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TECHNICAL REPORT

Industrial-process measurement, control and automation – Smart manufacturing –
Part 2: Use cases

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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colour inside

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The text of this Technical Report is based on the following documents:

Draft	Report on voting
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Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 63283 series, published under the general title *Industrial-process measurement, control and automation – Smart Manufacturing*, can be found on the IEC website.

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INTRODUCTION

In recent years, one observes that an increasing number of “buzzwords” are in discussion in the manufacturing area. The scope of the various “buzzwords” is not clearly defined, moreover, the scope addressed by the “buzzwords” is not congruent but overlapping. Each stakeholder involved in these discussions has another perspective to the various topics and the discussions address very different levels of detail and consider different contexts. This is illustrated in Figure 1.

“Smart Manufacturing is one of the buzzwords that addresses multiple stakeholders. The overall community is convinced that “Smart Manufacturing” will significantly affect the manufacturing industries and, therefore, standardization will consolidate the vision of “Smart Manufacturing” from different manufacturing industries sectors viewpoints. The discussions within standardization are sufficiently formal or precise in order to later have any claim regarding compliance to standards. Thus, standardization will consolidate the definitions and understanding of the “buzzwords” for its own usage.

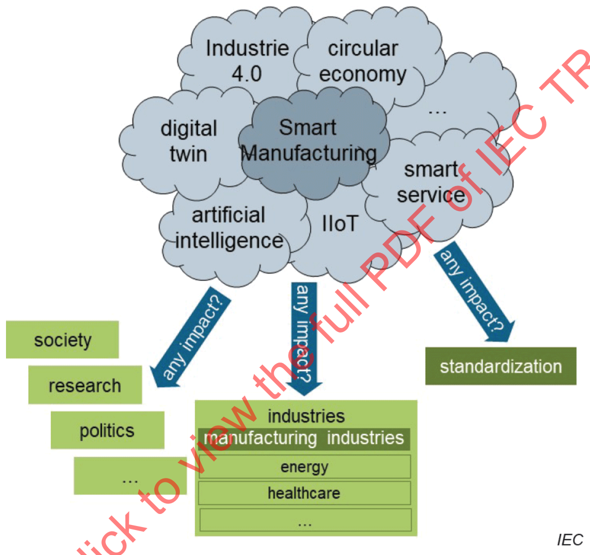

Figure 1 – Related subjects to Smart Manufacturing

In order to analyze the impact of “Smart Manufacturing” on standardization, the approach chosen is the collection and evaluation of use cases to obtain a sufficiently representative description of “Smart Manufacturing”. These use cases are described from the perspective of the manufacturing value chains. They illustrate what could be conceivable in the future in the context of “Smart Manufacturing”. Thus, a use case itself is explainable[1] to a manufacturing company. Experts in standardization will afterwards analyze these use cases to decide whether

- a specific use case provides no (new) input for standardization;
- a specific use case provides needs to maintain existing standards (this can be related to the content or the application areas);
- a specific use case provides input for additional measures to be elaborated in by standardization projects.

[1] A typical employee of a manufacturing company is not familiar with formal methods used to describe use cases as accurately as possible or even uses different terms, for example plant versus factory versus production system. Thus an explanation of the use cases is necessary.

Based on this approach the use cases will contribute to the following topics:

- Consolidation of the vision “Smart Manufacturing”: The use cases will describe the basic principles of traditional and future manufacturing value chains and will work out the additional, new opportunities enabled by digitalization.
- Consolidation of terms and concepts: The use cases will facilitate to come to agreements on basic terms and concepts. The description of terms and concepts will be in an application context and not here in a terms and definitions section.
- Justification of a general need for standardization: Based on the use cases, the fundamental gaps will be identified. It is intended to close the gaps that have not yet been filled up. Possibly, however, it is effective to first suitably upgrade the installed base based on already established standards.
- Elaboration of recommendations for standardization on an abstract level: Based on the use cases, the requirements – and not solution concepts – for standardization will be extracted to achieve a consensus for maintenance or new development of standards. It is intended to derive the recommendations from the use cases and ensure backward traceability to the use cases.

INDUSTRIAL-PROCESS MEASUREMENT, CONTROL AND AUTOMATION – SMART MANUFACTURING –

Part 2: Use cases

1 Scope

This Technical Report has the goal of analyzing the impact of "Smart Manufacturing" on the daily operation of an industrial facility. It focusses on the perspective of automation and control of the production system, but also on the supporting processes of ordering, supply chain management, design, engineering and commissioning, operational technology, life cycle management, and resource management.

These recommendations are accomplished on the basis of several carefully selected use cases that are familiar to manufacturing industry. Therefore, each use case is described, followed by an analysis of the possible influence of "Smart Manufacturing" and the assessment of the impact on existing and future standardization.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

3.1 General

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

NOTE In 3.2, all conceptual constituents of uses cases including their context are defined in a way that the document is self-explanatory. The definitions are fully aligned with IEC TR 63283-1 (65/683/DTR).

From these conceptual constituents the examples introduced in the various use cases are distinguished. These concrete roles are consolidated in 3.3, 3.4, 3.5 and 3.6 to provide a consistent cross reference of all concrete roles involved in the individual use cases of this document. For the sake of clarity, a distinction is made between business, human and technical roles. A technical role can be represented by a subject or an object, where a subject is an entity doing something, and an object is having something done to it. Thus, subjects have capabilities in the sense of having the ability to perform actions.

3.2 General terms and definitions

3.2.1
actor
entity that communicates and interacts

Note 1 to entry: These actors can include people, software applications, systems, databases, and even the power system itself.

[SOURCE: IEC 62559-2: 2015, 3.2]

3.2.2
role
set of characteristics that distinguish an entity's ability to exhibit a set of required behaviours

Note 1 to entry: In this document the entity is an actor.

[SOURCE: ISO 18435-1:2009, 3.22, modified – The word "resource" has been replaced by "entity" and the note has been added.]

3.2.3
Smart Manufacturing
manufacturing that improves its performance aspects with integrated and intelligent use of processes and resources in cyber, physical and human spheres to create and deliver products and services, which also collaborate with other domains within an enterprise's value chains

Note 1 to entry: Performance aspects include agility, efficiency, safety, security, sustainability or any other performance indicators identified by the enterprise.

Note 2 to entry: In addition to manufacturing, other enterprise domains can include engineering, logistics, marketing, procurement, sales or any other domains identified by the enterprise.

Note 3 to entry: In this document also the business context of manufacturing is considered.

3.2.4
standardization
activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context

Note 1 to entry: In particular, the activity consists of the processes of formulating, issuing and implementing standards.

Note 2 to entry: Important benefits of standardization are improvement of the suitability of products, processes and services for their intended purposes, prevention of barriers to trade and facilitation of technological cooperation.

[SOURCE: ISO/IEC Guide 2:2004, 1.1]

3.2.5
system
set of interrelated elements considered in a defined context as a whole and separated from its environment

Note 1 to entry: Such elements can be both material objects and concepts as well as the results thereof (e.g. forms of organization, mathematical methods, and programming languages).

Note 2 to entry: The system is considered to be separated from the environment and other external systems by an imaginary surface, which can cut the links between them and the considered system.

[SOURCE: IEC 61804-2:2018, 3.1.65]

3.2.6
use case
specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system

[SOURCE: ISO/IEC 19505-2:2012, 16.3.6]

3.3 Business roles

3.3.1
purchaser
legal entity requiring a good or a service in exchange for money or other resources

Note 1 to entry: A purchaser of a physical good can require it by selecting it from a catalog provided by a manufacturing company or by specifying an individual product order and requesting this specified physical good from a manufacturing company.

3.3.2
manufacturing company
legal entity being responsible for the design, development and manufacturing of a physical product in view of its being placed on the market, regardless of whether these operations are carried out by that legal entity itself or on its behalf

Note 1 to entry: Selling a physical product to a purchaser follows a negotiation procedure: on request of a purchaser specified by a product order, the manufacturing company prepares an offer. Upon acceptance of the offer by the purchaser, the manufacturing company delivers the product according to the assured product features.

Note 2 to entry: A product order can be specified by a purchaser and it is in the responsibility of the manufacturing company to assure the specified features. The purchaser can also select a product from a catalogue provided by a manufacturing company and it is in the responsibility of the purchaser to select an appropriate product.

Note 3 to entry: A product does not necessarily have to be manufactured individually for the purchaser, it can also already be in stock and delivered directly to the purchaser.

Note 4 to entry: A manufacturing company can act in the role of a supplier as well as in the role of a purchaser of another manufacturing company.

Note 5 to entry: Examples in the use cases: production resource supplier, robot supplier, gripper supplier, sensor supplier, physical asset supplier, device supplier, 3D printer supplier

3.3.3
non-physical asset supplier
legal entity delivering a non-physical product to a purchaser

Note 1 to entry: An example of a non-physical product can be a piece of information.

3.3.4
software application supplier
legal entity delivering a software application to a purchaser

Note 1 to entry: Examples in the use cases: engineering tool supplier, production system engineering tool supplier, simulation tool provider, virtual reality platform provider, data analysis tool supplier, device management system supplier, collaboration platform supplier.

3.3.5
broker
legal entity serving as an intermediary between a purchaser and a supplier or a provider

Note 1 to entry: A broker mediates a request from a purchaser to possible suppliers, selects one or more feedbacks received from suppliers and provides them to the purchaser.

3.3.6
computing and connectivity infrastructure operator
legal entity operating a computing and connectivity infrastructure (“IIoT-platform” operator)

3.3.7
collaboration platform operator
legal entity operating a collaboration platform

3.3.8
decentralized energy network operator
legal entity operating a decentralized energy network

3.3.9
service provider
legal entity managing and delivering one or more services to a purchaser

Note 1 to entry: Examples in the use cases: energy provider, value-based services provider, software integration services provider.

3.3.10
secure identity provider
legal entity operating a secure identity management system providing and verifying secure identities

3.3.11
standardization body
legal entity developing a standard and having the authority to do this

Note 1 to entry: Standards can be developed consensus based (for example in IEC) as well as by a consortium (for example of companies).

3.3.12
community
organization of different business stakeholders pursuing a common goal

3.4 Human roles

3.4.1
employee
person acting in a defined role within a company

3.4.2
customer
person specifying the requirements for a product or service to purchase the specified product from a supplier

Note 1 to entry: The focus is on technical perspective in contrast to a purchaser as a legal entity.

3.4.3
product developer
person developing a product according to the requirements of a specific customer or a market segment

Note 1 to entry: Examples in the use cases: production resource developer, physical asset developer, architect, challenge provider.

3.4.4
production system architect
person designing a production system or a modification (conversion) of an existing production system according to given boundary conditions, especially the ability to produce the specified range of products

Note 1 to entry: Examples in the use cases: maintenance coordinator, adaptable production system configurator, robot cell architect, production process developer, challenge provider.

3.4.5
system integrator
person integrating physical production resources into a production system based on specifications provided by a production system architect

3.4.6
production coordinator
person who creates, monitors, updates and controls the execution of a production plan

Note 1 to entry: A production coordinator controls the submission of offers to a customer or the concrete production of ordered products through suitable specifications for "design for manufacturing" and "request/order management". In extreme cases, it is conceivable that the bidding process as well as the production process are completely automated, and that the production coordinator does not need to interact with "design for manufacturing" and "request/order management".

Note 2 to entry: Example in the use cases: challenge provider.

3.4.7
production resource operator
person operating a production resource in a production system guided by a specific production order

Note 1 to entry: Example in the use cases: production system operator.

3.4.8
service and maintenance provider
person executing physical service activities related to a production system based on specifications provided by a production system architect

3.4.9
software developer
person developing a software application

Note 1 to entry: The requirements for the software application can either be formulated by a specific customer who wants to order the software application or by a product coordinator to offer the software application for a market segment to various customers.

Note 2 to entry: Example in the use cases: challenge provider.

3.4.10
data scientist
person using scientific methods, processes, algorithms, and systems to extract knowledge and insights from structured, semi-structured and unstructured data

3.4.11
software integrator
person integrating software applications according to the specifications of a customer and creating an integrated software solution

3.4.12
software orchestrator
person orchestrating the process of integrating software applications for their proper use

Note 1 to entry: The software application can comprise data bundled with physical assets.

Note 2 to entry: The proper use can be according to the identity and capability management, considering the company's operational guidelines.

3.4.13
IT administrator
person managing the IT infrastructure including general software applications within a manufacturing company

3.4.14
cyber security architect
person designing an operation infrastructure of a manufacturing company with respect to cyber security concerns

Note 1 to entry: Example in the use cases: challenge provider.

3.4.15
cyber security coordinator
person coordinating and managing the cyber security concerns within a manufacturing company

Note 1 to entry: Example in the use cases: challenge provider.

3.5 Technical roles acting as object only

3.5.1
product
physical entity produced by a manufacturing company and delivered to a purchaser

3.5.2
asset
entity owned by or under the custodial duties of an organization, which has either a perceived or actual value to the organization

3.5.3
product series
description of a product independent of a specific request or order of a customer

Note 1 to entry: The concrete considered information depends on the specific purpose.

3.5.4
planned production system
description of a production system which is planned to be built and commissioned some time

Note 1 to entry: Depending on the context, the description can be as planned or as built.

Note 2 to entry: The concrete considered information depends on the specific purpose.

3.5.5
product order
description of a product for a specific request or an order of a customer

Note 1 to entry: A product order includes a description in the form of a composite structure (i.e. a description of all constituents) including the quality requirements to be fulfilled (i.e. lists of property value statements, where the properties are standardized, e.g. CDD (IEC 61987), ECLASS (based on IEC 61360) et al., the quantity of (identical) entities to be delivered, desired delivery dates, if applicable, additional conditions such as a price per entity.

Note 2 to entry: A product order can be in the status “requested” or in the status “ordered”.

3.5.6
production order
description of production steps on how a product described by the product order can be produced

Note 1 to entry: A production order includes a product order and a sequence of production steps describing how to produce the product complying with all required conditions. The sequence includes the production resources used for the specific production steps, the boundary conditions, and the required materials, intermediates, auxiliaries, etc.

Note 2 to entry: A production order can be in the status “requested” or in the status “ordered”.

3.5.7
library
set of entity descriptions

Note 1 to entry: Examples in the use cases: library of product models, knowledge pool.

3.5.8
information about non-physical asset
description of a non-physical asset

Note 1 to entry: The concrete considered information depends on the specific purpose.

3.5.9
information about physical asset
description of a physical asset

Note 1 to entry: The concrete considered information depends on the specific purpose.

3.5.10
simulation model of non-physical asset
description of a non-physical asset, which can be simulated using some simulation tool

Note 1 to entry: The concrete model depends on the specific purpose.

Note 2 to entry: Example in the use cases: simulation model of technological process.

3.5.11
simulation model of physical asset
description of a physical asset, which can be simulated using some simulation tool

Note 1 to entry: The concrete model depends on the specific purpose.

3.5.12
energy price
amount of money for which energy is sold now or in the future

3.5.13
software application
description of software code, which can be handled, managed and configured or customized via settings

Note 1 to entry: The execution of a software application is a technical role acting as a subject.

Note 2 to entry: Examples in the use cases: process control system software.

3.5.14
interface
description of a shared boundary between system entities

Note 1 to entry: Within the scope of this document, the interface between a production resource and the production resource integration layer is considered in particular.

3.5.15
legal contract
description of a legal obligation between business roles

Note 1 to entry: Examples in the use cases: energy contract.

3.5.16
revenue model
description of mechanisms how revenues are generated based on offerings to a purchaser or a market segment

3.5.17
standard
description of obligations with the objective that somebody or something should comply with

Note 1 to entry: Examples in the use cases: reference frame, application frame, properties, procedures, interface.

3.5.18
CERT telegram
description of cyber security issues

3.5.19
external information
description from a source outside of a manufacturing company

3.5.20
solution board
description of solutions

3.5.21
challenge board
description of challenges

3.6 Technical roles acting as subject or object

3.6.1
development organization
organization managing different developers, who jointly develop results following an overall objective

3.6.2
production system
physical system, which is typically set up of production resources, to execute a production order

Note 1 to entry: Examples in the use cases: adaptable production system, which consists of a set of production resources including the boundary conditions in which materials and intermediates can be transferred from one production resource to another production resource and a design that makes it easy to modify or exchange production resources.

3.6.3
production resource
mechatronic entity characterized by production capabilities, where a production capability describes how a (intermediate) product is produced in the case of corresponding input conditions (presence of material, intermediates, etc.) and boundary conditions (tools, auxiliary materials, energy, etc.) and which quality parameters of the (intermediate) product are assured

Note 1 to entry: A production resource can assume the role of an energy provider or the role of an energy consumer

Note 2 to entry: Examples in the use cases: transportation resource moving but not processing products, storage resources storing but not processing products, robot, 3D printer.

3.6.4
device
physical component including computing capabilities that perform specific functions

Note 1 to entry: Examples in the use cases: connectivity device, which allows data to flow from one device to another; sensor (including computing capabilities), which is a specific measuring device connected to the physical process; gripper.

3.6.5
decentralized energy network
system consisting of a network of energy provider and energy consumer including an overall load management

3.6.6
design for manufacturing
system computing all feasible production orders based on a product order, an adaptable manufacturing system and additional conditions

Note 1 to entry: Additional conditions can be specified, for example, by a production coordinator.

3.6.7
request/order management
system selecting a production order from a set of feasible production orders and additional boundary conditions

Note 1 to entry: Additional boundary conditions can be specified, for example, by a production coordinator.

3.6.8
asset management
system managing the assets of a company in a uniform way

3.6.9
production management
system supporting the management and planning activities of the production coordinator in production execution and production planning (after commissioning)

3.6.10
production execution
system transforming planning information of production management and the production coordinator into a sequence of steps, which are then executed in an automatic way by the production system

3.6.11
condition prediction
system predicting the condition of a production resource

3.6.12
machine learning
system based on an algorithm that builds a prediction model based on sample data (also known as training data) to make predictions and to improve through experience without being explicitly programmed to perform the task

3.6.13
prediction model execution
system executing a provided prediction model, based on machine learning

Note 1 to entry: A prediction is made based on getting data from various sources, for example the behavior of a physical asset.

3.6.14
pattern recognition
system discovering and testing patterns in (typically large) data sets

Note 1 to entry: The overall goal is to extract information (typically with "intelligent" methods) from a data set and transform the information into a comprehensible structure for further use.

Note 2 to entry: Example in the use cases: decision support.

3.6.15
rules engine
system that automatically evaluates a certain set of rules and performs an action as soon as the condition for applying a rule is met

Note 1 to entry: Examples in the use cases: automated workflow engine, where the rules describe a workflow.

3.6.16
improvement indicators
system visualizing the impact of improvement measures

3.6.17
value-based service
system offering a function based on an intended purpose based on the analysis of data

Note 1 to entry: Examples in the use cases: benchmarking services.

3.6.18
software application store
system managing and provisioning a set of software applications

3.6.19
collaboration enablement
system enabling the simultaneous work of different users with various engineering tools

3.6.20
customizing enablement
system enabling the customization of a set of software applications via the settings of the individual software applications

3.6.21
secure identity management
system managing secure (verifiable) identities across a company and offering capabilities for registration, provision and verification in the sense that a recipient of an identity can check the provided identity

3.6.22
identity and capability management
system managing the identities and the associated capabilities within a company in a uniform way

3.6.23
engineering tool
system creating a set of information models, which typically serve as a specification for the creation of a physical entity or configuration data for a software application

Note 1 to entry: Examples in the use cases: product configuration order tool, production system engineering tool, product development tool, production resource engineering tool, robot cell engineering tool, documentation tool, software development tool, mapping tool, simulation tool, device management system, engineering tool landscape (which is a set of integrated engineering tools), operation infrastructure engineering tool, design tool.

3.6.24
exploration tool
system providing exploration capabilities in a structured set of data to a person

3.6.25
computing infrastructure
system providing a runtime environment for execution of software applications

3.6.26
computing and connectivity infrastructure
system offering connectivity capabilities for assets so that information between an asset and the infrastructure can be exchanged, and offering management capabilities of data including a runtime environment for execution of software applications and configuration capabilities

3.6.27
production resource integration layer
system integrating the capabilities of production resources into an automation system from which the individual capabilities of the production resources and basic capabilities of the control system can be monitored and controlled based on uniform principles

Note 1 to entry: Example in the use cases: process control system hardware.

3.6.28
virtual reality platform
system providing a simulated experience of the real world so that a person can take part in and interact with virtual features or items

3.6.29
presentation logic
system providing a decoupling of logical information from technology-dependent information required by visualization and control devices for interaction capabilities

3.6.30
operation infrastructure
system comprising the entire technical infrastructure of a manufacturing company, which includes the production system assigned to the shop floor and the IT system assigned to the office floor

Note 1 to entry: The operation infrastructure includes the execution of software applications according to the specifications provided by an identity and capability management and verifying the secure identities via a secure identity management.

Note 2 to entry: Various human roles act in the operation infrastructure in accordance with operation guidelines defined by the manufacturing company.

4 Abbreviated terms and acronyms

Table 1 defines the abbreviated terms and acronyms used in this document.

Table 1 – Abbreviated terms and acronyms

Abbreviation	Meaning
CAD	computer aided design
CERT	computer emergency response team
ERP	enterprise resource planning
IIoT	industrial internet of things
IIRA	Industrial internet reference architecture
IT	information technology
KPI	key performance indicator
MES	manufacturing execution system
PCB	printed circuit board

5 Conventions

5.1 General

The use cases in this document are referred and edited based on IEC 62559-2, see [1][2].

5.2 Description of use cases

This document takes the following approach for the development of use cases, see Figure 2. The background why this approach was chosen and the relation to similar approaches is described in Annex B.

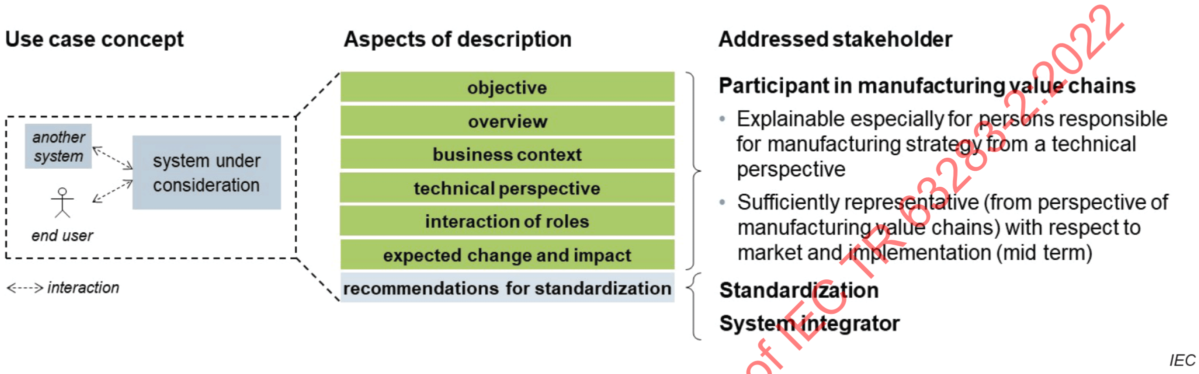

Figure 2 – Overall structure of use cases

Commonly, a use case concept includes the description of interactions of end-users, different systems and a system under consideration. Ideally, the system under consideration is a "Smart Manufacturing system". However, since there is no consensus today regarding the system boundary of a "Smart Manufacturing system", in a first step there was a conscious refrain from delimiting the system under consideration, instead concentrating on describing the interaction between different roles. A common understanding of the various roles involved in the different use cases was used. For this reason, the involved roles have been consolidated in Clause 3 Terms and definitions. At a later point in time, it is quite conceivable to define for each of these roles whether they are part of a "Smart Manufacturing system" or not.

