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DEPARTMENT OF INFORMATION SYSTEMS
ÚSTAV INFORMAČNÍCH SYSTÉMŮ

ISA-95

ISA-95

TERM PROJECT
SEMESTRÁLNÍ PROJEKT

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BRNO 2018

Abstract

This term project introduces ISA-95 standard which provides a formal specification and the description of the area of the system's integration in the manufacturing industry. It focuses on the level of the long-term planning of the production and manufacturing management level and describes the functions and data which is being exchanged between the mentioned levels. Defined models and exchanged information serves as the foundation utilized in the introduction of the automation and integration in the manufacturer's environment.

Abstrakt

Tento semestrální projekt představuje standard ISA-95, který je zaměřen na formální uchopení a popis integrace systémů v rámci výrobních společností. Zaměřuje se na úroveň dlohodobějšího plánování výroby a krátkodobého řízení výroby a popisuje funkce a data, která jsou mezi těmito úrovněmi předávány. Pomocí modelů funkcí a formálního popisu dat a objektů představuje základní stavební blok, který je využitelný při zavádění integrace a automatizace,

Keywords

ISA-95, integration, manufacturing management, MES, manufacturing models

Klíčová slova

ISA-95, integrace, řízení výroby, MES, modely výroby

Reference

HRIVŇÁK, Ján. *ISA-95.* Brno, 2018. Term project. Brno University of Technology, Faculty of Information Technology. Supervisor Prof. Ing. Tomáš Hruška, Ph.D.

ISA-95

Declaration

Hereby I declare that this term project was prepared as an original author's work under the supervision of Mr. Tomáš Hruška. All the relevant information sources, which were used during preparation of this thesis, are properly cited and included in the list of references.

. . . .
Ján Hrivňák
August 27, 2018

Acknowledgements

I would like to thank Mr. Hruška for the chance I was given.

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Chapter 1

Introduction

Most manufacturers are investing the substantial amounts to provide the automation of the process (manufacturing) layer of their business. Currently, the assembly lines which are being used for the mass production of the final goods are equipped with the various autonomous robots which are handling the manufacturing. However, the next step in creating the fully integrated production plant is the integration of the business processes with the physical processes which are being carried out.

The typical industrial company is managed via a few information systems.

- ERP — Enterprise Resource System being used to support the high level planning and management of the core business processes;
- MES — Manufacturing Execution System which is responsible for the more detailed management of the manufacturing processes which are carried out in the manufacturing plant;
- SCADA — Supervisory Control and Data Acquisition system which is responsible for the real time management of the single components being used for the production.

The ERP systems are the main source of the data which is used to plan and manage the complete manufacturing process. The SCADA system handles the low-level management tasks which are interacting with the assembly lines and equipment which is being used for the production. The MES system typically provides an interconnection between the planning and management in the long term and short term operational tasks which needs to be handled instantaneously. The integration of these information systems or manufacturing layers provides a strategic advantages as the right data can be used at the right time and the decisions impacting the core business of the manufacturers can be more detailed and accurate.

The RAMI 4.0 model is the current attempt to provide the cohesive and unified view on the different functions and aspects of the manufacturing process in order to provide the all relevant information in real time by networking of all the instances involved in adding value, and the ability to use those data to establish the optimum value stream at any particular time [?] and it is the result of the cooperation of the various German institutions.

The ISA-95 is the standard created by the ISA which aims to minimize the risks and costs and errors originated in the integration projects of the enterprise and control systems. The ISA, Instrumentation, Systems, and Automation Society, is the global non-profit organization which operates in the field of the standardization, certification, education and training in the field of the automation. The organization is known for the introduction of several standards which are used in the field of the various industries.

- ISA-84 (Functional Safety: Safety Instrumented Systems for the Process Industry Sector)
- ISA-88 (Batch Control)
- ISA-99 (Manufacturing and Control Systems Security).

According to the [6] "the ISA-95 is not present as the set of concrete principles and processes but rather a method and the way of thinking and working. It si composed of the several models and terminology. The models are grouped and provide the different views and perspectives on the integration aspects whilst the terminology sets the basic glossary which can be used to between the heterogenous integrated systems. The models and terminology are used for the analysis of the individual manufacturing company. According to the [6] A model is a useful representation of a specific situation or thing. Models are useful because they describe or mimic reality without dealing with every detail of it. They typically help people analyze a situation by combining a framework's ideas with information about the specific situation being studied ...". They help us make sense of the world's complexity.

The terminology defined by the ISA-95 is used to standardize the basic building blocks of the manufacturing company so that the the homogenous description of the company functions, activities, responsibilities and information flows can be reused and identified in the individual systems being integrated.

The ISA-95 standard consists of five official parts[1]:

- Enterprise-Control Systems Integration Part 1: Models and terminology - defines the various models and terminology which can be used in automation of information exchange projects between MES and ERP systems;
- Enterprise-Control Systems Integration Part 2: Object Model Attributes - expands the models introduced in the Part 1 and defines the detailed description of the exchanged information in form of the attributes;
- Enterprise-Control Systems Integration Part 3: Activity Models of Manufacturing Operations Management - focuses on the MES layer and provides models which can be used to describe the activities carried out at the MES level;
- Enterprise-Control Systems Integration Part 4: Object Models and Attributes of Manufacturing Operations Management - defines the supplementary activities carried out by the MES layer which needs to be executed such as maintenance, warehouse management and their connection to the ERP layer;
- Enterprise-Control Systems Integration Part 5: Business to Manufacturing Transactions - defines how the target systems of the communications and data flows should be handling the exchanged data;

[1] The IEC standard is continually being improved and the 6th part is present in the form of the Publicly available specification as the "pre-standard".

- Enterprise-Control Systems Integration Part 6: Messaging Service Model - defines a set of the messaging services which are used in the information exchange between Levels 3 and 4 and inside of the Level 3[2]

The ISA-95 methodology served as the basis for the creation of the IEC-62264 international standard by the International Electrotechnical Commission which covers the aspects and building blocks of the integration of the Enterprise-control systems. This paper discusses the RAMI 4.0 model, its aspects and ideas and introduces the IEC-62264 standard.

[2]The description of the levels and their significance and function is described in the chapter covering the Functional Hierarchy model.

Chapter 2

RAMI 4.0 model

2.1 Definition of the problem

The manufacturing processes which are the core business interests of the companies are relatively simple. The manufacturing process of the final product has to be created:

1. Define the final product so that the answer to the question "What is being produced?" is clear.
2. Define the order of the intermediate products, raw materials and technological processes which are required for the final product, answers the question "How is the final product being built?"
3. Produce.

After the manufacturing of the final product is clearly defined, the manufacturer has to solve a set of the issues which are not directly connected to the manufacturing itself but are however critical to the overall operation of the production. The production needs the continual planning based on the placed orders and the availability of the material and products required for the manufacturing. The planning is often carried out as an ad-hoc process when the scale of the production is small or various industry standard procedures are used such as the Material resource planning (MRP II) or Advanced planning and scheduling (APS). The manufacturer has to cover the areas of the order processing, availability of the materials for the production and their warehousing (also applies to the produced goods), accounting of the production, securing the human resources needed for the production, planning of the maintenance of the machinery and other areas. These areas are typically handled by the information systems called the "Enterprise resource planning" systems. In case the manufacturing process contains the advanced machinery and robotics, also the "Manufacturing Execution Systems" are used to control the actual machinery and processes which are carried by the equipment.

The challenge of the Industry 4.0 is the complexity of the IT technologies and processes happening during the production process and the relationships of the different areas which are shaping the final outcome. The integration of the systems to provide the correct and realistic data is the key and the first step in the creation of the fully connected manufacturing plant and manufacturers.

According to the Industrie 4.0 Working group, there are four aspects[4] of the Industry 4.0 which are of the interest as illustrated on the figure 2.1:

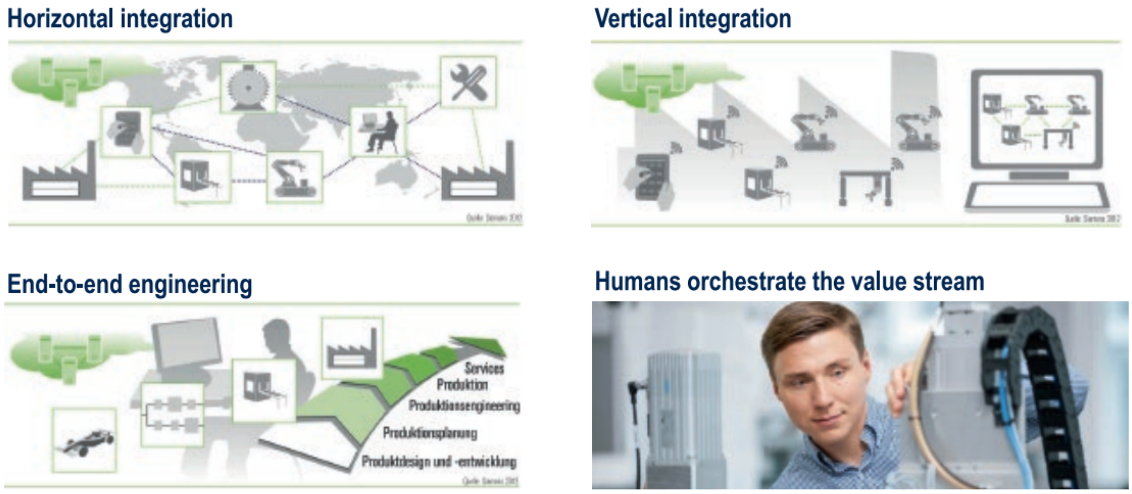

Figure 2.1: Four aspects of the RAMI 4.0 model

1. Horizontal integration via the value networks;
2. Vertical integration of the factory via the equipment hierarchy;
3. Lifecycle management and the end-to-end engineering of the manufacturing processes;
4. Human intervention in the orchestration of the value stream;

The Industry 4.0 Component described below is targeted to cover the mentioned aspects.

2.2 Overview of the RAMI 4.0 model

The Industry 4.0 is the area of the major focus of the most prominent manufacturing companies which are driving the advances and progress in order to increase the automation of the manufacturing and effectivity of the operation, decrease the manufacturing costs by the provisioning of the integration of the information systems and procedures. The current conceptual standard referred to in the Industry 4.0 is the RAMI 4.0[1] which connects the different standards and techniques covering the different aspects of the manufacturing processes.

According to the [9], the RAMI model is created in the 3D, as illustrated on the figure 2.2 in order to cover different interconnected technical and economical properties of the manufacturing process. The model is composed of the three interconnected axis which represents the different overview of the activities carried out during the production [4], namely:

- Right-hand horizontal axis — The perspective of the integration ability of the components within the factories and plants;
- Left-hand horizontal axis — The perspective of the market lifecycle of the products representing the value added by the manufacturing process through out time;

[1]Reference Architectural Model Industrie 4.0

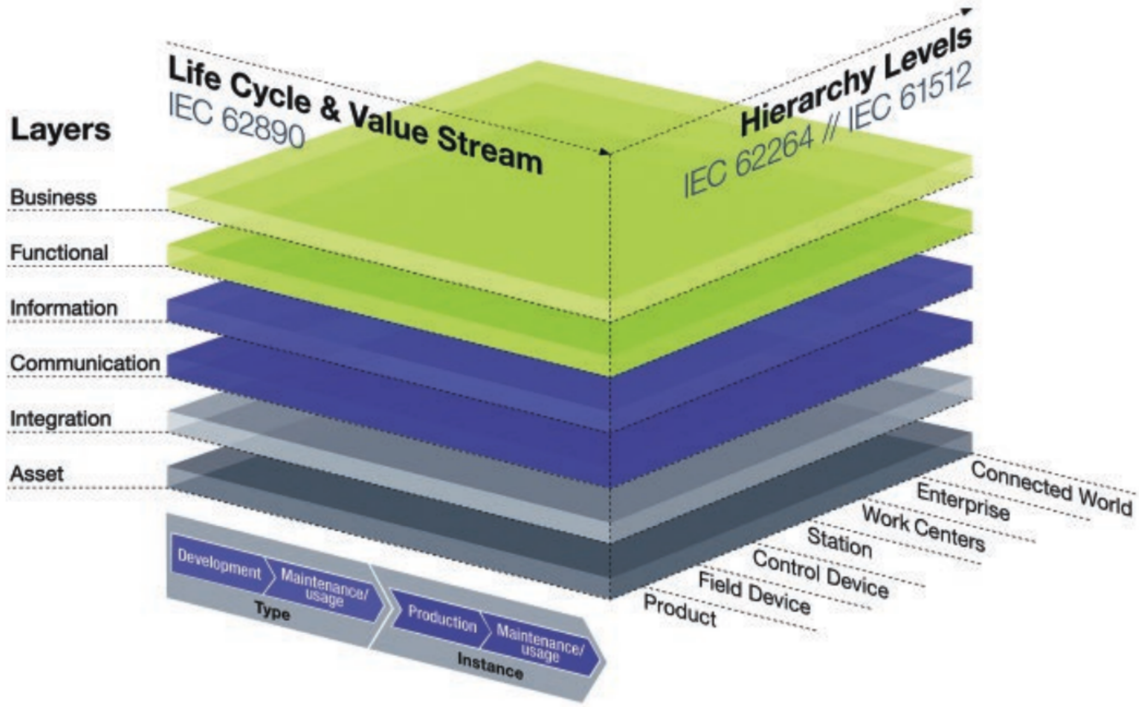

Figure 2.2: RAMI 4.0 model

- Vertical axis — The perspective of the functions, information, communication of the processes representing the various aspects of the manufacturing process.

