cases even vendor information, so that they are able to commit to reliable delivery dates while the customer is still on the telephone.

Information needed for automated available-to-promise:

– current finished goods inventory;
– current production plan for that product;
– realistic capacities of the production facility of that product;
– raw material inventories; or
– raw material purchasing capability.

B.6.2 Reduced cycle time

Cycle time is defined as the time it takes to produce a product from the time the order is placed.

Cycle time refers to responsiveness and completion time measures – the time required to fulfil commitments or to complete tasks (see Bibliography).

The reason that businesses concentrate on minimizing the total cycle time is generally to increase inventory turns. This has the net result of increasing a business's ROA (return on assets).

To reduce cycle time a business identifies areas where most of the delay and waiting occurs and addresses them appropriately. In most cases, the time needed to plan and react to changes is much longer than the time to build. Response time improvement requires all aspects of the planning, scheduling and execution to be taken into account. Reducing the time to plan allows more frequent analysis of forecasts and less dependence on forecasting data.

B.6.3 Asset efficiency

Asset efficiency is a focus on maximizing the effective and cost-effective use of assets in the production of products. The information obtained from the production environment will deliver to an enterprise realistic information on the production capabilities of the plant, train, unit, work cell, etc. Asset efficiency is the desire to better utilize the assets of a company. It usually involves all assets of a company, production, service, administration, support, sales, and marketing. Asset efficiency improves a company's ROA.

Asset efficiency may imply

a) operating to capacity, with timely maintenance;
b) operating equipment efficiently in terms of its operating parameters and its maintenance;
c) measurements such as counter readings per operating hours;
d) time, temperature, pressure/vibration, status or other detailed data;
e) maintenance schedules, operating/maintenance specifications, procedure times.

B.6.4 Agile manufacturing

Agile manufacturing is the ability to reconfigure production assets to meet market demand quickly. This requires the ability to change production using existing plants and equipment.

Agility in manufacturing is the ability to thrive in a manufacturing environment of continuous and often unanticipated change and to be fast to market with customized products. Agile manufacturing uses concepts geared toward making everything reconfigurable.

Agile enterprises may be supported by a networked infrastructure that can link multi-company teams into an integrated virtual corporation.

Agile manufacturing requires that production can quickly respond to changes in product definition and sometimes even change product production processes in mid-stream.

B.6.5 Supply chain optimization

The aim of supply chain management (SCM) is for each player in the supply chain to conduct business with the latest and best information from everyone else in the chain, guiding supply and demand into a more perfect balance. The purpose is to move product from the point of origin to that of consumption in the least amount of time and at the smallest cost.

Supply chain management helps managers do such things as integrate retail channels with manufacturing, drive demand from the point of sale, or eliminate inventory buffers in the distribution chain. SCM extends beyond the walls of the enterprise to suppliers and distributors.

Supply chain management moves to supply chain optimization when the supply chain is used to maximize the effectiveness of the whole, as well as maximizing the effectiveness of the individual parts.

Supply chain optimization involves making complex tradeoffs to satisfy business objectives of reducing operational costs and inventory, improving delivery reliability and response time, and service to the customer.

B.6.6 Quality and traceability

Quality and traceability can be a business driver in some businesses. This may be required by factors such as regulatory compliance, service cost measurement per product improvement, reliability to customers, and human resources tracking of exposure to hazardous items.

Quality and traceability requires that information that is typically kept within a manufacturing system be made available to other parts of an enterprise. This often requires integration of production control and quality assurance, with a corporate quality system.

B.6.7 Operator empowerment

Moving more decision-making to operations sometimes provides a competitive advantage, where operator decisions can have directly measurable financial impacts. The operations floor thus requires a significant increase in information that was accessible only from business offices in the past.

Empowerment: A condition whereby employees have the authority to make decisions and take action in their work areas without prior approval. The act of vesting appropriate authority in the hands of the people nearest the problems needs to be solved.

B.6.8 Improved planning

Improved planning is a key business driver for companies with expensive inventory, time-consuming production but fast customer changes, and variable demand. Improved planning requires access and use of information from throughout the corporation to move planning output from production requests and closer to production schedules.

Improved planning requires continual feedback on actual production and material consumption, as well as continual feedback on demand and inventories.

B.6.9 Summary

The business driver list is not all-inclusive. Any business driver that impacts cost, capacity, compliance, time, or analysis could be added to the list. Additionally, informational components of one business driver will also often be required when addressing other business drivers. The example in Clause B.6 is a basic situation that may provide a starting point for various business drivers.

B.7 Example business driver and information flow

An example of how business drivers and associated production functions generate the need for information flow throughout the business enterprise is described as follows.

The first business driver, available to promise, is a basic business driver. We assume a manufacturing business. In this business, there are certain functional steps that generate information flow between the business enterprise (office) and the production floor (control systems).

We will consider this business to be a general manufacturing facility. In a typical business day, we have customers who are requesting to buy our product. Armed with information from our sales personnel, we progress to the manufacturing floor. Here, information generation may be outlined in the following steps.

a) Current state: Where are we right now? Every business requires knowledge of its current manufacturing and business situation. This information is defined as production from plan and production performance and costs in the standard's data flow model.

b) Target state: Where do we want to go? In the normal course of business, new orders may be received, legal requirements change, and even the weather may have an informational impact through the business. So, there is information that flows between the business practices and manufacturing practices. This information is defined as schedule and pack-out schedule in the standard's data flow model.

c) Transition state: Prior to a change, there is a significant amount of information generated to anticipate how the changes will be managed. And when things actually change, there is history gathering of how the changes actually occur. This information is defined as production performance in the standard's object model.

d) Planning/Scheduling: For this business, the need for information regarding current state, target state and transition environment may occur may times per week, day or operations shift. The frequency of schedule update and the frequency of information uploads will depend on industry needs. A grouping or series of steps A, B, and C may be described as a schedule for the manufacturing floor. Or, the business offices may regard this as a plan. Either way, there is information that has to flow between the two to reconcile issues. This information is defined as production schedule in the standard's object model.

e) Planned versus actual: At certain times, a typical business has to review the actions in steps A through C to see if the business requires adjustments.

This is one method of describing steps that generate information flow between the business offices and the production floor in an available-to-promise enterprise.

Regardless of the specific business driver and associated functions identified, some of the steps described in the make-to-order example above are required to meet all business drivers. For example, many business drivers require the business to know what the current state of its business is.

B.8 Definitions

This clause presents terms sometimes used in describing key business drivers.

B.8.1 Current state reporting

Current state reporting is a collection of information that characterizes the current activity and conditions that exist in the manufacturing environment. This information is collected for the purpose of decision support. This information allows you to understand where you are in relation to current commitments. This information is described in the standard in the current production capability information. Some other terms often used in current state reporting include

a) production request: information on the current production schedule with respect to the actual product that has been requested for production;

b) production quantity: how much of the current production request has been completed (cumulative versus request)?;

c) current rate: what is the instantaneous rate of production of the product requested?;

d) quality: measure of the effectiveness of production - this measurement of product quality, yields data, waste, loss, yield, material, and energy balance);

e) physical equipment status: information on the maintenance state of the equipment, work cells, trains, etc., to determine the current and future availability of that equipment for the production of the next product;

f) predictive maintenance: a predictive determination of when equipment will need maintenance, and a mechanism to perform maintenance on the equipment at or before its expected error or failure time;

g) preventative maintenance: performing maintenance before an error or failure occurs, and a mechanism to perform maintenance, usually on a fixed-time or run-time schedule;

h) inventory status: data on materials that will impact the decision to proceed with the next product's production.

B.8.2 Turnaround time

Turnaround time is the time required to change a production mechanism for the purpose of producing a different product or the same product with different characteristics. The information that will determine the turnaround time includes

a) the current state of all items and current state of the production facility;

b) historical transition times, given the current state of the production facility;

c) standard operating procedures required for switchover;

d) resource requirements versus available (labour, material, equipment).

B.8.3 Campaigning

Campaigning is the planning of the execution of production based on the existing capacity, raw material, resources and production request. A campaign is usually a limited run of product through the production process. Campaigns can last from days to months depending on the products, processes, and production requirements. Control strategy and physical process changes may accompany campaigns.

One important aspect of campaigning is letting production know the sequence of events or scheduled runs ahead of time.

Campaigns generally deal with a single product, or a set of products with compatible processing or product requirements. Campaign planning has to also address previous product characteristics to maximize the agility of the change.

Campaigning is addressed in the standard through production schedules and production requests.

B.8.4 New targets

New targets describe what to make in the next time sequence and when to start – mainly an information demand that the control system places on the enterprise for a production order. New targets are handled in the standard through the production parameters in a production request.

The type of information required for new targets depends on the industry. New targets can be fixed numbers in a discrete environment and can be variable values, such as tables or functions, in continuous environments.

New targets may include the product quality characteristics.

B.9 Data reconciliation

Data reconciliation is a serious issue for enterprise-control integration. The data have to be valid to be useful for the enterprise system. The data are often determined from physical measurements that have associated error factors. This is usually converted into exact values for the enterprise system. This conversion may require manual or intelligent reconciliation of the converted values. Additional problems occur when the type of physical measurement, such as volume, is used to calculate information based on a related value, such as weight. For example, in the refining industry the operations floor changes the density of products, but measures by volume, then uses inference to calculate density and weight.

Systems have to be set up to ensure that accurate data are sent to production and from production. Inadvertent operator or clerical errors may result in too much production, too little production, the wrong production, incorrect inventory, or missing inventory.

Annex C
(informative)

Discussion on models

C.1 Introduction

It has long been the goal of the industrial systems engineer to integrate the operating units of a plant in order to be able to produce that plant's products at minimum unit cost and at maximum overall profit for the company involved. Early work in this field was based on plant design techniques that

a) closely coupled production units;

b) minimized in-process inventories and work in progress; and

c) made maximum use of in-plant energy sources to supply plant energy needs.

While excellent in initial concept, these techniques floundered because of lack of

– unit coordination;
– dynamic response; and
– market sensitivity.

Lack of unit coordination is exemplified by the presence of unpredictable plant interruptions and breakdowns in plant production processes that occur randomly in time and location, thus wreaking havoc with the productivity of such a close-coupled, low-inventory plant. Unforeseen changes in customer requirements, often making obsolete an inflexible manufacturing system, characterize the lack of dynamic response. A lack of market sensitivity is exhibited through limited flexibility in responding to changes in competition, in production cost items (such as energy and raw materials), and in regulatory requirements, any of which can invalidate the initial optimization criteria of a plant's design.

More recently, the trend in systems integration has been toward the use of automatic control in its broadest sense (including dynamic control, scheduling and the closure of information loops) to integrate all aspects of the plant's operations including closing the information loops within the plant. This latter trend then allowed a plant to compensate for unforeseen interruptions and breakdowns in its production processes and also allowed it to modify its product mix and its production rate as its customer's needs and desires changed. All of this is to be done while continually minimizing overall production costs to match the current plant condition. Thus we have the substitution of control and management techniques for initial design procedures in an attempt to counteract the forces that invalidated the original concept, and therefore to still accomplish the original goals.

It is well known which tasks such a system has to be able to carry out to accomplish these goals. Only since the advent of advanced computer technology has it been possible to handle the enormous computational load involved in carrying out these functions in real time and thus hoping to compensate for all of the factors affecting plant productivity and economic return.

Current technology is providing the technical capability to greatly facilitate the development of integrated automated systems. These trends include: (1) distributed, digital, microcomputer-based, first-level dynamic control systems; (2) standard real-time programming languages and configurable programming systems; (3) standard high-speed communications; and (4) corresponding major developments in database management techniques. These have resulted in computer systems that are able to integrate plant management, plant production scheduling, inventory management, individual process optimization, and unit process control for all of a plant's operating units treated as a whole.

However, to accomplish the design and development of such large-scale systems, the aid of overall design and operational standards and accompanying models of such systems are vitally necessary.

C.2 Requirements for the models

It is necessary in such a model to be able to show clearly all of the major operational characteristics of the relationships of the functions involved in a plant management and control system. These include the following, among others.

1) Subordination and aggregation: Which of the functions (a) are dependent upon others for direction (instructions) in carrying out their assigned tasks; and which of them (b) have the major function of supplying information necessary for other functions to help carry out the other's assigned tasks?

   Prime examples of subordination in item 1) are those of

   a) customer order processing;
   b) overall production scheduling;
   c) detailed production scheduling;
   d) production planning;
   e) process control of production unit.

   A prime example of aggregation in item 1) is the continued collection, averaging and smoothing of process control operational data to achieve the information that management needs for overall operational management of the plant and the company.

2) Connectivity and progression: How does data flow in the plant production system? Where does each item of data originate; through what intermediate functions does it flow; and where does the resulting information have its ultimate use?

3) Automatability and innovation: Can the function be automated or mechanized through electronic devices; that is, can the function be mathematically described? Or, does the function require innovation by a human for its ultimate successful completion?

4) Genericity: To the extent possible, the model developed to explain the scheduling and control system necessary for enterprise integration studies should be generic – that is, it should be able to be used to model the control system of any factory or plant, in any industry, anywhere, if at all possible. Each of the models presented here will be generic to the extent possible.

5) Semantics: It is also extremely important that the semantics or meaning of the various terms used in describing the concepts of the model(s) used be interpreted by all readers in exactly the same way. A powerful way to accomplish this is to use an *object model* to accomplish the required concept definition. Clause 7 of this standard presents such a capability.

A popular and effective way of illustrating item 1) above in a model is through the use of a hierarchical layered model, with each of the items of item 1) being subordinate, or below that above it in the list, in the model. At the same time, the aggregation occurs naturally, going upward in the same-layered fashion.

Unfortunately, it has not been possible to date to show all of the required capabilities listed above in one graphical representation of the system. Particularly difficult has been the representation of subordination and aggregation (hierarchical layers) and connectivity and progression (data flow) together. Thus, two separate representations are necessary and the coordination of the resulting two forms has been difficult.

Annex D presents a major table (Table D.12) that points out the coordination between both models in the PRM. Such a procedure appears to be necessary whenever a system is modeled from widely different aspects or views as occurs here.

The concepts of automatability versus innovation (that is, human input required) were handled in the PRM by the concept of external entities. External entities are those functions that are not included in the automated scheduling and control system, but for which a complete data transfer interface is provided. Thus, there are enterprise functions that require human input but cannot be part of the model since the functions involved cannot be modelled. However, they can take part in the plant integration since all needed communications are established.