For the description of a use case, a template has been developed, which is explained in Annex A. Following the objectives of this document, the sections of a use case indicated in green in Figure 2 can be understood by persons who are familiar with value added processes in the manufacturing industry. Persons responsible for manufacturing strategy from a technical perspective are to be addressed. In contrast, the last section indicated in grey in Figure 2 addresses those who are concerned with standardization, especially about possible future recommendations.

2 Numbers in square brackets refer to the Bibliography.

5.3 Selection guidance for elaborated use cases

The process of selection and elaboration of use cases was open for any use case proposal. But it was necessary for such proposals to be prepared following common quality criteria based on the use case template. In addition, it was ensured that the use cases are representative for "Smart Manufacturing". For this reason, a reference frame has been defined, see 5.4 Reference frame for use cases, in which the use cases were classified, see 5.5 Clustering of use cases[3]. A major challenge was to keep the individual use cases on a comparable level of detail. Therefore, the roles in the use cases have been consistently consolidated, see Clause 3 Terms and definitions. If many new roles had to be introduced to describe a use case, this was an indication that the level of detail of the intended use case is not appropriate.

Finally, the following basic assumption is important: each use case is a hypothesis. This means that there can be quite different or even complementary assessments regarding the relevance or feasibility of a use case. Ultimately, the market will decide which of these proposed use cases will prevail in the long term. It is important to formulate these theses coherently and comprehensibly in order to then be able to initiate a discussion regarding the assessment of the theses. Moreover, it is quite conceivable that some use cases are already being implemented in a specific area today. The decisive discussion, however, will be to what extent today's focused implementation will be technically and economically feasible in a much wider field of application in the future.

5.4 Reference frame for use cases

There are several suggestions for common reference frames. For this technical report, an approach developed by VDE/VDI was chosen. Details of this approach can be found in the VDE/VDI document [2]. A distinction is made between value added processes within a manufacturing company and across different companies:

Figure 3 shows the value-added processes within a manufacturing company. Individual use cases have been positioned regarding these core processes in this report.

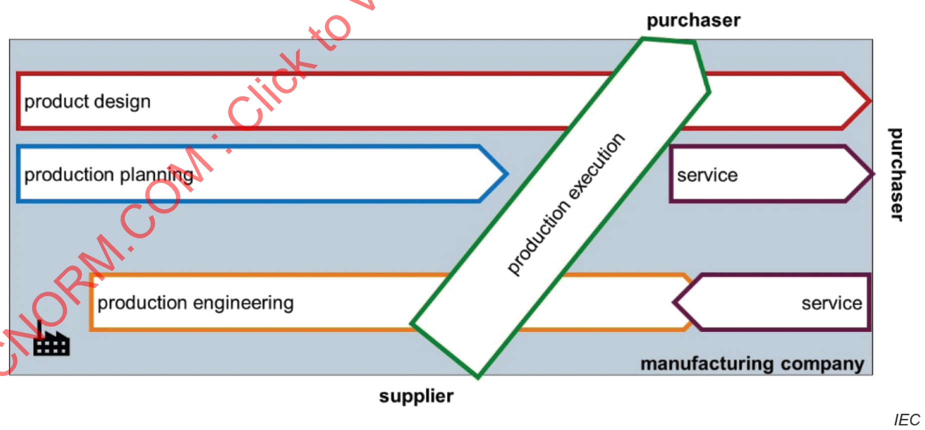

Figure 3 – Value added processes within a manufacturing company

- Product design: These processes include the product development (including research activities, prototypes, demonstrators and the development of platforms as basis for the development of portfolio elements); the development of portfolio elements, which can be offered to the market; the management of the existing portfolio elements offered to the market and the discontinuation management. Typically, these activities generate assets in the virtual world.

3 Even a use case without impact on standardization generates value if it completes the use case collection, because it sharpens the term "Smart Manufacturing".

- Production planning: These processes include the planning of the production process and during operation of the production system the production optimization and maintenance and disposal planning. Typically, these activities generate assets in the virtual world.
- Production engineering: This comprises erection of the production system and the reconfiguration during operation, maintenance and disposal. Typically, these activities generate assets in the virtual and physical world.
- Production execution: These processes include the production planning and scheduling, the execution of the production including quality management, supply chain management and the delivery to the customer. These activities generate assets in the virtual and physical world.
- Service: These processes address product-related services and production system related services. Typically, these activities generate assets in the virtual and physical world.

Figure 4 shows an example, without any claim to completeness, of the value-added processes to be found across different companies. The roles shown in Figure 4 are explained in 3.3 Business roles.

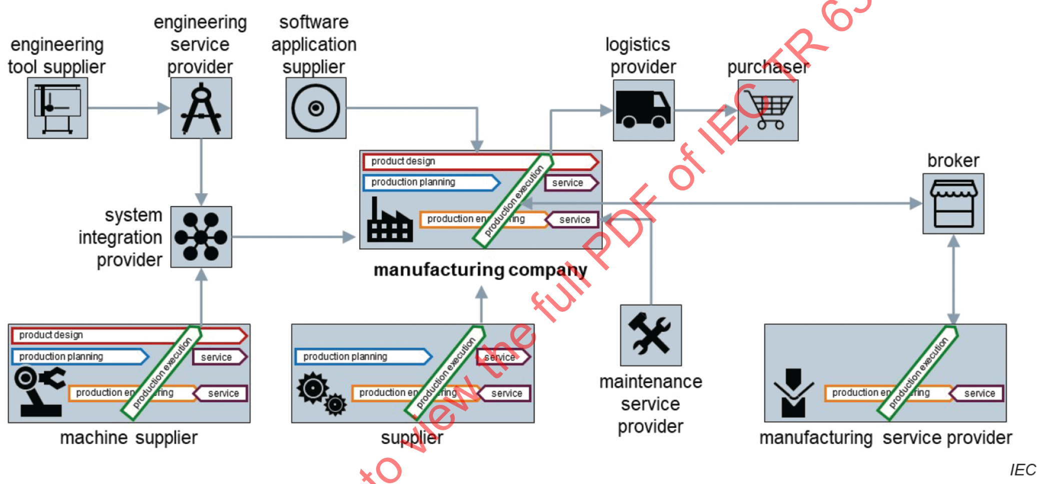

Figure 4 – Example for value added processes across different companies

Manufacturing companies are driven by improving the productivity, for example ensuring the necessary quality, increasing efficiency, reducing time-to-market or delivery-lead-time, or reacting in a flexible way to changes in the market. Moreover, manufacturing companies are also driven by opening new revenue streams, for example offering additional data-driven services, or expanding the product with additional digital features and thereby achieving a higher price or open up new markets.

5.5 Clustering of use cases

The use cases have been clustered following the value-added processes within a manufacturing company according to Figure 3. Various use case clusters are illustrated in Figure 5.

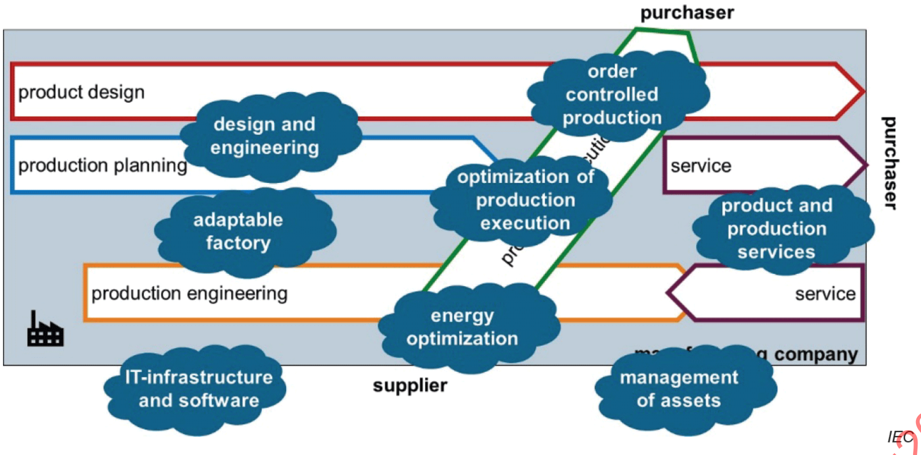

Figure 5 – Illustration of the use case cluster

5.6 Developing additional use cases

The use case collection in this document does not claim to be complete, but is intended to describe “Smart Manufacturing” in a representative way. The overall community is now asked to add new use cases or to refine individual use cases. The examples and guidance in this document are intended to support this.

This document can be updated if the overall community reveals a specific need for action. Annex D provides additional draft use cases which can be considered in an updated document.

6 Use cases

6.1 Use case cluster “Order-controlled production”

6.1.1 Manufacturing of individualized products

6.1.1.1 Objective

By using adaptable production systems, manufacturing companies want to offer individualized products to better address purchaser and market requirements.

6.1.1.2 Overview

The purchaser increasingly requires individualized products so that manufacturing companies have to offer an increasing number of products or product variants. This does not necessarily mean lot size 1 but could also apply to larger quantities of individualized products that can be ordered by a purchaser.

In order to be able to participate in this market trend, a manufacturing company will develop and implement a suitable strategy regarding the offering and production of individualized products by suitably balancing all objectives to be considered like cost effectiveness, time to market, flexibility, etc.

In this use case, it is assumed that a manufacturing company can satisfy purchaser requirements by an adaptable[4] production system; of course, other strategies are conceivable. The purchaser usually describes the requirements for a product in the form of a product order. On the other hand, the manufacturing company derives from such a product order a possible production plan and assures that it can produce it with the aid of its adaptable production system and make an offer to the purchaser. If a purchaser accepts the offer, the manufacturing company manufactures the product and delivers it to the purchaser.

The general understanding of the term "individualized product" is very broad. In this respect, manufacturing companies choose different individualization strategies to meet this requirement. Examples of this are, without claim to completeness and without defining them here in more detail strategies, such as engineering-to-order, configure-to-order, assemble-to-order, etc. This use case focuses on an individualization strategy of offering manufacturing services. An example of this individualization strategy is the offering of PCB assembly.

A core prerequisite for this use case is a precise, standardized specification of the product order. The narrower the scope of the products under consideration, the more realistic is the technical feasibility of the use case. Nevertheless, there are products for which the implementation of this use case is simply unrealistic from today's perspective. In this respect, this use case is to be viewed with a strong focus on the future.

Outsourcing of selected production steps is not covered in this use case, but in the use case "Outsourcing of production". Also, the delivery of the product is not covered in this use case, but in the use case "Inter-facility logistics".

In addition to the technical boundary conditions, legal framework conditions will also be taken into account when implementing this use case, such as the underlying legal contract, according to which the manufacturing company offers and delivers the product, or restrictions on procurement, to which the manufacturing company is a subject. Details regarding these aspects are not described in this elaboration.

6.1.1.3 Business context

Figure 6 illustrates the business roles involved in the use case "Manufacturing of individualized products".

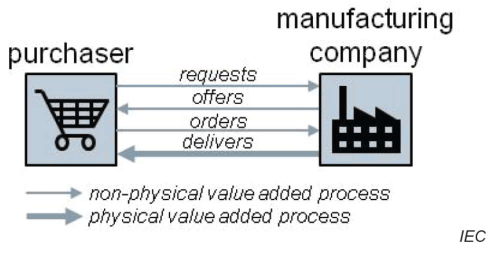

Figure 6 – Business context of "Manufacturing of individualized products"

6.1.1.4 Technical perspective

Figure 7 illustrates the human and technical roles involved in the use case "Manufacturing of individualized products".

4 In a flexible production system, production capabilities are kept available so that they can be used directly if needed. In the case of adaptable production systems, the reconfiguration of the production system is planned, but first carried out for use, see [3]. Insofar, adaptability is "broader" than flexibility.

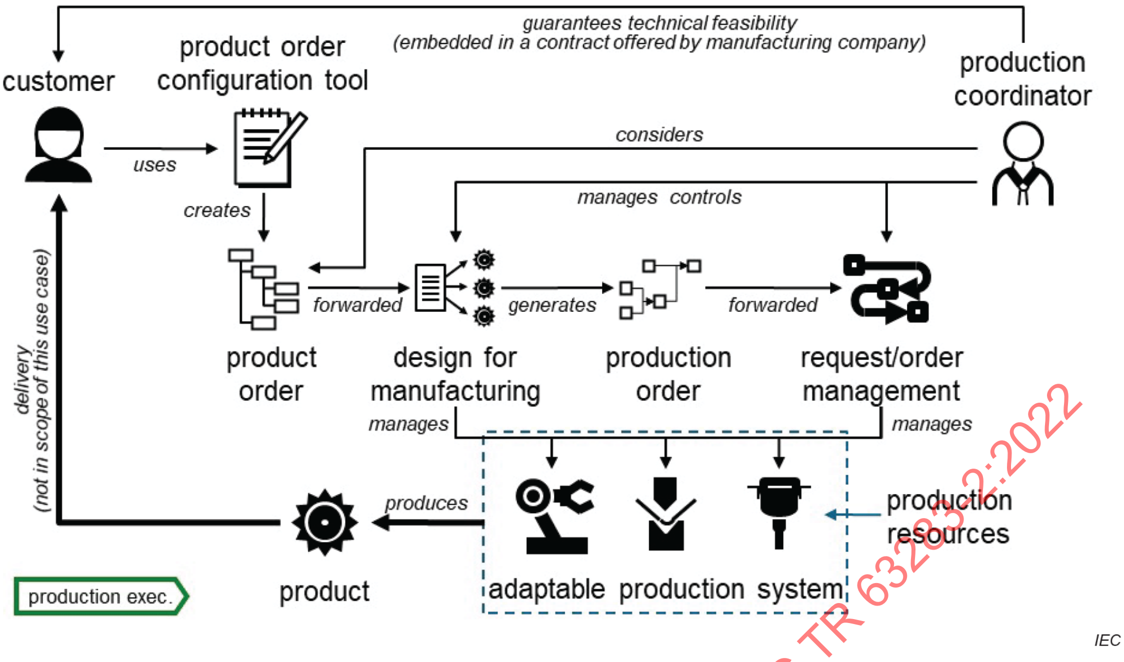

Figure 7 – Technical perspective of "Manufacturing of individualized products"

6.1.1.5 Interaction of roles

The customer defines individualized product order and makes a request to the manufacturing company: The customer uses a product order configuration tool and provides an individual product order:

- The product configuration tool could be provided by the manufacturing company, for example via a product catalogue with product variants offered to the market.
- The customer could also use some third party tool, where the manufacturing company accepts request from a customer based on the third party tool.

The product order is specified by a description in the form of a composite structure (i.e. a description of all constituents) including all quality requirements to be fulfilled (i.e. lists of property value statements, where the properties are standardized), the quantity of products to be delivered, the desired delivery date and, if applicable, other boundary conditions.

The manufacturing company receives an individual product order and the production coordinator checks from a technical point of view whether an offer will be provided to the customer: The production coordinator checks to what extent they are able to provide an offer according to the received individual product order. This concerns the

- presence of corresponding production resources with capabilities that allow for general production of the desired product;
- availability of the required production resources under the desired boundary conditions, for example delivery date or required quantity;
- consideration of further technical, business and strategic boundary conditions.

The content review of the individual product order will be carried out by the production coordinator with the help of design for manufacturing and request/order management. The production coordinator will use the design for manufacturing system to generate suggestions for feasible production orders (the production coordinator can also produce a production order manually using specific tools) and will use the request/order management system to produce a suitable production order (this could also be done by the production coordinator without support of the request/order management system). A production order is specified by a sequence of production steps. The production coordinator selects this production order as basis for the offer to the customer and will include additional information for the customer, for example the delivery date.

If the content review is positive, the manufacturing company provides a corresponding offer to the customer, including the applicable legal framework conditions, such as the time the manufacturing company is bound to the offer. The production resources required for this production order will be blocked for the planned periods in order to be able to meet the obligations in the event of acceptance of the offer by the customer. In the negative case, the manufacturing company will reject the request of the customer.

After receiving an offer, the customer decides whether to accept the offer or not. At least when accepting the offer, the customer notifies the manufacturing company and concludes an appropriate sales contract.

If the terms and conditions of an offer expires, the production coordinator will remove the blocked periods of production capacities from the corresponding production resources with the help of request/order management so that these periods can be now used for other possible production orders.

If the manufacturing company is commissioned by the customer, the production coordinator will change the status of the production order to "ordered". In addition, the production coordinator will ensure that all materials, intermediates and other resources needed for the execution of the production order are available at the planned production date so that production of the product will be smooth. It is the responsibility of the production coordinator to initiate appropriate measures, such as the ordering of important materials or intermediates, when preparing the offer (see also 6.1.3 Outsourcing of production).

The subsequent execution of the production and delivery of the product to the customer does not differ fundamentally from "traditional" production. Due to the individuality of the manufactured products, however, it is considered that

- the customer is sufficiently informed about the current status of the production of the product.
- the production coordinator is supported by sufficiently powerful tools to monitor and supervise the production, see also 6.1.2 Flexible scheduling and resource allocation.
- set-up processes and other processes, such as, for example, cleaning steps between different production orders, do not increase. This requires a possibly closer consideration of such effects in production planning, see also 6.1.2 Flexible scheduling and resource allocation.

6.1.1.6 Expected change and impact

The use case supposes a standardized and formal description of product orders and capabilities of production resources. Today, this degree of formalization typically applies only to very specific applications. In addition, powerful optimization algorithms will be used for this purpose, whereas today the tasks performed by these algorithms are mostly done manually.

Consequently, there will be a higher degree of automation of design for manufacturing and request/order management and the solutions found by the algorithms are typically better than solutions developed largely in a manual way. The use of algorithms can lead to a higher utilization rate of production resources.

The algorithms are so powerful that these concepts also provide the basis for calculation of a new solution in case of unexpected events within an acceptable time frame, see 6.1.2 Flexible scheduling and resource allocation, and for increasing flexibility by using external production resources, see 6.1.3 Outsourcing of production.

6.1.1.7 Recommendations for standardization

Standardization of product orders: this includes the structure, the required technical and economical properties and boundary conditions (for example, the identification, product specification, price, delivery information, etc.), and the description of quality criteria and assurances. A challenge is to find the right balance between the avoidance of lock-in effects of a manufacturing company and the interest of a company to differentiate its own products.

Standardization of production orders: this includes the structure, the relationship between requirements in the product order and assertions by the execution of the production steps, properties, constraints and operating conditions of the affected production resources (for example, the calendars with availabilities, predicted processing durations, effects on the state of wear, etc.) as well as the documentation of a manufacturing of a product.

Standardization of production capabilities of production resources: in addition to the content-related description, the comparability of capabilities should be formulated. The challenge is to find an adequate level of abstraction, as the subject matter is extremely complex, see also 6.2.4 Standardization of production technologies Use Case.

Standardization of the basic architectures: this includes the interfaces and interaction protocols of design for manufacturing and request/order management.

Adaptable production systems: it is recommended to examine to what extent existing standards limit the flexibility of the future production systems, for example, transportable production resources, performing production steps while the product or production resources are moving, information model, interfaces and interaction protocol of production resources, etc.

6.1.2 Flexible scheduling and resource allocation

6.1.2.1 Objective

A production coordinator wants to minimize downtime (outages) and optimize the usage of production resources.

6.1.2.2 Overview

Based on the current availability of production resources, materials, intermediates, etc., production plans are continuously recalculated to optimize the usage of production resources. This is not restricted to manufacturing of individualized products, but is also generally applied in the manufacturing of standardized or mass-produced products.

Because of unexpected events, such as an unplanned maintenance activity, rescheduling is necessary. This can affect a single but also several production orders and, in extreme cases, can result in the manufacturing company not being able to fulfill the guarantees contractually assured to the purchaser. This applies not only to unexpected events, but also to planned events, such as the planning of reconfiguration or maintenance activities that result in a request for a rescheduling.

It is the responsibility of the manufacturing company or the production coordinator to ensure the robustness of the production planning with the help of the request/order management.

6.1.2.3 Business context

Figure 8 illustrates the business roles involved in the use case “Flexible scheduling and resource allocation”.

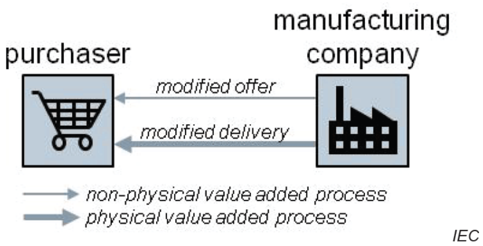

Figure 8 – Business context of “Flexible scheduling and resource allocation”

6.1.2.4 Technical perspective

Figure 9 illustrates the human and technical roles involved in the use case “Flexible scheduling and resource allocation”.

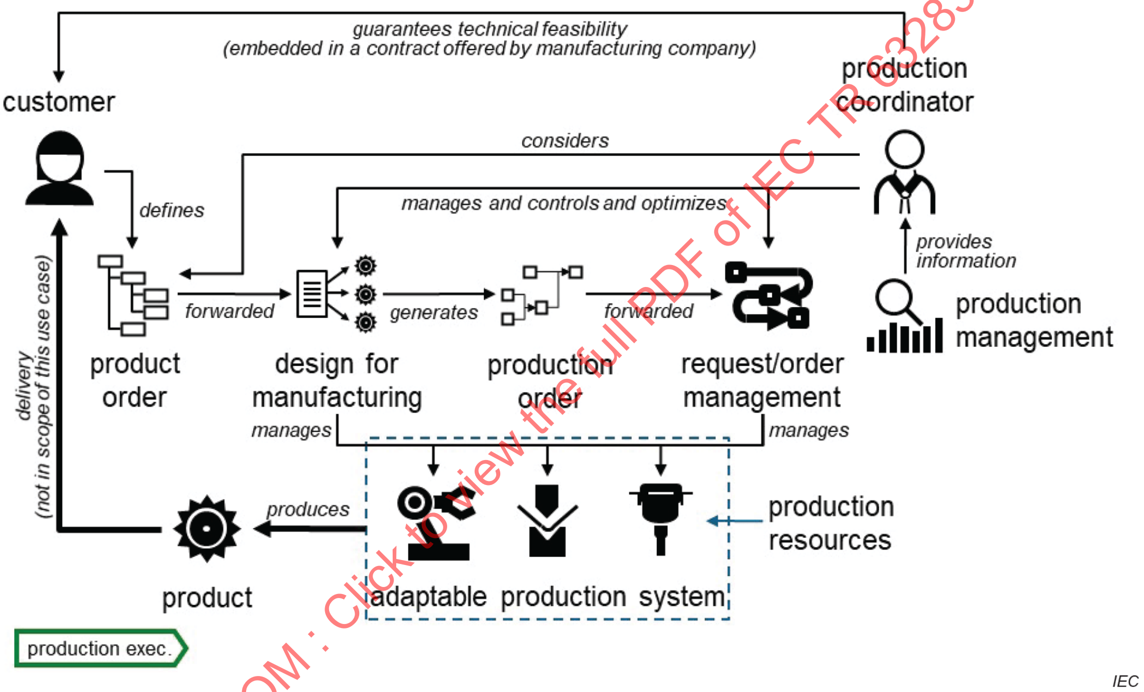

Figure 9 – Technical perspective of “Flexible scheduling and resource allocation”

6.1.2.5 Interaction of roles

In case an event occurs: typically, the production coordinator is notified of such an event by the production management, see 6.4.1 Optimization of operations. Examples of such events can be

- Unexpected events regarding the product, for example, damage or not sufficient quality of the produced product, so that rework or even a completely new production is necessary, quality or quantities of raw material are insufficient, etc.;
- Unexpected events during production, for example, damage of tools, parts, operating materials or whole machine, human stopping of a production resource because of an operating error to protect the production resource due to occupational safety issues, missing parts from other production steps or from external suppliers, etc.;
- A planned event, for example, the planning of the reconfiguration of the production system or the maintenance of a production resource. In this case it is also necessary to initiate a rescheduling, because of additional or reduced availability due to a planned reconfiguration, or because of changed availability due to a planned maintenance activity.