2.3 Vertical axis

As the manufacturer solves different problems, the issues are decomposed by the RAMI model into smaller parts which are handled separately. Every layer should be able to exchange information and events only with the adjacent layers and inside itself and no other communication should be happening as to maximize the cohesion and minimise the tight coupling between each layer[4].

Business layer

The business layer represents the business models and processes happening in the real physical world and translates them to the digital world. It provides the interface for the events which govern the manufacturing processes and works as the orchestrator for the whole operation. The orchestration is targeted to the individual business processes happening at this level as well as the individual functions which are the concrete compositions and form the representation of the business processes. Also, this layer is responsible of the integrity of the functions in the value stream and the alignement with the legal and regulatory frameworks and restrictions.

Functional layer

The functional layer represents the individual functions performed while the business processes of the manufacturer are executed and their composition is forming the processes. The formal description of the functions is present in this layer and it serves as the platform for the horizontal integration of the different functions within the manufacturer in order to ensure and persist the integrity of the information and process conditions. The decisions are created in this layer of the operation and may be delegated to the lower layers.

Information layer

This layer provides the run time environment for the processing of the events emitted by the execution of the manufacturing processes and is responsible for the management of the rules defining the handling of the individual events. The data representing the reality in the form of the models of the assets are persisted by this layer and the integration of the data from the different sources is happening in this layer in order to provide the value by the higher and new quality of the integrated and enhanced data.

Communication layer

The communication layer is responsible for the provisioning of the standardised and reliable means of the communication by the definition of the concrete protocols and data structures.

Integration layer

The integration layer is providing the services of the communication between the assets (typically machinery equipped by the sensors) with the higher layers. It enables the availability of the information from the assets to the IT information environment.

Asset layer

This layer represents the reality of the physical equipment such as axes, documents, diagrams of the machinery.

2.4 Horizontal axis – Life cycle and Value stream

This axis is providing the overview of the developed product, machinery, factories and other throughout the lifecycle phases and focuses on the added value of the product processing via the creation of the services based on each phase. This axis is conceptually divided into the phases of type and instance.

Type

Type in the context of the RAMI 4.0 model is similar to the type as seen in the object oriented programming languages. It serves as the blueprint of the idea defining the attributes and characteristics of the created product and represents the main idea of the product which is being developed. The areas covered by the type lifecycle are research and development of the new product, design orders the development, simulation and validation of the product designs and final testing. In this phase, the complete blueprint for the manufacturing of the final product is being created and serves as the basis for the production.

Instance

When the products are manufactured, the type blueprint serves as the recipe for the manufacturing process. Each manufactured product is the concrete instance of the product type possibly with the unique serial number and is delivered to the final customers. Conceptually, the instances of the product are viewed as the types by the customers up to the point of their installation in the machinery or their usage. The feedback for the instances typically leads to the improvements and modifications of the manufacturing process or type blueprints.

Value stream

A very popular method for the optimization of production systems is the Value Stream Mapping (VSM) of the Toyota Production System, which is used to visualize the production process and minimize the "seven wastes" (inventory, transportation, motion, waiting, over-processing, over–production and defects)[8]. The linking of the different value stream contains a potential for the improvements.

2.5 Horizontal axis – Hierarchy levels

The horizontal axis provides an overview of the different elements placed within the factory of the facility and focuses on the hierarchy of the elements so that it represents the manufacturing process as it is carried out. This level is based on the IEC-62264 standard which is described below and IEC 61512. The IEC 61512 is called "Batch control", consists of 4 parts and covers the terminology, defines the physical model, procedures, and recipes for the batch operation. The proposed hierarchy, as depicted on the figure 2.3, is based on the "Equipment Hierarchy model" of the IEC-62264 standard and is enhanced for the needs and requirements of the Industry 4.0 .

The control device which operates the machinery and equipment is from the perspective of the "IEC-62264 " the decisive point which is significant in the integration of the information systems from the shop floor to the high level management level. According to the [4], the "field device" representing the equipment itself which is part of the manufacturing process was added to the hierarchy in order to capture also the considerations and events happening within the machine or a system. The next step in the hierarchy which needs to be visible in the context of the Industry 4.0 is the product to be manufactured itself and it was added to the hierarchy as the most fundamental and lowest part of the hierarchy as "Product". This natural extension of the Equipment Hierarchy model represents the complete and homogenous consideration of the requirements of the product itself, the machines performing the actual manufacturing and the higher level segments and components which are part of the overall process.

As stated in the following chapters, the IEC-62264 standard defines and models the reality of the manufacturing and integrations in the context of the factory[2]. The RAMI 4.0 model proposes another extension[4] in order to enable the Industry 4.0 to gradually advance and provide the context for the collaboration of the group of factories within a single manufacturer or the integration with the external engineering companies, component

[2] Or the physical facility.

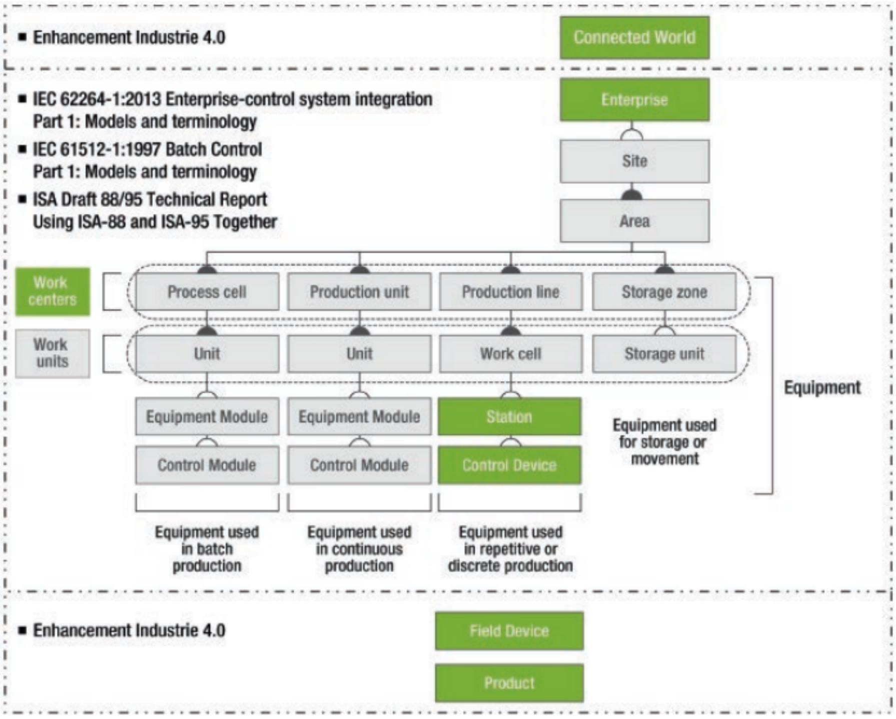

Figure 2.3: The RAMI 4.0 hierarchy

suppliers and customers[3] via the concept of the "Connected world" which is the topmost element in the hierarchy as the connection and integration point.

2.6 Industry 4.0 components as proposed by RAMI 4.0

According to the [4] the necessity to distinguish between the types and instances originates in the fact that various business partners are collaborating in the Industry 4.0 and the lifecycles of the each intermediate product or component needs to be considered.

- **Product** — manufacturer typically produces several products each with its own life cycle and unique position in the life cycle;
- **Order** — as the order is processed, it is a subject of the order processing with the different stages and the specifics has the impact on the overall manufacturing process;
- **Factory** — the provisioning of the factory has its own life cycle as it is planned, financed, constructed and recycled and it integrates different systems and machines;
- **Machine** — the equipment is ordered, designed, commissioned, operated, serviced and recycled.
- **Machine component** — the equipment is composed of different components each with its own life cycle;

[3]The collaboration in the context of the Industry 4.0 is meant to be carried out through the complete chain of participants, therefore it is not limited to the mentioned list only.

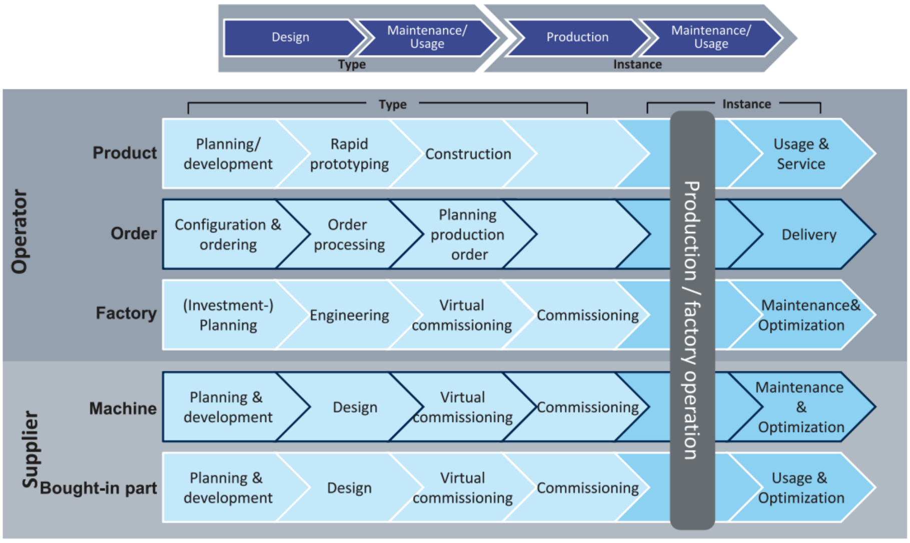

Figure 2.4: Industry 4.0 component lifecycles

The figure 2.4 illustrates the life cycle stages of the Industry 4.0 components and the transitions from the type and instance stages. The design and planning phase of each type is the source of the data and information which can be utilised during the usage of the given instance of the type. The information about the machinery part produced by the supplier (in the life cycle stage of the commissioning) is used during the planning and development (type) of the machine which will be used for the manufacturing and the instance of the part is used in the machine's commissioning process (instance). The factory type is also considering the information from the machine's "type" stage and the machine's "instance" is commissioned together with the factory "instance".

In order to provide the common definition and properties independently of the life cycle stage and hierarchy level, the notion of the Industry 4.0 component is introduced by the RAMI 4.0 model[4]. "An Industry 4.0 component can be a production system, an individual machine or station, or an assembly inside a machine. Each Industry 4.0 component, however different they may be, therefore moves along the life cycle of the factory in the field of tension between the relevance of the office floor and shop floor, and in contact with such central and significant factory systems as the PLM (Product Lifecycle Management), ERP (Enterprise Resource Planning) and Industrial Control and Logistics systems."

There are two hard requirements placed on the Industry 4.0 components as viewed by the RAMI 4.0 model. The composition of the network of the components (their structure) must be possible for any end points and its concept must meet the requirements on different focal areas — office floor or shop floor[4].

2.6.1 Industry 4.0 component properties

The properties of the Industry 4.0 component are illustrated by the figure 2.5. Each component must exist either as the type or instance, as described above. In order to enable the

[4]This terms are used to define clear separation of the responsibilities within the manufacturer where the shop floor refers to the actual manufacturing and the office floor refers to the more abstract functions of the manufacturer such as planning etc.