Figure C.1 illustrates the concept for the PRM. Those functions above the dashed line in this diagram require human involvement. Hence, they are considered external, but contributing, entities in the PRM. Functions below the dashed line are part of the management and control system that can be automated.

All parts of the Purdue Reference Model for CIM that are concerned with the scope of this standard are presented in Annex D.

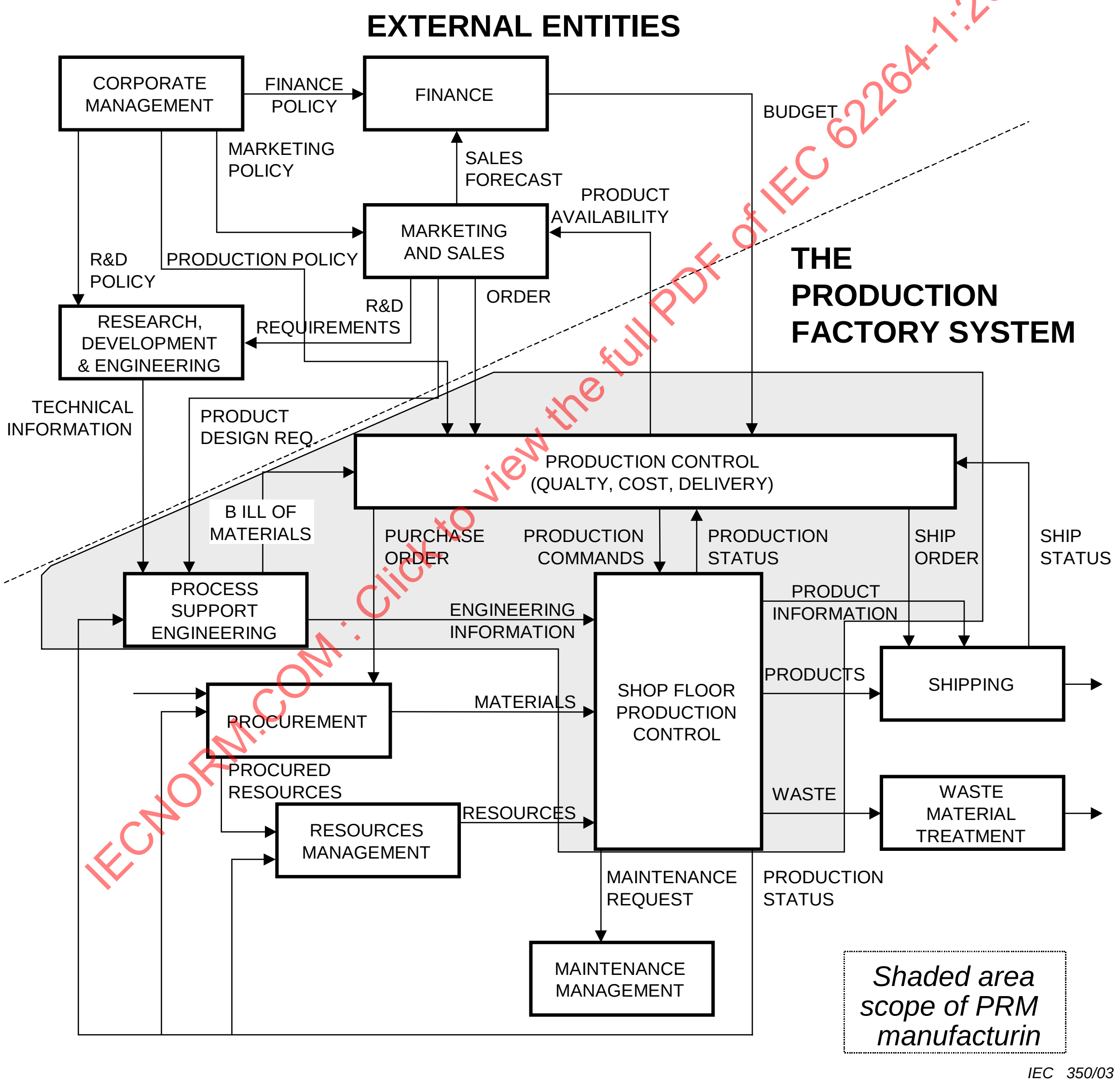


Figure C.1 – Scope for Purdue Reference Model (PRM) for manufacturing

Annex D
(informative)

Selected elements of the Purdue Reference Model

D.1 General

This annex contains selected portions of the complete published version of the Purdue Reference Model (see Bibliography), thereby providing a brief description of the PRM. The annex is included so that the models in this standard may be better understood in the context of the complete plant reference model. Some non-pertinent clauses and tables have been removed. References in the original document have been replaced with footnotes. The figures and tables have also been consecutively numbered.

Figure D.4 has been modified to show a different split between the production scheduling and management information systems and the control computation and control enforcement than in the original publication. The split is now shown between Levels 3 and 4, based on planned changes to the Purdue model as a result of the SP95 analysis, rather than between Levels 2 and 3 of the original.

D.2 Generic list of macro-functions

The overall applicability of the concepts of enterprise integration depends to a great extent on the development of a set of generic tasks, functions and macro functions to describe an enterprise integration system or indeed any enterprise. The Purdue Reference Model for CIM developed two such lists, one based on the scheduling and control hierarchy view and another based on the data flow diagram view of the reference model. It then proceeded to show the correlation of these two apparently widely different lists by cross-referencing the task titles used and their point of application in each view. For the sake of completeness, that material will be reproduced here, along with considerable related material on the architecture.

One of the most important graphical representations is the scheduling and control hierarchy view from the reference model as mentioned above. The hierarchy view that is shown in Figure D.1 categorizes the tasks carried out by the industrial control system for a complete plant or company. Figure D.2 shows that this same diagram with modifications only for the names of the functions involved will characterize the control tasks of either a continuous or discrete manufacturing industry plant. Figure D.3 expands the earlier diagrams to cover a company with multiple plants.

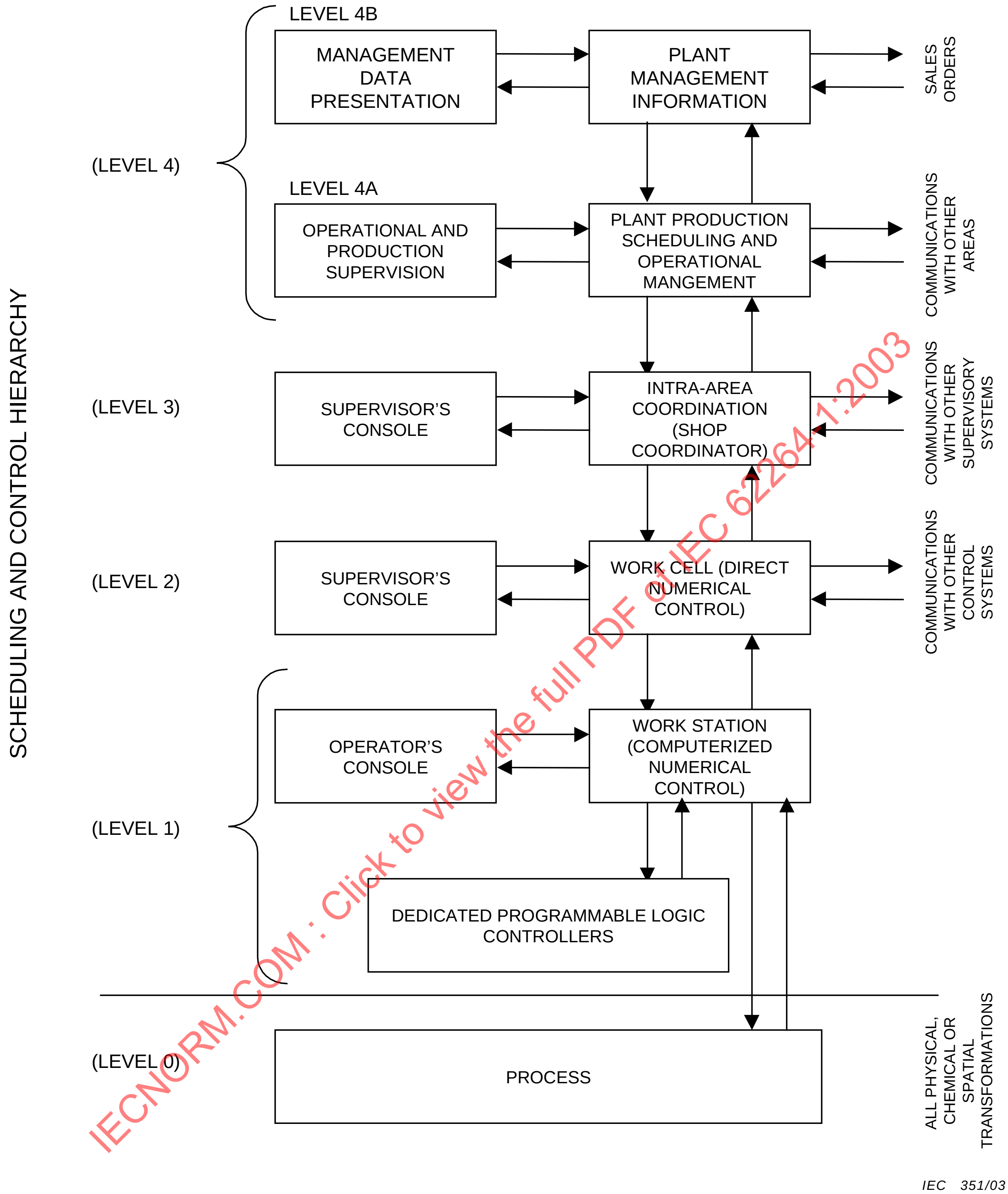


Figure D.1 – Assumed hierarchical computer control structure for a large manufacturing complex

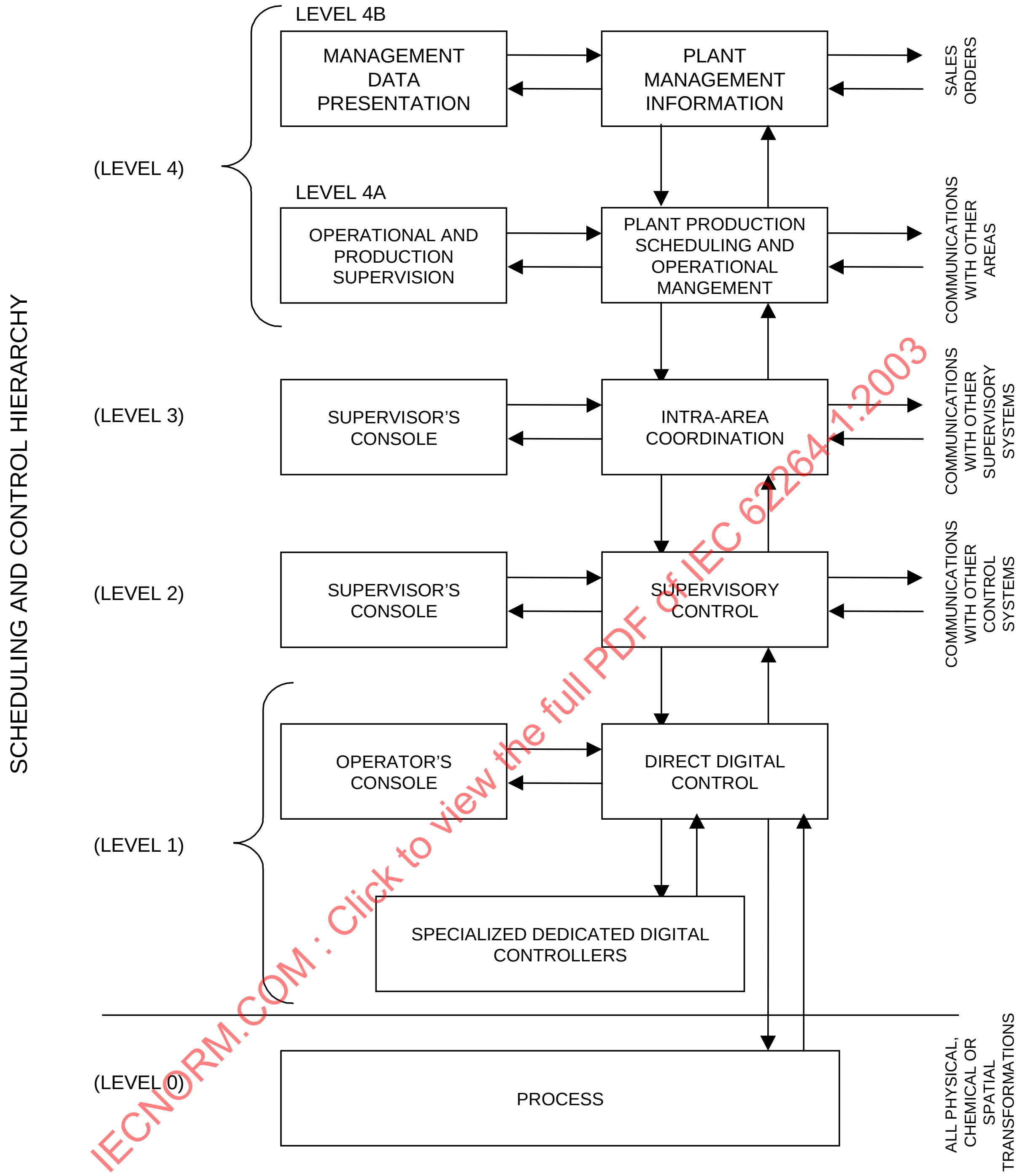


Figure D.2 – Assumed hierarchical computer control system structure for an industrial plant