The production coordinator will determine alternative production orders for the production orders affected by this event using the capabilities of design for manufacturing.

The ability to find alternative production orders depends on the basic flexibility of a production system (for example, existence of universal production resources), on the availability of alternative production resources that can take over the task of a production resource that is no longer available, and on available buffers (for example, flexibility of the delivery date, basically scheduled buffers for setup activities or material stocks, etc.), but also on the production order itself (for example, need for specific production resources to execute the production order).

With the help of request/order management, the production coordinator will then determine new production orders accordingly. This can lead to rescheduling of production orders, which were not affected by the event, because otherwise no alternative can be found[5].

If no alternative production order is found despite consideration of all possibilities, the production coordinator can try to find a solution by outsourcing individual production steps or the entire production order, see 6.1.3 Outsourcing of production.

If an alternative production order has been found, the production coordinator will appropriately document this rescheduling and execute the production following the new plan and boundary conditions. Typically, the production coordinator will inform the customer if, from the customer's point of view, there has been a significant change to a production order, for example, if the recalculation results in a delay in delivery.

In extreme cases, this can lead to the manufacturing company not being able to fulfill the guarantees contractually assured to the customer. This can affect both an offer and an accepted production order. In individual cases, the manufacturing company will probably try to explain the unexpected situation to the customer and negotiate a mutually agreed solution with the customer.

In extreme cases, it is conceivable that the entire recalculation and scheduling process runs fully automatically and the production coordinator only intervenes manually in exceptional cases.

6.1.2.6 Expected change and impact

See 6.1.1 Manufacturing of individualized products.

6.1.2.7 Recommendations for standardization

In addition to the recommendations mentioned in the context of standardization of production order in use case “Manufacturing of individualized products”, the possibility of prioritizing production orders should be considered.

Manufacturing change management: it is recommended to examine to what extent existing standards consider the future requirements of manufacturing change management, especially for adaptable production systems, for example, documentation issues, complexity of rescheduling algorithms, etc.

5 It is noted that a rescheduling of already existing production orders is usually also carried out in the use case “Manufacturing of individualized products”.

6.1.3 Outsourcing of production

6.1.3.1 Objective

A manufacturing company wants to cooperate globally between own factories to improve the efficiency of operations.

The manufacturing company wants to cooperate globally with external suppliers or wants to act as an external supplier in a very flexible and adaptable way to improve the efficiency of operations.

6.1.3.2 Overview

This use case is a supplement to the use case “Manufacturing of individualized products”, where a manufacturing company can supplement its own production capabilities or capacities by integrating a manufacturing service provider acting on the market. This can be applied both in terms of capacity, such as addressing demand peaks, as well as capability issues, such as the need for a highly individual production capability. It is also applicable to optimize the production capabilities within a company that are available across different locations and are not yet tightly integrated, or in case of occasional production problems. In extreme cases, this concept can even be applied to outsource the entire production.

The additional role of a broker for production services can be implemented by the purchaser or by the supplier or by a business role in its own right. In the case of an independent business role, the business relationship between purchaser and supplier brokered by the broker will be based on a legal frame contract provided by the broker. Regarding the kind of services offered by the broker, various examples are conceivable, for example merely a brokerage of a product order or the takeover of the design for manufacturing and a brokerage of production orders.

From the perspective of the manufacturing service provider, this use case helps to gain market access via the broker. On the other hand, the more formal the execution is via the broker, the easier it is to compare and substitute the manufacturing service provider.

It is noted that inter-facility logistics between the supplier and the purchaser as addressed by the use case “Inter-facility logistics” is considered as integral part of this use case.

6.1.3.3 Business context

Figure 10 illustrates the business roles involved in the use case “Outsourcing of production”.

Figure 10 – Business context of “Outsourcing of production"

6.1.3.4 Technical perspective

Figure 11 illustrates the human and technical roles involved in the use case “Outsourcing of production”.

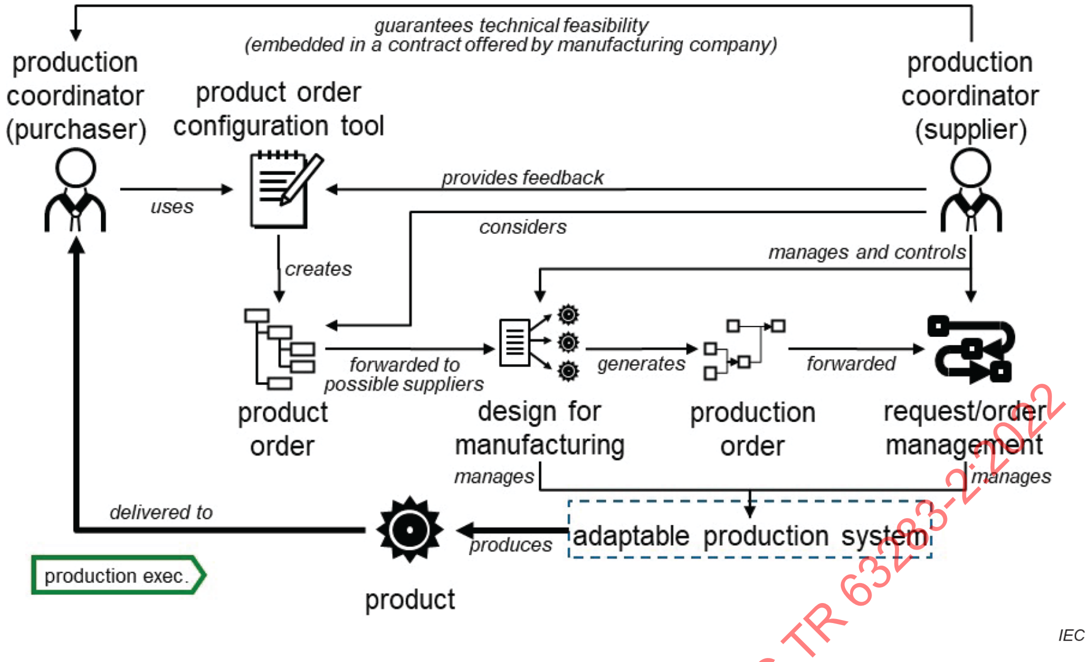

Figure 11 – Technical perspective of "Outsourcing of production"

6.1.3.5 Interaction of roles

In this use case, the roles represented in the technical perspective can be implemented differently than the business roles shown in the business context. From a technical point of view, the interaction principle of the roles is always the same, but due to different company boundaries, this can have an impact on the interface to the roles on the non-functional side, such as security aspects. The following principal characteristics of the business role broker are conceivable:

- The broker mediates between product orders, so the purchaser requires a product according to some structure and the supplier delivers a product according to this structure.
- The broker mediates between production orders, so the purchaser requires production according to a sequence of production steps and the supplier delivers production according to that production order.
- The broker takes over the design for manufacturing, so the purchaser asks for a product according to some structure, the broker generates potential production order to produce the product and looks for a supplier that produces according to such a sequence of production steps.

Onboarding/offboarding of a supplier: The supplier registers at the broker and thereby accepts a legal frame contract specified by the broker. Depending on the business model of the broker, registration payments are charged. During the registration, the broker can perform an analysis of the onboarding supplier's production capabilities. This could include a systematical assessment of factors such as risks for continuous reliable supply, financial stability and many other factors that are currently performed during supplier development. Conceptually, the supplier will not publish the own production capabilities and capacities, but it is conceivable that the supplier will specify which requests are received from the broker. Since from the perspective of the supplier, highly sensitive classified information is exchanged as part of the mediation – for example offer information, which could enable conclusions to be drawn on capacity utilization – such legal frame contracts pay special attention to the aspect of data usage rights. As soon as a supplier deregisters, the broker will not consider the supplier for future requests.

Onboarding/offboarding of a purchaser: The purchaser registers at the broker to be able to submit requests to the broker and, thereby, accepts a legal frame contract specified by the broker. Depending on the business model of the broker, registration payments are charged. With a request, sensitive information can also be published from the purchaser's point of view. For example, it would be possible to draw conclusions about market demand for the purchaser's products.

Purchaser forwards a request to the broker: The broker distributes the request to all suppliers who are interested in this request. Depending on the business model, the broker can treat the various suppliers differently, for example, if the broker differentiates between “premium” and “standard” suppliers. The requested suppliers have the possibility to make an offer within a given period. The broker collects the submitted offers, sorts them by some own criteria, and forwards to the requesting purchaser the best offers from the own point of view.

The internal creation of an offer by the supplier is carried out as described in the use case “Manufacturing of individualized products”. The supplier tries to create the offer by automated means in order to be able to deal with an expected large number of inquiries, or to be able to concentrate on the best queries from the own point of view. At least the supplier tries to automatically ignore requests that cannot be accepted due to lack of production capabilities or capacities.

The purchaser selects the best offer from the submitted offers and submits an order to the corresponding supplier. The subsequent process at the supplier side also takes place as described in the use case “Manufacturing of individualized products”.

If due to unexpected events, see 6.1.2 Flexible scheduling and resource allocation, a supplier cannot comply to the own offer, the broker can try short-term remedies – following the same procedures – to identify an alternative supplier.

The purchaser will pay for the delivered product. The actual cash flow depends on the business model of the broker, for example, direct transfer to the supplier or indirectly via the broker. In addition, depending on the business model of the broker, further payments are charged, such as fees for a successful mediation.

The broker can offer additional services to the design for manufacturing services. Examples include logistics services, optimization services with respect to the various offerings of different suppliers or quality assurance services with respect to the delivered product. Such services are integrated appropriately in the interaction. Typically, these services will probably be executed automatically. Here, the broker will certainly find a balance between universal services for a broad market and specific services for a dedicated market segment.

6.1.3.6 Expected change and impact

The use case describes a broker, which is universally applicable to any production technology. Today, such brokers exist only for specific market segments, for example, for sheet metal processing, PCB assembly or additive manufacturing.

Such a broker as an independent business stakeholder in the market has the following fundamental effects on value added processes:

- Automated negotiations with potential suppliers open up greater market access for the supplier and easier integration of the supplier into the purchaser's supply chain.
- The typically deep integration of production design, production system planning and engineering is decoupled via the design for manufacturing capability offered by the broker, so that the strategic discussion about one’s own core competence in terms of product design versus production technologies becomes more important for manufacturing companies.

6.1.3.7 Recommendations for standardization

The recommendations for standardization mentioned in the context of the use case “Manufacturing of individualized products” can also be derived from this use case.

To make the onboarding of supplier and purchaser to a broker as simple as possible, the negotiation protocols and interaction mechanisms between broker and supplier or purchaser should be standardized.

Standardization of the content of the additional services that add value to the supplier or purchaser in the context of this use case, for example, to increase the incentive, should be offered by the broker or even another independent business role.

Since highly sensitive information are provided and exchanged during negotiations from both the supplier's and purchaser’s perspective, quality criteria should be defined for the underlying legal frame contracts. However, it remains to be observed which business models for a broker will prevail on the market in the long term.

6.1.4 Engineering of design for manufacturing and request/order management

6.1.4.1 Objective

A production system architect is supported by engineering tools and optimization algorithms in the development of designs for manufacturing and a request/order management for an adaptable production system.

6.1.4.2 Overview

The design for manufacturing and the request/order management are the core capabilities that are postulated in the use cases “Manufacturing of individualized products”, “Flexible scheduling and resource allocation”, and “Outsourcing of production”. This use case describes how these core capabilities are developed and therefore complements the use case “Modularization of production systems”, which describes how to set up and manage an adaptable production system.

The approach assumes that the design for manufacturing and the request/order management are both based on a “universal core”. In the broadest sense, these are specific optimization algorithms that are provided by a software application supplier. On the one hand, the optimization algorithms is configured regarding the concrete underlying adaptable production system and, on the other hand, regarding the concrete optimization goals. Conceptually, these are two different configuration approaches. Integration into a common engineering tooling environment is conceivable, but is not emphasized here.

The aim is to execute the design for manufacturing and the request/order management as far as possible automatically with minimal human intervention. It is important to find the balance between the degree of automation and the breadth of applications. Ultimately, the market will determine to what extent the described approach can be implemented technically and economically.

Production resources are expected to provide their production capabilities and capacities to the design for manufacturing and to the request/order management in a standardized manner.

6.1.4.3 Business context

Figure 12 illustrates the business roles involved in the use case “Engineering of design for manufacturing and request/order management”.

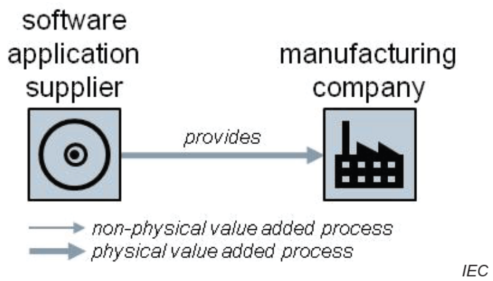

Figure 12 – Business context of "Engineering of design for manufacturing and request/order management"

6.1.4.4 Technical perspective

Figure 13 illustrates the human and technical roles involved in the use case "Engineering of design for manufacturing and request/order management".

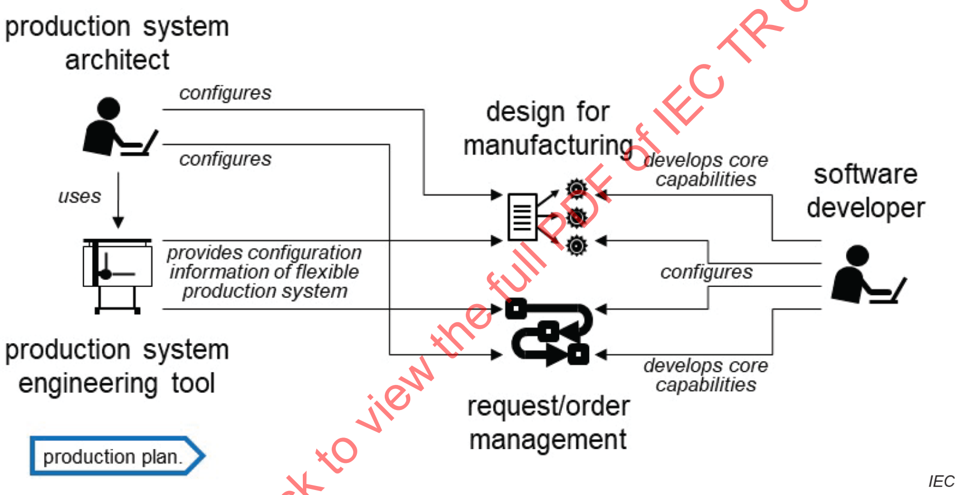

Figure 13 – Technical perspective of "Engineering of design for manufacturing and request/order management"

6.1.4.5 Interaction of roles

The software developer develops core capabilities of the design for manufacturing: For a given product order, the design for manufacturing generates potential production orders, all of which can be executed, in principle, by the underlying adaptable production system. For this purpose, the production order is transformed into a sequence of individual production steps, whereby each of these production steps can be executed by a specific production resource. It is also ensured that the execution of the various production steps in their logical and temporal order is possible by means of the adaptable production systems. In order to enable a higher-level optimization, the degrees of freedom possible for this generation are considered.

Possible degrees of freedom are:

- A product order can be implemented by different sequences of production steps. If, for example, a sheet with two holes is required, it often does not matter which of the two holes is produced first.
- In the adaptable production system, several production resources with the same capabilities can be available, so that different assignments with regards to the individual production steps are possible.
- Required product characteristics can be generated by different production capabilities. For example, the two holes required in the sheet could be drilled or punched.

The software developer develops core capabilities of the request/order management: Based on the adaptable production system, the request/order management decides whether a given production order can be implemented at all regarding its capacities within the required boundary conditions. For this purpose, the availability calendars of the affected production resources are duly synchronized and a common time slot is found in which the production resources can execute the production order. Similarly, to enable a higher-level optimization, the possible degrees of freedom are explicitly specified so that alternative production orders can be determined in case of re-planning at a later time, for example due to a new order or the unplanned downtime of a production resource.

The production system engineering tool provides configuration information of the adaptable production system: This includes the overall layout of the production system as well as the specific production capabilities and capacities of the individual production resources. If these change, for example as described in the use case "Modularization of production systems", the production system engineering tool will automatically make the updated information available.

The software developer and the respective production system architect configure the design for manufacturing and the request/order management: This configuration information can be used to parametrize the concrete optimization strategies of the design for manufacturing and the request/order management. These are primarily higher-level aspects that can be largely determined independently of the actual production resources. Due to the complexity of the optimization algorithms, it is quite conceivable that dedicated knowledge from the supplier of the core capabilities of the design for manufacturing and the request/order management is considered for this configuration.

Testing of configured design for the manufacturing and request/order management: These overall capabilities are complex and are carefully tested and debugged for correctness and stability. This is certainly a key challenge regarding the implementation of this use case. One aspect of this is the transparency of the generated solutions for persons. Since persons will often remain the last authority to overrule decisions of the design for manufacturing and the request/order management, they need appropriate means to interact with these complex capabilities.

6.1.4.6 Expected change and impact

The use case supposes generic design for the manufacturing and request/order management capabilities that effectively assist persons executing these tasks. It is conceivable that within a specific scope the design for the manufacturing and the request/order management can be executed even in an automatic way. Today, the design for manufacturing is usually an order-independent task in the development of the product portfolio, while the use case assumes that a specific design for manufacturing is applied for each product order.

Consequently, this use case opens up the optimal exploitation of the adaptability (and thus also flexibility) of a production system, especially regarding a non-pre-designed product portfolio, as is currently the case with manufacturing service provider, for example.

6.1.4.7 Recommendations for standardization

From this use case the recommendations for standardization mentioned in the context of the use cases "Manufacturing of individualized products" and "Modularization of production systems" can also be derived.

In order to be able to automate the design for manufacturing as far as possible, a formalization and standardization of capabilities of production resources is an essential prerequisite, especially an information model is needed to describe production (and further) capabilities by properties and classes. This particularly concerns the formalization to which extent a production capability can guarantee the required product quality criteria. See also 6.2.4 Standardization of production technologies.

Based on a standardization of the calendars with availabilities of the production resources the request/order management can be automated as far as possible. Standardized concepts for describing the degree of freedom to reschedule effectively in the event of changes are of central importance in this case.

Based on a standardization of the overall layout of adaptable production systems the configuration of the design for manufacturing and the request/order management can be focused on the parametrization of the core capabilities.

6.1.5 Intra-facility logistics

6.1.5.1 Objective

A production coordinator wants to transport materials, products, and tools within a production system and to use storage capabilities of the production system in an efficient way.

6.1.5.2 Overview

The introduction of an adaptable production system due to the increasingly requests for individualized products brings with it the demand for adaptable intra-facility logistics.

Focusing on the manufacturing industry, the intra-facility logistics can be considered as a special case of production. Thus, transportation and storage resources are special production resources, and therefore the use cases “Manufacturing of individualized products”, “Modularization of production systems” and “Flexible scheduling and resource allocation” can be conceptually applied to implement adaptable intra-facility logistics. It is noted, however, that intra-facility logistics is considered an integral part of the production system.

The overall objective of intra-facility logistics is the planning and control of an efficient, effective flow and storage of goods and services between the point of origin and the point of consumption. Efficiency will result in optimal use of the available resources and effectiveness will result in delivering on what is committed, for example, price, quality, response time, flexibility. Key decisions include the warehouse design, the setup of the stock keeping units, and the used equipment and technology.

In adaptable logistics systems, destinations and routes can be changed during transportation, for example in case of an unexpected event or a changed production order. Present technologies to transport goods in manufacturing are, for example, autonomous guided vehicles or robots. These (autonomous) technologies are subject to safety constraints and follow safety constraints.

Due to these considerations, the recommendations for standardization from the use case “Intra-facility logistics” are similar to the recommendations derived from the use cases “Manufacturing of individualized products”, “Modularization of production systems”, and “Flexible scheduling and resource allocation”. It is be noted, however, that logistic aspects could probably be easier to implement, since typically pure logistics capabilities are less complex than production capabilities.

6.1.5.3 Business context

Figure 14 illustrates the business roles involved in the use case “Intra-facility logistics”.

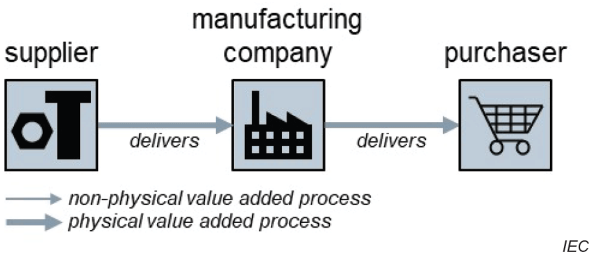

Figure 14 – Business context of "Intra-facility logistics"

6.1.5.4 Technical perspective

Figure 15 illustrates the human and technical roles involved in the use case "Intra-facility logistics".