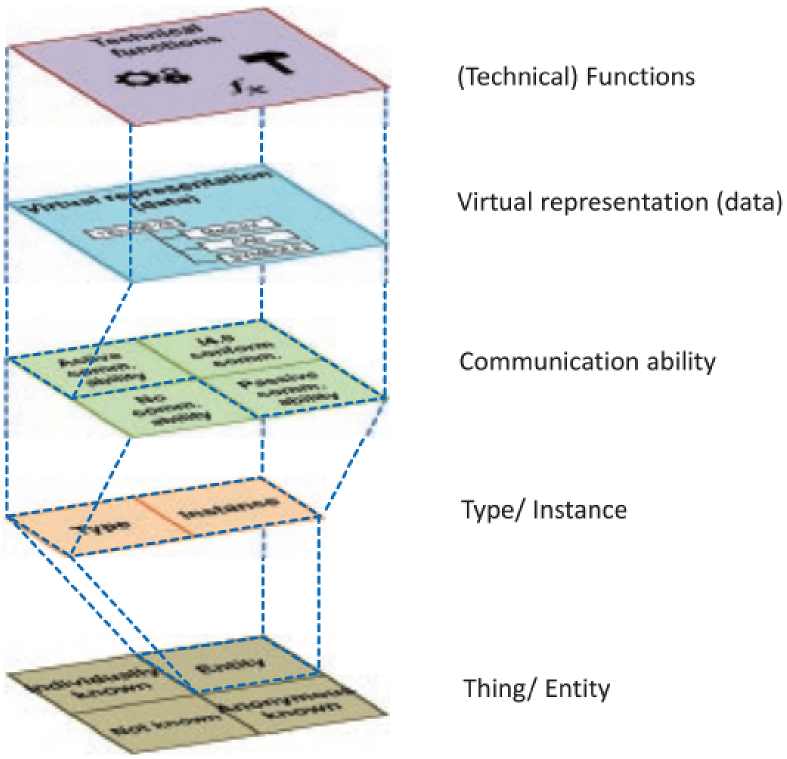

Figure 2.5: Properties of the Industry 4.0 component

integration and collaboration of the components and the ability to work with the properties of the component, at least one information system must maintain the connection with the object. The component can contain at least the passive communication ability in order to be considered the Industry 4.0 component[4] so that the existing objects[5] can be enhanced and incorporate to the Industry 4.0 infrastructure. The RAMI 4.0 therefore places a great emphasis on the communication aspects of the components and the Industry 4.0 compliant communication ability via the communication layer of the vertical axes serves as the foundation of the Industry 4.0 components environment.

The virtual representation of the object is represented by the information about the object which can be kept by the object itself and made available by the Industry 4.0 compliant communication or by the information system which enables the communication with the object. The technical functionality provides additional added value of the object in form of e.g. software for the manipulation of the object etc.

2.6.2 Administration shell

The RAMI 4.0 model introduces the notion of the "administration shell" as the required part of the Industry 4.0 component which provides the communication ability for the classical component and contains the virtual representation and technical functionality of the object. There are four possible configurations of by object illustrated by the figure 2.6 as seen by the RAMI 4.0[4]:

1. Entire machine is constructed as the Industry 4.0 component by the manufacturer;

[5] Applies mainly to the existing machines.

2. Important part of the machine, e.g. electric block, is considered the component in itself so that its properties can be retained during the life cycle of the machine;

3. The intermediate assembly from the supplier can be considered as the Industry 4.0 component e.g. in order to be processable by the asset management systems;

4. The software can be an important asset in the life cycle of the manufactured product.

The "administration shell" does not have to be tightly coupled with the Industry 4.0 component itself and the figure 2.6 serves as the logical overview of the components' composition. The actual deployment may be (and often is) in the form of the decoupled elements and the component in the meaning of the machine, its part or the sensor does not have to carry the virtual representation or the technical functionalities as those are provided to the connected world by the administration shell typically in form of the higher level information systems. The "passive communication ability" which is required from the Industry 4.0 component[6] is used for the communication of the administration shell with the component itself[4].

In the perspective of the internal representation of the Industry 4.0 component, the RAMI 4.0 model also proposes a usage of the manifest[7] and the resource manager which represents the interface to the outer Industry 4.0 components and enabled the usage of the component's data and functions.

2.6.3 General characteristics of the component

The "Industrie 4.0" if the Technical Committee 7.21 of the VDI/VDE Society Measurement and Automatic Control defines a component as the element designating an object in the physical world or the information playing the particular role in the system or is intended for such role[4]. This description can be used for the majority of the elements present or used in the manufacturing process and each has a relationship with the function it performs in the system. The Industry 4.0 component is the specific type of the component which possesses the passive or active communication ability but not all the components in the Industry 4.0 system are necessarily Industry 4.0 components. The following chapter contain a description of the generic characteristics of the Industry 4.0 components.

Identifiability

The network of the connected Industry 4.0 components forming an Industry 4.0 system needs to provide a way to uniquely identify each component (and therefore a physical object which may be represented by the component). The information systems are increasingly working on the form of the connected networks. The identifiability requirement helps accessing all the required data in real time. The provided information is used throughout the value streams and life cycles of the production.

Industry 4.0 compliant communication

The RAMI 4.0 model proposes and expects the communication of the components based on the available and used standards in order to be able to create a network of cooperating

[6] Also, active communication ability can be used.
[7] Selected on account of the .JAR file, see Manifest at: http://docs.oracle.com/javase/7/docs/technotes/guides/jar/jar.html#JAR_Manifest

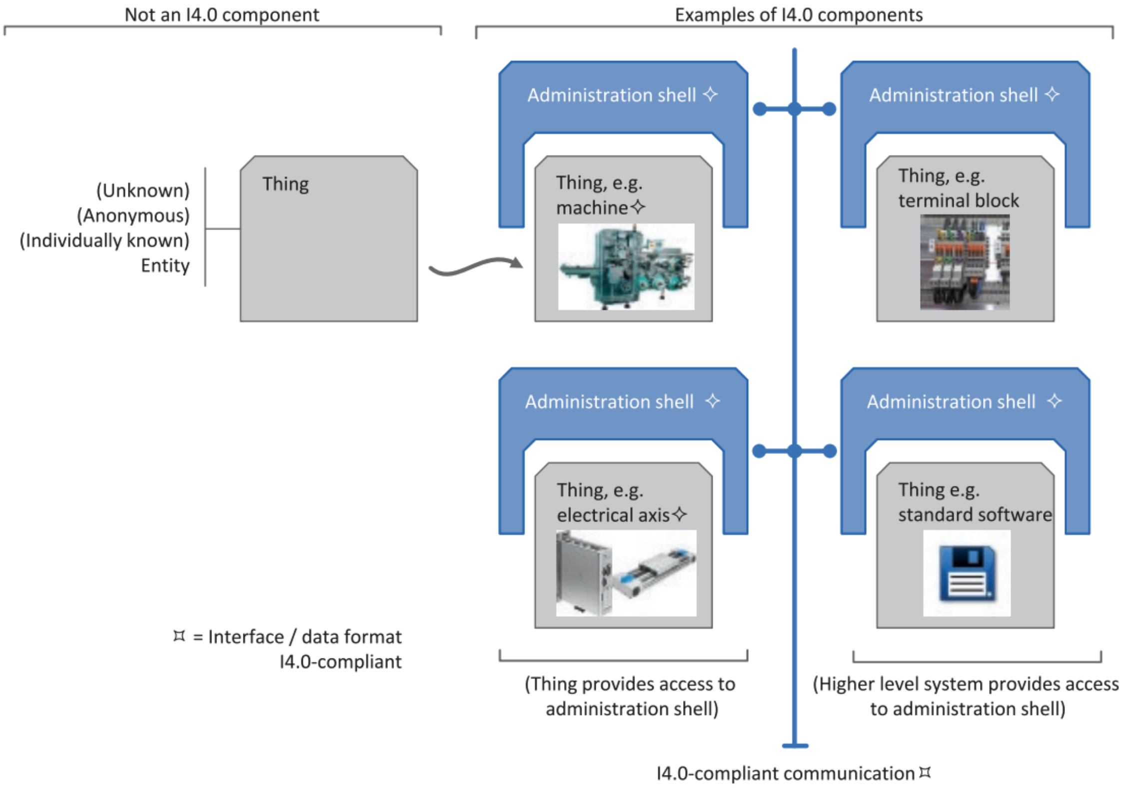

Figure 2.6: The Industry 4.0 component examples

components which are adding value by the created synergies. The communication should be based on the SOA pattern and fundamentals [8] and utilising the resource manager.

Industry 4.0 compliant services and states

As the components needs to be able to be participating at the different levels of operation, they need to operate with different protocols as needed.

Virtual description

The static characteristics as well as the dynamic description of the component's behaviour needs to be contained within the component and serves as the digital footprint of the physical component. The manifest describes the characteristic features of the real component, relationships between the features, possible relations to other documents and the description of the component's functions. The manifest serves as the public descriptor for the features and functions of the component.

Industry 4.0 compliant semantics

The exchange of information between two or more Industry 4.0 components requires unequivocal semantics.

[8] Service Oriented Architecture described at https://en.wikipedia.org/wiki/Service-oriented_architecture

Security and safety

The component must provide the protection of the data and functionality as well as cooperate in the security of the parent such as the machine.

Quality of Services

In order to be able to cooperatively work in the network of connected devices, the certain qualities needs to be met and maintained.

State

As the manufacturing process is stateful, the components needs to transparently report its state during each phase and lifecycle. The components are used together and the business functions must be coordinated.

Nestability

The hierarchy of the components can be constructed in order to provide the added value.

2.7 Overview of the standards and concepts of the RAMI 4.0

The following section provides the overview of the standards and technologies used and referenced by the RAMI 4.0 model of the Industry 4.0 . The figure 2.7 provides the overview of the relationships between the components[9].

The center of the standards and the concepts of the RAMI 4.0 is the notion of the component and the connected administration shell which is the main entry point of each individual RAMI 4.0 enabled component[7]. It serves as the source of the data and information about the component and provides the functions and functionalities of the Industry 4.0 component. The shell is the required element of each component to be considered as Industry 4.0 . The Industry 4.0 component is tightly coupled with the state and life cycle during the execution of the business processes as the actual execution changes the state of the whole system and its elements.

The standards describing the hierarchy and logical and physical separation of the manufacturing plants are present in two forms.

IEC-62264 — focuses on the integration of the different layers of the operation and tries to describe the bridge between the fundamentals happening in two time frames. The first are the processes and agenda happening on the day to month time frames such as logistics, warehousing, supply of the materials for the production, strategic planning of the operations. The second are the functions required for the actual processing happening in the minutes to day time frame. These two operational modes need to be integrated in order to enable the transparent and real time flow of the information and provide the flexibility needed for the constantly changing external environment. The chapter 2 describes this standard in more detail.

IEC 61512 — focuses on the specific type of the production called the batch processing which has the specific needs and this standard describes the equipment and processes needed