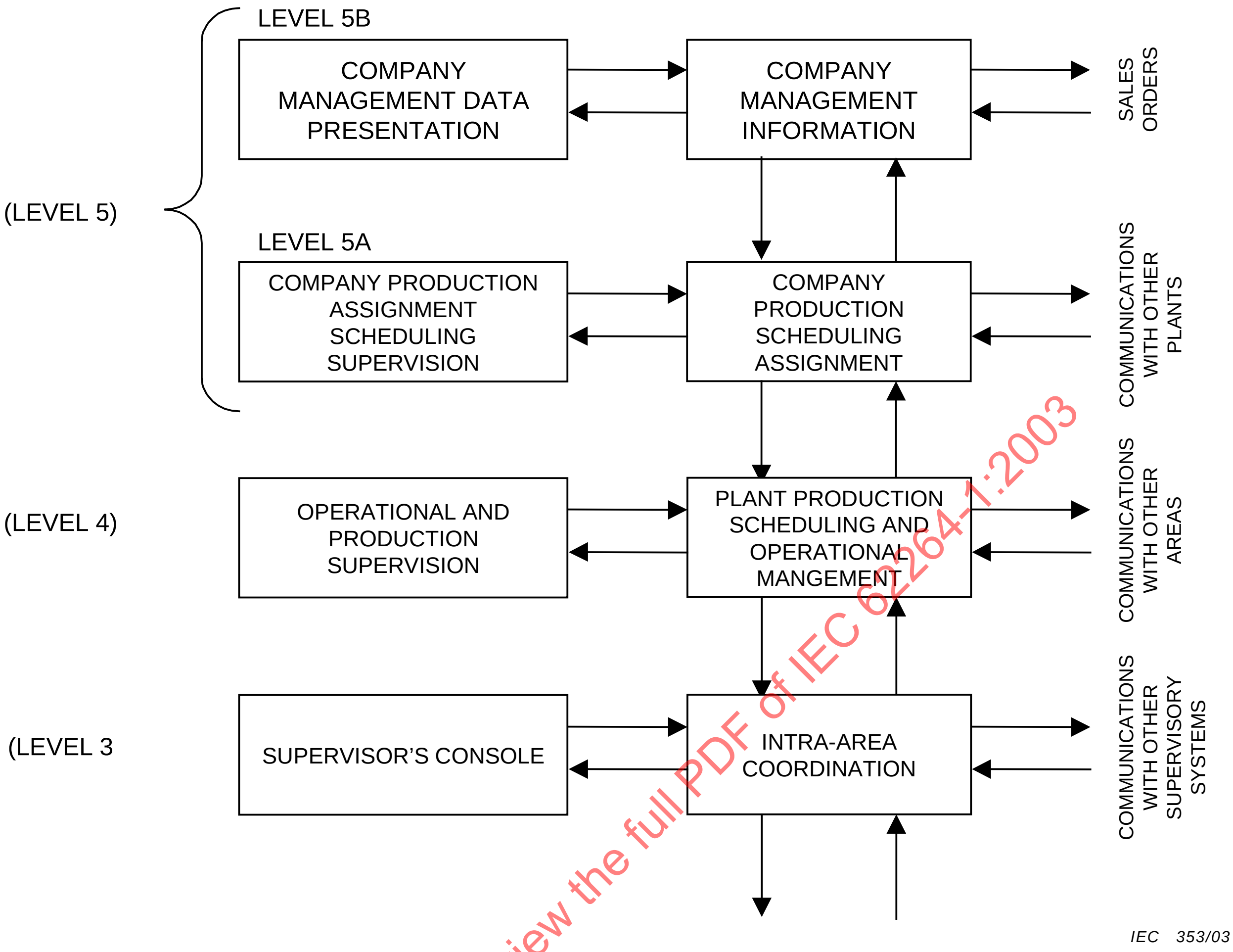


Figure D.3 – Assumed hierarchical computer control structure for an industrial company to show Level 5 and its relationship to Level 4

D.3 One form of generic tasks in a plant-wide hierarchy

Overall automatic control of any large modern industrial plant, regardless of the industry concerned, involves each of the requirements listed in Table D.1.

Thus the automation of any such industrial plant becomes the managing of the plant's information systems to assure that the necessary information is collected and used wherever it can enhance the plant's operations – true information systems technology in its broadest sense.

Another major factor should also be called to our attention here. It has been repeatedly shown that one of the major benefits of the use of digital computer control systems in the automation of industrial plants has been in the role of a control systems enforcer. In this mode, one of the control computer's main tasks is to continually assure that the control system equipment is actually carrying out the job that it was designed to do in keeping the units of the plant production system operating at some best (near optimal) level. That is, to be sure that in the continuous process plant, for instance, the controllers have not been set on manual, that the optimal set points are being maintained, etc. Likewise, it is the task of dynamic control to assure that the plant's production schedule is carried out, i.e., to enforce the task set by the production scheduling function.

Often the tasks carried out by these control systems have been ones that a skilled and attentive operator could have readily done. The difference is the degree of attentiveness to the task at hand that can be achieved over the long run.

As stated earlier, all of this is to be factored into the design and operation of the control system that will operate the plant, including the requirements for maximum productivity and minimum raw material and energy usage. As the overall requirements, both energy and productivity based, become more complex, more sophisticated and capable control systems are necessary.

While the above tasking list is truly generic for any manufacturing plant – continuous or discrete – it is necessary to rearrange it in order to come up with a more compact set of tasks for further discussion.

Therefore, what is needed is an overall system for any manufacturing plant which has the capabilities shown in Table D.2.

In view of Item 2 of Table D.2, Table D.3 presents some observations of the differences in process improvement technologies (i.e., near optimization) for continuous versus discrete optimization.

Because of the ever-widening scope of authority of each of the first three requirements in turn, they effectively become the distinct and separate levels of a superimposed control structure, one on top of the other. Also in view of the amount of information which is passed back and forth among the above four “tasks” of control, a distributed computational capability organized in a hierarchical fashion would seem to be the logical structure for the required control system. This is true of any plant regardless of the industry involved.

As just noted, a hierarchical arrangement of the elements of a distributed, computer-based control system seems an ideal arrangement for carrying out the automation of the industrial plant just described. Figures D.1, D.2 and D.3 lay out one possible form of this distributed, hierarchical computer control system for overall plant automation.

In the context of large industrial plants or of a complete industrial company based in one location, the detailed tasks that would be carried out at each level of the hierarchy can be readily described. These tasks are easily subdivided into those related to production scheduling, control enforcement, systems coordination and reporting, and reliability assurance (Table D.4).

Table D.1 – Generic list of duties of all integrated information and automation systems

1	An extensive system for the automatic monitoring of a large number of different plant variables operating over a very wide range of process operations and of process dynamic behaviour. Such monitoring will detect and compensate for current or impending plant emergencies or production problems.
2	The development of a large number of quite complex, usually non-linear, relationships for the translation of some of the above plant variable values into control correction commands.
3	The transmission of these control correction commands to another very large set of widely scattered actuation mechanisms of various types.
4	Improvement of all aspects of the manufacturing operations of the plant by guiding them toward likely optima of the appropriate economic or operational criteria. Results may be applied to the control correction commands of Item 2 above and/or to the plant scheduling functions of Item 8 below.
5	Reconfiguration of the plant production system and/or of the control system as necessary and possible to assure the applicable production and/or control system for the manufacturing situation at hand.
6	Keeping plant personnel, both operating and management, aware of the current status of the plant and of each of its processes and their products including suggestions for alternate actions where necessary.
7	Reduction of plant operational and production data and product quality data to form a historical database for reference by plant engineering, other staff functions and marketing.
8	Adjusting the plant's production schedule and product mix to match its customers' needs, as expressed by the new order stream being continually received, while maintaining a high plant productivity and the lowest practical production costs. This function is also provided for appropriate plant preventive or corrective maintenance functions.
9	Determination of and provision for appropriate inventory and use levels for raw materials, energy, spares, goods in process and products to maintain desired production and economics for the plant.
10	Assuring the overall availability of the control system for carrying out its assigned tasks through the appropriate combination of fault detection and fault tolerance, redundancy, and fail-safe techniques.
11	Maintaining interfaces with the external entities which interact with the plant production system such as corporate management; marketing; accounting; corporate research, development and engineering; external transportation; suppliers and vendors; purchasing; customers; and contractors.

Table D.2 – An overall plant automation system provides

1	An effective dynamic control of each operating unit of the plant to assure that it is operating at its maximum efficiency of production capability, product quality and/or of energy and materials utilization based upon the production level set by the scheduling and supervisory functions listed below. This thus becomes the control enforcement component of the system. This control reacts directly to compensate for any emergencies which may occur in its own unit.
2	A supervisory and coordinating system, which determines and sets the local production level of all units working together between inventory locations in order to continually improve (i.e., optimize) their operation. This system assures that no unit is exceeding the general area level of production and thus using excess raw materials or energy. This system also responds to the existence of emergencies or upsets in any of the units under its control in cooperation with those units' dynamic control systems to shut down or systematically reduce the output in these and related units as necessary to compensate for the emergency. In addition, this system is responsible for the efficient reduction of plant operational data from the dynamic control units, described just above, to assure its availability for use by any plant entity requiring access to it as well as its use for the historical database of the plant.
3	An overall production control system capable of carrying out the scheduling functions for the plant from customer orders or management decisions so as to produce the required products for these orders at the best (near optimum) combination of customer service and of the use of time, energy, inventory, manpower and raw materials suitably expressed as cost functions.
4	A method of assuring the overall reliability and availability of the total control system through fault detection, fault tolerance, redundancy, uninterruptible power supplies, maintenance planning, and other applicable techniques built into the system's specification and operation.

Table D.3 – Notes regarding optimization (improvement) of manufacturing efficiency

In discrete manufacturing optimization (improvement) is generally carried out in scheduling.
In continuous manufacturing optimization (improvement) is generally carried out both in control and scheduling.

Table D.4 – Summary of duties of control computer systems

I.	Production scheduling
II.	Control enforcement
III.	Plant coordination and operational data reporting
IV.	System reliability and availability assurance
Item I of the above list (production scheduling) corresponds to Item 3 of the list of Table D.2.	
Item II of the above list corresponds to much of Items 1 and 2 of the list of Table D.2.	
Items III and IV of the above list require the cooperative operation of all items of the list of Table D.2. The plant coordination part comprises the detailed interpretation and expansion of the overall production schedule of Item 3 of Table D.2.	

It is our contention that such lists can outline the tasks that are carried out in any industrial plant, particularly at the upper levels of the hierarchy. Details of how these operations are actually carried out may vary drastically, particularly at the lowest levels, because of the nature of the actual process being controlled. We all recognize that a distillation column will never look like or respond like an automobile production line. But the operations themselves remain the same in concept, particularly at the upper levels of the hierarchy.

Thus it is our further contention that despite the different nomenclature in different industries the major differences in the control systems involved is concentrated in the details of the dynamic control technologies used at Level 1 and the details of the mathematical models used for optimization at Level 2.

The differences are thus concentrated in the details of the control and operation of the individual production units (the application entities) of the factory. Commonality is in the support functional entities (computational services, communications, database technology, management structure, etc.). Sensing and communication techniques are exactly the same in both systems. The same optimization algorithms can be used. Computer systems technology and programming techniques should be the same and production scheduling technology should be identical to name only a few.

Thus the duties of the hierarchical computer system can be established as outlined in Table D.4 and in Figure D.4. Therefore Levels 1 and 2 will concentrate on performing Task II of Table D.4, Levels 3 and 4 will carry out Task I and all will be involved in assuring the implementation of Task III and the integrity of Task IV, overall reliability and availability.

Possibilities of major reduction in the costs, development manpower effort, and time required to produce an integrated industrial control system then devolves upon the factors listed in Table D.5.

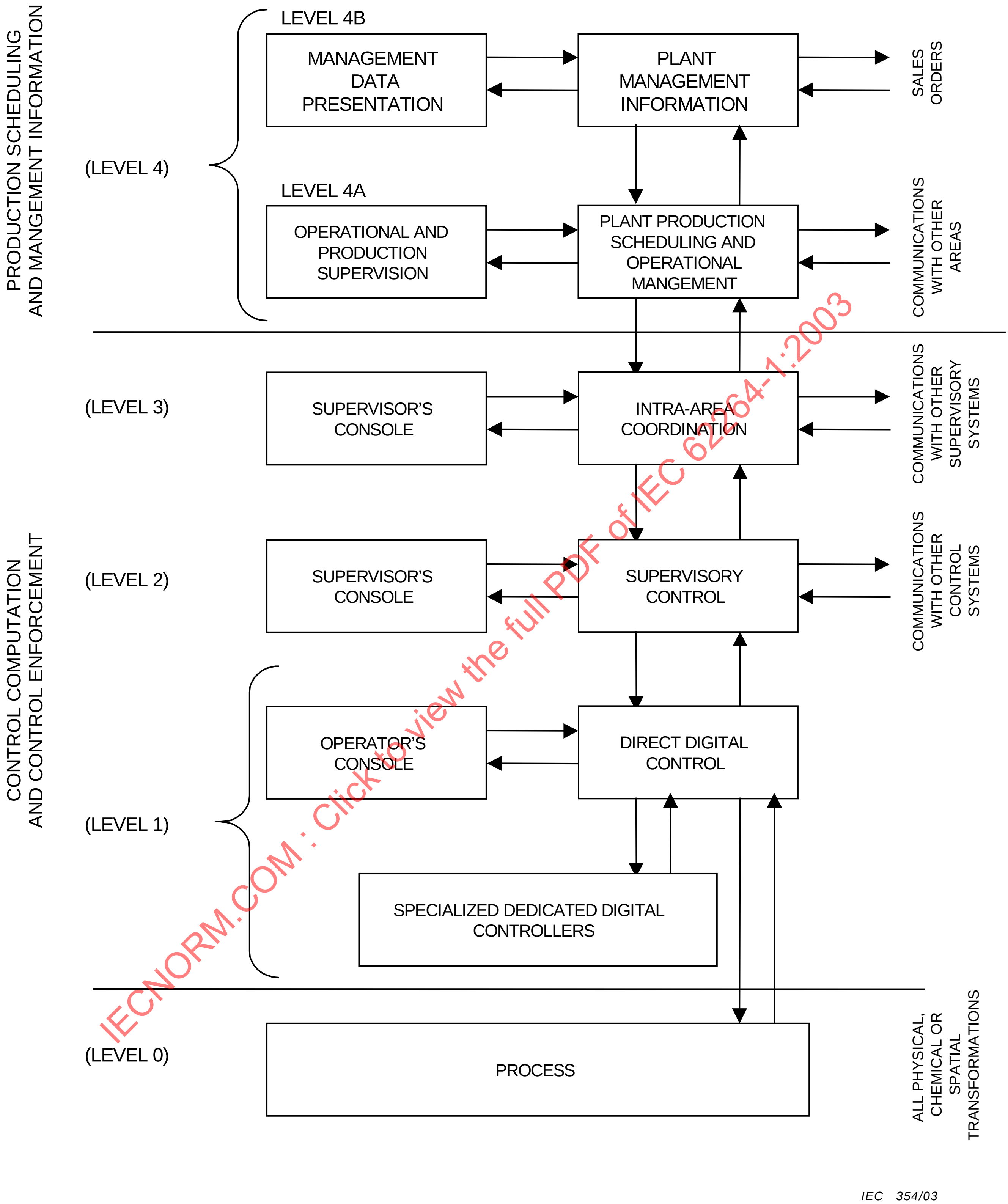


Figure D.4 – Definition of the real tasks of the hierarchical computer control system (as modified)

Table D.5 – Potential factors for facilitating integrated control system development and use

1.	Potential commonality of control system structure in terms of the:	
	A.	Computer systems
	B.	Communications systems
	C.	Database organization
	D.	Relationship to plant management and operational structure (personnel)
2.	Commonality of the techniques of application of:	
	A.	Software engineering and programming
	B.	Communications
	C.	Data base management
	D.	Control systems engineering
	E.	Production scheduling
	F.	Operations research and optimization

Table D.6 – Required tasks of the intra-company management information system (Level 4B of Figure D.1 or Figure D.2 or Level 5 of Figure D.3)

III. System coordination and reporting
- 1. Maintain interfaces with:
  - A) Plant and company management
  - B) Sales and shipping personnel
  - C) Accounting, personnel and purchasing departments
  - D) Production scheduling level (Level 4A)
- 2. Supply production and status information as needed to:
  - A) Plant and company management
  - B) Sales and shipping personnel
  - C) Accounting, personnel and purchasing departments
  - D) This information will be supplied in the form of:
    - 1) Regular production and status reports
    - 2) On-line inquiries
- 3. Supply order status information as needed to sales personnel

IV. Reliability assurance
- 4. Perform self-check and diagnostic checks on itself

NOTE 1 There are no production scheduling or control actions required at this level. This level is solely for use as an upper management and staff level interface.