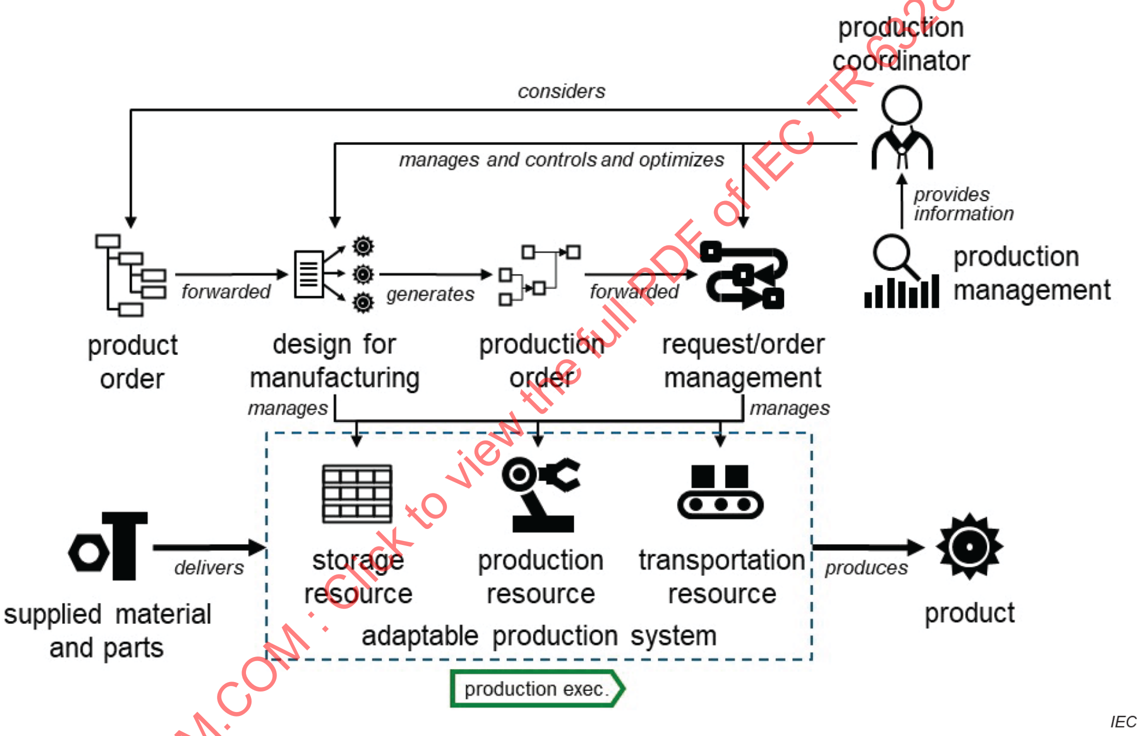

Figure 15 – Technical perspective of "Intra-facility logistics"

6.1.5.5 Interaction of roles

This use case extends the use case "Flexible scheduling and resource allocation" by additionally addressing the intra-facility concerns in the design for manufacturing and the request/order management. Nevertheless, the interaction of roles in this use case are in principle the same as in the use case "Flexible scheduling and resource allocation".

6.1.5.6 Expected change and impact

If focusing solely on intra-facility logistics, no new concepts are described in this use case. In general, high-performance intra-facility logistics has been already implemented today based on existing concepts and solutions.

6.1.5.7 Recommendations for standardization

Regarding the already mentioned recommendations for standardization in the use cases “Manufacturing of individualized products”, “Modularization of production systems” and “Flexible scheduling and resource allocation”, the following specializations result:

- standardization of interfaces of transportation, storage or production resources describing how products can be delivered (drop-off) or received (pick-up) so that goods and information can be exchanged (examples of information in addition to sources and destinations to be standardized are requirements for vibration, orientation, size, weight, temperature or hazardous information);
- standardization of identification of exact spatial location;
- standardization of maps and navigation systems helping to find optimal routes.

From a strategic point of view, it should be considered to what extent standardization activities in logistics are decoupled from the original standardization activities in production, since faster results can be expected due to the lower complexity of logistics capabilities.

6.1.6 Decision support for product configuration

6.1.6.1 Objective

A manufacturing company wants to support its customers during the product configuration so that customers order configured products appropriately.

6.1.6.2 Overview

This use case is based on a product configuration tool that a manufacturing company provides to its customers for configuring and ordering its products. The focus in this use case is on a product that can be combined from many relatively loosely coupled sub-systems, such as an automation system consisting of various devices and communication components. This use case is less applicable to complex integrated systems such as a car or a specific production machine.

There are typically mandatory boundary conditions that are followed when combining the individual sub-systems to form an overall system. In addition, there are usually additional recommendations regarding such a combination, for example, such as the redundant design of an overall system, which is under the responsibility of the customer. Such recommendations are complex and are usually documented today in the corresponding manuals for the products.

In the use case, the order data specified by a customer is analyzed regarding the product configured by the customer. This analysis is based, on the one hand, on the configuration model for the product and, on the other hand, on the specific orders, repeat orders and complaints from the past, in order to provide the customer with information about a current order, for example, to possibly add supplementary aspects to the order.

The configuration and ordering by a customer as part of this use case is independent of the strategy applied by the manufacturing company to process the orders, such as make to order, assemble to order or make to stock.

The focus of this use case is on the analysis of the order information. This information is enriched with information about the specific customer, for example, his specific orders, reorders or returns, and be linked to service information obtained from the application of the products, see also the use case “Feedback loops”.

6.1.6.3 Business context

Figure 16 illustrates the business roles involved in the use case “Decision support for product configuration”.

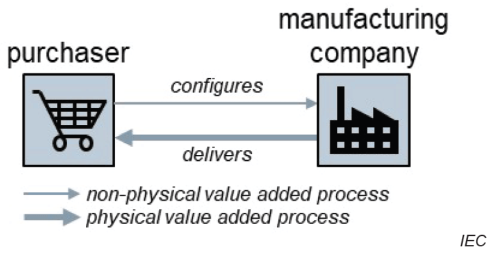

Figure 16 – Business context of “Decision support for product configuration”

6.1.6.4 Technical perspective

Figure 17 illustrates the human and technical roles involved in the use case “Decision support for product configuration”.

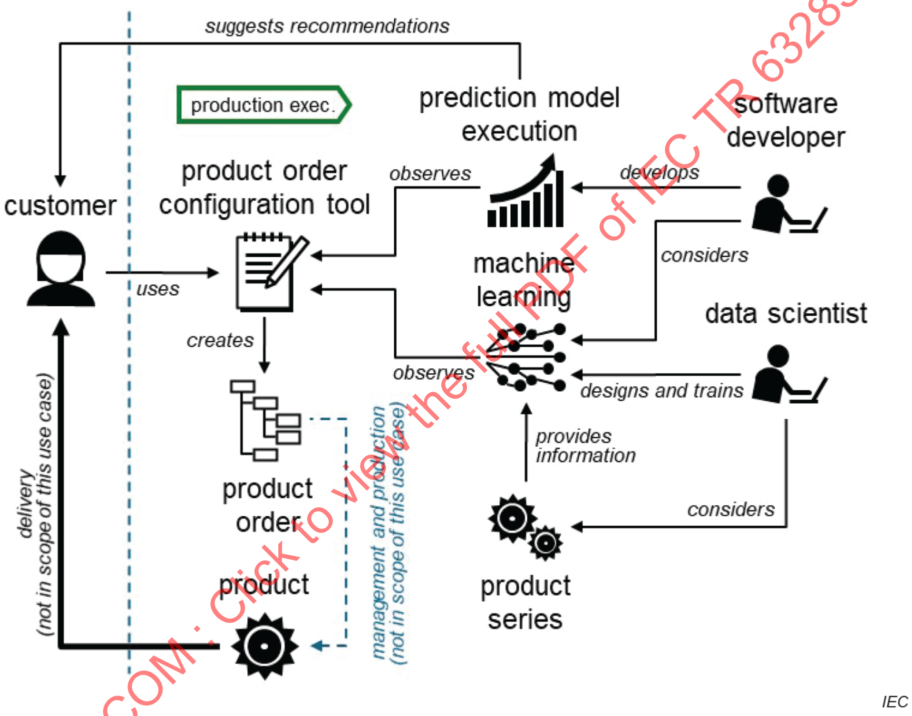

Figure 17 – Technical perspective of “Decision support for product configuration”

6.1.6.5 Interaction of roles

The data scientist develops and trains a prediction model: Using data mining and machine learning methods, the data scientist prepares and trains a prediction model. The data scientist also integrates the configuration model of the product series in an appropriate way into the prediction model. Based on initially available data, for example, based on the previous orders by customers, the prediction model is trained until a maturity of the prediction model is achieved. As a results, this can be used to suggest recommendations to a customer configuring a product order using the product order configuration tool.

The software developer develops a prediction model execution and integrates it: The software developer uses the prediction model provided by the data scientist and integrates an execution of this prediction model in the context of the overall product order configuration system of a manufacturing company, especially considering data provided by a product order configuration tool.

The prediction model is executed while a customer configures a product order using the product order configuration tool. The execution of the prediction model performs the following tasks:

- Suggestions of recommendations to a customer using the product order configuration tool. A distinction is made between product configurations, which the manufacturing company prescribes in a mandatory way and product configurations, where the manufacturing company only makes recommendations, but the ultimate responsibility then lies with the customer.
- Collection of data from usage of the product order configuration tool possibly combined with additional information about the customer, for example previous orders, reorders, returns, complaints or experience level of the customer with respect to the product.

The data scientist optimizes the prediction model: Based on the usage of the product order configuration tool and the reaction of the prediction model execution, the data scientist optimizes the prediction model. At some point in time, the data scientist provides the software developer an update of the prediction model from which the software developer, in turn, generates an update of the prediction model execution.

The software developer provides an update of the prediction model execution: The integration of such an update is feedback-free, without affecting the usage of the product order configuration tool by a customer.

6.1.6.6 Expected change and impact

This use case supposes novel algorithms from the field of machine learning. The performance and availability of such algorithms are continuously increasing as part of the current dynamic technological development.

The value proposition of this use case is improved decision support capabilities.

6.1.6.7 Recommendations for standardization

Standardization of concepts to describe options for configuring products, for example, variants, options or restrictions for combining product properties, or constituent elements of a product.

6.2 Use case cluster “Adaptable factory”

6.2.1 Modularization of production systems

6.2.1.1 Objective

A manufacturing company wants to setup an adaptable production system based on interchangeable production resources to better react on changing the purchaser’s respective market demands.

6.2.1.2 Overview

The purchaser increasingly requires individualized products so that manufacturing companies have to offer an increasing number of products or product variants and shorten their time-to-market (both in the sense of shorter innovation cycles of products as well as shorter reaction to purchaser inquiries). Therefore, production systems are reconfigured more often, which requires adaptable production systems.

Typically, different manufacturing companies use different production resources from various production resource suppliers, as well as different control systems from control system suppliers. This leads to more individual integration efforts, which becomes more significant the more frequently the production systems are rebuilt and reconfigured.

This use case postulates universally usable production resources, which can be easily reconfigured or interchanged to create different production setups. For this purpose, interface descriptions of production resources are standardized, especially with respect to control system integration. This use case is not about “fully automated” plug and produce, but about the standardized process control system integration into a uniform “basic infrastructure”. Because of such unified production resource interface descriptions, engineering and manufacturing-process management get much more efficient.

While there are standards at the communication level that pursue a similar goal, this use case addresses the machine level too. This approach is being promoted in the process industry under the term “module type package (MTP)” according to 65E/663/NP (IEC 63280), see [4]. This use case is an enabler for the use case “Manufacturing of individualized products”.

6.2.1.3 Business context

Figure 18 illustrates the business roles involved in the use case “Modularization of production systems”.

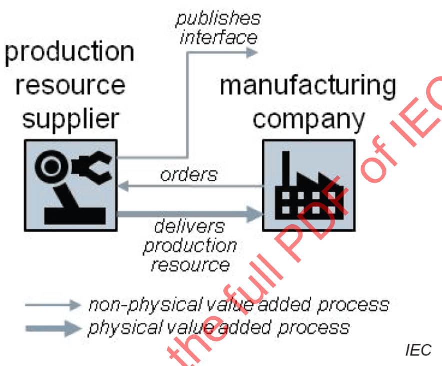

Figure 18 – Business context of “Modularization of production systems”

6.2.1.4 Technical perspective

Figure 19 illustrates the human and technical roles involved in the use case “Modularization of production systems”.

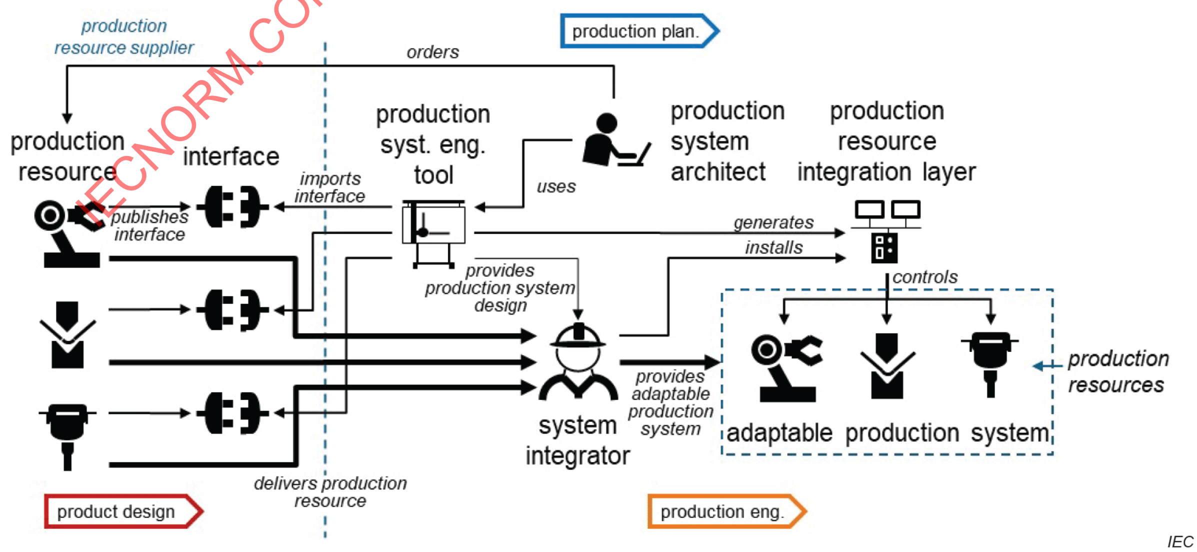

Figure 19 – Technical perspective of “Modularization of production systems”

6.2.1.5 Interaction of roles

The interaction of roles includes a development of a model series, which will follow the same process and methodologies as today. The supplier only considers requirements and specifications defined by a standardized interface description for production resources.

The supplier of a production resource publishes the interface of the production resource compliant to the standard: Regarding the standardized interface description, the production resource can be considered as a “black box”. In particular, the following characteristics of the production resource are defined or made accessible via the standardized interface description:

- connection ports regarding material, energy and information;
- capabilities for parameterization;
- logical interfaces for information exchange;
- graphical representation of information about the production resource in a superordinate screen for the operator of the production resource.

It is conceivable that other aspects of production resources will be unified via the standard. Examples include technological capabilities, requests for maintenance, rules for configuration, and procedures for selection according to given requirements, model of internal states or model of the underlying technological process.

The production system architect designs the overall layout of the adaptable production system using a production system engineering tool: The production system architect will create a block flow diagram. Each block in the block flow diagram represents requirements regarding a certain process step of the adaptable production system, for example, the input and output characteristics. This provides a conceptual separation between the superordinate layout of the production system and the technical details of the individual production resources used. Through this decoupling, it is then possible to easily rebuild production systems by adding, replacing or removing production resources. At some time, the production system architect will select and order a specific production resource for each block. For this purpose, the production system architect uses the published interface description from the suppliers of production modules and will check to what extent the production resources offered by the supplier meet the requirements. Before ordering each production resource, the production system architect will review the overall layout including the selected production resources. By analogy, the production system architect also applies this approach if removing an existing production resource or replacing it with another one.

The supplier of a production resource produces and delivers the production resource complying with the order received from the production system architect: The production and delivery will follow the same process and methodologies as today. The supplier of the production machine will additionally provide an interface description for the delivered production resource. Based on this description, the delivered production resource will publish to the production resource integration layer.

Updating the production resource integration layer: It is assumed that the production resource integration layer will be installed by a system integrator during initial installation. This concerns the physical installation of hardware entities including the required system software and integration from an application perspective into the overall adaptable production system. In case of later update, due to the addition of new production resources or the removal, also replacement, of existing production resources, it is conceivable that no specific system integration competence is needed. By importing the supplied interface description via the production system engineering tool, the setup of a new production resource – and analogously also the reconfiguration of existing production resources – can be largely automated.

The setup and reconfiguration concerns:

- the establishing of the logical communication between the production resource and the production resource integration layer;

- the parameterization according to the parameter values delivered in the interface description;
- the preparation of the superordinate screens for the operator of the production resource.

Configuration of the production resource integration layers with respect to application-specific logic: The production system architect defines the logical relationships between the individual production resources with the help of the production system engineering tool. Examples include interlocking conditions between production resources or procedures when starting or stopping the entire adaptable production system. The corresponding application-specific logic of the production resource integration layer is automatically generated by appropriate capabilities of the production system engineering tool.

Physical integration of the delivered production resource into the overall adaptable production system: The system integrator places the delivered production resources at a suitable place and connects the production resources via pipes, cables, etc. with the physical "backbone" of the adaptable production system. Additionally, the system integrator connects the production resource according to material, energy and information flow as it is specified by the production system architect using the production system engineering tool. After the physical communication connection has been established, the logical communication of the production resource with the production resource integration layer can take place.

6.2.1.6 Expected change and impact

The use case supposes a standard so that, on the one hand, the production resource supplier provides standardized interface descriptions for their production resources and, on the other hand, the supplier of production system engineering tools and control systems supports these standards. Today such a standard is not established on the market.

Consequently, a part of the value added by the system integrators will shift to the supplier of production resources. This will lead to more modular production systems and, thus, improve the adaptability of production systems.

6.2.1.7 Recommendations for standardization

Standardized interface descriptions for production resources concern the following aspects:

- the connection ports regarding material, energy and information in the physical world;
- the logical interfaces for information exchange based on a standardized description of the underlying semantics and interaction mechanism;
- the capabilities for parameterization of production resources based on a standardized description of the underlying "black box" model of the considered production resource as a basis for vendor-independent production system engineering tools that especially affects the interconnection of ports and the setting of parameter values;
- the graphical representation of information about the production resource in a superordinate screen for the operator of the production resource based on a standardized description of interactive graphical information displayed on a screen that includes the display of alarms and messages;
- the standardization of the information that a production system engineering tool provides for the individual production resources in order to be able to generate the application-specific capabilities of the production resource integration layer in an automated manner as far as possible. This also includes the subject of overall archiving capabilities. This standardized information can also be made available to other applications, such as the design for manufacturing or request/order management, in the sense of seamlessly integrated production system engineering.
- Finally, it includes a standardized concept about multilingualism.

Other concrete contents of a production resource can be standardized and be included in the standardized interface description. Examples include technological capabilities, requests for maintenance, rules for configuration, procedures for selection according to given requirements, model of internal states or model of the underlying technological process.

Standardization of the overall layout of the adaptable production system: This is the basis for an overall organization principle of engineering information about a production system.

Standardization of the production resource integration layer: This includes the architecture and capabilities.

Standardization of the physical "backbone": This addresses the connection and exchange of material, energy, and information.

6.2.2 Reconfiguration of adaptable production systems

6.2.2.1 Objective

A manufacturing company wants to easily reconfigure its production system due to changed boundary conditions such as a changed customer or market requirements.

6.2.2.2 Overview

This use case is a complementation to the use case "Modularization of production systems", in which the preparation and upgrading of a production system with a view to simple reconfiguration is described. Therefore, this use case does not describe any reconfigurations for which classic engineering processes of a production system are generally required.

The trigger for this use case comes from an external source. This trigger can, for example, be the result of a tactical or strategic decision resulting from the use case "Support for tactical and strategic decision making", but also the result of an operational decision as an insight from a use case similar to "Flexible scheduling and resource allocation", "Outsourcing of production" or "Optimization of operations".

Regarding reconfiguration, a distinction is made between the following two cases:

- Reconfiguration is the use of an existing production capability of a production resource in another overall process flow, for example a recipe is changed.
- Reconfiguration is changing a production resource or production system. This can affect physical changes such as a physical reconfiguration of a production resource or the addition or removal of a production resource from the production system. This can also affect software changes.

This use case only addresses the last case. The first case is addressed by the use case "Optimization of operations".

The reconfiguration is usually planned by an employee of the manufacturing company, while the design of the modularized production system in accordance with the use case "Modularization of production systems" can also be executed by a production system architect from an external company that offers appropriate engineering services. The preparation regarding reconfiguration reduces both the effort for the reconfiguration and the requirements for the skills for planning and carrying out the reconfiguration.

The use case also includes the case that a production resource is already owned by the manufacturing company and does not have to be procured, but is not currently integrated into the operation of the production system.

The reconfiguration carried out as part of this use case is registered in the asset management system, see 6.3.1 Administration of assets.

6.2.2.3 Business context

Figure 20 illustrates the business roles involved in the use case “Reconfiguration of adaptable production systems”.

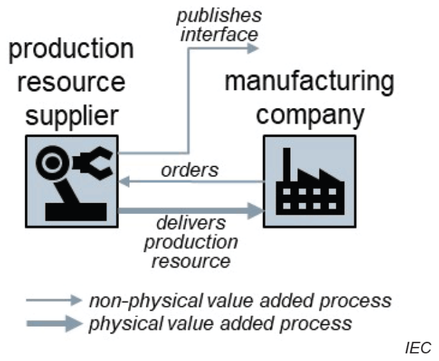

Figure 20 – Business context of “Reconfiguration of adaptable production systems”

6.2.2.4 Technical perspective

Figure 21 illustrates the human and technical roles involved in the use case “Reconfiguration of adaptable production systems”.

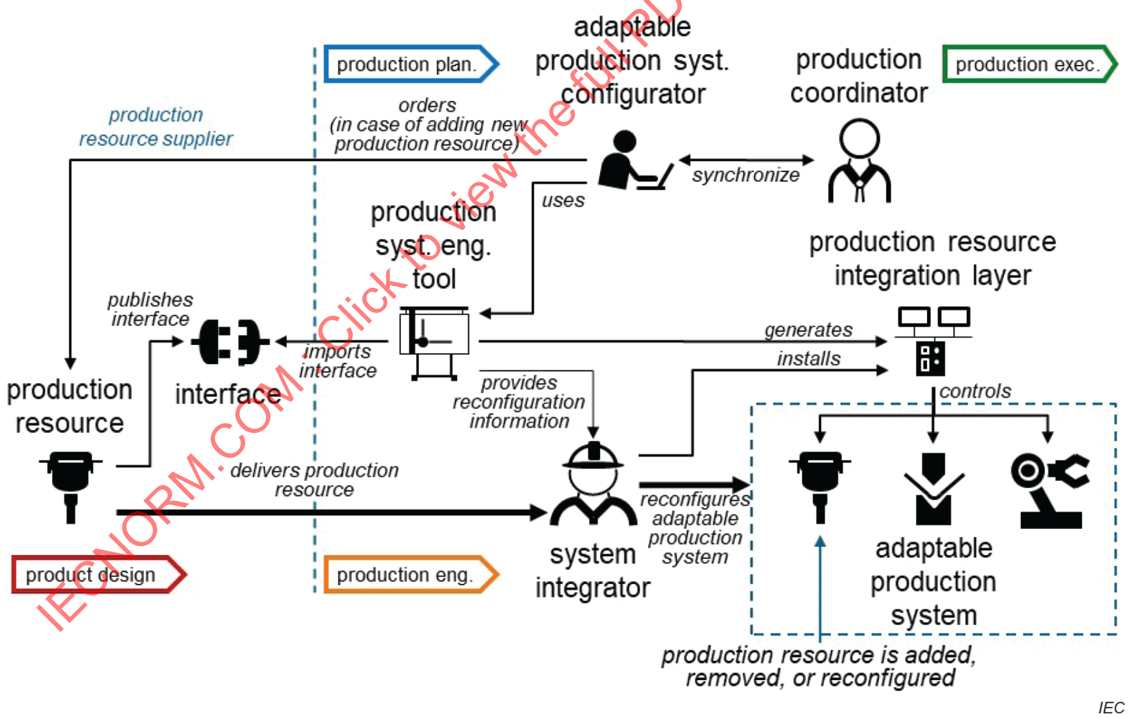

Figure 21 – Technical perspective of “Reconfiguration of adaptable production systems”

6.2.2.5 Interaction of roles

This use case complements the use case “Modularization of production systems”. Therefore, only the extensions and differences to the corresponding section of the use case “Modularization of production systems” are explained here regarding the interaction of roles.