[9] Retrieved from http://i40.semantic-interoperability.org/index.html

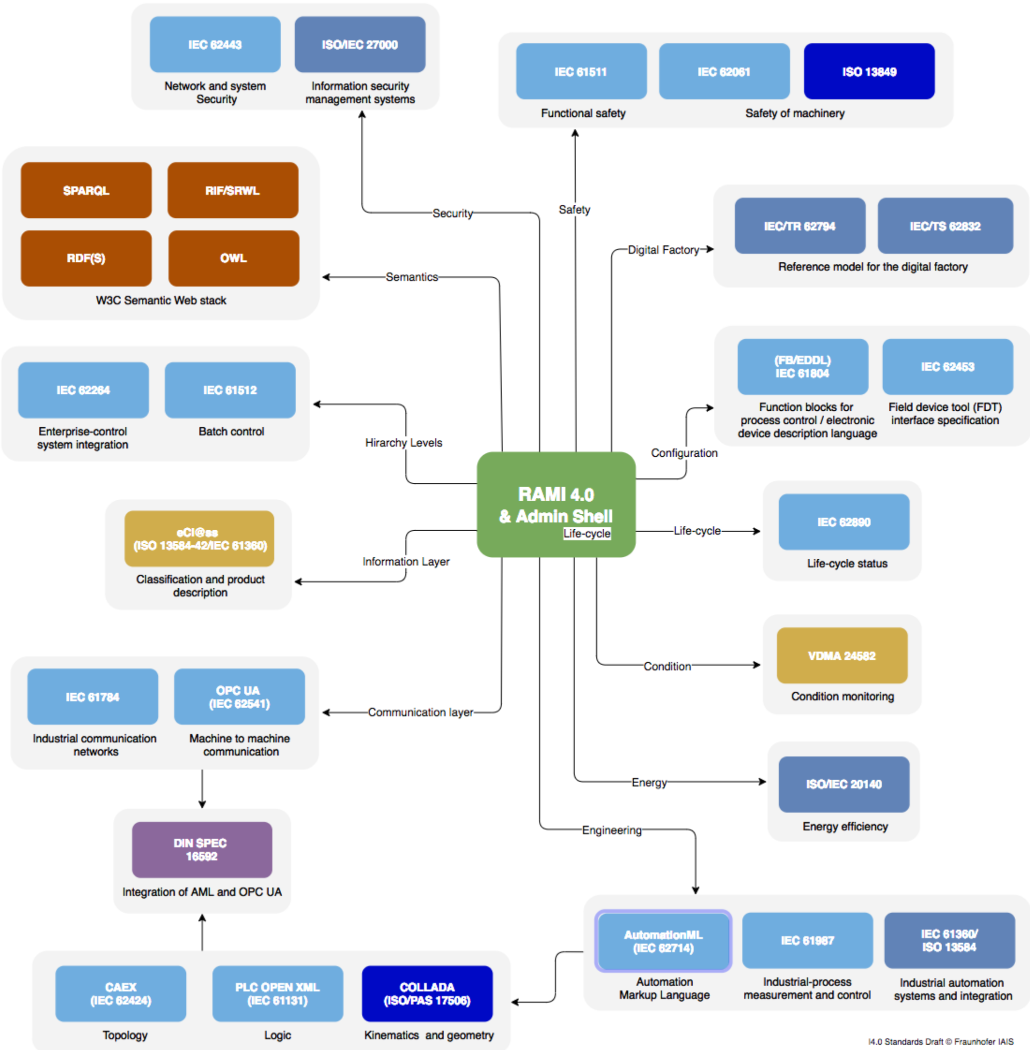

Figure 2.7: Overview of the standards used by the RAMI 4.0 model

to manufacture in the batches. Apart from the IEC-62264 , this standard provides the description of the physical model of the batch manufacturing, the proposed way of the description of the manufacturing procedures and its elements and the recipes used in the manufacturing process.

The classification of the goods and services is provided by the eCl@ss standard which was created by the leading multinational companies and manufacturer such as Siemens, Volkswagen, SAP or Bayer AG. This concept provides the ISO/IEC compliant data standard for the unambiguous description of the products in order for the data to be easily shared across the industries, languages and companies. The eCl@ss is a hierarchical classification system which is based on the ISO 13584 series of the standards for the Industrial automation systems and integration consisting which provide the representation for the data and objects. The eCl@ss also uses the IEC 61360 Common Data Dictionary. It consists of the Segments, Main groups, Groups, Commodity classed and Properties, e.g. 16-00-00-00 (Segment „Food, beverage, tobacco“), 16-04-00-00 (Main group „Fruit“), 16-04-03-00 (Group „Berry fruit“), 16-04-03-01 (Commodity class „Blackberry“)[5].

The communication ability and protocols to be used between the Industry 4.0 components is covered by the OPC UA[10] which is the machine to machine communication protocol developed by the OPC Foundation. This framework is adhering to the concepts of the service oriented architecture with the concepts of the security tied with the protocol itself and focuses on the communication with the industrial machinery and systems for the data collection and control. The IEC 61784 set of standards defines an industrial communication networks based on the Fieldbus (IEC 61158) concepts which define a hierarchy of the distributed control systems[7].

The AutomationML is the neutral data format based on the XML which aims to provide the description of the plant engineering information so that the different landscapes such as the mechanical engineering, electrical design and others can be interconnected. The AutomationML is used together with the CAEX format for the description of the topology, PLCOpenXML for the description of the logic of the industrial control programming and COLLADA for the kinematics and geometry of the plants.IEC 61987 is used for the description of the measurement strategies and concepts for the controlling and measurement equipment.

Safety of the Industry 4.0 is described by the IEC 61511, 62062 and 13849 standards. The IEC 62890 provides the consistent data model covering the whole life cycle and the concept of the digital factory is described by the IEC 62832 standard.

The language and concept of choice used to provide the description of the information, assets and physical world used by the RAMI 4.0 model and information systems adhering to the RAMI should be the semantic web stack based on the Resource Description Framework (RDF) which provides the means to create the semantical descriptions of the reality via the conceptual relations between entities using the XML format.

[10]Open Platform Communications Unified Architecture

Chapter 3

IEC-62264 standard

3.1 Basic concepts

The IEC-62264 standard is the result of the standardisation procedure based on the ISA-95 methodology. The ISA -95 is the methodology and standardised package providing the information and foundation of the integration on the manufacturing plant level and focuses on the integration of the ERP and MES level information which can be afterwards used in the integration of the different manufacturers and different functional vertical areas.

Both the ERP and MES areas are focused on the different aspects of the manufacturing reality. The ERP systems are focused on the issues and problems originating in the longer term planning of the whole manufacturing and tries to solve the fundamental questions regarding the business direction of the manufacturing while the MES systems are handling the day-to-day operational problems and this kind of systems is responsible for the actual manufacturing process and guarantee that the production happens on the planned machinery and the production process is creating value as expected.

These two aspects are fundamentally different (in the terminology and solved problems) and the IEC-62264 tries to create the bridge enabling the bidirectional real time communication and understanding so that the decision making process could be based on the most recent and exact information.

3.2 Part 1 – Models and terminology

The part 1 of the IEC-62264 standars presents various models and terminology which can be used throughout the integration projects. The models and terminology are providing a link which is used during the preparation and execution of projects with the main focus on the automation of the information exchange between the MES and ERP systems. The main area of the focus is the introduction of the common language and models which can be exchanged and the framing of the different functionalities executed by the MES and ERP systems so that the responsibilities are clear and the integration strategy and means of communication can be based on the common foundation. The next chapter presents the most important models which are described by the first part of the IEC-62264 and focuses on the different aspects of the manufacturing from the perspectives of the business processes, physical and logical segmentation and individual functions performed by the different parts of the manufacturer.

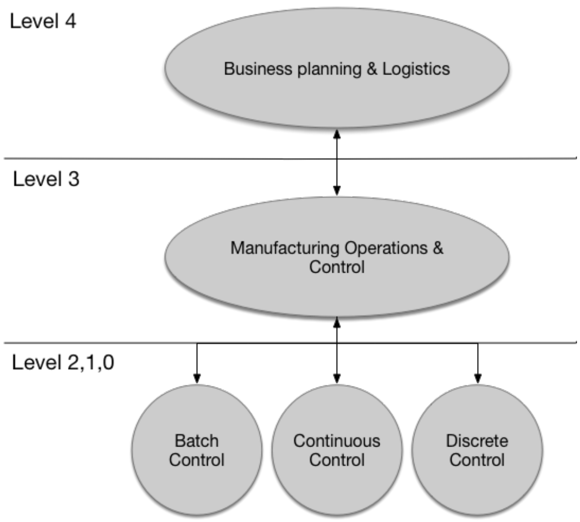

Figure 3.1: Functional Hierarchy Model

3.2.1 The Functional Hierarchy model

The main responsibility of the Functional Hierarchy model is providing a differentiation of the functions executed by the manufacturer into separate layers. The clear distinction between the layers must be ensured so that the concepts of the Master Data Management can be followed and the framing of the standard is clear.

Each manufacturing company, according to the IEC-62264 standard[1], operates on 5 levels (from the perspective of the information and process details). The figure 3.1 depicts the main layers which are being discussed. The most abstract layer called "4^{th} level" covers the "Business planning & Logistics" activities. It is responsible for the long term planning and scheduling of the manufacturing operations and typically is realised using the ERP system. This layer is also referred to as the Enterprise domain and the processes which are being solved there have the time frames from years to days and the scope could be outside of the production plant. The business decisions governing the overall trends of the enterprise and could have serious impacts on the efficiency and the future of the company.

The layer which is operated with the knowledge and decisions from the above is the "3^{rd} level" and is also referred to as "Manufacturing Operations & Control". It is responsible for the management of the processes with the time frames of days to minutes. The management of the execution of the manufacturing processes is happening at this level and typically, the MES information systems are being used for these purposes. This layer is responsible for the management of the actual manufacturing and typically directly communicates with the machinery via either the standardised or proprietary communication protocols.

The layers 2 and 1 are responsible and cover the processes which are responsible for the manufacturing itself and the actual orders for the automated equipment (or the human employees as the matter of a fact) are generated in this layer. The layer 0 is the manufacturing process itself.

The levels 3 to 0 are together called the "Control domain".

3.2.2 The Equipment Hierarchy model

The assets of the company are typically organised in the hierarchical manner. The Equipment Hierarchy Model 3.2 is used to define the responsibilities for the function levels defined by the Functional Hierarchy Model 3.1. It covers the distinction of the parts of the manufacturer.

The manufacturer according to this model is separated to the different levels. At the Enterprise domain level, there is a manufacturer itself as the whole. The Enterprise can be divided into one or more Sites where the manufacturing plants are operating. The Sites does not have to be considered equal and the standard does not expect the same functions to be carried out by every Site. Some Sites can be producing the final products while the others could be focused on handling the sales or research and development of the procedures and product definitions. The Sites are further divided into smalled parts called Areas. The Area can contain one or more Work Centers which is a general term for one of the specific units creating or adding value. The standard also differentiate between the type of the manufacturing process, as illustrated on the 3.1.

Batch processes are the manufacturing processes where the characteristic is the maximum capacity of the equipment and this places a limit on the production (e.g. volume of the tank, mixer, bin etc.). The **Continuous process** is happening when the production is executed in the continuous stream at a particular stream (e.g. water purification etc.). The **Discrete processes** are manufacturing processes which can be measured by the number of countable final products (e.g. production of motherboards). From the perspective of the Equipment Hierarchy model, four types of work centers are distinguished:

- Process Cell — covers the equipment where the batch processes take place and can be divided into Units, such as mixers, bins etc.
- Production Unit — covers the equipment where the continuous processes take place and also can be divided into Units.
- Production Line — covers the equipment for the discrete processes and Work cells are responsible for the creation of the parts of the product.
- Storage Zone — can be divided into Storage Units (typically warehouses).

3.2.3 The Functional Enterprise Control model

The functional control model depicted on the figure 3.3 provides on overview of the different functions which are being carried out by the manufacturer. Each manufacturer has to execute these functions in order to be able to produce products, however they can have different names and does not necessarily have to be executed by the dedicated department.

The standard separates the manufacturer into twelve unique functions and describes each of the functions. The functions themselves are either part of the Enterprise domain, Control domain or are present at the boundary of these levels and carry out activities falling to both domains (indicated by the wide dotted line). Obviously, the specifics of the manufacturer determines the overall importance of the specific function in the context of the particular manufacturer. For example, for the automotive company, the material control is the very complex matter which needs to be resolved as the final product is composed of the variety of the materials and intermediate products while the water purification company does not consider the material control function to be the crucial for their core business.

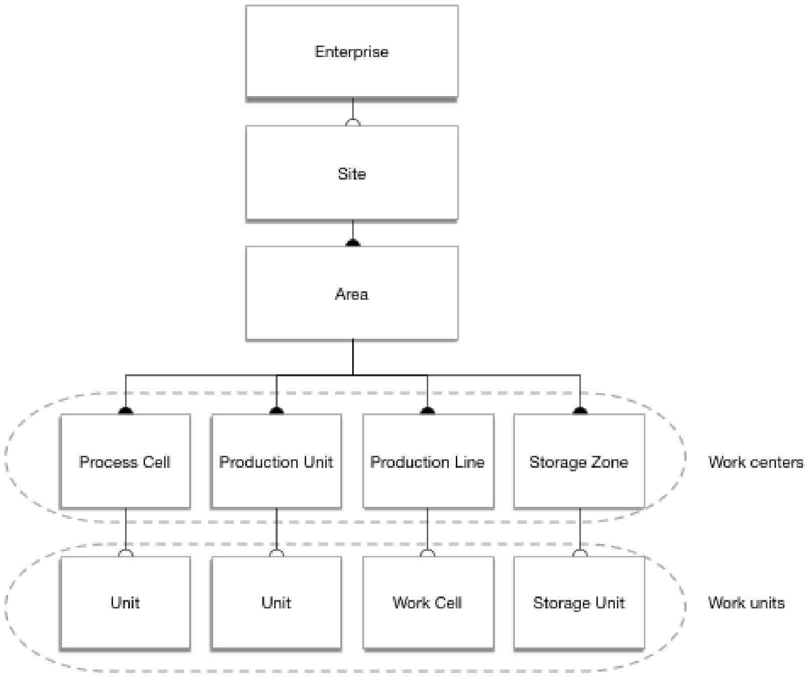

Figure 3.2: Equipment Hierarchy Model

The functional enterprise control model is meant to be used as the measurement of the responsibilities and the basis for the decision about the areas which needs the support of the IT integration projects and automation. The rest of the chapter describes each function and the description of the data flows is present in the table 3.1.