NOTE 2 Roman numeral subdivisions of Tables D.6 to D.10 correspond to the same headings in Table D.4.

Table D.7 – Duties of the production scheduling and operational management level (Levels 4A or 5A)

I. Production scheduling
- 1. Establish basic production schedule.
- 2. Modify the production scheduling for all units per order stream received, energy constraints, power demand levels, and maintenance requirements.
- 3. In coordination with required production schedule develop optimum preventive maintenance and production unit renovation schedule.
- 4. Determine the optimum inventory levels of raw materials, energy sources, spare parts, etc., and of goods in process at each storage point. The criteria to be used will be the trade-off between customer service (i.e., short delivery time) versus the capital cost of the inventory itself, as well as the trade-offs in operating costs versus costs of carrying the inventory level. This function will also include the necessary material requirements planning (MRP) and spare parts procurement to satisfy the production schedule planned. (This is an off-line function.)
- 5. Modify production schedule as necessary whenever major production interruptions occur in downstream units, where such interruptions will affect prior or succeeding units.

III.	Plant coordination and operational data reporting	
	6.	Collect and maintain raw material and spare parts use and available inventory and provide data for purchasing for raw material and spare parts order entry and for transfer to accounting.
	7.	Collect and maintain overall energy use and available inventory and provide data for purchasing for energy source order entry and for transfer to accounting.
	8.	Collect and maintain overall goods in process and production inventory files.
	9.	Collect and maintain the quality control file.
	10.	Collect and maintain machinery and equipment use and life history files necessary for preventive and predictive maintenance planning.
	11.	Collect and maintain manpower use data for transmittal to personnel and accounting departments.
	12.	Maintain interfaces with management interface level function and with area level systems.
IV.	Reliability assurance	
	13.	Run self-check and diagnostic routines on self and lower-level machines.

NOTE There are no control functions as such required at this level. This level is for the production scheduling and overall plant data functions

Table D.8 – Duties of the area level (Level 3)

I.	Production scheduling	
	1.	Establish the immediate production schedule for its own area including maintenance, transportation and other production-related needs.
	2.	Locally optimize the costs for its individual production area while carrying out the production schedule established by the production control computer system (Level 4A) (i.e., minimize energy usage or maximize production for example).
	3.	Along with Level 4A modify production schedules to compensate for plant production interruptions, which may occur in its area of responsibility.
III.	System coordination and operational data reporting	
	4.	Make area production reports including variable manufacturing costs.
	5.	Use and maintain area practice files.
	6.	Collect and maintain area data queues for production, inventory, and manpower, raw materials, spare parts and energy usage.
	7.	Maintain communications with higher and lower levels of the hierarchy.
	8.	Operations data collection and off-line analysis as required by engineering functions including statistical quality analysis and control functions.
	9.	Service the man/machine interface for the area.
	10.	Carry out needed personnel functions such as: A) Work period statistics (time, task, etc.) B) Vacation schedule C) Work force schedules D) Union line of progression E) In-house training and personnel qualification
IV.	Reliability assurance	
	11.	Diagnostics of self and lower-level functions

NOTE No control actions are required here. This level handles detailed production scheduling and area coordination for the major plant subdivisions.

Table D.9 – Duties of the supervisory level (Level 2)

II.	Control enforcement	
	1.	Respond to any emergency condition, which may exist in its region of plant cognizance.
	2.	Optimize the operation of units under its control within limits of established production schedule. Carry out all established process operational schemes or operating practices in connection with these processes.
III.	System coordination and operational data reporting	
	3.	Collect and maintain data queues of production, inventory, and raw material, spare parts and energy usage for the units under its control.
	4.	Maintain communications with higher and lower levels.
	5.	Service the man/machine interfaces for the units involved.
IV.	Reliability assurance	
	6.	Perform diagnostics on itself and lower-level machines.
	7.	Update all standby systems.

NOTE This level and those below it carry out the necessary control and optimization functions for the individual production units to enforce the production schedule set by levels 4A and 3.

Table D.10 – Duties of the control level (Level 1)

II.	Control enforcement	
	1.	Maintain direct control of the plant units under its cognizance.
	2.	Detect and respond to any emergency condition, which may exist in these plant units.
III.	System coordination and reporting	
	3.	Collect information on unit production, raw material and energy use and transmit to higher levels.
	4.	Service the operator's man/machine interface.
IV.	Reliability assurance	
	5.	Perform diagnostics on itself.
	6.	Update any standby systems.

NOTE 1 It has repeatedly been shown that one of the major benefits of the use of digital computer control systems in the automation of industrial plants has been in the role of a control systems enforcer. In this mode, one of the control computer's main tasks is to continually assure that the control system equipment is actually carrying out the job that it was designed to do in keeping the units of the plant production system operating at some best (near optimal) level.

NOTE 2 That is, to be sure that in the continuous process plant, for instance, the controllers have not been set on manual, that the optimal set points are being maintained, etc. Likewise, it is the task of dynamic control to assure that the plant's production schedule is carried out, i.e., to enforce the task set by the production scheduling function.

NOTE 3 In the Purdue Reference Model definition there are no informational transformations at Level 0.

NOTE 4 Sensors determine the state of the physical equipment or the material being transformed therein. All operations on the resulting data are informational. Sensor outputs are considered part of Level 1.

NOTE 5 Actuators are considered part of Level 0 – commands to them are considered Level 1.

D.4 Tasks of each level of the hierarchy

In the context of any large industrial plant, or of a complete industrial company based in one location, the tasks that would be carried out at each level of the hierarchy are as described in Tables D.6 to D.10. Note that these tasks are subdivided within each table into those related to production scheduling, control enforcement, systems coordination and reporting, and reliability assurance (Table D.4). As was mentioned above, these tables outline the tasks which are carried out in any industrial plant, particularly at the upper levels of the hierarchy.

Figures D.5 to D.10 show the application of the scheduling and hierarchy view to a variety of industries showing also that the computer control system discussed here is pyramidal as well as hierarchical. Figure D.10 is an entirely different appearing diagram as originally developed by the Cincinnati-Milacron Company. However, with the current CIM hierarchy levels imposed, it can be readily seen that this diagram converts direct to the others.

Figures D.5 to D.10 also bring out an important aspect of this model in relation to those proposed by some other developers, that is, inventories and associated material handling equipment in relation to the manufacturing processes themselves are treated just like any other process. Thus they are considered to have process control inputs and outputs and their dynamic behaviour can be modelled mathematically in order to develop the appropriate overall control system for the functions served by the inventory and its associated material handling equipment.

D.5 The data flow graph, a functional network view of the CIM reference model

There is need in the reference architecture to have a mechanism to show the interconnection and precedence of the several tasks assigned to the overall mill-wide control system which is not shown by the scheduling and control hierarchy view. An excellent method for showing this is the so-called data flow graph or information flow graph using a technique known as structured analysis (see Bibliography), also known as the Yourdon-DeMarco technique.

This clause will develop such a representation as derived from the CIM reference model. The basis for this work will be a data flow model, contributed to the Purdue Reference Model for CIM project by The Foxboro Company in August 1986 (see Bibliography). The original document has been considerably modified by the Workshop CIM Committee to match the nomenclature, etc., of other parts of the model's documentation.

As noted above, this method diagrams the interconnection of the several tasks carried out by the control system and allows the potential for an ever greater detailing of these tasks in the form of sub-tasks and the resulting interconnections of these sub-tasks with each other and the main tasks. These diagrams are restricted to the model as defined in the Purdue Reference Model for CIM (i.e., the definable scheduling and control system for the manufacturing facility and including only interfaces to the external influences), i.e., the integrated information management and control system of Figure D.1 and the information systems architecture of this text.

The set of diagrams begins with the interconnection of the influencing external entities on the factory itself (Figure D.12). In the present model, one very important external influence on the factory is the company management itself. As noted in Figure D.13 management interfaces through the staff departments which provide services to the factory itself or express management's policies in sets of requirements to be fulfilled by the factory.

It will be immediately noticed by the reader that the two lists of tasks and functions we are developing here look entirely different even though each is a complete listing within itself. This is because these two different models of the information architecture show different ones of the task and function relationships. The scheduling and control hierarchy shows subordination, precedence, time horizon and span of control, while the data flow diagram shows connectivity and precedence. Thus, since there is no layering in the data flow diagram (subordination) and no connectivity in the scheduling and control hierarchy, their views of the tasks and functions are greatly different. This results in a different definition of each task in many cases particularly because of a difference in span of concern. Therefore, the description and labels may be (and are) different between the two models.

Table D.11 presents the functions and tasks listed on the diagrams of Figures D.16 to D.28. Table D.12 makes a comparison of the tasks listed in Tables D.6 to D.10 versus those on Figures D.16 to D.28 as discussed just above.

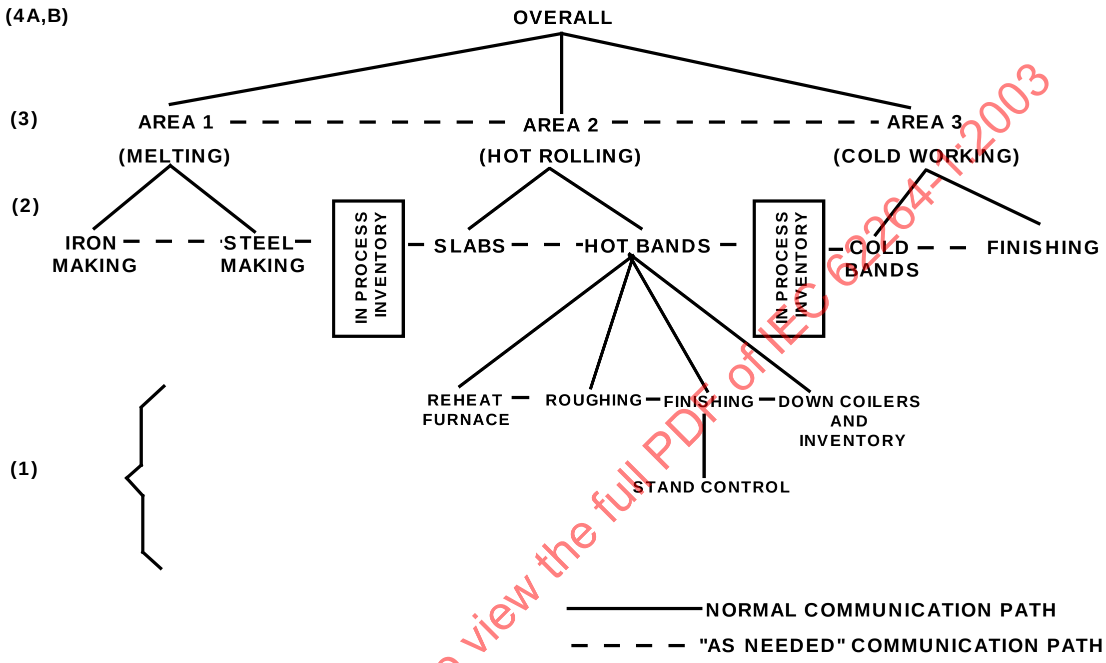


Figure D.5 – Hierarchy arrangement of the steel plant control to show relationship of hierarchy to plant structure

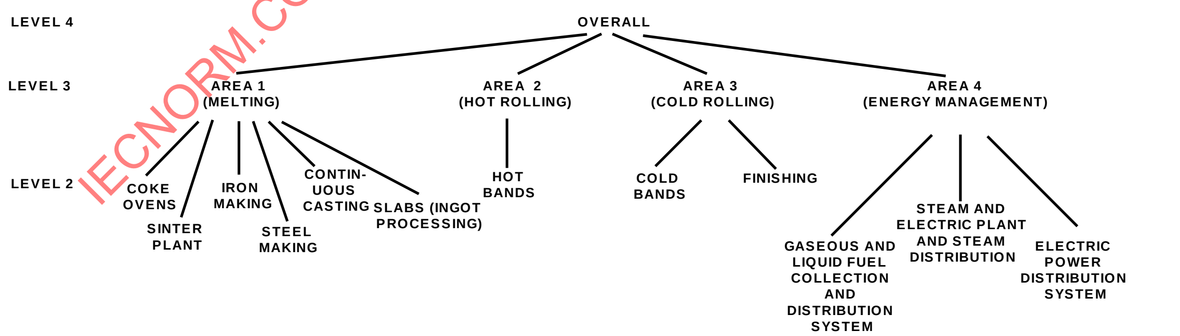


Figure D.6 – Hierarchy arrangement of the steel plant control system as studied for energy optimization