Usually, the production coordinator initiates the reconfiguration. After initiation, the adaptable production system configurator plans the reconfiguration from a technical point of view and then synchronizes with the production coordinator on a specific schedule.

In principle, the adaptable production system configurator acts in exactly the same way as the production system architect in the use case “Modularization of production systems”. However, in this case, the reconfiguration takes place in the context of the modular design of a production system, so that the conversion is less complex than the original planning and construction of the production system. Typically, the adaptable production system configurator belongs to the manufacturing company, while the original planning and construction can have been carried out by a third-party company. Because of the less complexity, the adaptable production system configurator can only be provided with selected features of the production system engineering tool.

The reconfiguration of the production system resource layer follows the same principles as for the use case “Modularization of production systems”, where only the necessary changes have to be considered.

The system integrator acts in the same way as in the use case “Modularization of production systems”, except they only make the changes due to the reconfiguration.

6.2.2.6 Expected change and impact

See use case “Modularization of production systems”, because the reconfiguration considered in this use case is based on the requirements created by the use case “Modularization of production systems”.

6.2.2.7 Recommendations for standardization

See use case “Modularization of production systems”, where the reconfiguration considered in this use case is based on the requirements created by the use case “Modularization of production systems”.

6.2.3 Migration to adaptable production systems

6.2.3.1 Objective

A manufacturing company wants to migrate from an existing production system to an adaptable production system to optimize production.

6.2.3.2 Overview

Regarding the practical implementation of conceivable future use cases, securing the investments of the manufacturing companies is important. Migration opportunities are typically developed following a step-by-step approach starting from an installed base of a manufacturing company towards an adaptable production system. In this context, there are two different interests and goals resulting from different kinds of production resource suppliers and operators:

- The supplier of a production resource will usually sell the production resources satisfying a published standardized interface description not only to manufacturing companies, who want to operate an adaptable production system, but also to those who want to operate a “traditional” production system.
- The operator of an adaptable production system also wants to integrate in the own production system, production resources from manufacturing companies, who do not (yet) offer a standardized interface description for their production resource.

Regarding the first goal, it can be assumed that the standardized interface description is just an add on. Therefore, in principle, the production resource can also be integrated into existing production systems according to a "traditional" engineering process. It can be the case that some of the additive features based on the standardized interface description – for example a simplified engineering or a standardized visualization – cannot be used by the manufacturing company or only with restrictions. Therefore, this goal will not be considered further here.

This use case assumes that someone who operates independently of the production resource supplier develops a standardized interface description and possibly other required capabilities of the production resource and, finally, makes these results accessible to the overall business processes of the manufacturing company. It is ultimately the responsibility of the manufacturing company to commission this production resource. However, it is also conceivable that an engineering service provider will develop an own business model based on the development and provision of such interfaces and capabilities.

This use case is a supplement to the use case "Modularization of production systems".

6.2.3.3 Business context

Figure 22 illustrates the business roles involved in the use case "Migration to adaptable production systems".

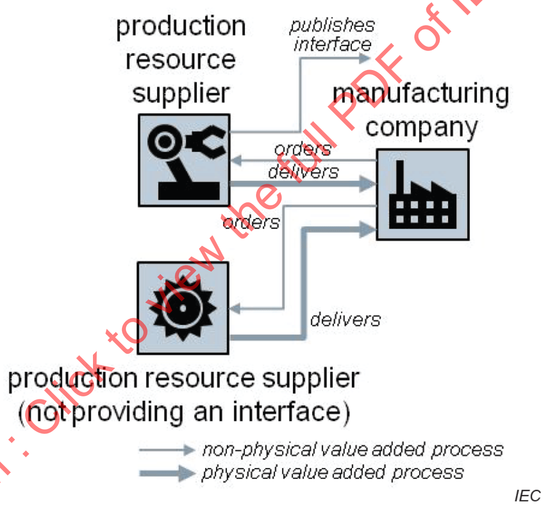

Figure 22 – Business context of "Migration to adaptable production systems"

6.2.3.4 Technical perspective

Figure 23 illustrates the human and technical roles involved in the use case "Migration to adaptable production systems".

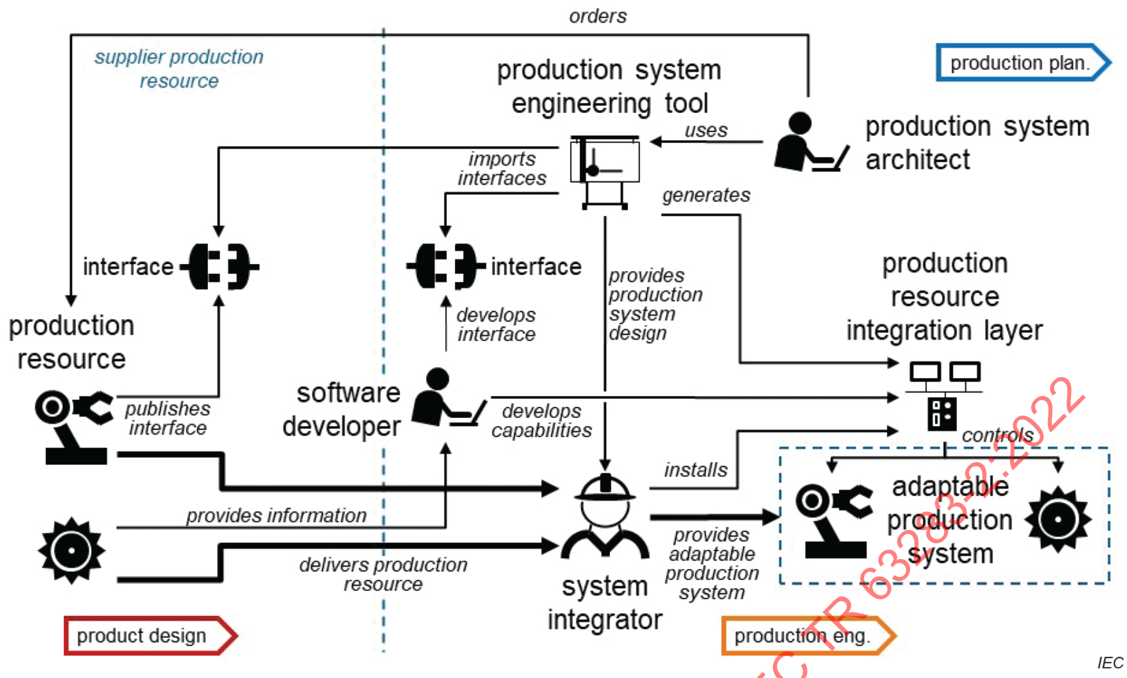

Figure 23 – Technical perspective of "Migration to adaptable production systems"

6.2.3.5 Interaction of roles

The overall workflow with respect to the production resource, for which a standardized interface description is published, is similar to the workflow in the use case "Modularization of production systems". Therefore, only the additional aspects of creating a standardized interface description and further capabilities are discussed below. Since the integration of production resources in a physical production system is independent of whether a standardized interface description has been published by the production resource supplier, the physical integration is also not considered below.

The software developer gets the information about the production resource from the supplier of the production resource: Based on the information provided by the supplier of the production resource and the requirements provided by the manufacturing company with respect to intended use of the production resource, the software developer develops an overall concept and clarifies the feasibility both with the supplier of the production resource and with the manufacturing company.

The software developer develops interface for the production resource: Both the procedure and the developed interface do not differ, as if the supplier of the production resource had published such a standardized interface description. Only the concrete development is provided by someone who is independent from the supplier of the production resource.

The software developer provides additional capabilities for the production resource: Depending on the scope of capabilities that are published in the standardized interface description, additional capabilities are developed and provided appropriately by the software developer in addition to the capabilities provided by the supplier of the production resource. Examples here are the provision and management of an availability calendar or control entities for visualization of the production resource. It can be that the computing capabilities provided by the production resource are insufficient or the supplier of the production resource does not allow a change in the software application of the delivered production resources. For this purpose, the software developer uses the computing capabilities of the production resource integration layer and deploys the capabilities, which are logically assigned to the production resource, on the production resource integration layer.

6.2.3.6 Expected change and impact

See 6.2.1 Modularization of production systems

6.2.3.7 Recommendations for standardization

In addition to the recommendations mentioned in the use case "Modularization of production systems", the mechanisms of publishing interfaces of production resources should be standardized and open. Not only suppliers of production resources should be able to publish such interfaces, but also other business stakeholders such as users of production resources or independent service providers offering such interfaces. Then manufacturing companies can define interfaces for the own production resources and prescribe these definitions to the production resources suppliers. Consequently, they can organize their internal engineering, operation and service processes based on their internal guidelines processes independent of the concrete delivered production resources.

6.2.4 Standardization of production technologies

6.2.4.1 Objective

A manufacturing company requires production resources that comply with semantically defined production capabilities in order to improve production efficiency and flexibility (for example, by outsourcing or insourcing of production orders).

A production resource supplier wants to offer production resources complying with semantically defined production capabilities, but also wants to be able to offer unique selling propositions.

6.2.4.2 Overview

A manufacturing company requires interoperability and easy integration of the production resources – typically provided by different suppliers – used in the production system. The manufacturing company even requires a simple interchangeability of the production resources. Therefore, the production resource suppliers often comply with certain standards, as a minimum they agree within their industrial segment. Suppliers of production resources also want to differentiate themselves in the market through unique selling propositions of their production resources.

The content subject for standardization is very broad, ranging from a common agreement on certain product characteristics or commands such as switching on and off, or general configuration options of certain production resources such as the number and sort of axes of a machine tool up, to an overall standardization of production capabilities per se.

The standards can be based on a layered architecture. For example, a standard on commands could be applied widely to all production resources and, therefore, generally, could be used as a common basis. On top of this, extensions for individual industrial segments could be developed. Finally, a production resource suppler could use the same mechanisms and tools to develop a further extension to formulate own unique selling propositions.

Several activities that implement parts of this are already observable on the market emphasizing different topics. An example is the development of OPC-UA companion specifications in the various branches of mechanical engineering. Typically, these activities are based on medium-term development roadmaps.

There is no systematic, consistent, formalized description of production capabilities. Due to the complexity of this topic, a total claim is probably not fully feasible even in the long term. An initial approach like DIN 8580 [5] claims to name the production processes in discrete manufacturing and to describe their effects. However, the current degree of formalization is not yet enough to cover use cases such as "Manufacturing of individualized products" or "Outsourcing of production".

This use case is an enabler for the use cases “Manufacturing of individualized products”, “Flexible scheduling and resource allocation”, and “Outsourcing of production”, especially with respect to the general and overarching topic of production capabilities. This use case supports the use case “Modularization of production systems”.

6.2.4.3 Business context

Figure 24 illustrates the business roles involved in the use case “Standardization of production technologies”.

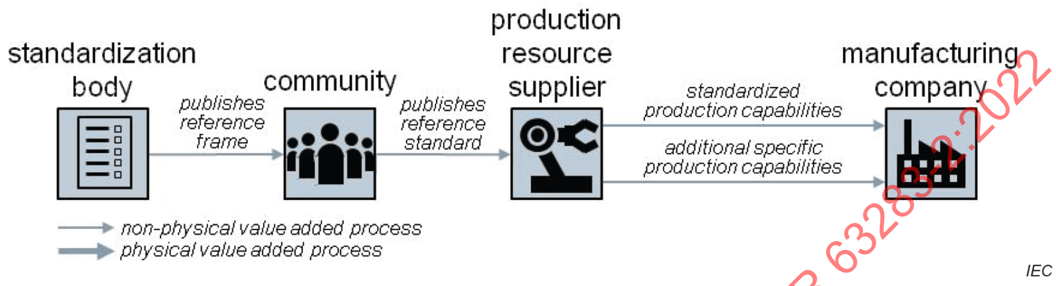

Figure 24 – Business context of “Standardization of production technologies”

6.2.4.4 Technical perspective

Figure 25 illustrates the human and technical roles involved in the use case “Standardization of production technologies”.

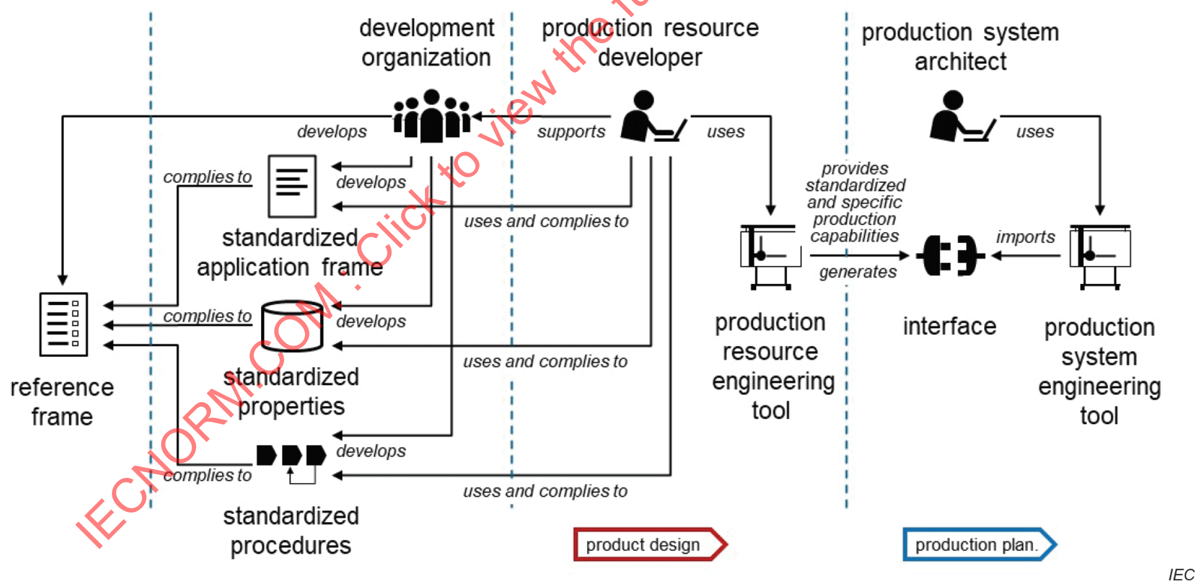

Figure 25 – Technical perspective of “Standardization of production technologies”

6.2.4.5 Interaction of roles

The overall workflow corresponds to how this is implemented in practice today, so this process is outlined here only briefly. The real challenge will be to identify the right content for standardization, where the effort for development are adequately related to the generated benefits:

- Standardization body develops reference frame under participation of the affected development communities and makes it available.

- Development communities, for example, an industrial segment such as the supplier of machine tools, develop – based on the reference frame – a common application frame, define the common properties and the processes which is followed. They are supported by the development departments of the affected companies.
- Production resource developer develops the production resource guided by the specifications provided by the development organization.

Production resource developer tests compliance of the delivered production resources with respect to a standard: Especially for suppliers of production resources, many engineering activities today are order-dependent and many of the customer specific features of a production resource are only tested during commissioning. Depending on the level of content defined by a standard, capabilities of a production resource are increasingly developed and tested independent of an order.

6.2.4.6 Expected change and impact

The use case supposes a standardization of production technologies. Today there is no systematic, consistent, formalized description of production capabilities, although various activities can be observed on the market in selected branches, such as mechanical engineering.

This use case is the prerequisite for the implementation of the use cases “Manufacturing of individualized products”, “Flexible scheduling and resource allocation”, and “Outsourcing of production”.

6.2.4.7 Recommendations for standardization

The developed standards should also be available in machine-readable form and be portable and interpretable by engineering tools and software applications to support effectiveness in application.

Concerning the production capabilities, formalized descriptions should be standardized for the following aspects:

- product characteristics, including quality requirements, for example, the shape of a hole in a sheet, including the required tolerances or specific company own, or external industrial standards body or regulatory engineering specification and standards;
- material properties, for example the material of the sheet to be processed;
- production characteristics, including assurances of the result of the production characteristics, for example, drilling, punching, or milling, including guaranteed tolerances;
- description of the physical environment conditions to be considered, for example, temperature, pressure, or humidity;
- description of the method of manufacture requirements for the tools to be used, for example, the material of the drill or milling head to be used or even a specific production resource series, along with operator possible specific skills or trained need or even certification (as per produced and supplied when purchased or periodic capability testing calibration) and testing of the tools or production resource utilized;
- description of the required production resource capabilities and the overall production path, for example, speed, feed rate, pressure or the distance to the successor production resource, this could also include pre-authored exact CNC G-Code, PLC code, robot program or recipe variable file to produce a component or batch;
- criteria for evaluating different production capabilities with respect to a given product characteristic, for example, a comparison of the extent to which drilling or punching a hole in a metal sheet is better suited;

- standardized compliance information regarding the product and process specification for the product to be manufactured, for example, process key process variable data and production resource information, which should be collected for evidence, quality, and traceability purposes whether for internal uses or for regulatory demands. This also extends to exact data format and contractual requirements considering supply chain management and transparency.

Note that the examples are not focused on mechanical processes, even if this is suggested by the icons and the use of the term manufacturing. For process automation it is already possible to describe ambient conditions using for example IEC 61987 – Common Data Dictionary. STEP and other initiatives from the Oil and Gas industry also go a long way to describing the equipment and processes involved.

6.2.5 Adaptable robot cells

6.2.5.1 Objective

A manufacturing company wants to optimize the production process by using robots.

6.2.5.2 Overview

In the wide field of robotics this use case focuses on the following setup:

- Robots in an assembly or test cells are considered. A typical robot cell is characterized by several collaborating robots, each equipped with a specific gripper and specific sensors, and typically vision systems for object detection.
- Usually the robot cell is closely integrated into the overall production flow in the context of production planning and production control as well as into the supply chain regarding the materials and intermediate products supplied.
- Often the robot cell is flexible so that it can be easily reconfigured when manufacturing another product or changing the manufacturing process, without any need for an external system integrator. This reconfiguration also affects the robot, including the gripper and sensors. In this respect, a robot cell is able to be re-engineered beyond a specific range of tasks defined in advance.

In addition to the setup described above, there are other areas of application for robotics that are not addressed by this use case:

- Standard industrial robots, for example, for welding or painting: In the manufacturing industry, the largest inventory of robots with a long experience of use is currently found in such application areas. The innovation is mainly driven by the large robot supplier companies. The capabilities of the robots are integrated into the application via system integrators.
- Low end collaborative robots, so-called cobots: Typically, these robots are not programmed, but taught, and no complicated sensors are used. Often the cobots are used for stand-alone applications such as loading or unloading. Most tasks currently performed by human assistants are supported or taken over by the cobots. In this respect, there is only a loose integration into the overall production process. Possible industrial applications based on cobots are currently in a development phase.
- Autonomous mobile robots: These are applications in the area of intra-facility logistics. This aspect is addressed by the use case “Intra-facility logistics”.

The business and technical environment of the considered robot cells is influenced by the following developments:

- Sensors, especially cameras, grippers and robots, but possibly also an intelligent evaluation of the sensor data, especially object recognition in images, are provided by different companies and are subject to different innovation cycles.

- The intelligent recognition of objects in pictures is the subject of innovations driven by computer vision technologies.
- The coordination of several robots and the integration of a robot cell in the overall production process is the subject of innovations driven by autonomous systems technologies.

From a user perspective, the core challenges for the robot cells under consideration are:

- Reduction of the effort for system integration. This affects both the various components and subsystems such as robots, grippers and sensors as well as the integration into the overall production process.
- The need for a simple and safe conversion of the cell due to changes in the product or production process.
- Mastering the complexity of a cell by the user resulting from the integration of new technologies into the cell. This also includes, for example, the topic of security, see use cases "Cyber security infrastructure and setup", "Cyber security management and maintenance", and "Engineering for cyber security".
- Considering the individual level of education of the various users. This applies to the system integrator for the first integration, the operator of the cell for the operation of the cell, and the specialist who can convert a cell due to changing boundary conditions. Typically, these specialists are employees of the company that operates the cell.

The operation of the robot cell is not considered in this use case.

6.2.5.3 Business context

Figure 26 illustrates the business roles involved in the use case "Adaptable robot cells".

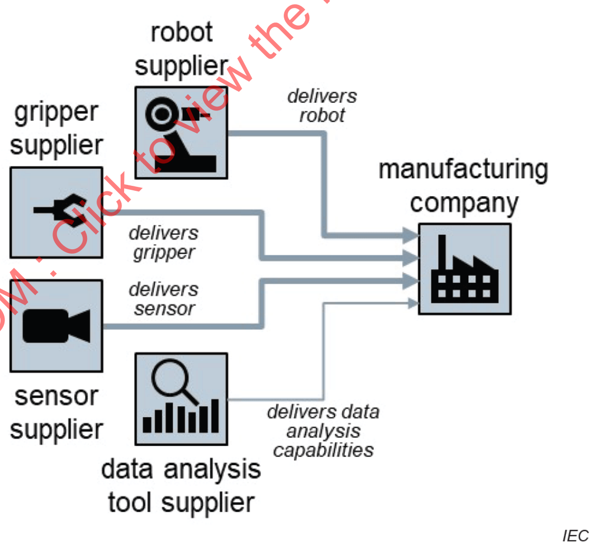

Figure 26 – Business context of "Adaptable robot cells"

6.2.5.4 Technical perspective

Figure 27 illustrates the human and technical roles involved in the use case "Adaptable robot cells".