The **Research, Development and Engineering** and **Marketing and Sales** functions are enclosed in rectangles as they can be carried out by the external entities[1]. The Order Processing, Procurement, R&D and Engineering, Marketing and Sales, Product Shipping Administration, and Product Cost Accounting are all functions which are part of the Enterprise domain. The function Production Control is a pure Control Domain function, with tasks on Levels 3, 2, and 1. The functions Production Scheduling, Material and Energy Control, Maintenance Management, Quality Assurance, and Product Inventory Control are at the boundary of the Enterprise and Control domains as they all carry out tasks partly on Level 4 and partly on Levels 3 and lower.

The **Order Processing** function is responsible for the processing of the orders of the final products from the customer. Based on the data about the orders, the manufacturing is being planned and executed. The **Product scheduling** function is responsible for the creation of the long term production planning which is the responsibility of the Enterprise domain and uses the inputs from the available orders. The short term planning, which is the specialisation of the Control domain is also carried out by this function. The main output of the Product scheduling is the production plan. The activity of the scheduling needs to ensure the availability of the materials, energy and intermediate products which are required during the manufacturing.

The **Production Control** function is the only individual function of the Control domain and the main responsibility is the management of the production itself. The lower level functions (see the figure 3.1) are connected and communicate with this function. The

[1] From the perspective of the automation projects and manufacturing itself.

production control sends the instructions to the manufacturing equipment according to the created schedule, informs about the capability of the production based on the maintenance data, requests the material and energy needed for the actual production and processes the production quality information.

The **Material and Energy Control** function handles the supply of the materials and energy which is needed for the production based on the information about placed orders and actual information from the production. The **Procurement** is tightly coupled with the Material and Energy Control as its main responsibility is the actual procurement of the needed materials for the production.

The **Quality Assurance** function covers one of the most critical activities carried out by the most of the manufacturers[2]. Responsibilities of the QA is to determine the quality of the production in order to minimize the faulty products and therefore minimize the maintenance costs. This function is using and combining the data about the manufactured products (the real-time information concerning the manufacturing, such as various measurements and sensoric data), the information about the production recipes (which serves as the metric for the measurements data) and standards. It ensures the final product is built according to the customer requirements and best standards.

The **Product Inventory Control** function is providing a storage and inventory information about the final products and manages the shipping to the customer[3]. The **Product Cost Accounting** function is responsible for the handling of the costs of the final product based on the order information, energy and material costs and shipping. The activity of cost determination also considers the performance of the manufacturing and sets the objectives for the manufacturing process. The **Product Shipping Admin** function is responsible for the handling of the delivery of the manufactured products.

The **Maintenance Management** function is gradually starting to be crucial part of the manufacturing and the producers are starting to focus on the possible outcomes of this function. The responsibility of this function lies in the fact that the continuous production needs to be maintained as the direct and indirect costs of the stopped production are increasing. In case the manufacturer is not producing due to the equipment failure or ongoing maintenance, the manufacturing has to be replanned in order to utilize the personnel. The automation of this function and utilisation of the analytical methods in order to produce predictions for the maintenance needs are the current focus of the projects in the industry.

Table 3.1: Data flows of the functions

Manufacturing function	
Data flow	**Description**
Order processing	
Production Orders	As the orders are being processed, the information about what is expected to be built is provided to the Product scheduling function.

Continued on next page

[2]There are examples, where the quality control is not the most crucial part, however, it can not be omitted.

[3]The schedule of the shipments is managed by the Product Scheduling function as the order does not necessarily have to be composed of one final product.

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Manufacturing function	
Data flow	**Description**
Finished Goods Waiver	Defines the approvals for deviation from normal product specifications which may be negotiated with the customer from specifications defined in the standards and customer requirement.
Product scheduling	
Availability	In order to plan, inform and work with the customers, the availability of the manufacturing capacity is provided by the Product scheduling function.
Long Term Material and Energy Requirements	According to the production plan created by this function, information about the needed materials and energy required for the manufacturing is passed to the Material and Energy Control function which is responsible for the supply of the required components.
Schedule	The main output of this function is the manufacturing schedule which is passed to and subsequently executed by the Production Control function. It 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.
Pack Out Schedule	Provides the consolidation of produced items of one or more SKUs (stock-keeping unit) for delivery to customers, inventory after the successful manufacturing[4].
Production Control	
Production From Plan	Flow contains information about the current and completed production results from execution of the plan and specifies what was made, how much was made, how it was made, and when it was made.
Production Capability	Defines the current committed, available, and unattainable capability of the production facility and includes materials, equipment, labor, and energy.
Short Term Material and Energy requirements	Represents the requirements for resources that are needed for currently scheduled or executing production and they may include requests for materials that may include deadlines, reservations for materials, indications of actual consumption and others.
Maintenance Standards and Methods	Represents the accepted practices and procedures that maintenance must follow in performing its functions.
Maintenance Requests	Represent planned request or an unplanned request due to an unplanned event, such as a lightning strike on a transformer for the maintenance function.
Product and Process Information Request	Represents the request for new or modified product definitions and process definitions.

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[4]Considering not only the fact the product was produced, but also quality requirements.

Continued from previous page

Manufacturing function	
Data flow	**Description**
Product and Process Technical Feedback	Informs about the performance of production equipment and product. This information generally results from performance tests and study requests to operations control.
Process Data	Informs about production processes, as related to specific products and production requests and may be used by quality assurance as part of the QA functions, and may be used by product inventory control where this information is needed as part of the finished product deliverables.
In Process Waiver Report	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.
Production Performance and Cost	The actual use and results associated with specific production activities. This includes materials, labor hours, energy, and equipment usage. Results may be 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.
Material and Energy Control	
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.
Material and Energy Inventory	Represents the currently available material and energy that can be used for short-term planning and for production. This information deals with raw materials.
Incoming Order Confirmation	Represents the notification that the material or energy has been received.
Incoming material and energy receipt	Apart from the availability of the production capacity, also information about the materials needed for the production are processed. This flow represents the notification that the material or energy has been received and provides the additional information needed for cost accounting.
Procurement	
No outgoing informational flows.	
Quality Assurance	

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Manufacturing function	
Data flow	**Description**
QA Results	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. 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.
Standards and Customer Requirements	Represents the specific values for attributes of the product that satisfy the customer needs. This may include specific processing specifications as well as material properties. This information may result in changes or additions to material, equipment, and personnel properties and associated tests.
Product Inventory Control	
Finished Goods Inventory	Represents the information on the current inventory of finished goods that is maintained by product inventory control. This may include quantity, quality, and location information that can be used for scheduling of new production, and as feedback on previously scheduled production. This is the total finished product available for distribution or shipment.
Confirm to ship	Represents the information about the actual shipment of product.
Product Cost Accounting	
No significant informational flows.	
Product Shipping Admin	
Release to ship	Represents the information about the permission to ship the product.
Maintenance Management	
Maintenance purchase order requirements	Represents the information about materials and supplies required to perform maintenance tasks.
Maintenance Responses	Represents the logged status or completion of routine, scheduled, or unplanned maintenance.
Maintenance Technical Feedback	Represents the 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.
Research, Development and Engineering	
Product and Process Know How	Represents the standard operating procedures, recipes, critical safety limits, and analytical methods.

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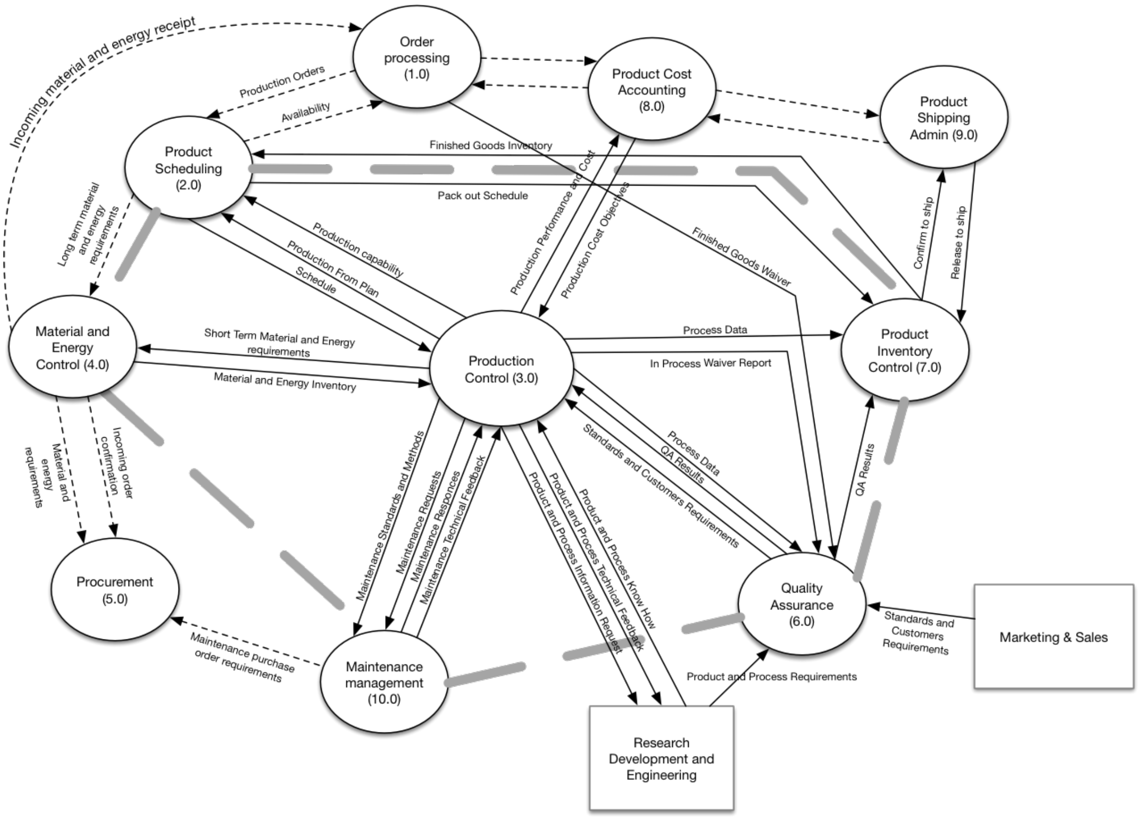

Figure 3.3: Functional Enterprise Control Model

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Manufacturing function	
Data flow	**Description**
Product and Process Requirements	Represents the information about the performance of production equipment and product. This information generally results from performance tests and study requests to operations control.
Marketing & Sales	
Standards and Customers Requirements	Represents the specific values for attributes of the product that satisfy the customer needs. This may include specific processing specifications as well as material properties. This information may result in changes or additions to material, equipment, and personnel properties and associated tests.