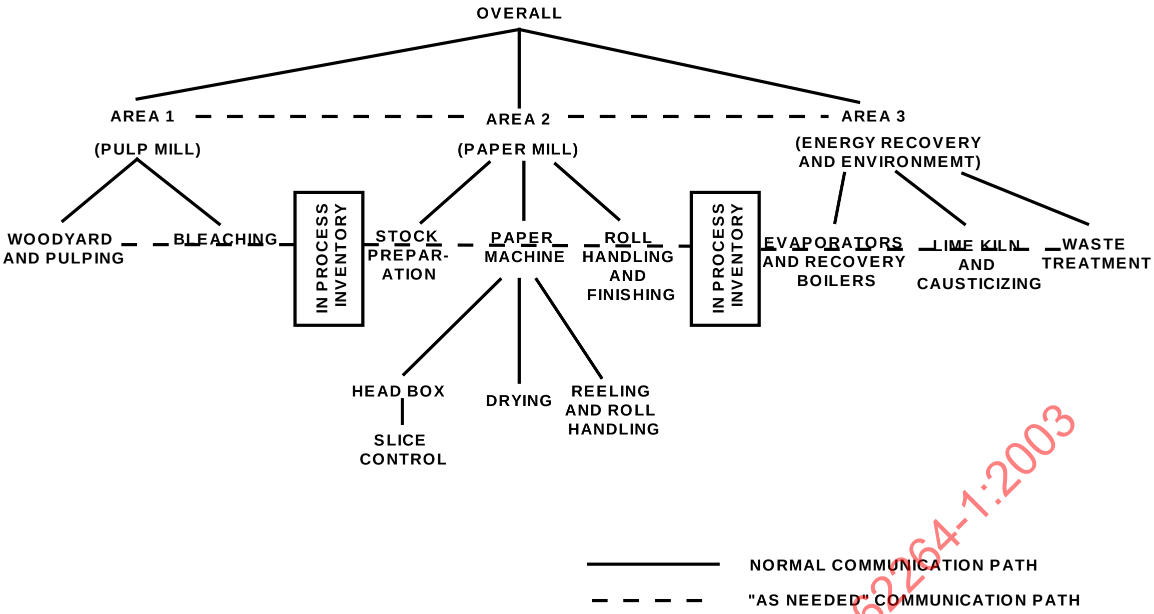


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Figure D.7 – Hierarchy arrangement of the paper mill control to show relationship of hierarchy to plant structure

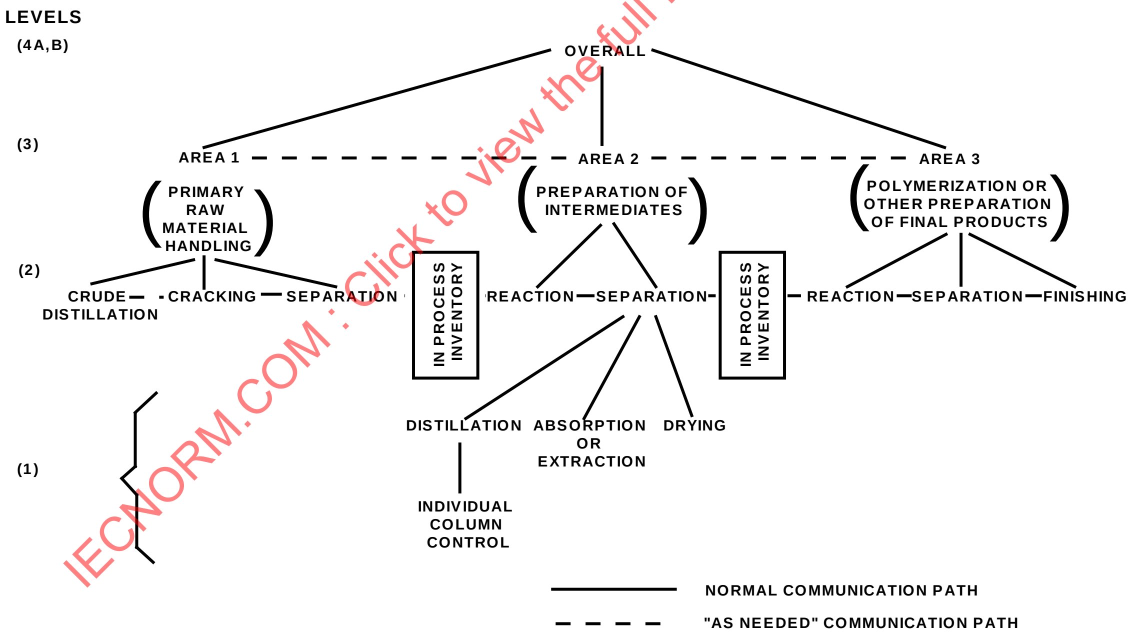

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Figure D.8 – The hierarchy control scheme as applied to a petrochemical plant

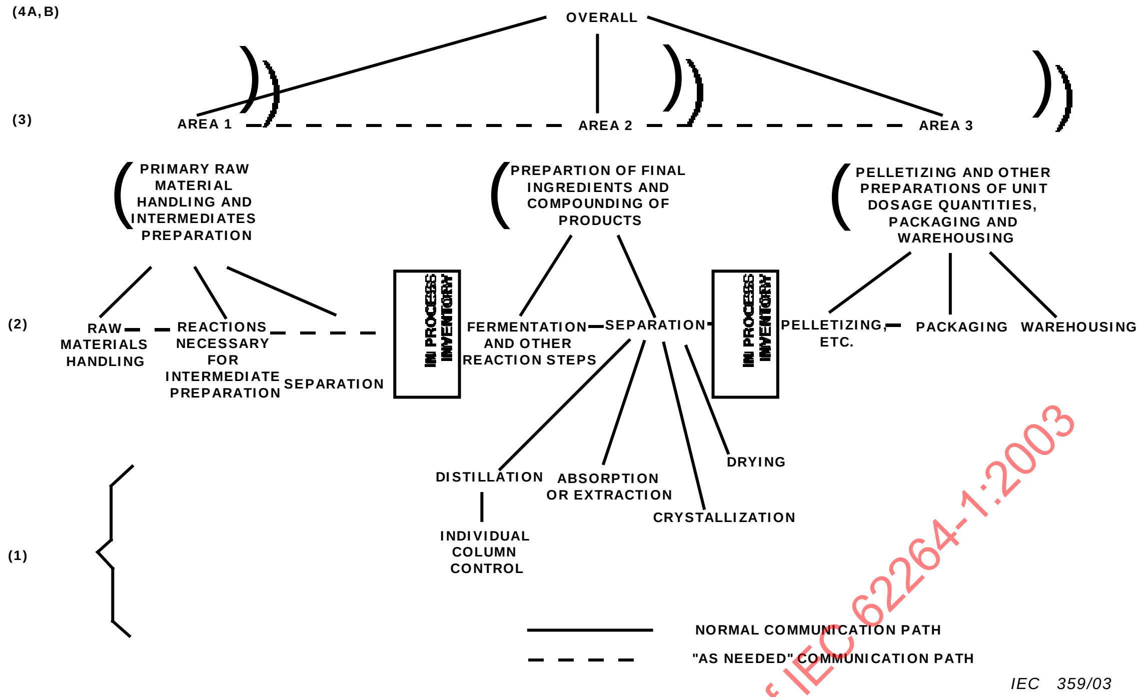

Figure D.9 – The hierarchy control scheme as applied to a pharmaceuticals plant

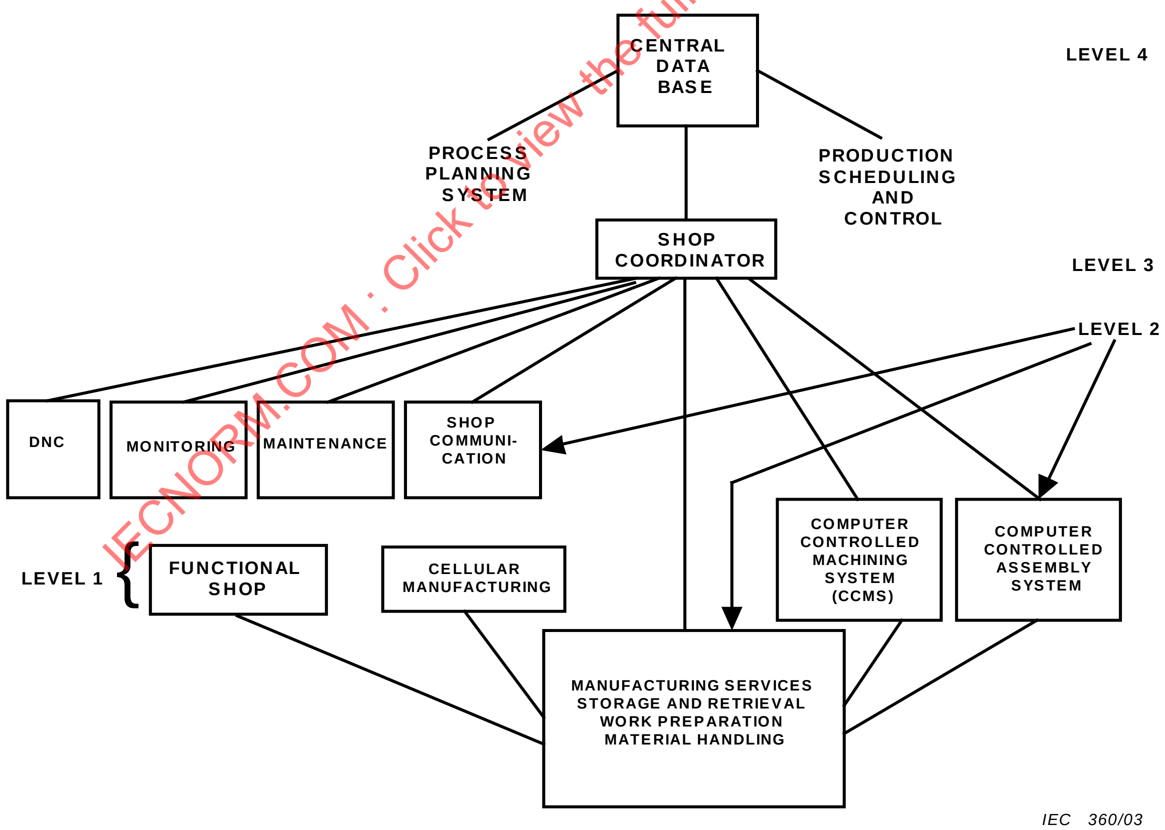

Figure D.10 – Computer-integrated manufacturing system (CIMS) (Cincinnati-Milicron proposal)

Table D.11 – Information flow model of generic production facility mini-specs (definition of functions)

FIRST ORDER ENTITY DIVISIONS

0. FACILITY MODEL CONTEXT – Figure D.16
External entities
Marketing and sales
Corporate R. D. and E.
Supplier
Vendor
Customer
Transport company
Accounting
Purchasing

1. ORDER PROCESSING – Bubble 1 of Figure D.16 and Figure D.17
Customer order handling, acceptance and confirmation
Sales forecasting
Waiver and reservation handling
Gross margin reporting
Determine production orders

2. PRODUCTION SCHEDULING – Bubble 2 and Figure D.18
Determine production schedule
Identify long-term raw material requirements
Determine pack-out schedule for end-products
Determine available product for sales

3. PRODUCTION CONTROL – Bubble 3 and Figure D.19
Control of transformation of raw materials into end product in accordance with production schedule and production standards
Maintenance of processing equipment
Plant engineering and updating of process plans, etc.
Issue requirements for raw materials
Produce reports of performance and costs
Evaluate constraints to capacity and quality
Self-test and diagnostics of production and control equipment

4. MATERIALS AND ENERGY CONTROL – Bubble 4 and Figure D.23
Keep stock of raw materials
Reorder raw materials according to production requirements
Accept delivery of raw materials, request QA tests and release for utilization after approval
Reporting on RM and energy utilization
Reporting on RM inventory to production

5. PROCUREMENT – Bubble 5 and Figure D.24
Place orders with suppliers for RM supplies, spare parts, tools, equipment and other required materials
Monitor progress of purchases and report to requisitioners
Release incoming invoices for payment after arrival and approval of goods

6. QUALITY ASSURANCE – Bubble 6 and Figure D.25
Testing and classification of incoming material and end products
Set standard for production QA in accordance with market and technology requirements
Assist production with exceptional and effective QA tests

7. PRODUCT INVENTORY – Bubble 7 and Figure D.26
Keep stock of produced end-products
Make reservation for specific product on list in accordance with product selling directives
Pack-out end-product in accordance with schedule
Report on inventory to production scheduling
Report on balance and losses to product cost accounting
Arrange physical loading/shipment of goods in coordination with product shipping administration

Table D.11 – Information flow model of generic production facility mini-specs (definition of functions)*(continued)*

8.	COST ACCOUNTING – Bubble 8 and Figure D.27 Calculate and report on total product cost Report cost results to production for adjustment Set cost objectives for production
9.	PRODUCT SHIPPING ADMINISTRATION – Bubble 9 and Figure D.28 Organize transport for product shipment in accordance with accepted orders requirements Negotiate and place orders with transport companies Accept freight items on site and release material for shipment Prepare accompanying documents for shipment (BOL, customs clearance) Confirm shipment and release for invoicing to general accounting Report on shipping costs to product cost accounting
(10.0 MAINTENANCE (defined as a FIRST ORDER ENTITY in the ISA-95.00.01-2000 model))	
SECOND-ORDER ENTITY SUBDIVISIONS	
1.1	PRODUCTION FORECASTING (LONG RANGE) – Bubble 1.1, Figure D.17 The orders expected within the next period of time are predicted The prediction is based on the sales history and function of the market expectation Forecasting makes use of the traditional statistical techniques (smoothing, seasonal indices, etc.) The forecasting period is set by the confidence of market expectations Market expectations are influenced by outside factors, for example, economical or political situation, or by inside factors, for example, long-term contracts, production problems
1.2	HISTORIAN – Bubble 1.2 , Figure D.17 Create and update a sales history file with clarification of product, customer, shipping method
1.3	ORDER ENTRY – Bubble 1.3, Figure D.17 Main interface with customer for inquiries and orders Supply product price and availability Handle order entry and amendments Give confirmation and progress of entered orders
1.4	PRODUCTION ORDER – Bubble 1.4, Figure D.17 Based on active and forecasted orders determine the required production
1.5	ORDER ACCEPTANCE – Bubble 1.5, Figure D.17 Handle the acceptance for delivery of entered orders Acceptance is based on ability to manufacture and availability of product customer credibility is checked In specific cases the product specifications can be waived in accordance with marketing policies to ratify a particular customer or market need
2.1	PROCESS PRODUCTION ORDERS – Bubble 2.1, Figure D.18 Produce detailed production requirements from sales production orders Highlight specification requirements for non-standard requests Produce production order entry in scheduling file and append shipment requirements
2.2	BALANCE IN PROCESS AND PRODUCTION INVENTORY – Bubble 2.2, Figure D.18 Identify ordered quantities against produced products and initiate pack-out of specific shipments Identify availability of on-hand product Highlight variance in production schedule Maintain capacity estimates for production facility in terms of products
2.3	PRODUCTION FORECASTING (SHORT TERM) – Bubble 2.3, Figure D.18 From existing production orders and known capacity, produce specific schedule entries for production rates and specifications Set long-term raw material order rates to meet production schedule Produce a long-term forecast report