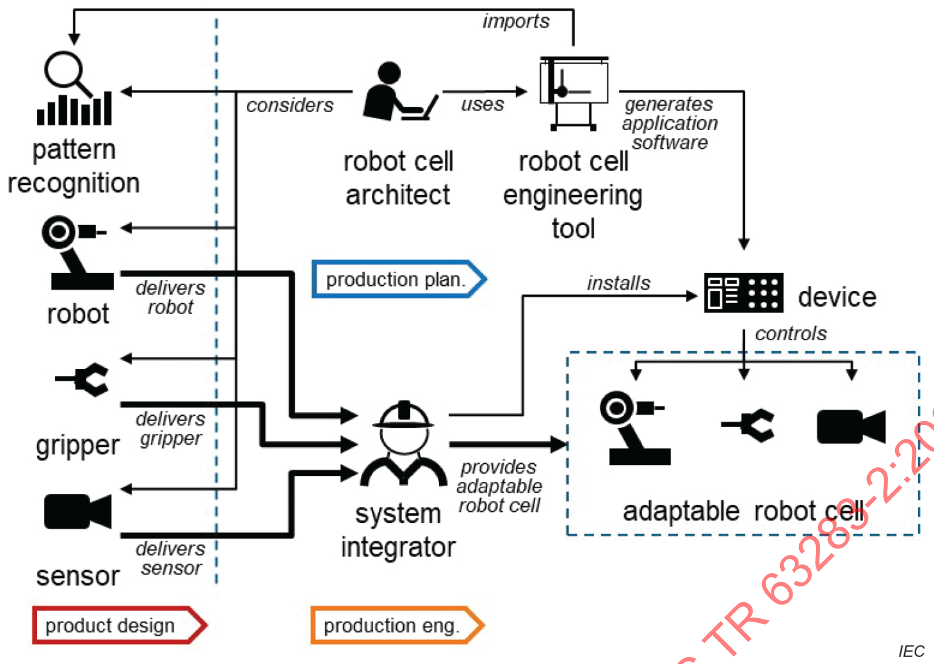

Figure 27 – Technical perspective of "Adaptable robot cells"

6.2.5.5 Interaction of roles

The robot cell architect designs the robot cell based on the requirements resulting from the production process. This is a typical engineering task, where a solution concept is developed and then implemented by integrating various supplied systems and components, especially a robot, gripper, sensor and pattern recognition. As part of these engineering activities, the robot cell architect mainly determines the adaptability of the robot cell, i.e. in what form and to what extent the robot cell can be easily converted later. The robot cell architect uses a robot engineering design tool that offers specific functions and features for the design of robot cells for these engineering tasks.

The system integrator assembles the robot cell according to the specifications of the robot cell architect. This includes the installation of the mechanical and electrical components and systems as well as the installation of appropriate system software on the device that controls the robot cell.

In this use case, the robot cell architect and system integrator act in two roles: first for the initial design and assembly of the robot cell, which can be executed by an external company, and then for the conversion of an existing robot cell, which is typically executed by employees of the manufacturing company that operates the robot cell. In principle, in both roles the same tasks are carried out, however, the degree of freedom of action of the robot cell architect and system integrator are limited when converting a robot cell. Therefore, there are lower qualification requirements regarding the execution of the conversion tasks. The degree of freedom regarding a conversion are essentially determined by the robot cell architect during the initial design of the robot cell.

6.2.5.6 Expected change and impact

The use case supposes that the technologies on which the various components and systems of a robot cell are based – in particular the intelligent functions – are constantly evolving. This affects both their performance and their costs, so that permanently new possibilities and/or improved cost-benefit calculations arise due to the constantly changing boundary conditions.

Consequently, the use of robots increases driven by technological innovations.

6.2.5.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- standardized interfaces for gripping and image recognition, especially on a semantic level;
- standardized mechanisms regarding collaboration strategies (on different integration levels), to integrate robotics easily into the overall production processes and workflows;
- homogeneous programming concepts including a standardized programming platform architecture for robot cells;
- standardized compliance information regarding the product and process specification for the product to be manufactured, for example process key process variable data and robot cell information, which should be collected for evidence, quality, and traceability purposes whether for internal uses or for regulatory demands. This also extends to exact data format and contractual requirements considering supply chain management and transparency.

6.3 Use case cluster “Management of assets”

6.3.1 Administration of assets

6.3.1.1 Objective

A manufacturing company wants to create added value through an optimized asset usage, reliability and efficiency.

6.3.1.2 Overview

The asset is a physical or logical entity owned by or under the custodial duties of an organization, having either a perceived or actual value to the organization so that the entity is administered through its life cycle.

The asset can be physical or non-physical (as an information entity). An asset can be a higher-aggregated entity, for example, a production system or a production resource, moreover, it can also be just a part, for example, a drive, a sensor, a pipe, or a cable. An asset can either have been purchased or created internally.

By generation and provision of information, concerning the history and the predicted future behavior, decision making can be supported. For example, the maintenance of the production system or the delivered products can be optimized. However, the maintenance of assets is only one aspect in the context of asset management. Others include, for example, asset replacement or expanded asset use.

There are various categories of assets. Typically, assets related to product series are generated during product design, for example, CAD models, test procedures or requirement specifications. During production planning, production system related assets are typically generated, for example, layout models, and automation software or installation procedures. During production, production order related assets are typically generated, for example, production order, orders from suppliers or the final manufactured products. In addition to the technical assets considered here, there are other assets, for example, defined from a strategic, commercial or sales perspective of a manufacturing company.

It is a good practice to structure and organize the information management within a company in an asset-oriented way. In this use case, a logical view of asset management is taken. The deployment of asset information, for example, on the asset itself or on a higher-level entity, in which the asset is installed, or even on a separate computing infrastructure, is a design decision that needs to be made on an individual basis.

6.3.1.3 Business context

Figure 28 illustrates the business roles involved in the use case “Administration of assets”.

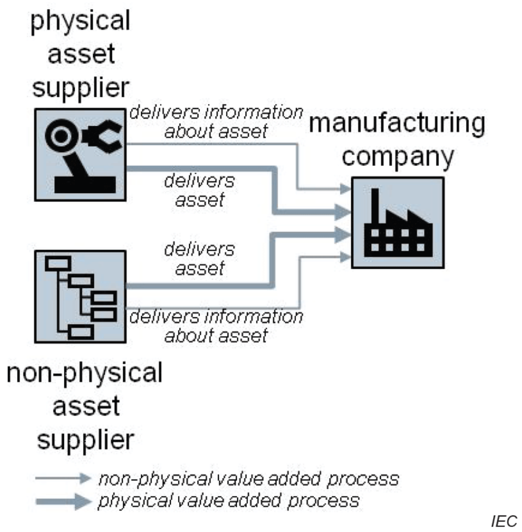

Figure 28 – Business context of "Administration of assets"

6.3.1.4 Technical perspective

Figure 29 illustrates the human and technical roles involved in the use case "Administration of assets".

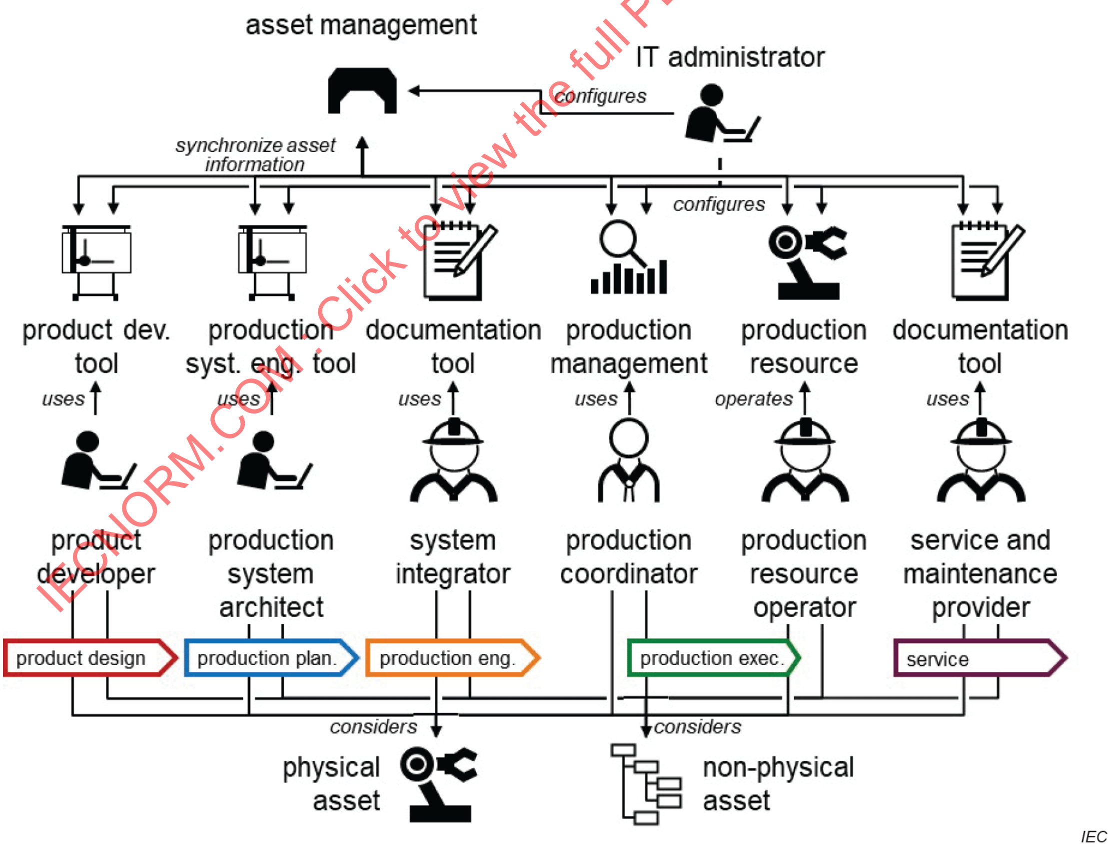

Figure 29 – Technical perspective of "Administration of assets"

6.3.1.5 Interaction of roles

As mentioned above, assets do not necessarily have to be sourced externally, but can also be generated within the company.

The product developer provides asset information: The product developer decides which deliverables that are generated during the product development process are to be uniformly managed in asset management in the form of assets across the company over their entire life cycle, for example, specifications, models, or simulations. The product developer also defines for these individual assets which information is managed in the form of life cycle entries in the asset management, for example, milestones, releases or specific values of parameters. If supplies from other companies are included, the relevant information that a supplier provides will also be incorporated into the asset management process.

The production system architect provides asset information: The production system architect determines which deliverables that are created in the context of the production planning process, are to be uniformly managed in the asset management in the form of assets across the company over their entire life cycle, for example, production system layout documentation, specifications of required production resources, or maintenance planning strategies. The production system architect also defines for the individual assets which information is managed in the form of life cycle entries in the asset management process, for example, information about as-planned, as build and as-maintained or procedures of a reconfiguration of a production resource, and will also integrate information of supplies from other companies, for example, the used production resources, into asset management.

The production coordinator provides asset information: The production coordinator determines which deliverables that are created in the context of the production execution process are to be uniformly managed in the asset management process in form of assets across the company over their entire life cycle, for example, production orders, documentation of test procedures, or manufactured products. In addition, for each of these assets, the production coordinator defines what information is managed in form of life cycle entries in the asset management process. For example, this includes the produced or tracking information on assembled parts and the executed manufacturing procedures and information of supplies from other companies, for example, the used production resources, into the asset management process. While much of this information is already available in various IT systems, for example ERP or MES systems, these existing IT systems are suitable synchronized with the asset management. In this use case, this aspect is considered as part of the production management.

The system integrator provides asset information: During the physical construction of the production system, the system integrator uses a suitable documentation tool to enter information about the activities and the assets administered in the asset management. It is the responsibility of the individual responsible for the asset – in this use case it is assumed that this is the production system architect – to configure the documentation tool used by the system integrator so that the integration of the required information in the asset management process can be done very effectively.

The production resource operator operates a production resource: During the operation of a production resource guided by the production resource operator system, usage information of the production resource that is relevant for the asset management is typically generated. It is the responsibility of the individual responsible for the production resource – in this use case it is assumed that this is a joint responsibility of the production system architect and production coordinator – that the production resource has been integrated into the production system in such a way that the usage information of the production resource is automatically made available to the asset management process.

The service and maintenance provider provides asset information: While performing service activities on the production system, the service and maintenance provider use a suitable documentation tool to enter information about the service activities and the assets administered in the asset management process. It is the responsibility of the individual responsible for the assets – in this use case it is assumed that this is the production system architect – to configure the documentation tool used by the service and maintenance provider so that integration of the required information in the asset management can be done effectively.

Various engineering tools synchronize internal information about assets with the asset management system: The configuration of the synchronization is defined by the users of the corresponding engineering tools during their creation and management of the individual assets, which are in their responsibility. In doing so, they determine how the information from the perspective of the respective engineering tool is mapped to the uniform description according to the asset management system and according to which rules the synchronization of this information takes place.

The IT administrator configures and manages asset management and the engineering tool used from an IT perspective: Since the administration of assets is a company-wide task, the further role of IT administrators is considered. Typical tasks include, for example, cross-company user management, access authorizations or version management of the engineering tools used. It is a good practice to ensure that the users of the asset management are able to create and delete assets and to update information of an asset as simply as possible.

6.3.1.6 Expected change and impact

The use case supposes a uniform approach within a company regarding all assets. Today, there are typically various approaches for asset management in place.

Consequently, the various information about assets can be evaluated uniformly and comprehensively. Such a unified approach is a lever for effective engineering of an asset management.

6.3.1.7 Recommendations for standardization

Information about assets should be managed in the form of standardized life cycle entries in the asset management system. Regarding a universal evaluability, however, the content should also be described in a sufficiently formal manner, including the considered context, for example in the form of qualifiers, see for example [5].

Standardization of a common and system-wide concept of the underlying time should be taken in account.

The concrete content in the life cycle entries should also be standardized. However, which should be industry-specific according to[6] the use case “Standardization of production technologies”. This is particularly important to transfer information provided by suppliers seamlessly to the asset management system.

In the context of standardization, there are already activities in the area of asset management, for example for plant asset management, see [7], where the aspects “asset health management” and “provision and archiving of information” are described.

6.3.2 Virtual representation of physical assets

6.3.2.1 Objective

A manufacturing company wants to create added value through optimized asset usage, reliability and efficiency.

6 According to, because assets are not necessarily production resources.

6.3.2.2 Overview

This use case is complementary to the use case “Administration of assets”, which pursues the same goal. However, regarding the administration of assets, there are additional special aspects that are considered:

- For physical assets, there can be a transfer of ownership. If asset information is stored on the asset itself, the information is updated before the handover to prevent, for example, the transfer of intellectual property.
- For non-physical assets (as information entities), it is usually guaranteed that the IT systems recognize changes of the information. However, physical assets are subject to continuous change, for example, wear, rotting, expansion, and, therefore, one explicitly establishes measures to recognize such changes. Either suitable sensors and evaluations are installed, or the physical asset is monitored by persons.
- There is an unambiguous relationship between the physical asset and the information entity that holds the information about the asset in the asset management system.
- An important aspect is the physical tracking of physical assets. Due to the quantity of assets of a manufacturing company, it is becoming highly challenging to track and manage each asset on a day-to-day basis, especially when assets are frequently transported to different operation points.

There are already several different conceptual solutions for managing assets – especially for physical assets. For example, in process automation, NAMUR NE 107 has become a quasi-industrial standard and allows uniform treatment of device diagnosis information. However, these solutions are still limited to special areas of application.

6.3.2.3 Business context

Figure 30 illustrates the business roles involved in the use case “Virtual representation of physical assets”.

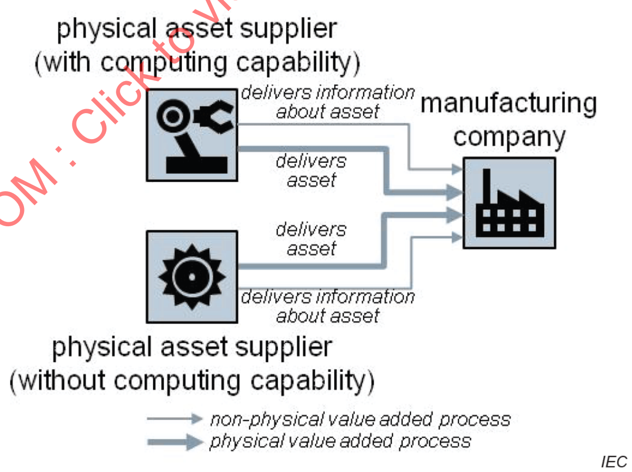

Figure 30 – Business context of “Virtual representation of physical assets”

6.3.2.4 Technical perspective

Figure 31 illustrates the human and technical roles involved in the use case “Virtual representation of physical assets”.

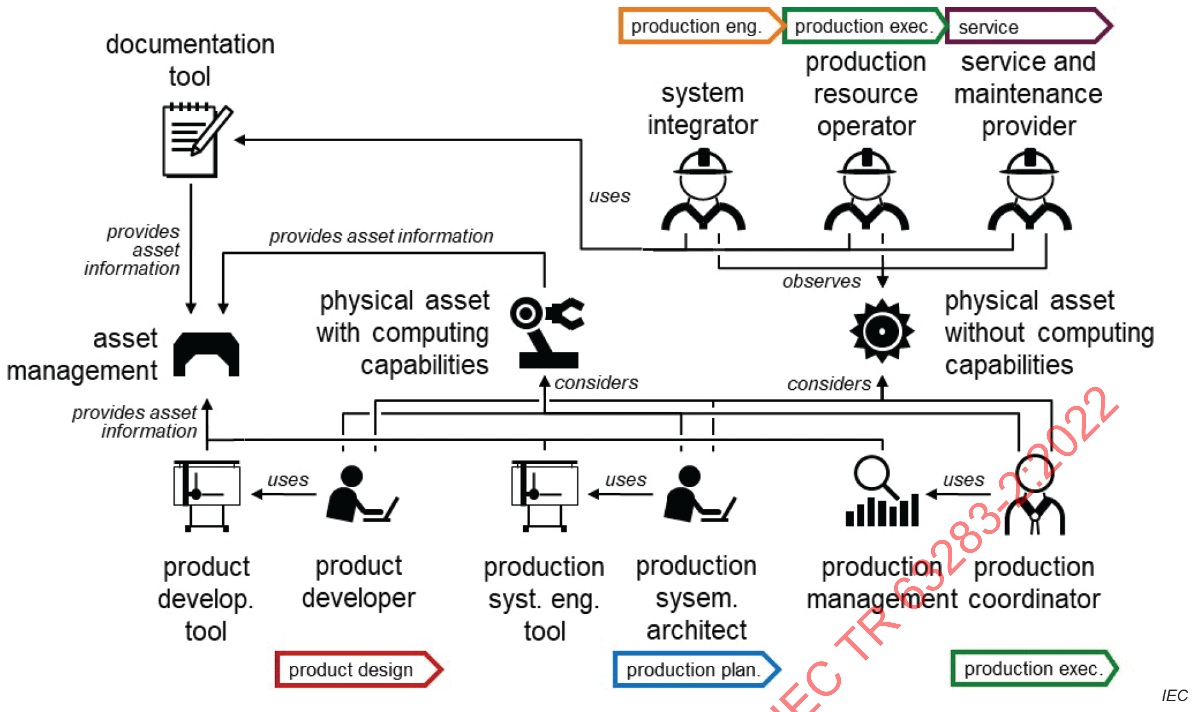

Figure 31 – Technical perspective of “Virtual representation of physical assets”

6.3.2.5 Interaction of roles

In this use case, the physical assets do not necessarily have to be sourced externally, but can also be generated within the company. A distinction is made between physical assets with computing capabilities that recognize changes themselves, and assets without computing capabilities, where changes are recognized by persons – possibly with the help of appropriate sensors.

Regarding the roles of the product developer, the production system architect and the production coordinator, there are no changes in this use case compared to the use case “Administration of assets”. However, for the physical assets, properties are defined which are observed later and managed in the form of life cycle entries in the asset management.

Even if physical assets have sensor capabilities to automatically detect changes – where the asset needs suitable computing capabilities – there is no change compared to the use case “Administration of assets”. The example in the form of a production resource shown can be transferred directly to this use case.

For physical assets without computing capabilities, the roles of the system integrator, the production resource operator, and the service and maintenance provider are responsible for explicitly monitoring the asset with respect to changes. Examples of such changes are the bending of parts due to temperature changes, the wear of parts due to friction, or the breaking of parts due to faulty manufacturing or excessive stress. To integrate the recognized changes in the asset management, the various roles use documentation tools that enable them to easily identify the asset under consideration and then simply transfer the changed information to the asset management system.

6.3.2.6 Expected change and impact

See 6.3.1 Administration of assets

6.3.2.7 Recommendations for standardization

Uniform identification of physical assets: The underlying mechanisms should be as lightweight as possible in order to be able to economically identify even low value assets.

Standardization of the physical localization of assets: The underlying mechanisms should be as lightweight as possible in order to be able to economically localize even low value assets.

Standardization of information regarding physical tracking and tracing of assets should be considered.

6.3.3 Feedback loops

6.3.3.1 Objective

A product developer feeds knowledge gained in the later product design phases back into the earlier product design phases of a new or optimized product design.

A production system architect feeds knowledge gained in the later production system engineering phases back into the earlier production system engineering phases to optimize the product system design.

The production system architect feeds knowledge gained in production system engineering back to product design to better align product and production system design ("design for manufacturing").

A production coordinator feeds knowledge gained in production execution back to production execution to optimize production.

The production coordinator feeds knowledge gained in production execution back to production planning or product design to optimize production system design respective product design.

A manufacturing company wants a purchaser (respective market) to feed experience gained in usage (respective perception) of the delivered product back to the manufacturing company to optimize the offering to the purchaser (respective market).

A system integrator, the production resource operator and the service and maintenance provider provide feedback from erection respective operation respective service of production system back to the production system architect to optimize the production system design.

6.3.3.2 Overview

This use case is about allowing experiences and knowledge in the sense of "lessons learnt" to flow back in a chain of effects and, thus, to optimize the core systems of considerations of a manufacturing company, namely the product series, the produced and delivered products, the planned production system, and the production system that is operating. After such feedback, a creative "design" decision is taken, either by the product developer or by the production system architect or by the production coordinator. Human actors are responsible from a technical perspective to take care of a transparent and seamless information flow and information base along the entire life cycle of the core systems of consideration.

This use case focuses on the discovery by a human actor. Of course, effects can also be automatically detected, and corresponding notifications automatically generated. These can then also be forwarded to people who are not considered in this use case, for example, to an external supplier who has not complied to some requirements. In these cases, however, such automatic detection is planned ahead and requires adequate modeling. This modeling is not within the scope of this use case, but for example in the use cases "Optimization of operation through machine learning", or "Optimization in design and engineering through machine learning".

In this use case, a simplified chain regarding the notification is assumed. Notifications can also take place within a role, for example, within product design or production planning due to the division of labor in these value added processes. The role of sales is not explicitly considered in this use case.

6.3.3.3 Business context

Figure 32 illustrates the business roles involved in the use case “Feedback loops”.

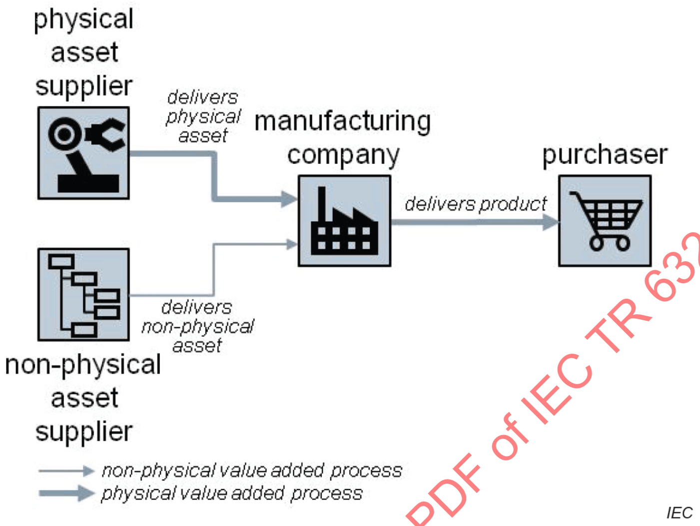

Figure 32 – Business context of “Feedback loops”

6.3.3.4 Technical perspective

Figure 33 illustrates the human and technical roles involved in the use case “Feedback loops”.