3.2.4 Manufacturing Operations Management model

The Manufacturing Operations Management model as depicted on the figure 3.4 introduces four categories of activities which are coordinating the personnel, equipment, material and energy required for the production and manufacturing during the conversion of the raw materials and parts into the final products[1]. These activities cover those performed by

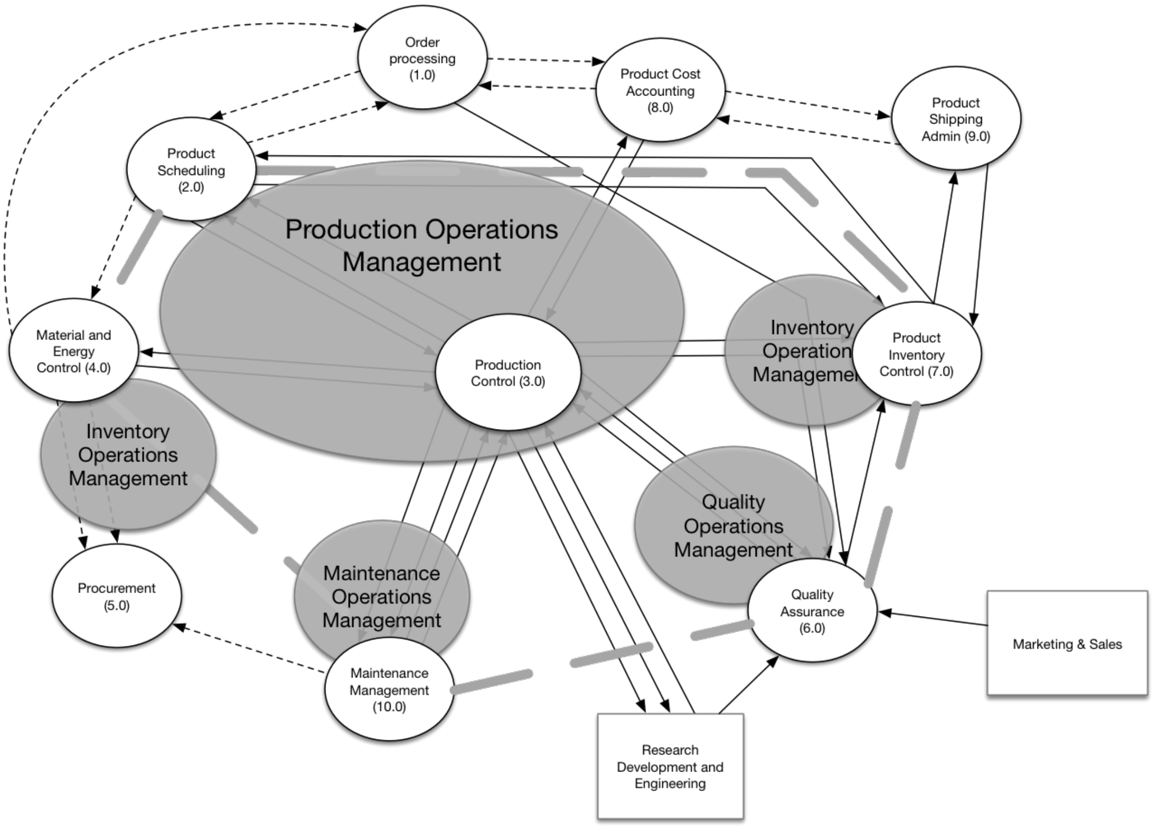

Figure 3.4: Manufacturing Operations Management model

the physical equipment, employees or information systems. The operations management activities are further described by the 3^{rd} part of the IEC-62264 .

3.2.5 Manufacturing Operations information

The model introduced in the previous chapter is using four main categories of information as illustrated by the figure 3.5. There are four categories of information relating to the four categories of the manufacturing operations management activities:

- Schedule information — describing the order for certain type of work to be carried out;
- Performance information — describing the performance of the work which was carried out;
- Definition information — providing the description of the work that can be performed;
- Capability information — describing the potential capability of the wark which can be carried out;

3.2.6 Object models

The main focus of the object model is the definition of the actual materials, their definitions and the information about the definitions and this model is used to organize the materials.

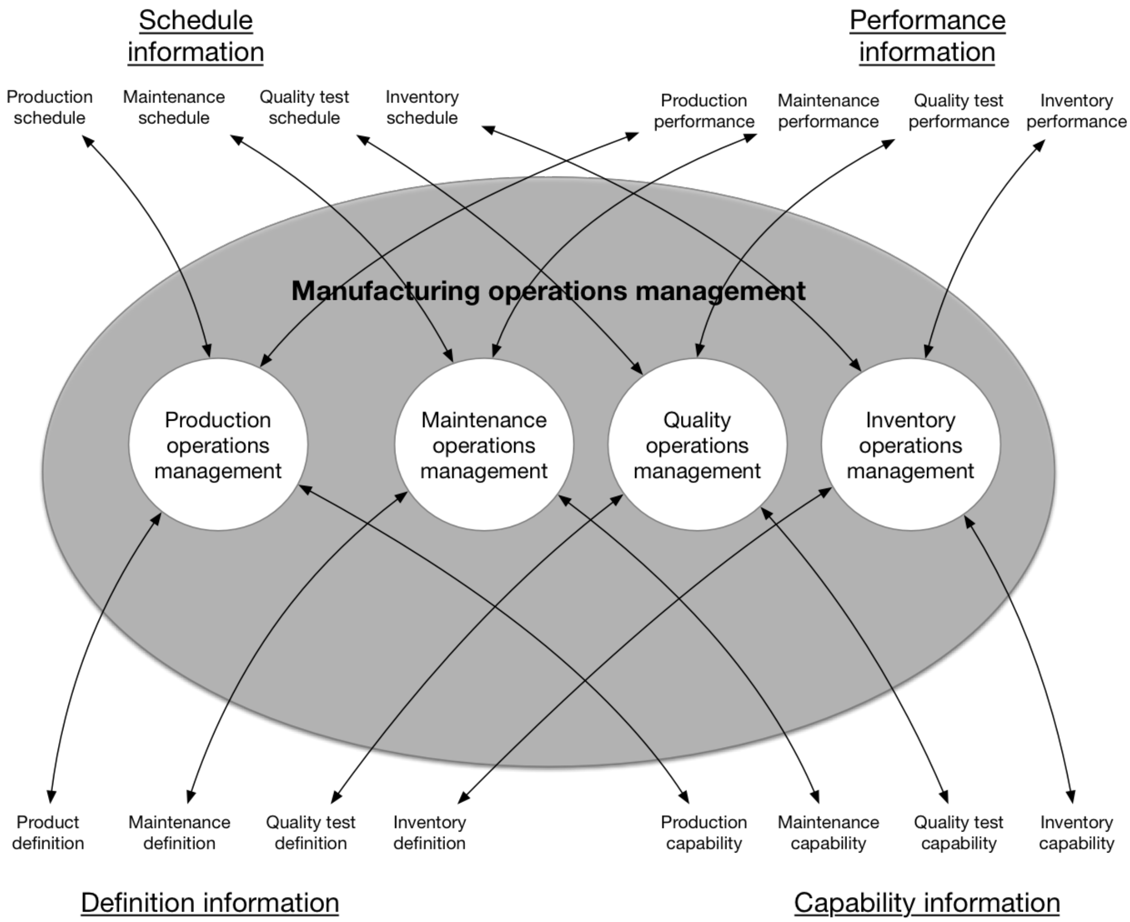

Figure 3.5: Manufacturing Operations Management model

The need to organize and standardise materials originates in the fact, that materials and references to materials are used within the different information flows between the functions. In order to provide the standardised form of the materials, the normalisation process needs to be carried out. The analysis of the informational flows determined the fundamental data which are being exchanged. Based on the identified data, the standard information exchange model was developed by the SP95 committee where the data appears only once.

The Equipment, Material and Personnel basic data were identified and they are used within the description of the information flows in the Functional Enterprise Control Model. Apart from the data building blocks, the standard introduces the notion of the Process Segment which groups the Equipment, Material and Personnel into the logical groups[5] according to the specific part of the process being carried out. Example of the process segment is Mixing. For the Mixing process, one needs the equipment (Mixer), raw ingredients (Material) and personnel (Operator).

The Categories of Information Exchange model

There are four areas illustrated by the figure 3.6 where the information described in the previous chapters fall:

- Information required to produce a product;
- Information about the capability to produce a product;
- Information about actual production of the product;
- Information about the plan of the production;

The production capability information defines what resources are available for the manufacturing process from the perspective of the personnel, material and equipment. The product definition information is specifying what is the concrete recipe for the manufacturing of the concrete product, such as assembly instructions. The production schedule is defining the plan of the manufacturing and answers the question what needs to be produced and when will the production occur. The performance information defines what and how much has been produced and which resources were used. Each of the areas is covered by the specific model which details the specifics. The following section outline one of the models used.

Production capability model

The production capability information is the collection of information about all resources for production for selected times. It 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 and is depicted on the figure 3.7.

Personnel capability is defined as a set of references to persons committed, available or unattainable at the given time. Equipment capability identifies the equipment and its availability. Material capability defines the material and its availability for the production. Process segment is defined as a logical grouping of personnel resources, equipment resources,

[5]Please note, that not every section is mandatory. E.g. for the Inspection, only inspector is needed.

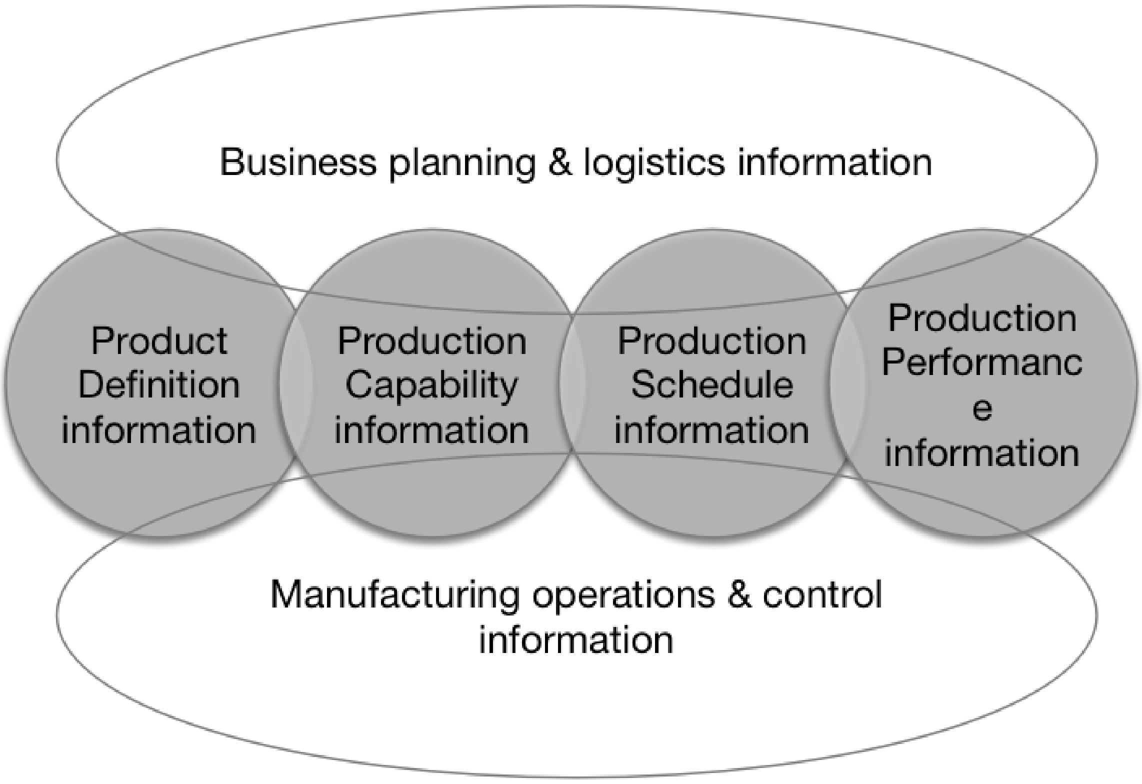

Figure 3.6: Categories of Information Exchange model

and material that is committed, available, or unavailable for a defined process segment for a specific time.

Similar principle is applied to the Personnel, Equipment and Material and the standard specifies models used to describe the characteristics of these objects and relationships between models on the "categories of information exchange" level and more detailed levels.

The information structure for Production Schedules, Production Capability, Product Definition Information, and Production Performance is fully standardised. On this level, the user no longer has the freedom to add Properties; rather, all characteristics are defined by the IEC-62264 in the form of standard Attributes. On the other hand, the more detailed models (equipment, material and personnel) are constructed using the pattern of properties of the resources which can be modified and enhanced as the relevancy of the properties differ among the industries and even individual companies. The IEC-62264 defines only a few very basic attributes, namely ID and Description.

The IEC-62264 information model with its associated Objects, Attributes, and Properties has as its objective standardization of the exchange of information between enterprise and control systems. The standard makes no verdict on the information exchange technology to be used, such as XML or ASCII. Nor does it posit any requirements in terms of data types, such as string or numeric.