Table D.11 – Information flow model of generic production facility mini-specs (definition of functions)*(continued)*

2.4	PRODUCTION SCHEDULING – Bubble 2.4, Figure D.18 Produce formal production schedule Modify production schedule to account for production variances and interruptions Modify production schedule to account for inventory and shipments
3.1	PROCESS SUPPORT ENGINEERING – Bubble 3.1, Figure D.19; Figure D.20 Issue request for modification or maintenance Coordinate maintenance and engineering activities Provide technical standards and methods to maintenance function Follow-up on equipment and process performance Provide technical support to operators Follow-up on technological developments Provide specifications for purchase order requests
3.2	MAINTENANCE – Bubble 3.2, Figure D.19; Figure D.21 *(10.0 in the ISA-95.00.01-2000 model)* Provide maintenance for existing installations Provide preventative maintenance programme Provide equipment monitoring programme to anticipate failure including self-check and diagnostic programmes Place purchase order request for materials and spare parts Develop maintenance cost reports Coordinate outside contract work effort
3.3	OPERATIONS CONTROL – Bubble 3.3, Figure D-19; Figure D.22 Supervise the operations of production process Keep track and report on production costs and performance Interpret the production plan in terms of the set points to individual units Diagnostics and self-check of production and control equipment
3.4	OPERATIONS PLANNING – Bubble 3.4, Figure D.19 Set up a daily production plan as function of the production schedule Check schedule against raw material availability and product storage capacity Determine percent of capacity status Modify production plan hourly to account for equipment outage, manpower and raw materials availability
4.1	MATERIAL AND ENERGY REQUIREMENT CONTROL – Bubble 4.1, Figure D.23 Determine supplier of new materials based on short- and/or long-term requirements from planning or manufacturing taking existing inventory into account Set up transfers of materials and energy to manufacturing Issue purchase request for new material and energy supplies Notify incoming material and energy control on expected incoming orders
4.2	OPTIMUM MATERIAL AND ENERGY INVENTORY LEVELS – Bubble 4.2, Figure D.23 Continuously calculate and report inventory balance and losses of RM and energy utilization
4.3	INCOMING RAW MATERIAL AND ENERGY CONTROL – Bubble 4.3, Figure D.23 Receive incoming material and energy supplies and request QA tests Transfer material and energy to storage and/or classify for use after QA approval Notify purchasing of accepted material and energy supplies to release payment
4.4	RAW MATERIAL AND ENERGY ROUTING – Bubble 4.4, Figure D.23 Set up and monitor the movement of material and energy in storage Update inventory of all movements and changes
4.5	RAW MATERIAL AND ENERGY INVENTORY REPORTING – Bubble 4.5, Figure D.23 Reporting of inventory to production
4.6	RAW MATERIAL AND ENERGY MOVEMENT CONTROL – Bubble 4.6, Figure D.23 Control and monitor transfer of materials
4.7	DRAW MATERIALS AND ENERGY MEASUREMENT VALIDATION – Bubble 4.7, Figure D.23 See 3.3.4

Table D.11 – Information flow model of generic production facility mini-specs (definition of functions)*(continued)*

5.1	ORDER PLACEMENT – Bubble 5.1, Figure D.24 Order preparation for raw materials, spare parts, etc., for presentation to the vendors based on procurement contracts negotiated by company purchasing Updating of vendor library and purchasing files of vendor's performance on orders
5.2	PROCESS REQUESTS – Bubble 5.2, Figure D.24 Collection and processing of unit requests for raw materials, spare parts, etc., for order placement to vendors Checking of requests for those materials versus historical files and budgets to assure correctness of requests
5.3	COST CONTROL – Bubble 5.3, Figure D.24 Certification of invoices on raw materials and spare parts based on satisfactory receipt of requested materials or parts
6.1	SET STANDARDS AND METHODS – Bubble 6.1, Figure D.25 Issue standards to manufacturing and testing laboratories in accordance with requirements from technology, marketing and customer services
6.2	RAW MATERIALS EVALUATION – Bubble 6.2, Figure D.25 Testing of incoming raw materials and approval for use if in accordance with set standards Collect and maintain quality control file for data for quality control analysis
6.3	EVALUATION OF PRODUCT – Bubble 6.3, Figure D.25 Test of final product and report results to classification Collect and maintain quality control file for data for quality control analysis
6.4	CLASSIFICATION AND CERTIFICATION – Bubble 6.4, Figure D.25 Classify quality and properties of end-product in accordance with set marketing standards Waiver classification on exceptional basis according to the request from product selling Report QA results and classification to finished product inventory control Certify that product was produced according to standard process conditions Report process data and certification to finished product inventory control
6.5	QA MEASUREMENT VALIDATION – Bubble 6.5, Figure D.25 Checking of product data versus customer's requirements and statistical quality control routines to assure adequate quality before shipment Maintenance of quality statistics on each item checked for continuing quality control studies.
6.6	LABORATORY AND AUTOMATIC ANALYSIS – Bubble 6.6, Figure D.25 Conduct of metric, chemical and physical tests on sample product items to obtain data for on-going quality control tests Transmission of this data to analysis facilities and quality control systems to assure future quality of product
6.7	ANALYSE PROCESS CAPABILITY – Bubble 6.7, Figure D.25 Use SQC methodology to examine product data to determine process capability of meeting product specifications Relay process deviations to process engineering for re-evaluation to upgrade process Relay methods deviation to standards and methods group for corrective action
7.1	INVENTORY SUPERVISION – Bubble 7.1, Figure D.26 Coordinate all activities in product inventory control Set up transfers of material to packing unit in accordance to pack-out schedule Request replenishment of packing materials Handle reservations and update inventory accordingly
7.2	LOSS CONTROL – Bubble 7.2, Figure D.26 Continuously calculate and report on inventory balance and losses
7.3	INVENTORY REPORTING – Bubble 7.3, Figure D.26 Generate daily, weekly ... reports on actual amounts of materials in storage

Table D.11 – Information flow model of generic production facility mini-specs (definition of functions)*(continued)*

7.4	PRODUCT SHIPPING – Bubble 7.4, Figure D.26 Set up and monitor transfers of products to customer in accordance with requirements from shipping administration Report confirmation of shipment for release of invoicing
7.5	PRODUCT ROUTING – Bubble 7.5, Figure D.26 Set-up and monitor the routes of product transfer and update inventory on changes
7.6	PHYSICAL PRODUCT MOVEMENT CONTROL – Bubble 7.6, Figure D.26 See 4.6
7.7	INVENTORY MEASUREMENT VALIDATION – Bubble 7.7, Figure D.26 See 3.3.4
8.1	COSTS BALANCING AND BUDGET – Bubble 8.1, Figure D.27 Establishment of criteria and tests to assure that operational budget is being followed Collection of raw material, labour, energy and other costs for transmission to accounting
8.2	RAW MATERIAL AND PARTS COSTS (ACCOUNTS PAYABLE) – Bubble 8.2, Figure D.27 Collection of cost data on all raw materials and spare parts in inventory or procured for the plant
8.3	PRODUCT INCOME (ACCOUNTS RECEIVED) – Bubble 8.3, Figure D.27 Collection of data of product shipped or in inventory Release invoice data to cost accounting at standard cost
8.4	PRODUCTION COSTS – Bubble 8.4, Figure D.27 Collection of data on costs of production in the plant – labour, energy, raw material usage, spare parts usage, etc.
9.1	SHIPMENT SCHEDULING – Bubble 9.1, Figure D.28 Classify accepted order and produce shipping schedule
9.2	SHIPPING COSTS – Bubble 9.2, Figure D.28 Calculate and report cost of shipping
9.3	SHIPMENT CONFIRMATION – Bubble 9.3, Figure D.28 Update shipping schedule to indicate that shipping has been done and configuration of shipments
9.4	RELEASE FOR INVOICING – Bubble 9.4, Figure D.28 Notify accounting of shipment in order to release invoice
9.5	RELEASE SHIPMENT – Bubble 9.5, Figure D.28 Send information for shipment to product shipping
9.6	PREPARE SHIPPING DOCUMENTS – Bubble 9.6, Figure D.28 Issue bill of lading, customer clearance, documents that are required with shipment

Table D.11 – Information flow model of generic production facility mini-specs (definition of functions)*(continued)*

THIRD-ORDER ENTITY SUBDIVISIONS
3.1.1 PROJECT MANAGEMENT – Bubble 3.1.1, Figure D.20 Management of engineering function Coordination of equipment and process modification Cost and progress reporting Project planning Design follow-up with corrective action
3.1.2 EQUIPMENT AND PROCESS DESIGN MODIFICATION – Bubble 3.1.2, Figure D.20 Establish design basis of new project Supply necessary information to allow cost estimating Report and coordinate specialists' assistance Provide Technical Information to Operators
3.1.3 ENGINEERING SPECIALISTS – Bubble 3.1.3, Figure D.20 Provide support and advice in special area Follow-up on state of the art in technology Assess plant process and equipment performance Adjust standards and methods to needs and progress Monitor the interpretation of design basis during detailed engineering
3.1.4 STANDARDS AND METHODS – Bubble 3.1.4, Figure D.20 Establish standards for process equipment, design techniques and process operational methods (practice files) Promulgate such standards within the process support engineering functions and within the operational groups of the factory
3.1.5 PROJECT COST CONTROL – Bubble 3.1.5, Figure D.20 Provide cost estimates of planned projects Follow-up and report on costs of projects in execution
3.1.6 PROCESS ANALYSIS AND PROJECT DETAILED ENGINEERING – Bubble 3.1.6, Figure D.20 Conduct plant performance studies Provide details for the construction of equipment or process modification project in accordance to design basis Issue report for ordering of new equipment Issue specifications to vendor Report on engineering and committed equipment costs
3.1.7 EQUIPMENT MODIFICATION CONSTRUCTION – Bubble 3.1.7, Figure D.20 Provide for construction of project Report on cost and labour
3.1.8 DRAFTING DOCUMENTATION – Bubble 3.1.8, Figure D.20 Maintain master copies of all plant drawings for units under its cognizance Responsible for updating drawings and associated documentation as units are modified Supply copies as needed
3.2.1 MAINTENANCE PLANNING – Bubble 3.2.1, Figure D.21 Organization and supervision of requested maintenance Reporting on performed maintenance Coordinate planned work with operators and plant supervision Monitor and update maintenance history file
3.2.2 MAINTENANCE COST CONTROL – Bubble 3.2.2, Figure D.21 Follow-up on used spare parts, report maintenance labour and report on maintenance costs

Table D.11 – Information flow model of generic production facility mini-specs (definition of functions)*(continued)*

3.2.3	SPARE PARTS – Bubble 3.2.3, Figure D.21 Supervise spare parts warehouse Supply necessary parts to maintenance crews Report on inventory to planning for reordering Report to cost control on used parts Accept and control new delivered parts from vendors
3.2.4	MAINTENANCE CREW SUPERVISION – Bubble 3.2.4, Figure D.21 Perform requested maintenance work Supervise and coordinate with outside contractors Report on technical activities to files Report on installation and equipment performance to engineering
3.2.5	DOCUMENTATION – Bubble 3.2.5, Figure D.21 See Item 3.1.8
3.3.1	OPERATIONS SUPERVISION – Bubble 3.3.1, Figure D.22 Set objectives for process operation Supervise people in operation of the process and equipment Deal directly in the resolution of exception conditions Issue modification or maintenance requests Set and report production capacity limits Monitor and report on production cost and performance
3.3.2	OPERATIONS COST CONTROL – Bubble 3.3.2, Figure D.22 Calculate total operating costs Maintain short-term economic balances of energy and materials Capture maintenance and engineering costs chargeable to operations
3.3.3	PHYSICAL PROCESS CONTROL – Bubble 3.3.3, Figure D.22 Stabilize process variables to defined operating set points Alarming of operating variables for exceptional conditions Maintain operation against constraints or at specifications Response to operators and process engineers' requests Response to emergencies
3.3.4	OPERATIONAL MEASUREMENT VALIDATION – Bubble 3.3.4, Figure D.22 Assess the validity of the measurements for further use within their limits of confidence Tag measurement data with quality and time
3.3.5	EQUIPMENT MONITORING – Bubble 3.3.5, Figure D.22 Assess the operating performance and limits of process equipment Alarming of equipment status variables against constraints Indicate performance against expected equipment life cycles
3.3.6	PRODUCTION BALANCING AND OPTIMIZATION – Bubble 3.3.6, Figure D.22 Optimization of production process to set objectives within equipment constraints Maintain material and energy balance to indicate exceptional conditions Perform performance tests where necessary to determine capacity Monitor product quality against specifications and standards

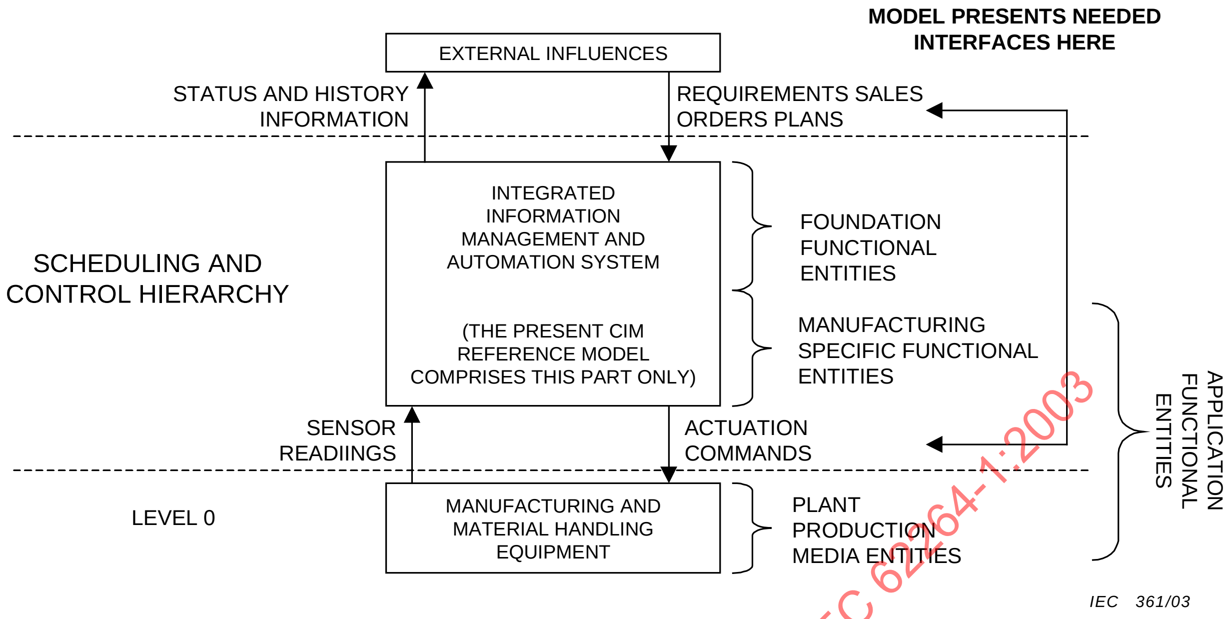

Figure D.11 – Relationship of the several classes of functional entities which comprise the CIM reference model and computer-integrated manufacturing itself