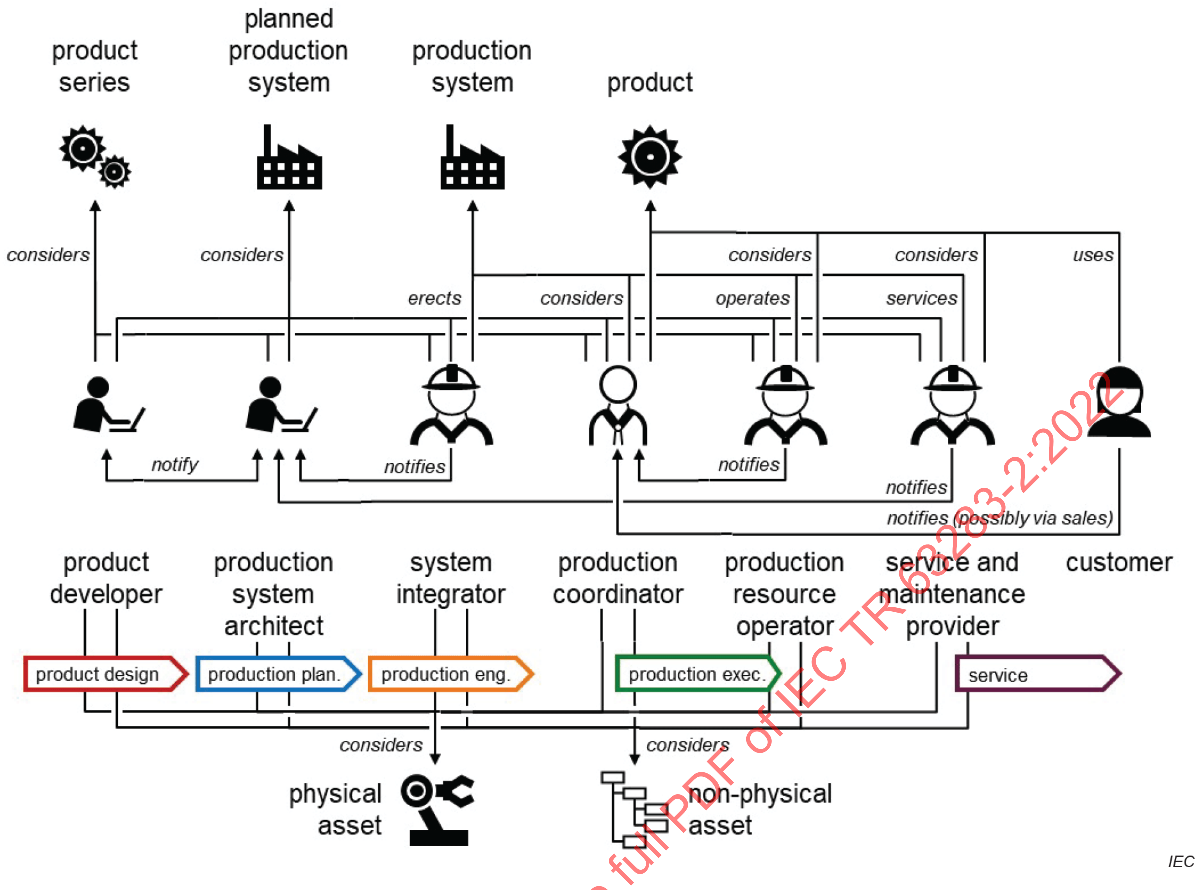

Figure 33 – Technical perspective of "Feedback loops"

6.3.3.5 Interaction of roles

During their activities in the various value added processes, the individual human actors observe the core systems of consideration, namely the product series, the produced and delivered products, the planned production system and the production system. They assess – under additional consideration of various physical and non-physical assets – to which extent these subjects comply to their intended purpose. Unless, in their view, this is the case, they notify corresponding other human actors:

- The product developer and the production system architect initially only consider product series and the planned production system, because products and the production system are not existing yet. In later notifications, for example, regarding products produced or delivered, or the maintenance planning process of the production system, they also consider products and the production system, which for reasons of clarity is not illustrated in the graphic representation of the technical perspective.
- The system integrator also considers – in addition to the product series and the planned production system – the production system being set up. In later conversions of the production system, the system integrator also considers the produced products, which for reasons of clarity is not illustrated in the graphical representation of the technical perspective, and passes on the own observations to the production system architect, who can pass these on to the product developer.
- The production coordinator, the production resource operator and the service and maintenance provider consider all core technical systems of consideration. The operator production resource notifies the production coordinator, who forwards the notification. The production coordinator and service and maintenance provider notify the production system architect, who can forward the notification to the product developer.
- The customer considers the delivered product. This includes all associated artifacts, for example, an instruction manual. Even if it is part of the product series or has been generated

from it, is regarded as logically related to the product. The customer notifies the production coordinator about the own finding or perception, since sales is not regarded as an independent stakeholder here.

6.3.3.6 Expected change and impact

This use case does not describe new concepts, but describes more the reason for activities that are explained in other use cases. The activities and processes supposed by the use cases are already executed today, but typically they are applied less systemically.

6.3.3.7 Recommendations for standardization

This uses case generates no (new) recommendations for standardization, especially since the content of the feedback is not already considered in earlier planning phases.

6.3.4 Update and functional scalability of production resources

6.3.4.1 Objective

A production resource provider wants to design a product having minimal impact on downtime during an update of hardware or software.

A manufacturing company wants to have minimal impact on downtime during the update of a production resource by a hardware or software update.

A production resource supplier wants to offer additional functionality based on software, which can be unlocked after the production resource was sold and can be used by a manufacturing company to create additional revenue streams.

The manufacturing company wants to use only that functionality of a production resource, which is needed for a specific purpose, but wants to be able to react on market changes very flexible by upgrading (or even downgrading) a production resource.

6.3.4.2 Overview

The production resource can request for hardware or software updates during the life cycle of the production resource. But there is the request that the downtime of the production resource required for an update is minimal.

For “classical” updates of hardware, firmware, and base software for, for example, the operating system, system integrator is usually involved, who physically installs these updates to the production resource. Although this case is shown in the picture with the technical perspective, this aspect is in principle not new compared to the procedure today. Therefore, it is not considered in detail later.

The focus in this use case is on the application software. The production resource supplier encapsulates functions in software applications, which they can deploy or unlock while the production resource is running. “Classical” engineering is not assumed, but reconfiguration of the software during the operation of the production resource. In practice, however, there are limitations to be met, if such reconfigurations are performed. For example, that the production resource first is transferred to a defined internal state.

It is also conceivable that such functions or software applications do not have to be purchased by the manufacturing company, but could be paid based on a pay-per-use model offered by the production resource supplier.

This use case is related to the use case “Migration to adaptable production systems”, in case the manufacturing company already operates production resources with published standardized interface descriptions and now wants to design the production system to be adaptable.

This use case considers the capability of dynamic reloading of software applications from a user perspective and the use case "Device configuration" addresses this aspect from a technical perspective.

This use case is also not about general value-based services (see the use case "Value-based services for production resources"), but the impact of update is locally restricted to the production resource. In this use case the update does not require the installation of additional software outside of the production resource. However, one can consider this use case as a special case of the use case "Value-based services for production resources".

6.3.4.3 Business context

Figure 34 illustrates the business roles involved in the use case "Update and functional scalability of production resources".

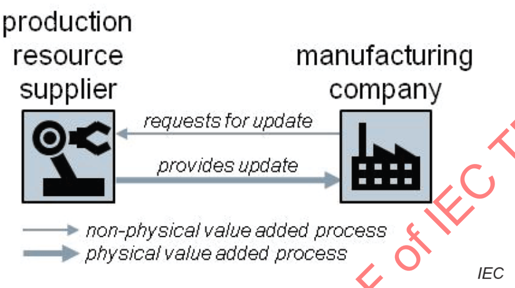

Figure 34 – Business context of "Update and functional scalability of production resources"

6.3.4.4 Technical perspective

Figure 35 illustrates the human and technical roles involved in the use case "Update and functional scalability of production resources".

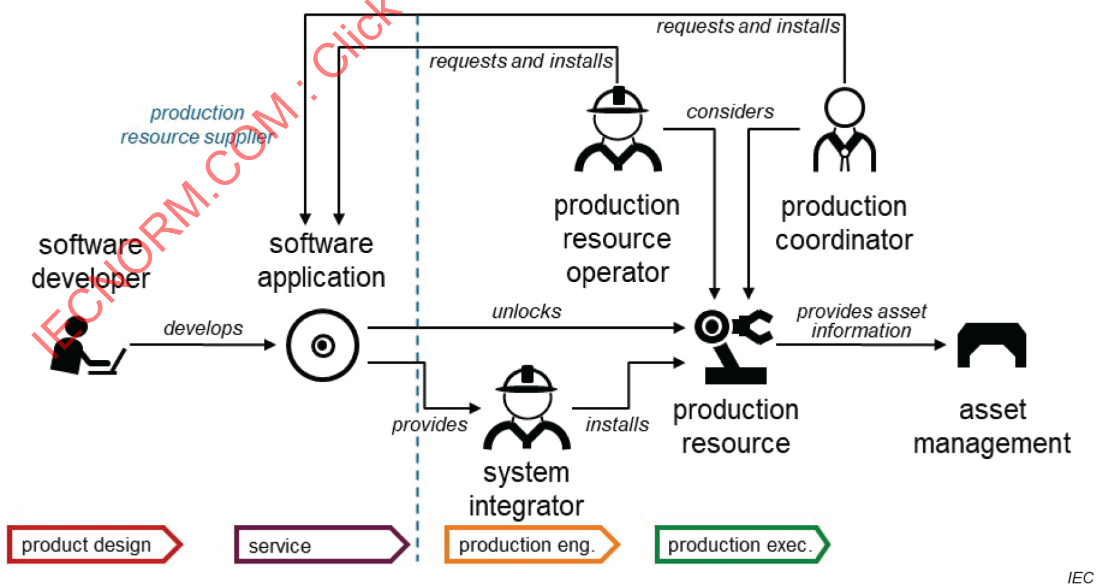

Figure 35 – Technical perspective of "Update and functional scalability of production resources"

6.3.4.5 Interaction of roles

The software developer of the production resource provider develops in the context of product design a software application: The software developer first develops a suitable software architecture that individual software applications can be added or removed without any impact on the other applications and overall system. The software developer also adequately tests these general principles. In addition, it is assumed that the used runtime system offers suitable capabilities for dynamically reloading software applications. In doing so, the software developer also specifies the procedure for updating whether, for example, the production resource is in a certain state during the update, and also consider that a connection to the internet is not possible or allowed by the manufacturing company. After developing a specific software application, the software developer tests it sufficiently. Non-functional requirements, such as, for example, reliability, security, or availability, are considered. After testing the software application can be released to be used.

The production resource supplier or the production coordinator requires an update or downgrade for a production resource: The production resource supplier delivers a corresponding software application. The production resource operator or the production coordinator initiate the installation of the software application, which follows the approach of installing apps from an app store on a device. Afterwards, the installed functions can be used or the uninstalled functions can no longer be used. Alternatively, the production resource supplier can already have installed all the software applications on the production resource upon and the software application is locked or unlocked when needed.

The asset management is notified about the software update: Typically, the software applications installed on the production tools, including the versions, are managed in the asset management system.

In the special case of the “classical” update of hardware, firmware or basic software, the system integrator is still involved and performs the update physically on the production resource. In the case of hardware updates, this typically complies with specific maintenance procedures for exchange or manipulation of entities. This normally requires the production resource to be brought into a maintenance state. If remote access is required from outside the company during the update, additional constraints are taken into account.

6.3.4.6 Expected change and impact

The use case supposes that the production resource supplier develops the application software of its production resource in such a way that it can be easily updated without involving a system integrator and first transfer the production resource to a maintenance state without any need.

Consequently, this use case enables new software service offerings of the production resource supplier even based on usage-based revenue streams.

6.3.4.7 Recommendations for standardization

The production resource suppliers should be supported with runtime systems with dynamic reloading capabilities. Those concepts should be standardized so that the production resource supplier can focus on its own core competency, namely, on the creation of the application itself and not on the application of specific dynamic reloading concepts

The processes used to dynamically reload software applications should be standardized.

6.3.5 Condition monitoring of production resources

6.3.5.1 Objective

A production coordinator wants to take precaution by predicting respective foreseeing any unexpected events regarding the wear of the production equipment to optimize the production process and minimize downtimes.

6.3.5.2 Overview

To ensure seamless production parameters of every process as well as its associated production resources are monitored. A significant change of the parameters could indicate an arising fault. With this information the production coordinator can take precautions. The aim of condition monitoring is to predict and foresee any unexpected events regarding the wear of the production resources and, therefore, to enable responding in time to ensure an undisturbed operation of the production system.

The core of this use case is to provide to the production coordinator and the operator of the production resource with information about the condition of the production resources, so that they can then take appropriate actions on that basis.

From a technical point of view, one identifies deviations from a normal state in the current behavior of a production resource. On this basis, drifts towards a critical behavior of the production resource are detected. This case requires a deep knowledge of the technological relationships of the production resource.

It is assumed that, by developing the production resource, the production resource supplier has the competence to make this predictive capability available to the manufacturing company. In order to develop this capability, the production resource supplier can include other engineering service providers, such as specialists in the creation of forecasting models.

The use case “Simulation in operation” can support the development of a condition prediction.

This use case includes a specific example of the use case “Standardization of production technologies" regarding condition prediction of production resources.

6.3.5.3 Business context

Figure 36 illustrates the business roles involved in the use case “Condition monitoring of production resources”.

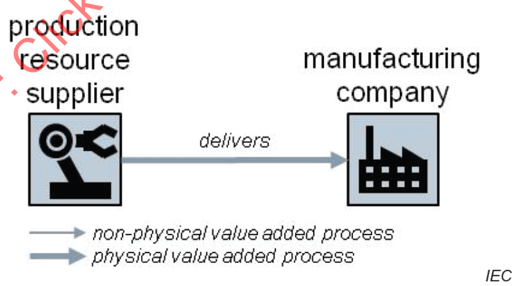

Figure 36 – Business context of “Condition monitoring of production resources”

6.3.5.4 Technical perspective

Figure 37 illustrates the human and technical roles involved in the use case “Condition monitoring of production resources”.

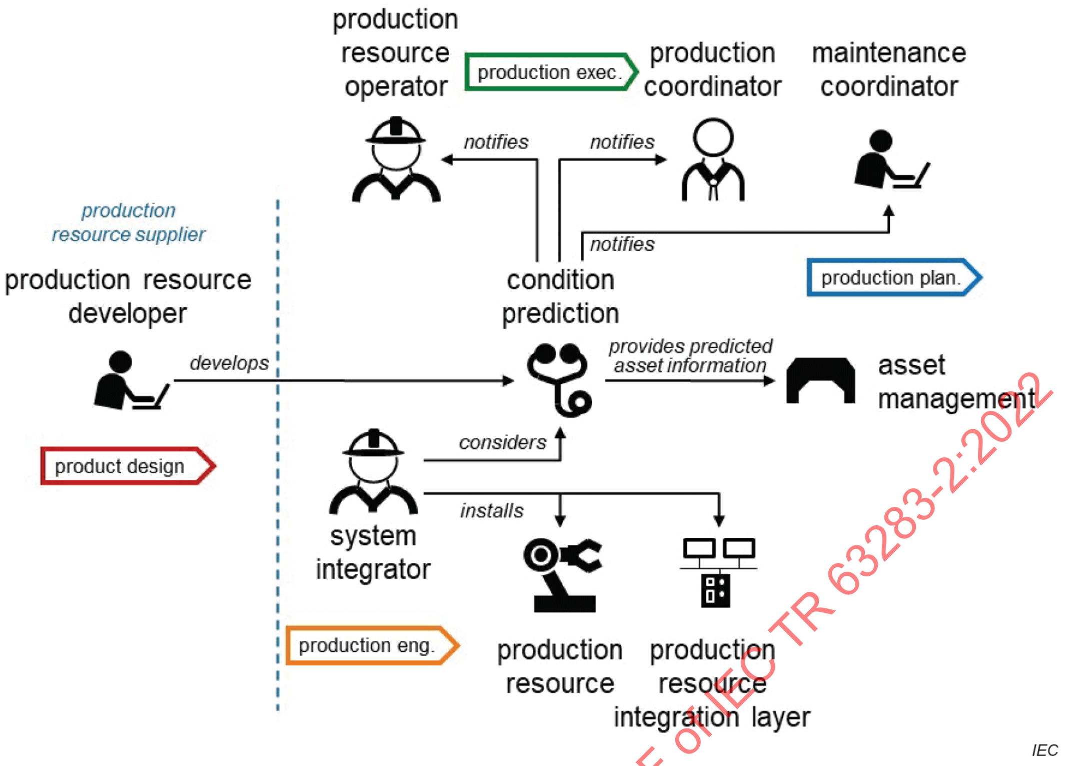

Figure 37 – Technical perspective of "Condition monitoring of production resources"

6.3.5.5 Interaction of roles

The production resource developer develops condition prediction capabilities: This is a "classical" development task in the context of design and development of a production resource.

The system integrator installs condition prediction capabilities: The condition prediction is connected to the production resource so that information provided by the production resource can be monitored. The production resource integration layer is used to provide the required computing capabilities for the condition prediction (in the case that the production resource itself does not provide appropriate computing capabilities).

The condition prediction continuously monitors the usage information provided by the production resource and updates the condition of the production resource in the asset management system. In critical situations the production resource operator, the production coordinator and the maintenance coordinator are notified timely.

6.3.5.6 Expected change and impact

The use case supposes systematic and standardized processes and data evaluation regarding condition monitoring of production resources. In current installations of production resources some condition monitoring functions are already in operation. But typically, they are very domain and implementation specific.

Consequently, this use case improves efficiency of production resources and the overall production system. Depending on the degree of standardization of production technologies, see use case "Standardization of production technologies", the possibility can arise that condition prediction capabilities are also offered by independent service providers on the market.

6.3.5.7 Recommendations for standardization

Regarding standardization, this use case addresses the condition prediction aspect of production resources, which is a special case of the use case “Standardization of production technologies”.

Regarding the condition prediction, the preparation of the result of the prediction should be standardized, both regarding a uniform administration in the asset management system and regarding a uniform, universal evaluation of the effects related to the entire production system.

6.3.6 Self-optimization of production resources

6.3.6.1 Objective

A production coordinator of the respective manufacturing company wants to optimize usage of production resources and minimize downtime (outages).

6.3.6.2 Overview

Self-optimization is an approach to flexible and reactive automation. Production resources learn from previous actions, for example, optimized scheduling, and use such knowledge for further evaluations. An example of a possible self-optimization goal is the use of resource saving production methods, for example, wear-optimized methods, to reduce costs through stable production system operation at some optimized working point.

Self-optimization can be done conceptually in different ways: through persons or controlled by persons or fully automatic. The focus in this use case is the machine learning controlled by persons in a well-defined and “stable” context of a production resource.

In machine learning, especially for training, many and representative data are required from the production resources to be optimized. This training is done by the production resource supplier, because it is expected that the production resource supplier has access to the usage information of its worldwide installed and operating production resources, see 6.7.2 Benchmarking of production resources.

Conceptually, the self-optimization consists of two interlinked control loops: an underlying “classical” control loop of the production resource, which also ensures aspects such as safety, and an overlying control loop, the control strategy of the production resource is optimized.

For this use case, the production resource supplier and manufacturing company agree in advance in terms of data access and data usage based on a legal contract.

This use case is an extension of the use case “Condition monitoring of production resources”.

6.3.6.3 Business context

Figure 38 illustrates the business roles involved in the use case “Self-optimization of production resources”.

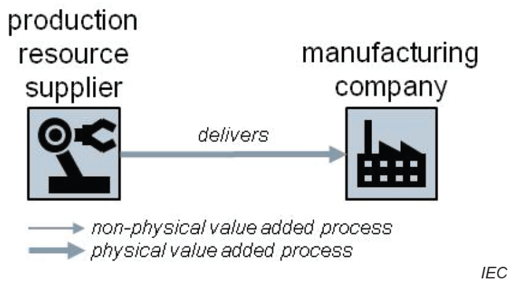

Figure 38 – Business context of "Self-optimization of production resources"

6.3.6.4 Technical perspective

Figure 39 illustrates the human and technical roles involved in the use case "Self-optimization of production resources".

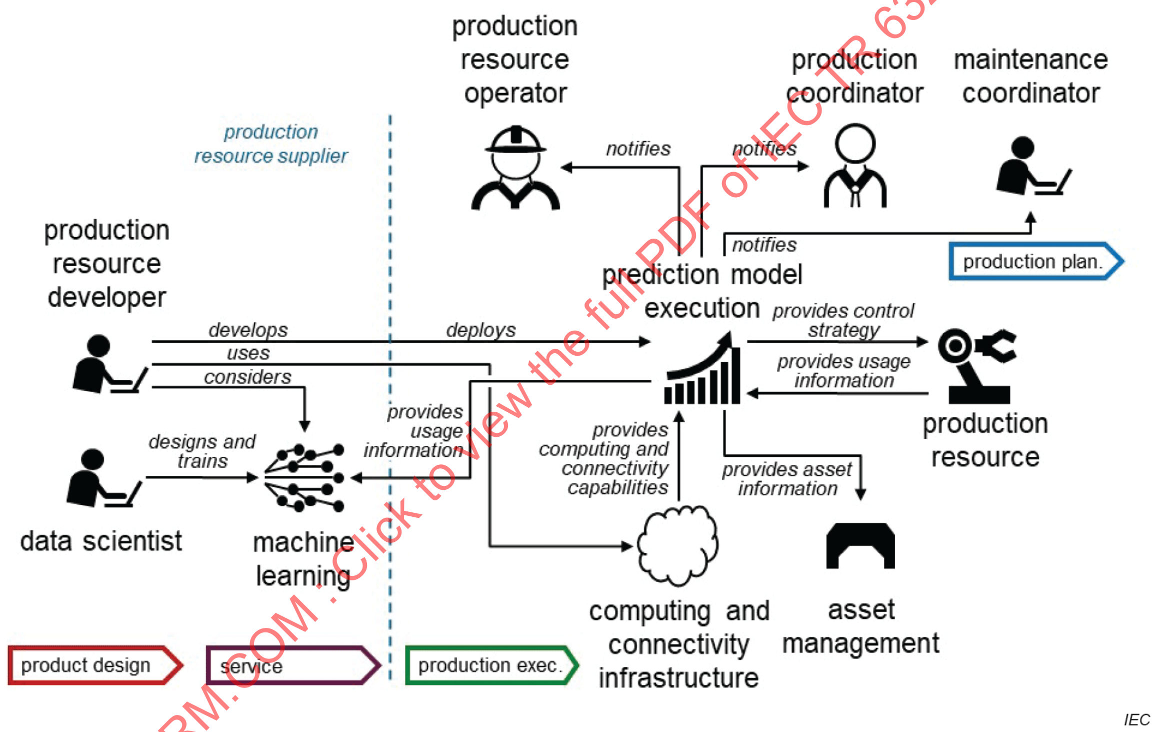

Figure 39 – Technical perspective of "Self-optimization of production resources"

6.3.6.5 Interaction of roles

The data scientist develops and trains a prediction model: Using data mining and machine learning methods, the data scientist prepares and trains a prediction model on the basis of initially available data until a maturity of the prediction model is achieved, that the prediction model can be used for a self-optimization of a production resource.