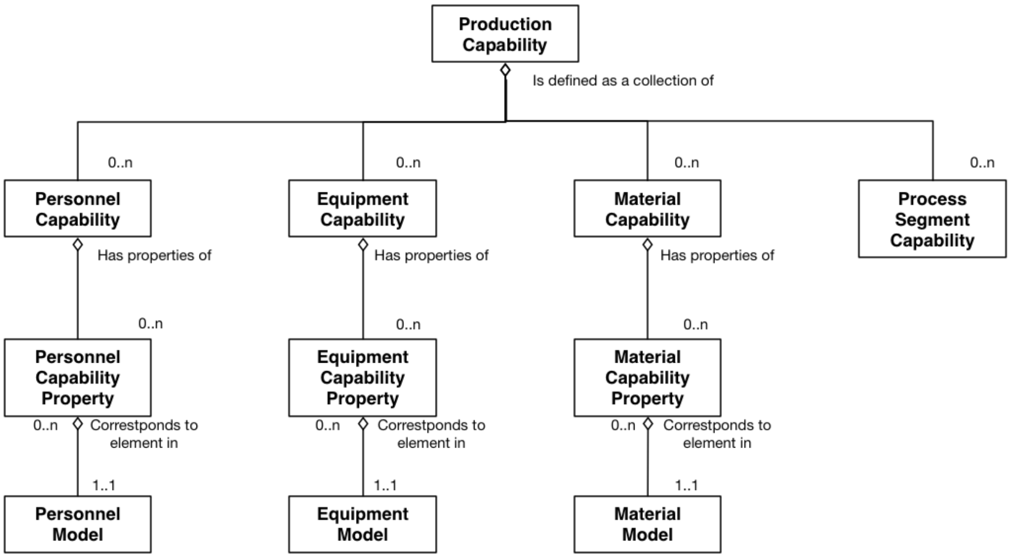

Figure 3.7: Production capability model

3.3 Part 2 – Object Model Attributes

The second part of the IEC-62264 [2] standard builds on the foundation created by the first part which creates a context of the processes and functions carried out by the manufacturer and defines information flow and data blocks which are being used.

The focus of the Part 2 is the definition of the attributes for the objects used by the models and provides the examples of the attributes. The models and objects of the Part 1 and Part 2 of the standard are trying to:

- emphasize good integration practices of control systems with enterprise systems during the entire life cycle of the systems;
- can be used to improve existing integration capability of manufacturing control systems with enterprise systems;
- can be applied regardless of the degree of automation.

The standard terminology and a consistent set of concepts and models which are being used for the integration of the control and enterprise systems leads to the benefits listed below and may be used to reduce the efforts associated with the implementation of the integration projects and ease the interoperability of the different domains.

- reduce the user's time to reach full production levels for new products;
- enable vendors to supply appropriate tools for implementing integration of control systems to enterprise systems;
- enable users to better identify their needs;
- educe the cost of automating manufacturing processes;
- optimize supply chains;
- reduce life-cycle engineering efforts.

3.3.1 Object identification

Many objects in the information model require unique IDs. These IDs shall be unique within the scope of the exchanged information. This may require translation of the IDs of the exchanged information from a system's internal identification. For example, a unit may be identified as resource "R100011" in the scheduling system and "East Side Reactor" in the manufacturing system. A unique identification set shall be agreed to in order to exchange information.

The object IDs are defined only to identify objects within related exchanged information sets. The object ID attributes are not global object IDs or database index attributes.

3.3.2 Data types

The attributes defined are abstract representations, without any specific data type defined. A specific implementation will define how the information is represented. For example:

- an attribute may be represented as a string in one implementation and as a numeric value in another implementation;
- a date/time value may be represented in ISO standard format in one implementation and in Julian calendar format in another;
- a relationship may be represented by two fields (type and key) in data base tables or a specific tag in XML;

The IEC-62264 proposes the following data values to be used in the exchange of the information described by the table 3.2 and are derived from the ISO-15000-5 Core Component Technical Specification with the semantic meaning defined by the standard[2].

Table 3.2: Proposed Simple Value Types

Type	Description
Amount Type	Defines the number of monetary units specified in a currency (which can be explicit or implicit).
Binary Object Type	Defines a data types representing the graphics, pictures, sounds, video and other forms of the information which can be stored as the finite sequence of binary characters.
Code Type	Defines a character string ised to represent an entry from a fixed set of enumerations.
Date Time Type	Defines a particular point in time together with a supplementary information identifying a timezone information. It is using the ISO 8601 CE (Common Era) Calendar extended format together with the abbreviated version.
Identifier Type	Defines a character string used to uniquely identify and distinguish one instance of an object from others present in the same information schema.
Indicator Type	Defines a list of two mutually exclusive boolean values, e.g. "True" and "False".
Measure Type	Defines a numeric value determined by the object measurement along the specific unit of measure.

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Type	Description
Numeric Type	Defines a numeric information which is either computed, counted or sequenced without the need for the unit of quantity or measure.
Quantity Type	Defines a counted number of non-monetary units also containing fractions.
Text Type	Defines a character string.

Apart from the simple types as described by the table 3.2 the IEC-62264 also defines the units of measure for the values in order to ensure the information is not misinterpreted during the exchange. The more complex types are defined as well in form of and Arrays (represented by the "[]"), rangle types (represented by the "" with the usage of dots), series for the representation of the enumerations (represented using the "<>") and structured types using the simple and complex types described above.

3.3.3 Example — Production capability model

The standard itself provides the concrete definitions of the attributes for the models used and defined in the Part 1. The list states the attributes and the descriptions of each attribute. The table 3.3 provides an example of the attributes of the production capability model as stated by the standard.

Table 3.3: Production capability model attributes

Attribute name	Description	Example
ID	Defines a unique instance of a production capability for a specified element of the equipment hierarchy model [Part 1 Section 5.2] (enterprise, site, area, process cell, production line, or production unit).	1999/12/30-HPC52
Description	Contains additional information and descriptions of the production capability definition.	"One day's production capability for the Boston Widget Company."
Capability Type	The capability type: Available, Unattainable, or Committed.	Available
Reason	Defines the reason for the capability type.	Available for Production
Location	For example, if committed, then committed for production or for maintenance, or if unavailable, then the reason for the unavailability.	Boston Widget Company
Element Type	An identification of the associated element of the equipment hierarchy model.	Enterprise
Start Time	Zero or more as required to identify the specific scope of the production capability definition.	1999-12-29 11:59
End Time	A definition of the type of associated element of the equipment hierarchy model.	1999-12-30 12:00

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Attribute name	**Description**	**Example**
Published Date	The starting date and time of the production capability.	1999-11-03 13:55

3.4 Part 3 – Activity Models of Manufacturing Operations Management

The 3rd part focuses entirely on the MES layer (Level 3) and presents models and terminology you can use to analyse and describe activities within the MES layer. These emphasize good practices for manufacturing operations and can be used to improve existing production systems. They can be applied in heavily automated companies and in companies that work largely by hand.

The figure 3.4 depicts the main interest of the 3rd part of the standard. The Control domain is separated into four groups of activities[3]: Production activities, Inventory activities, Maintenance activities, and Quality activities. The standardself defines for formal models as described in the Part 1:

- Production Operations Management — includes the activities of the Production Control which is completely present in the Level 3 domain and subset of activities of the Product Scheduling;
- Maintenance Operations Management — including the subset of activities in the Maintenance management function present in the Level 3;
- Quality Operations Management — including the subset of activities in the Quality Assurance function present in the Level 3;
- Inventory Operations Management — including the activities of the Inventory Control and Material and Energy Control functions;

3.4.1 Generic activity model

In order to support each of the mentioned activities, standard defines the generic activity model[3] of the operations management depicted on the figure 3.8. This model is used as the template and for the four categories, the specific models are proposed by the IEC-62264 , however it is possible to apply this generic model also to other types of activities within the manufacturer. The main idea behind the model is the request and responce cycle which starts with the requests or schedules, converts them to the detailed schedule, dispatches and manages the work, collects the data about the execution and converts them to the response.

The flow of information defined by the standard is depicted on the generic model between the activities regarding the same category. However, there are also information flows happening between the different categories. The IEC-62264 expects the interactions in the detailed scheduling because of the need to coordinate the work tasks assigned to the same resource at the given time and three types of interactions are defined:

- Interaction between the Detailed production scheduling and Detailed inventory scheduling as the information about the start and end of the production, material and inventory requirements for the production needs to be coordinated;

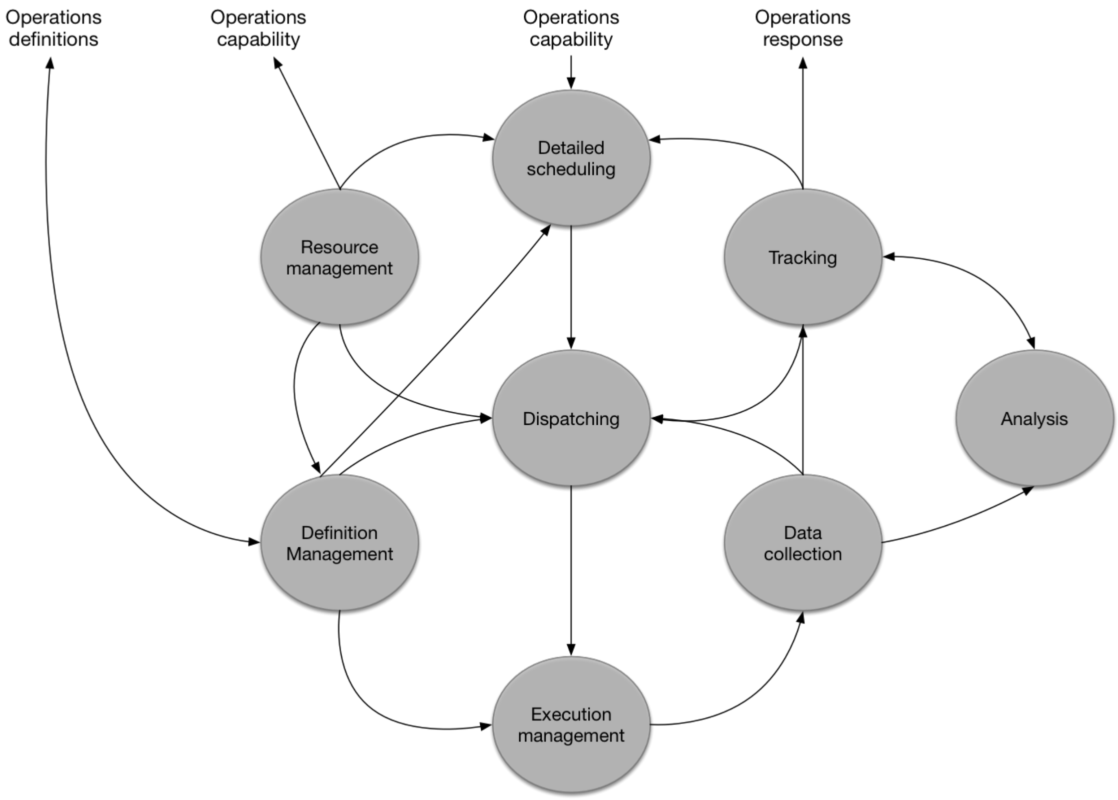

Figure 3.8: Generic Activity model of Manufacturing Operations Management

- Interaction between the Detailed production scheduling and Detailed maintenance scheduling as the information about the capability and capacity is needed and the machinery's maintenance needs to be planned;
- Interaction between the Detailed production scheduling and Detailed quality test scheduling as the quality of the products and materials needs to be verified depending on the required level;

3.4.2 Production operations management activity model

The production operations management activities are focus towards the coordination, direction, management and tracking of the functions which use the raw materials, energy, equipment, personnel and information to manufacture the products. The general activities include:

- reporting on the production;
- collecting and maintaining the data about the production, inventory and others;
- perform the data collection and analysis;
- perform the personnel functions such as the time tracking for the work statistics, schedules of the personnel etc.;
- optimize the costs of the individual production;