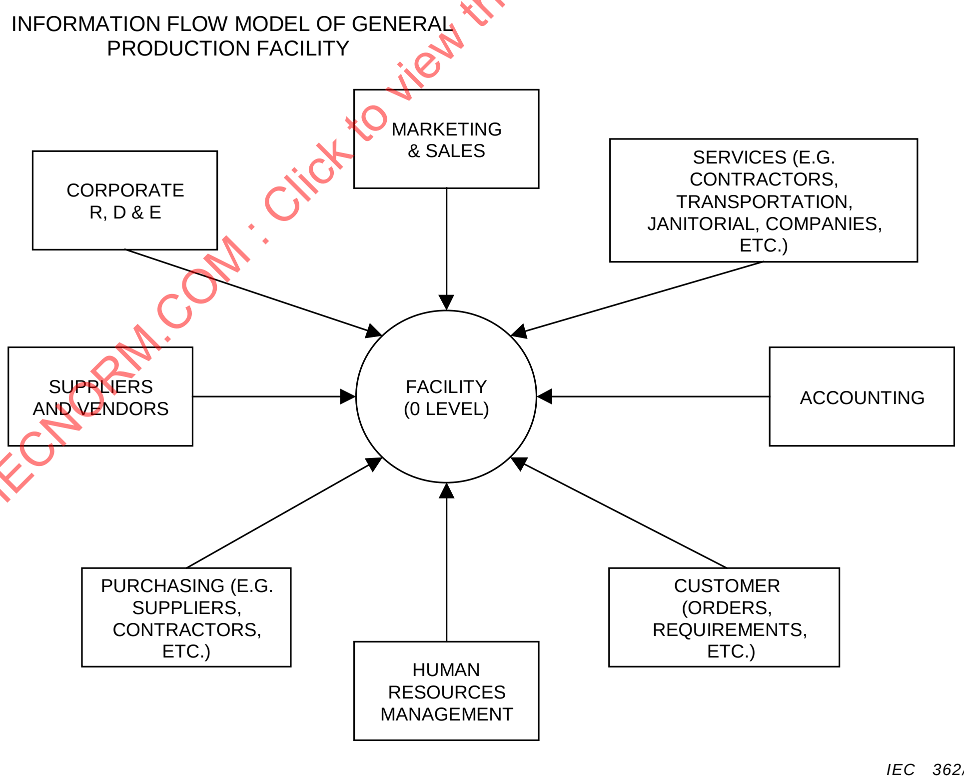

Figure D.12 – Major external influences as used in the data flow model

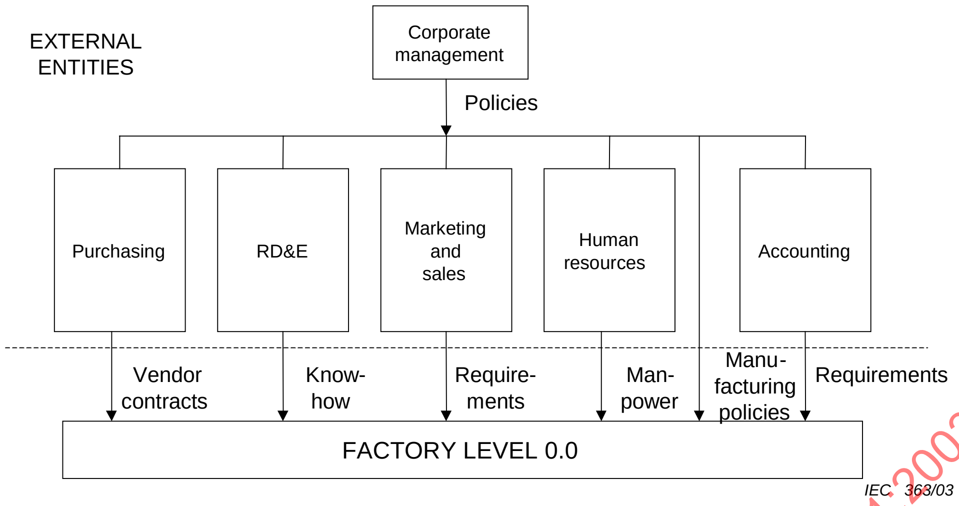

Figure D.13 – Requirements interfacing of corporate management and staff functional entities to the factory

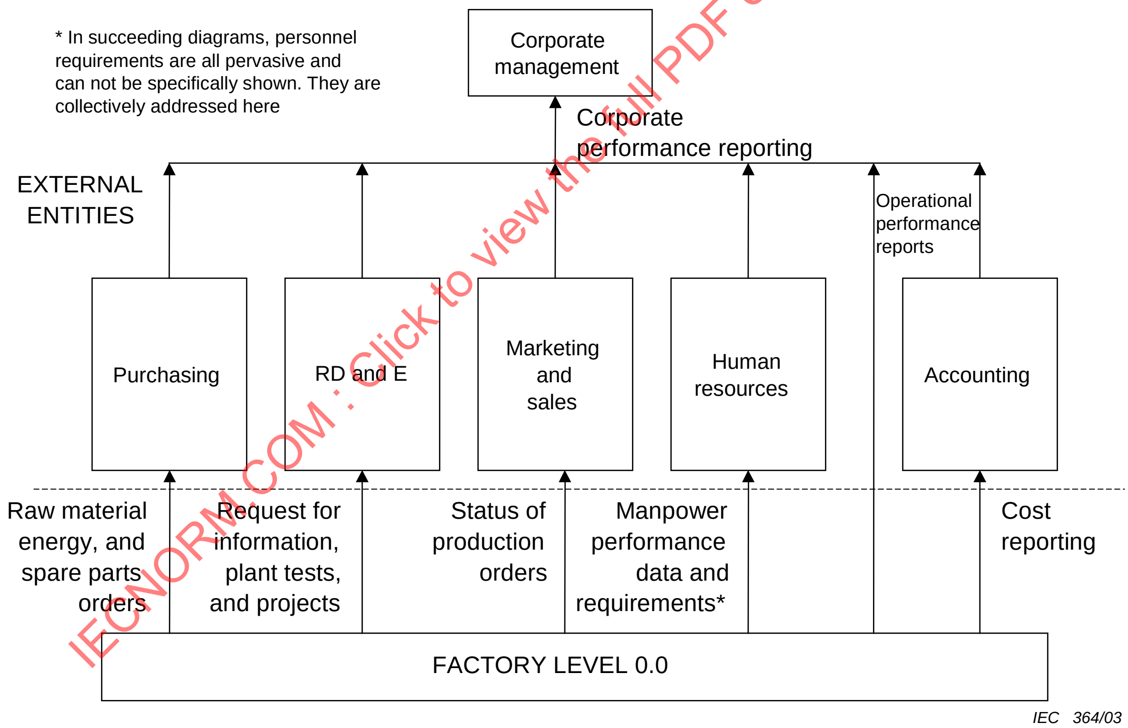

Figure D.14 – Report interfacing to corporate management and staff functional entities from the factory

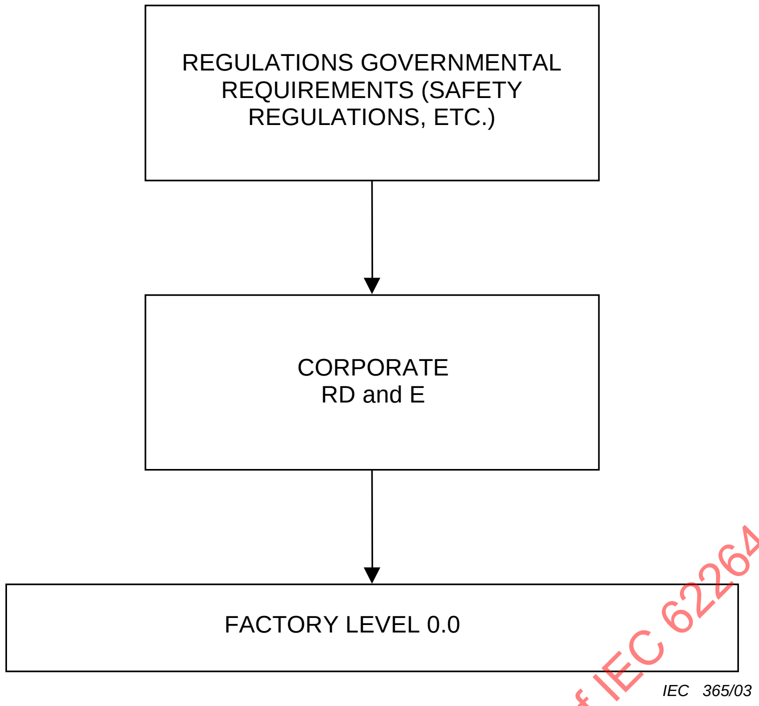

Figure D.15 – Interface of government regulations, etc., to the factory

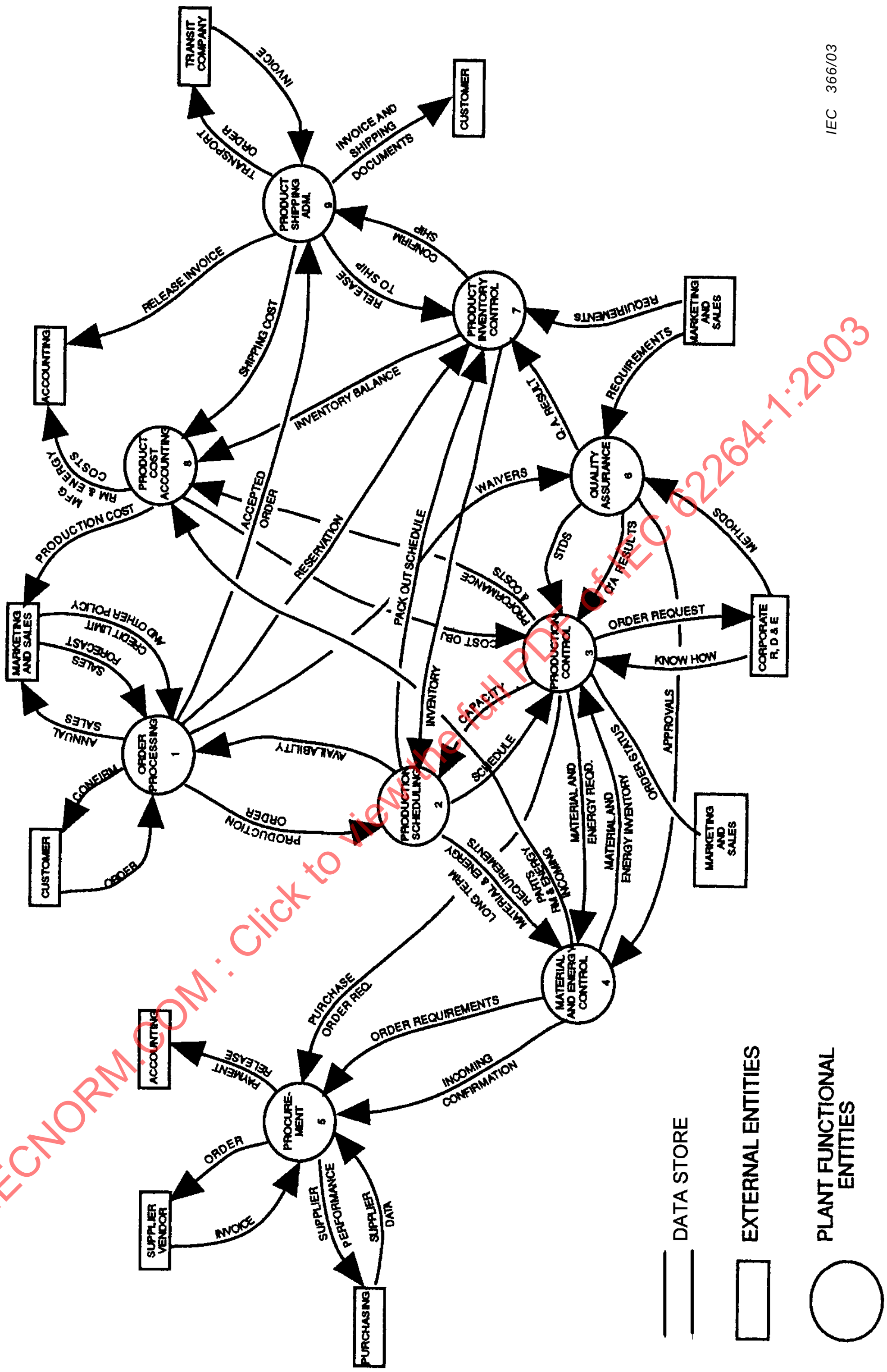

Figure D.16 – 0.0 facility model

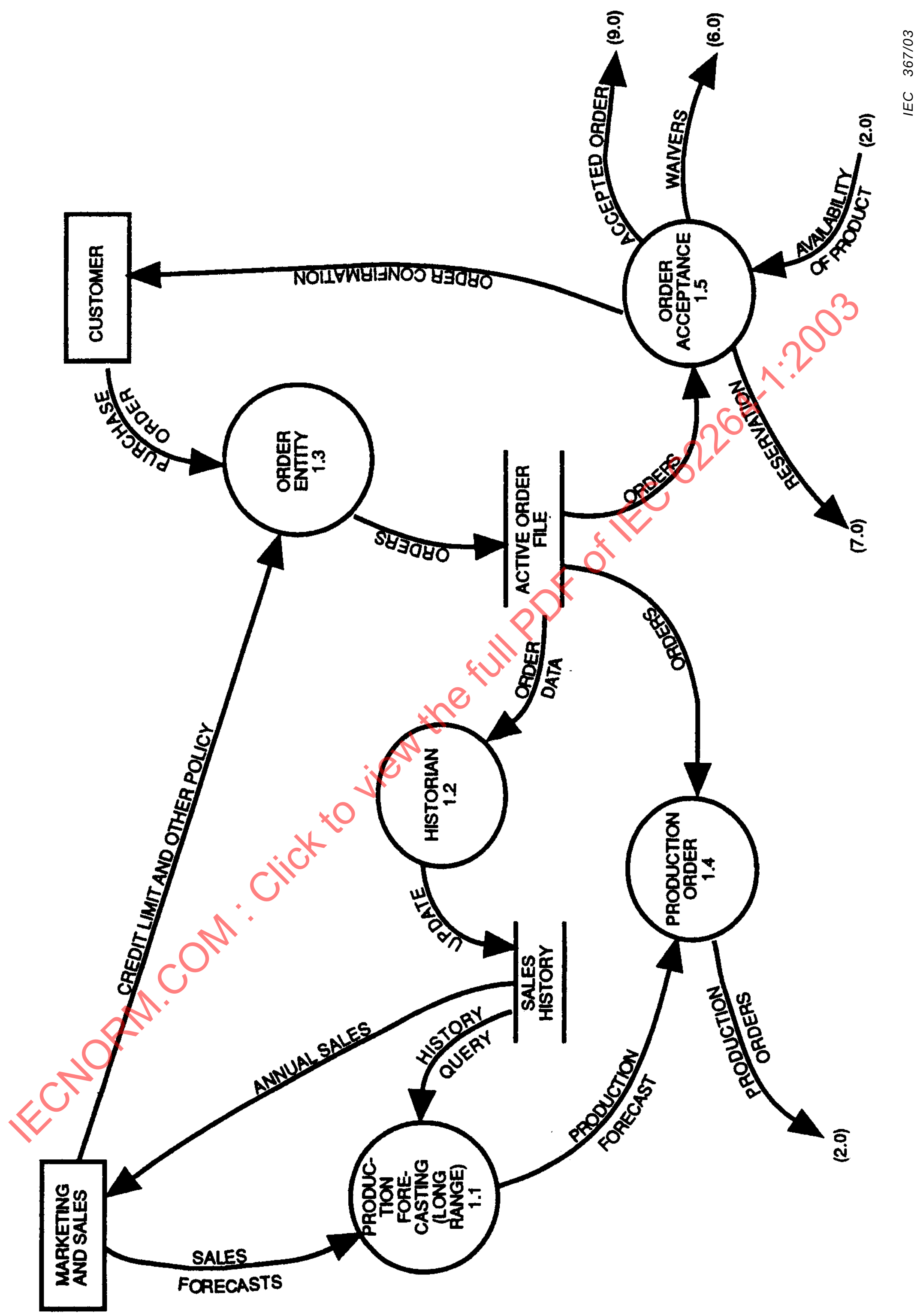

Figure D.17 – 1.0 order processing

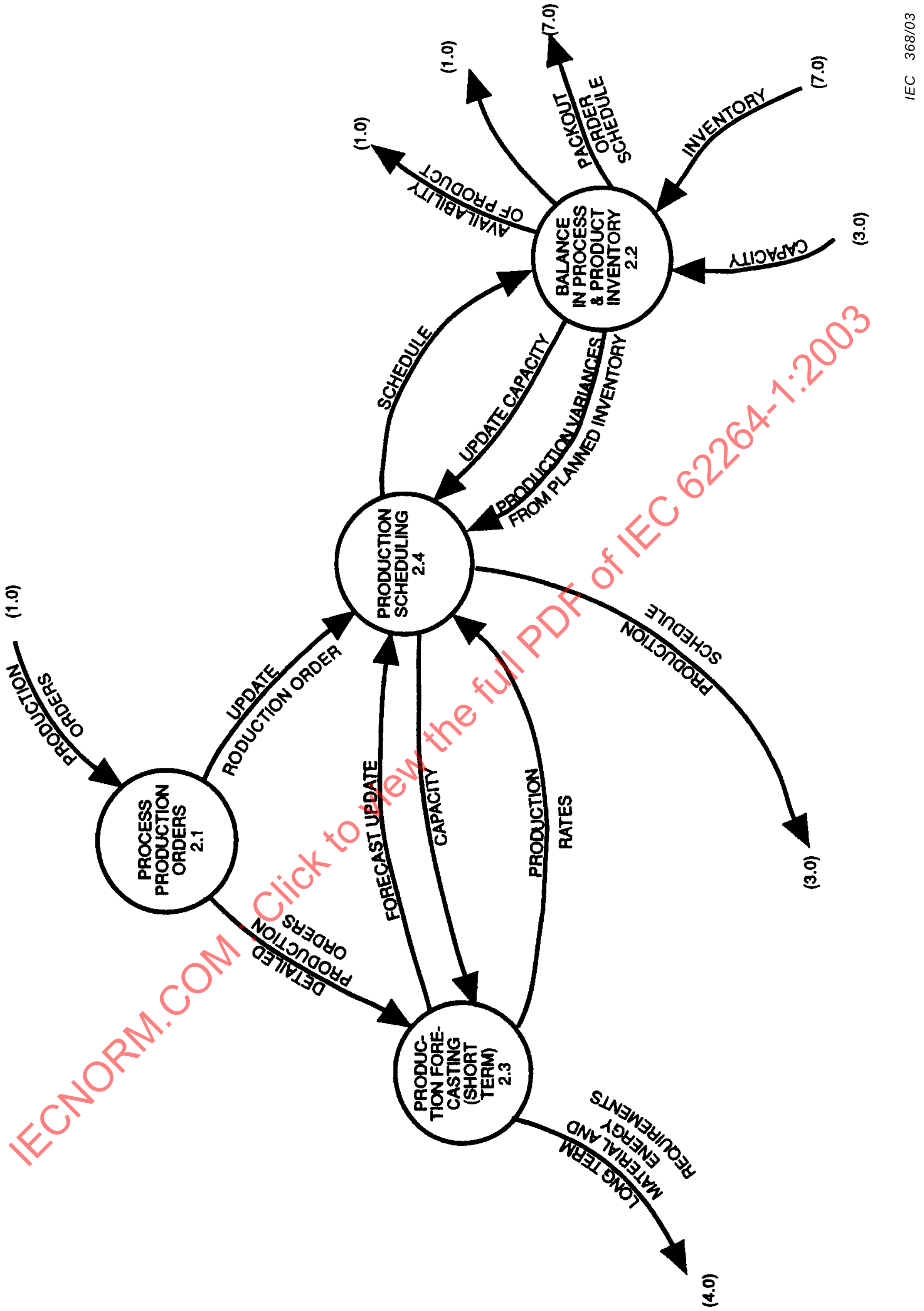

Figure D.18 – 2.0 production scheduling

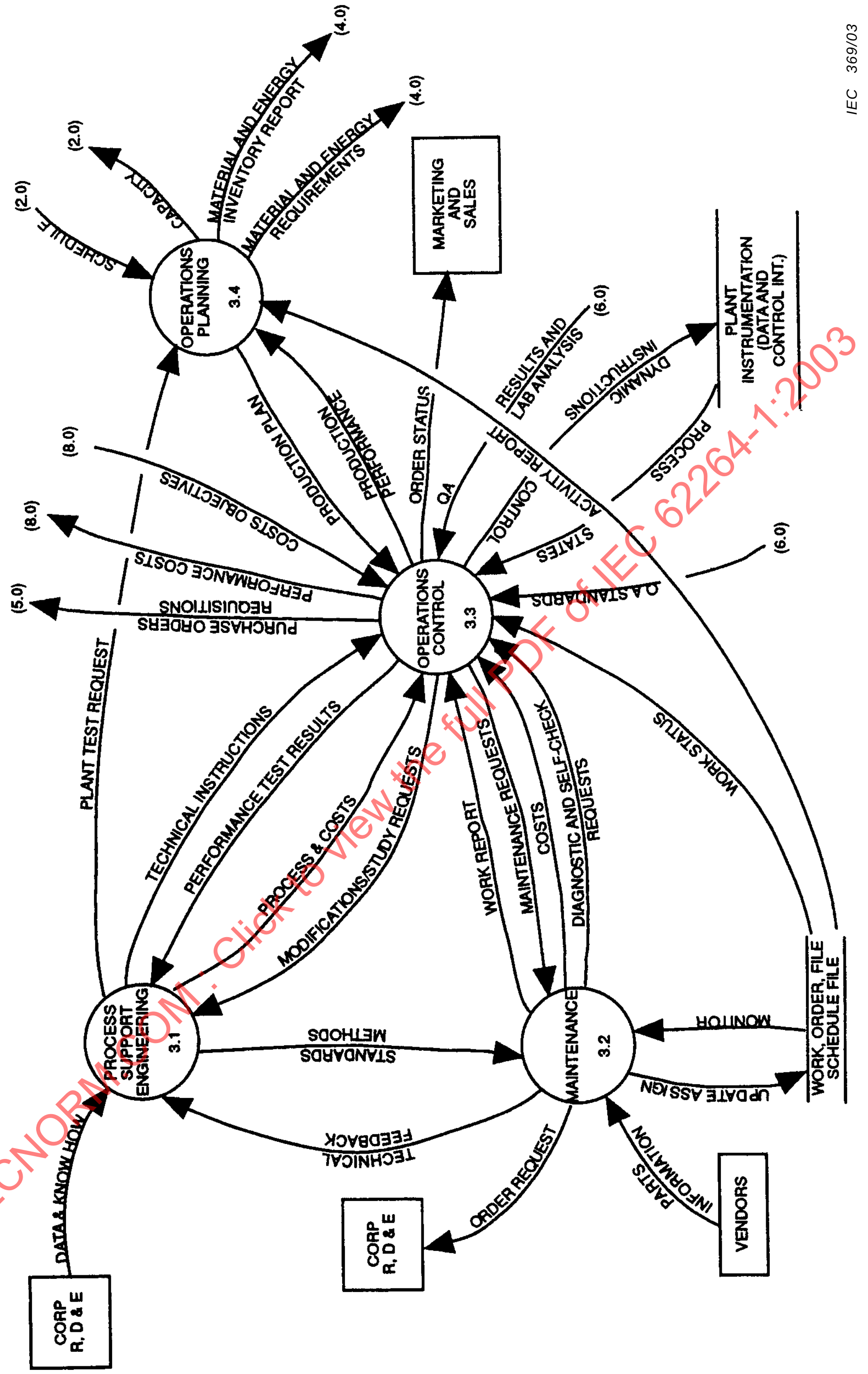

Figure D.19 – 3.0 production control

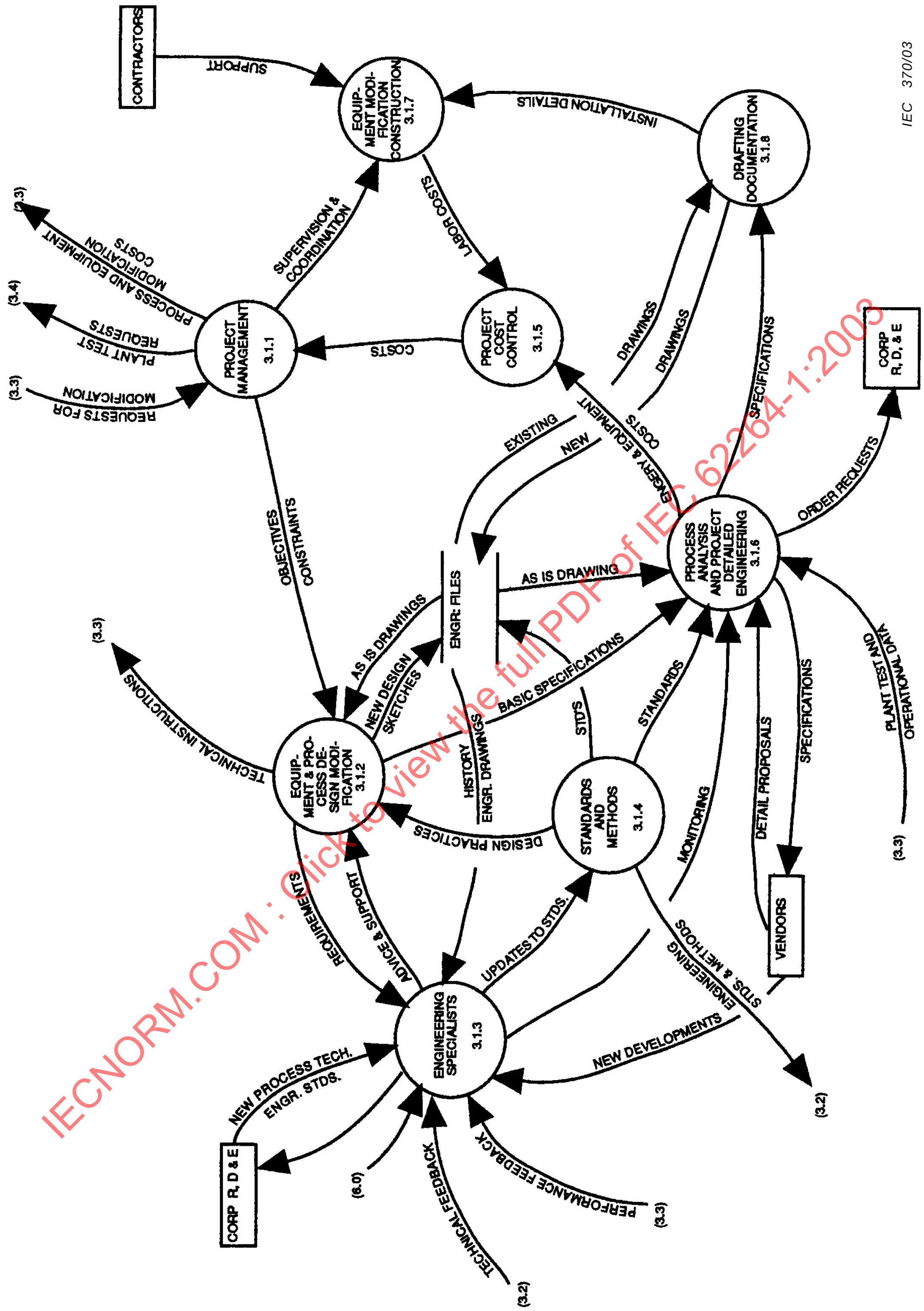

Figure D.20 – 3.1 process support engineering