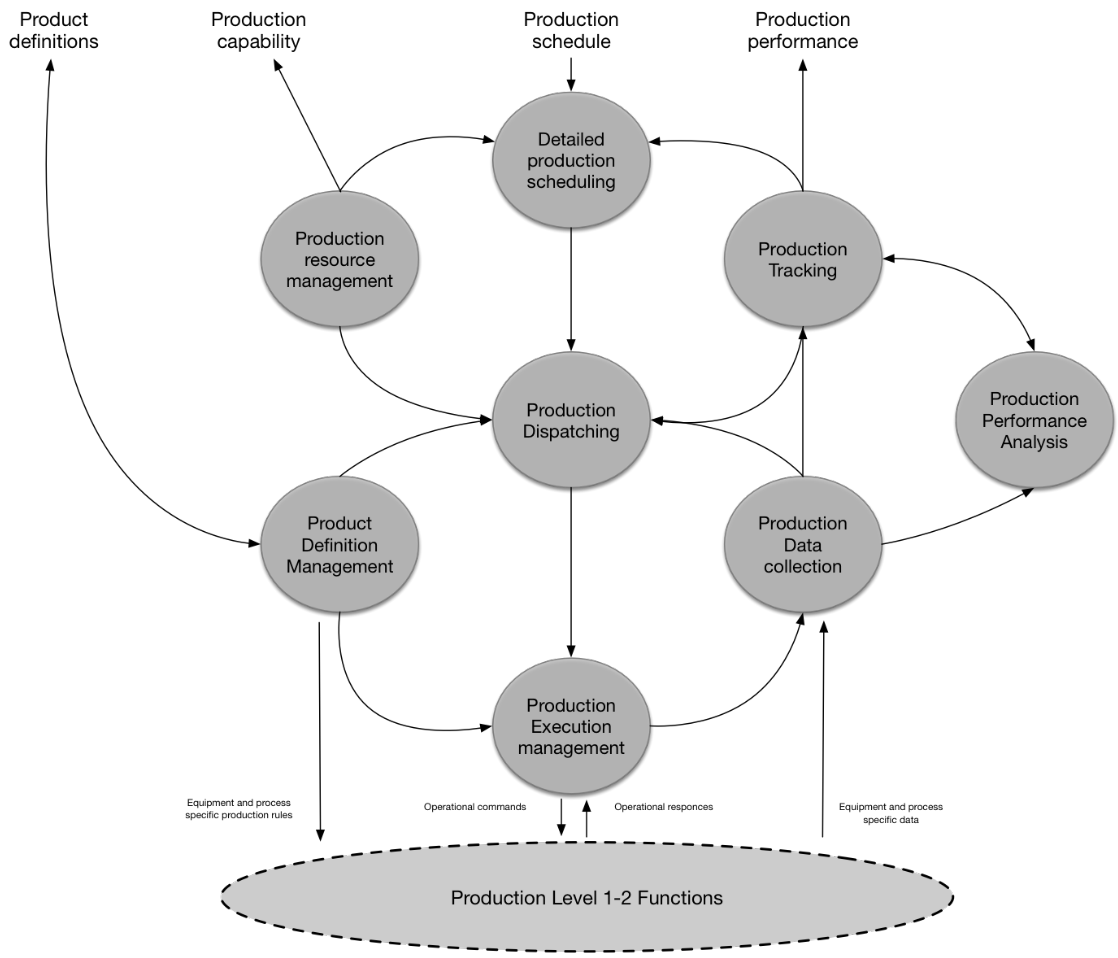

Figure 3.9: Production Operations Management Activity model

- modify the production schedules;

The model depicted on the figure 3.9 represents the logical overview of the production activities. It is not intended[6] to represent the actual separation of the activities, rather the tool to identify the activities and defines what is being done, not how it should be organised. The "Product definition", "Production capability", "Production schedule" and "Production performance" are the information exchanged with the Level 4 functions whilst the information on the bottom part of the model are exchanged with the sensing and control functions. The "Equipment and process specific production rules" define a specific instructions for the Level 2 based on the specific task being executed such as the programmes for the CNC machines. The "Operational commands" represent the requests sent to the Level 2 such as the commands to start or complete the elements of the job order. The "Operational responses" are the responses to the sent commands and "Equipment and process specific data" are monitoring information about the performed process and resources.

From the perspective of the production operation, Production Resource Management ensures the availability of the materials, personnel and equipment for the production. The instructions for the manufacturing are maintained by the Product definition Management,

[6] Also applies to other activity models.

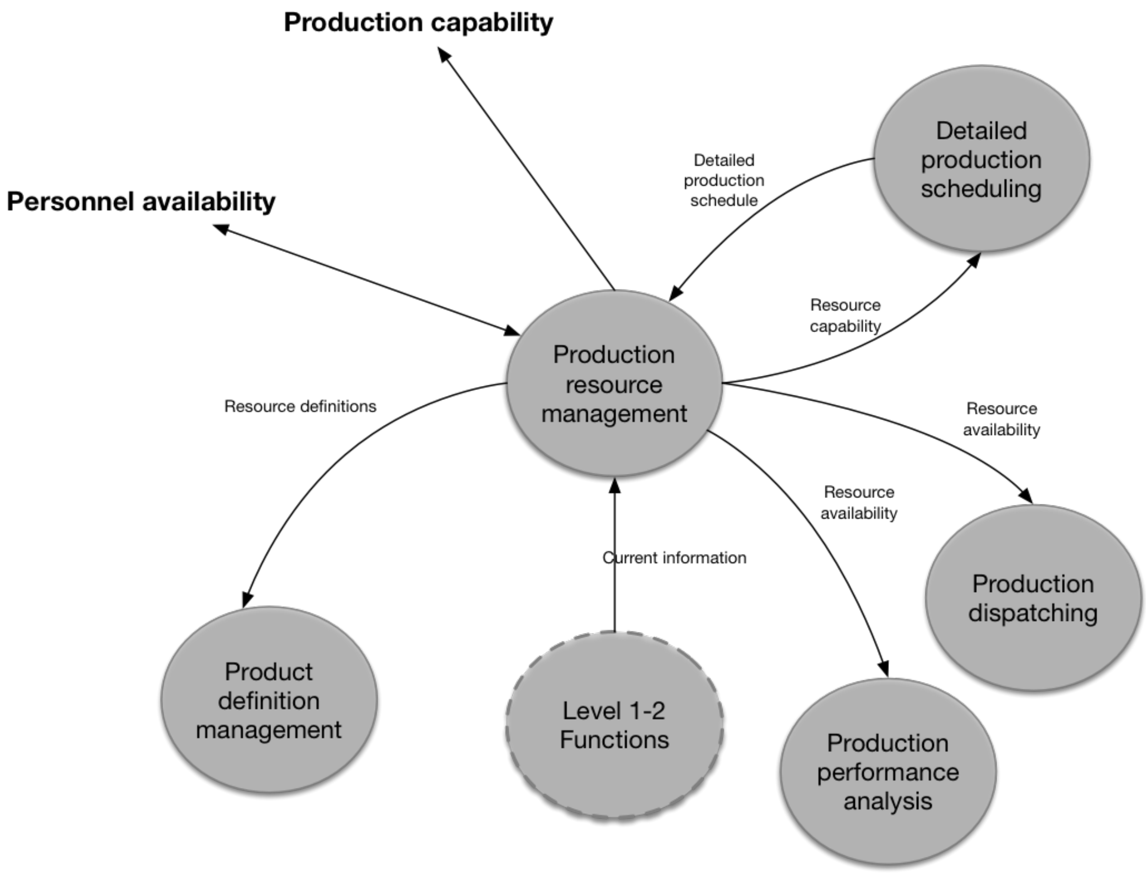

Figure 3.10: Production Resource Management activity

whilst the detailed planning and scheduling of the production is handled by the Detailed Production Scheduling activity. The Production Dispatching assigns the orders and tasks to the teams. The Production Execution Management activity function ensures the manufacturing actually occurs and the performance data and process data are gathered by the Production Data Collection. The Production Tracking is transforming the data into information for the subsequent analysis and optimization of the manufacturing by the Production Analysis.

3.4.3 Production resource management

As the example of the more detailed activities, the Production resource management activity is depicted on the figure 3.10. This model covers the activities for the management of the information about the resources required by the production and relationships between the resources and schedules. The resources include the machinery, tools, labour with the required skills and trainings, materials and energy. The direct control of the resources is present in other activities. The management may be handled by the information systems (such as the reservation systems) or manually.

3.5 Part 4 – Object Model Attributes for manufacturing operations integration

The 4th part of the standard focuses on the other aspects of the Control domain different from the manufacturing process itself. Systems for the maintenance procedures, laboratory information management, warehouse management needs to be able to communicate with each other, with the MES system controlling the production and with the Enterprise domain functions. This part of the standard contains formal data models for the information flows concerning the mentioned functions.

The definitions together with the descriptions of the attributes are provided for the different information present in the activity models as depicted on the figure 3.11.Each of the exchanged information is described by the set of the attributes.

Work capability

As an example, Work capability represents the collection of information about the resources for the work for future and past times. The attributes are:

- id – unique identifier;
- description – additional information and descriptions of the work capability, e.g. Pallet movement capacity;
- capacity type – used, unused, total, available, unattainable or committed;
- reason – defines a reason for the type, e.g. Stability tests for the committed;
- confidence factor – value of confidence of the capacity value;
- hierarchy scope – defines where the exchange information fits in the role based equipment hierarchy, w.g. Washington Brewery company;
- start and end times – defines when the capacity starts and ends;
- published date – defines when the capacity was published or defined;

3.6 Part 5 – Business to Manufacturing Transactions

The 1st and 2nd parts of the standard are creating the dividing line between the Enterprise and Control domain and sets the responsibilities of the ERP and MES information systems which are typically in control of the mentioned domains. The exchanged information is clearly separated from the perspective of the ownership and the structure is being defined by these parts of the standard. However, they do not cover the data processing and manipulation. The 5th part of the standard defines and specifies how the originating and receiving systems should interact with the data. Transactional aspects of the data are being considered.

The specified Transactions are constructed using Messages which have a prescribed content. The Messages are comprised of the Application Identification Area which is specifying the “routing” information (who is the sender and receiver and where the response should be sent to) and Data Area which is being constructed using Verbs and Nouns. Verb and

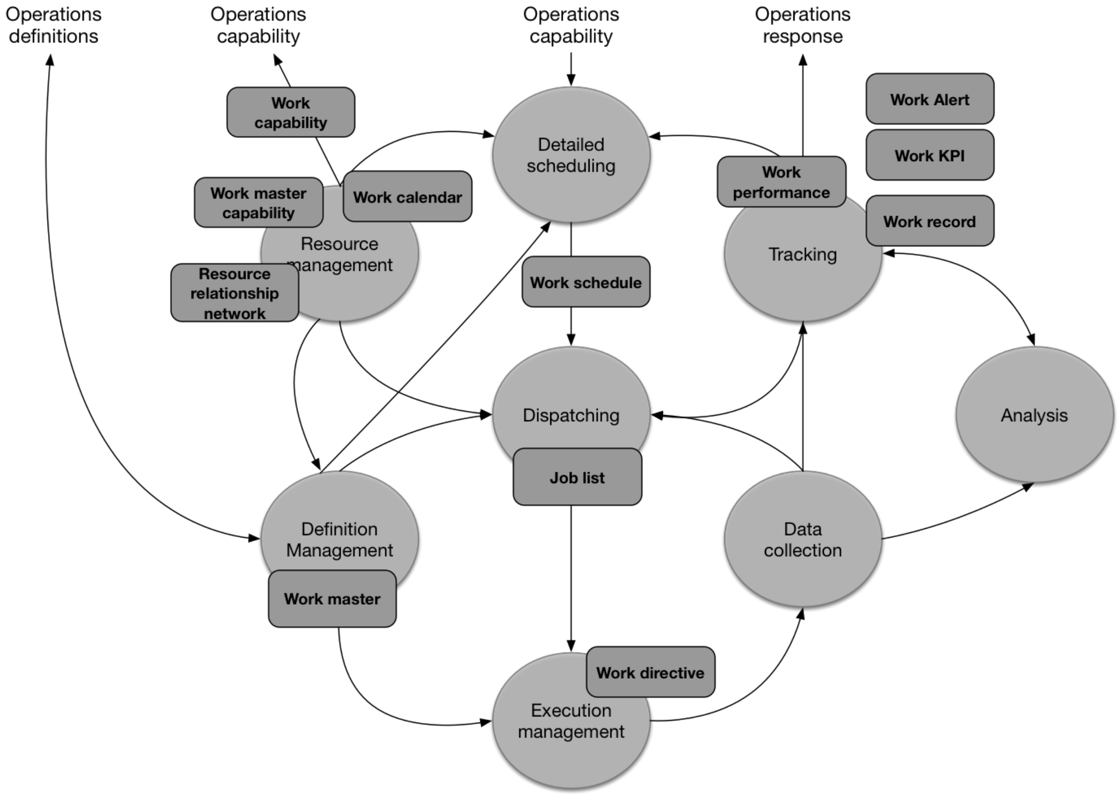

Figure 3.11: Information exchange model

Noun together creates a unique command. Nouns are representing the objects defined in the 1st part of the standard.

Verbs, on the other hand, are new construct of the 5th part of the specification and differ based on the model being used for the exchange on information:

- Pull Model — this mode of operation expects the receiving system to actively ask for the required data using the GET and SHOW verbs;
- Push Model — this mode of operation states that the system sends data on its own initiative using verbs PROCESS, CHANGE or CANCEL and the receiving system responds with the ACKNOWLEDGE or ACCEPT verbs;
- Publish Model — this mode operates on the Publish/Subscribe principle when the sending system does not know about the receiving systems and uses verbs SYNC ADD, SYNC CHANGE, and SYNC DELETE;

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