The production resource developer develops a prediction model execution and deploys it in the context of a production resource: The developer uses the prediction model provided by the data scientist and integrates an execution of this prediction model in the context of the operation of a production resource. The developer uses a computing and connectivity infrastructure that offers capabilities for executing the prediction model on the one hand, and connectivity capabilities on the other to provide the data scientist with operational data for optimizing the prediction model.

The prediction model is executed while the production resource is operating: The execution of the prediction model performs the following tasks:

- optimization of the control strategy of the production resource;
- collection of usage information of the production resource;
- update of the asset management system with information about the production resource on appropriate occasions, such as a change in the control strategy;
- notification of the operator production resource, the production coordinator and the maintenance coordinator at appropriate occasions, for example, when recognizing the emergence of some critical situation.

The data scientist optimizes the prediction model: Based on the data from the operation of the production resource and the reaction of the prediction model execution, the data scientist optimizes the prediction model. At some point in time, the data scientist provides the production resource developer an update of the prediction model from which the developer, in turn, generates an update of the prediction model execution.

The production resource developer provides an update of the prediction model execution: If an update of the prediction model execution takes place at the manufacturing company, the use case “Update and functional scalability of production resources” is taken into account.

6.3.6.6 Expected change and impact

The use case supposes the application of machine learning, which is presently not widely used. Because of the focus on production resources the challenge to have representative data available for learning purposes is mitigated.

The value proposition behind this use case is the reduction of the effort for the prediction model design and especially the prediction model maintenance along the entire life cycle of the production resource.

6.3.6.7 Recommendations for standardization

The workflows and mechanisms related to machine learning should be standardized. This concerns the initial modeling, the generation of a prediction model execution from a model as well as the incremental improvement of a created prediction model.

In order to be able to use general methods and tools of data mining and machine learning in this use case, the underlying computing infrastructure should assert certain technical requirements. This is considered in the use case “Device configuration”.

6.4 Use case cluster “Optimization of production execution”

6.4.1 Optimization of operations

6.4.1.1 Objective

A production coordinator wants to optimize production according to specific KPIs, for example, minimize downtime (outages) or maximize usage of production resources or to improve quality of products.

6.4.1.2 Overview

This use case is primarily about the optimized use of a production system. The scope is not limited to a single site, but the optimization is also across sites of a company. The planning regarding order processing and the interface to the purchaser, including the entire supply chain, is addressed by the use cases “Manufacturing of individualized products”, “Flexible scheduling and resource allocation” and “Outsourcing of production”.

The core tasks in the context of optimization of operations include:

- Optimization of resources and production processes: Based on the experience of using the production system, the used resources and the underlying production process are optimized, for example, to achieve better product quality or higher throughput.
- Resource management and planning: Optimization of any kind of resources across a production system and different sites as well as within a production system across different orders to meet some specific KPIs.
- Maintenance management and planning: Improvement of resource availability, minimization of unplanned downtimes (outages), and reduction of maintenance costs, where different maintenance activities and strategies can be applied. For example, corrective maintenance, where immediate required actions are executed, or preventive maintenance, where actions are scheduled and executed based on various indicators like conditions, time or predictions.
- Reconfiguration management and planning: Coordination of rebuilding and configuration activities with respect to the production system with the required design and engineering activities of the production system engineering.

To optimize production, information from various sources is consolidated, analyzed and evaluated in order to derive suitable actions. It is conceivable that the production coordinator derives these actions as well as that the actions are automatically generated and even automatically executed.

The benefit gained by optimization of production typically cannot be specified in a generally valid manner. Often individual cases are considered.

6.4.1.3 Business context

Figure 40 illustrates the business roles involved in the use case “Optimization of operations”.

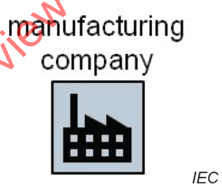

Figure 40 – Business context of “Optimization of operations”

6.4.1.4 Technical perspective

Figure 41 illustrates the human and technical roles involved in the use case “Optimization of operations”.

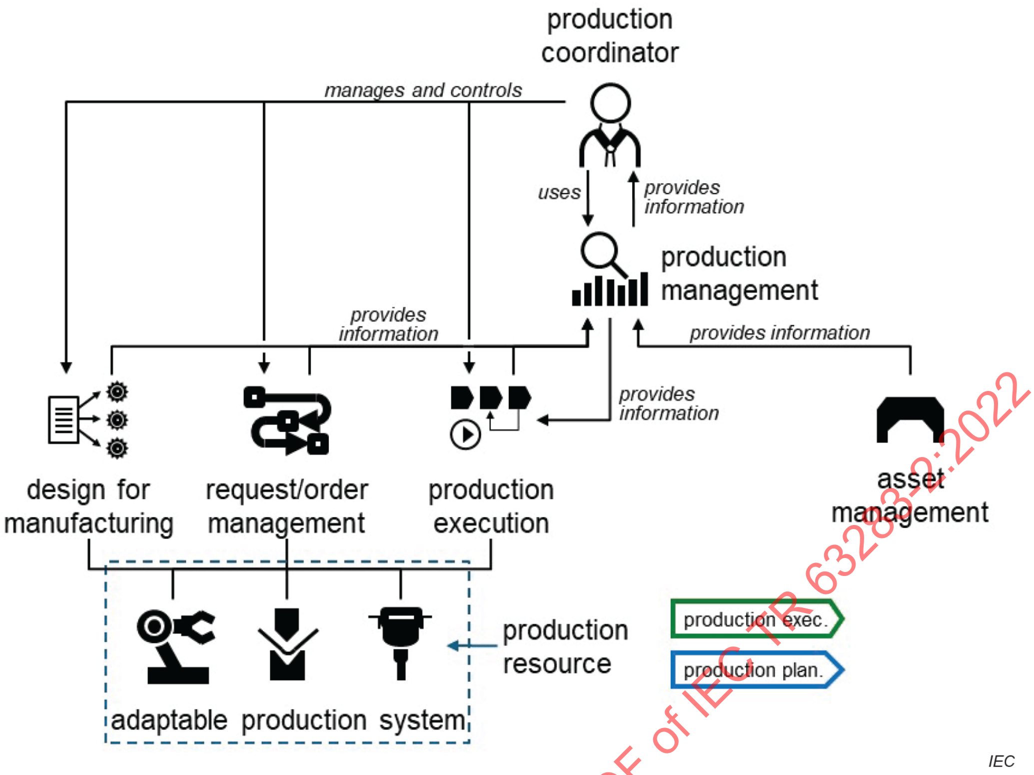

Figure 41 – Technical perspective of "Optimization of operations"

6.4.1.5 Interaction of roles

The production coordinator is supported by the production management regarding the planning activities in the context of the optimization of production:

- In addition to the production management, the production coordinator also uses the technical roles such as the design for manufacturing, the request/order management and the production execution for special planning tasks.
- For the planning of order processing including the entire supply chain – the actual production execution – the production coordinator uses the technical roles such as the design for manufacturing and the request/order management.
- In order to plan the optimized use of the production system – to plan the maintenance, service and reconfiguration of the production system – the production coordinator uses the technical role of the production management.

The production management consolidates all information provided by the design for manufacturing, the request/order management, the production execution and the asset management to provide the production coordinator with a comprehensive, consistent information base for the planning activities.

The production management provides production execution with the planning information required for operational execution. The production coordinator can intervene in the operational execution of production execution.

The production management and the production execution is developed by the production system architect as part of the engineering of the production system in cooperation with the product developer.

6.4.1.6 Expected change and impact

In principle, the described functions are already available today in various applications. The implementation and usage of such solutions is usually driven by the question of profitability: how much effort and investment in such a solution is spent (both once for the creation as well as during the usage) and what is the resulting benefit. Due to new technology maturity (for example, more efficient optimization algorithms), changed cost structures (for example, easier data exchange or simplified engineering) and changed business conditions (for example, demand for greater flexibility, shifting of added value between business partners in the value network), opportunities can arise that suddenly facilitate economic implementation of some individual cases.

Consequently, the use case will result in an improvement of operation.

6.4.1.7 Recommendations for standardization

From this use case, no specific new recommendations for standardization can be derived. The recommendations for standardization based on specific content aspects are addressed in the corresponding other use cases.

6.4.2 Simulation in operation

6.4.2.1 Objective

A production coordinator wants to simulate a model of production to optimize production, to check the principle feasibility, to reduce risks resulting from reconfigurations of the production system, and/or speed-up reconfigurations of the production system.

6.4.2.2 Overview

This use case is closely related to the use cases “Simulation in design and engineering” and “Virtual commissioning of production systems” (for general remarks to simulation see 6.6.2 Simulation in design and engineering. Nevertheless). It is not the purpose of this use case to explain or cover the broad field of the simulation in operation in detail, but only – without pretension to any completeness – to focus on some important issues.

Simulation in the operation phase allows for the comparative valuation of short-term and situation-dependent process sequence variations, such as the examination of useful strategies and responses to disturbances and alterations in advance, as well as the examination of long-term development trends. Typical issues are examination of:

- schedule alternatives in the production execution;
- different variants as a basis for operative decision-making, for example, for situation-dependent production resource allocations, production order sequences, batch sizes and personnel deployment;
- emergency strategies or measures for immediate reaction before they are realized, in terms of their effects on the production system or product;
- variants for prognosis proposed, for example, altered product structure, product mix and output, changes in working time models, production resources, and production order sequences or regarding outsourcing or insourcing of production capabilities.

This use case focuses on the use of a simulation model by the production coordinator. Using appropriate tools, the production coordinator configures the simulation, executes it and then evaluates the result of the simulation. The focus here is therefore the easy configuration, execution and usage of a simulation.

The development of the simulation is not considered in this use case. Simulation development is part of the design and engineering activities, which the production system architect carries out together with the product developer, see especially 6.6.2 Simulation in design and engineering". Usually, the models that are used for simulation in operation rely on models that are also needed in design and engineering.

Due to the variety of the topics that need to be addressed in production execution and production planning (after commissioning), the activities executed for simulation in operation vary with regard to objective, depth of detail of the consideration and the regarded time horizon, which is reflected in simulation in operation typically by many different models and often also different tools are used.

6.4.2.3 Business context

Figure 42 illustrates the business roles involved in the use case "Simulation in operation".

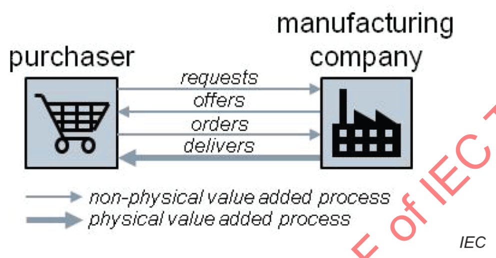

Figure 42 – Business context of "Simulation in operation"

6.4.2.4 Technical perspective

Figure 43 illustrates the human and technical roles involved in the use case "Simulation in operation".

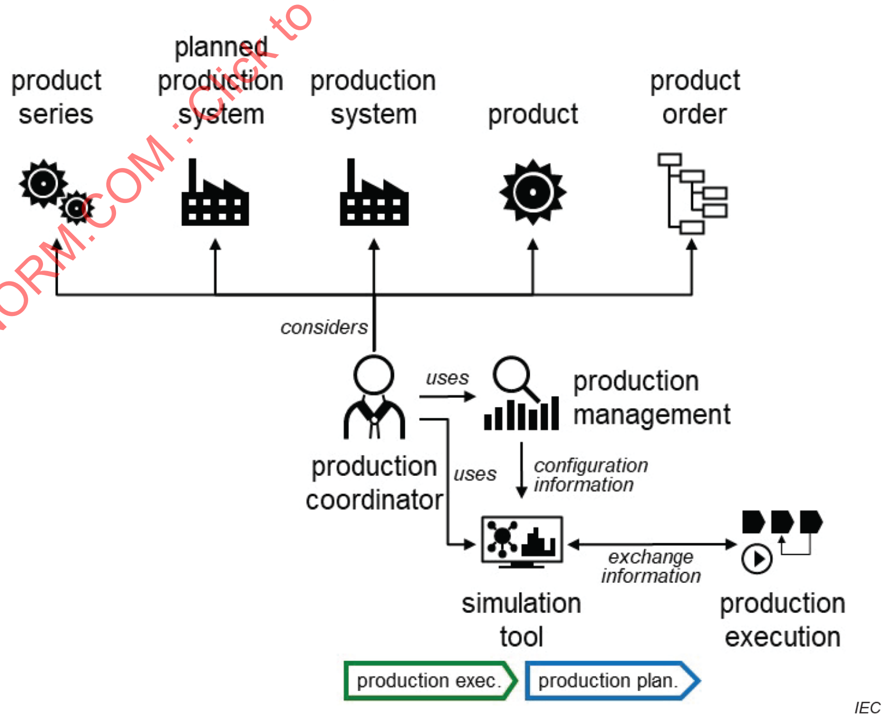

Figure 43 – Technical perspective of "Simulation in operation"

6.4.2.5 Interaction of roles

The production coordinator considers some specific situation in operation based on available information about product series, planned production system, production system, product and product order and defines in a creative step the purpose of the simulation to be executed.

The production coordinator considers the available simulation models regarding the specific purpose and configures a simulation using the simulation tool, production management and production execution:

- The simulation tool provides the capabilities for performing simulations.
- Production management provides information about the production system regarding the configuration of a simulation.
- Production execution provides information about the current state of the production system.

The required capabilities of the various technical roles are developed accordingly during the creation of the technical roles.

After these preparations, the production coordinator then carries out the actual simulation runs and interprets the result of the simulation runs regarding the intended purpose. The production coordinator then decides how to integrate the insights from the simulation into the own considerations.

6.4.2.6 Expected change and impact

Simulation in operation is already being used today, but these simulations are often developed regarding a specific application and are very specific. Thus, the maintenance of these simulations over the life cycle of the production system is usually complex. However, increasing the use of simulation in operation, more out-of-the-box approaches for simulation tools and models could be established, which in turn lowers the threshold for using simulation in operation. This can create self-reinforcing effects.

Consequently, the use case will result in an improvement of operation.

6.4.2.7 Recommendations for standardization

The focus in this use case is on uniform functions and models, so that standardized simulation tools can be provided, thus lowering the hurdle for using simulation in operation. Possible approaches to standardization are, for example:

- standardization of specific purposes of models to be used for simulation in operation, for example by standardizing KPIs for operation;
- standardization of specific simulation models for operation, for example for the purpose of validating of specific standardized KPIs;
- standardization of functions and user guidance of simulation tools to be used in operation.

In addition to the economies of scale fueled by standardization, there will probably still be solutions that are specialized which add specific value for special cases.

6.4.3 Optimization of operation through machine learning

6.4.3.1 Objective

A production coordinator wants to be supported in the optimization of operation.

The manufacturing company has an interest in making the knowledge of key persons more transparent to secure business after retiring of key persons.

6.4.3.2 Overview

The production coordinator executes creative activities for production execution and production planning (after commissioning) and evaluates the outcome of the own work to determine the extent to which the own creative decisions will serve their intended purpose. The production coordinator revises the own decision and makes a new decision. Over time, patterns of goal-oriented and less-targeted decisions will be created, and these decisions are collected in the context of this use case. This collection is used to generate “suitable” suggestions to the production coordinator to support the decision making. In extreme cases, it is even conceivable that the production coordinator will be replaced by some algorithm.

This use case is quite generic and postulates that the machine learning methods are used to create a suitable model for generating suggestions for decisions. In practice, there are already various, sometimes quite specific, applications implemented. Overall, there is currently a dynamic environment in which such approaches are evolving technologically.

The use case is conceptually identical to the use case “Optimization in design and engineering through machine learning”, except that its application is in the value added processes of production execution and production planning (after commissioning) design and engineering. The use case “Self-optimization of production resources” is also comparable, but in this use case it is assumed that the collection of the training data for machine learning and the training of the model is driven by the same company and, therefore, the contractual agreement regarding usage of data is easier to design.

6.4.3.3 Business context

Figure 44 illustrates the business roles involved in the use case “Optimization of operation through machine learning”.

Figure 44 – Business context of “Optimization of operation through machine learning”

6.4.3.4 Technical perspective

Figure 45 illustrates the human and technical roles involved in the use case “Optimization of operation through machine learning”.

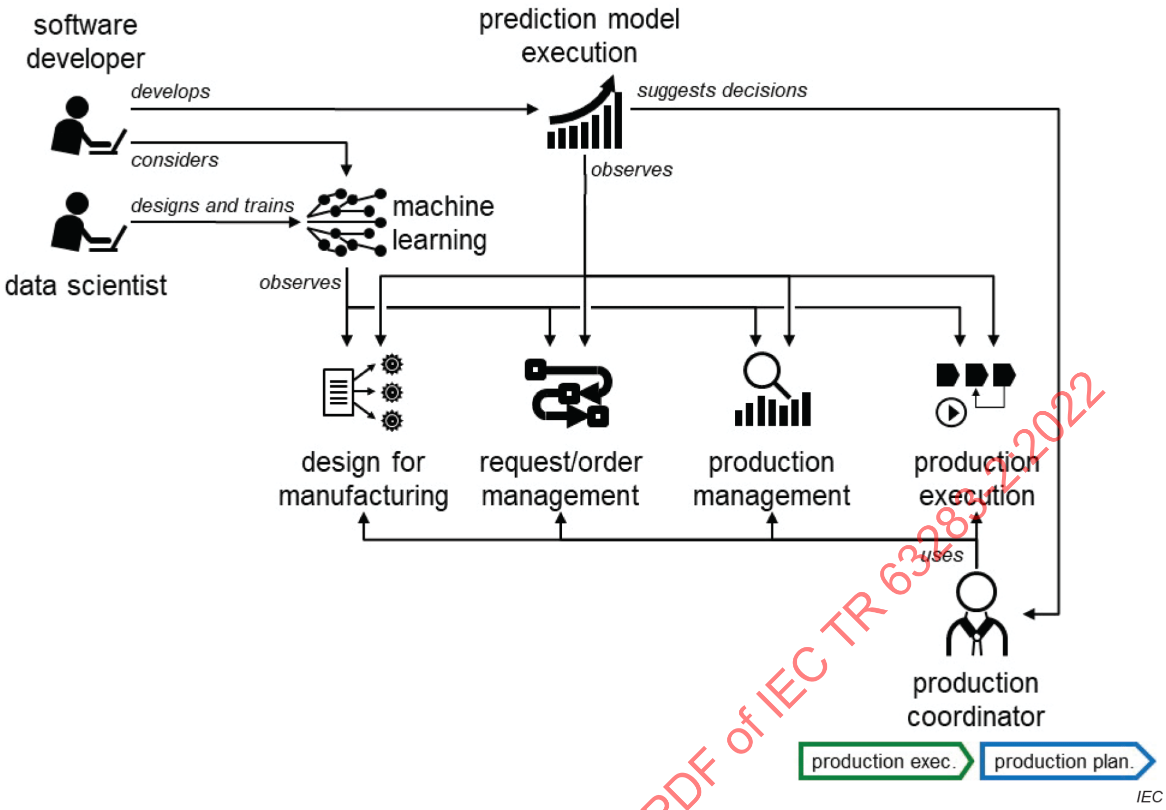

Figure 45 – Technical perspective of "Optimization of operation through machine learning"

6.4.3.5 Interaction of roles

The data scientist develops and trains a prediction model: Using data mining and machine learning methods, the data scientist prepares and trains a prediction model on the basis of initially available data until a maturity of the prediction model is achieved. In this case, the prediction model can be used for an optimization of production execution and production planning (after commissioning) value added processes.

The software developer develops a prediction model execution and integrates it: The software developer uses the prediction model provided by the data scientist and integrates an execution of this prediction model in the context of a production management capability of a manufacturing company, especially considering data provided by the design for manufacturing, the request/order management, the production management and the production execution. An IT administrator can be involved, but this is not illustrated in the graphical representation of the technical perspective.

The prediction model is executed while the production coordinator uses the production management including the design for manufacturing, the request/order management, and the production execution: The execution of the prediction model performs the following tasks:

- suggestions of decisions to the production coordinator;
- collection of data from the design for manufacturing, the request/order management, the production management, and the production execution.

The data scientist optimizes the prediction model: Based on the data provided from the usage of the production management (and the design for manufacturing, the request/order management and the production execution) by the production coordinator and the reaction of the prediction model execution, the data scientist optimizes the prediction model. At some point in time, the data scientist provides the software developer with an update of the prediction model from which the software developer, in turn, generates an update of the prediction model execution.

The software developer provides an update of the prediction model execution: The integration of such an update is feedback-free, without affecting the work of the production coordinator.

6.4.3.6 Expected change and impact

The use case supposes the application of machine learning, which in today's practice is not widely used. However, the challenge is that the data available for learning is representative and that meaningful and actionable suggestions are generated for the production coordinator.

The value proposition behind this use case is the reduction of the effort for the prediction model design and, especially, the prediction model maintenance along the entire life cycle of the production system.

6.4.3.7 Recommendations for standardization

The workflows and mechanisms related to machine learning should be standardized. This concerns the initial modeling, the generation of a prediction model execution from a model as well as the incremental improvement of a created prediction model. Nevertheless, the subject is currently evolving in a dynamic environment.

6.4.4 Service workflow management for production systems

6.4.4.1 Objective

A manufacturing company wants to process service requests during operation of the production system in an efficient and effective manner.

6.4.4.2 Overview

This use case addresses the automated processing of service requests during the operation of a production system. The term service request is used in a broad sense in this use case. It is not only about intangible services, but also includes, for example, orders of physical entities such as spare parts, auxiliaries, material or intermediates.

Service processes in manufacturing companies are complex due to the involved technical systems and processes as well as the technical and business workflows. Often, these service processes are individual for a manufacturing company and various companies from the value network of the manufacturing company are involved, for example, suppliers of spare parts, auxiliaries, material or intermediates or external service providers for maintenance and repair. Today, the management and execution of service processes and workflows is often still done manually, which typically leads to errors and inefficiencies when processing service requests.

A prerequisite for the use case is a common information base, such as an asset management system. Service requests are standardized, for example, regarding the cause, purpose, recipient, boundary conditions (technical, temporal, commercial), or responsibilities. This standardization enables automated distribution of service requests to the correct recipients and monitoring their processing of the service requests.

The standardization also includes the interfaces to tools so that these tools can receive and process service requests and can provide appropriate feedback. The workflow with respect to service requests also is consistently integrated into the corresponding user interfaces of the tools. For example, in the event of an alarm or error message, the corresponding information can be easily forwarded, including the context information, directly to the relevant actors so that they can initiate appropriate measures, see also the use case "Human-machine interface".

6.4.4.3 Business context

Figure 46 illustrates the business roles involved in the use case "Service workflow management for production systems".

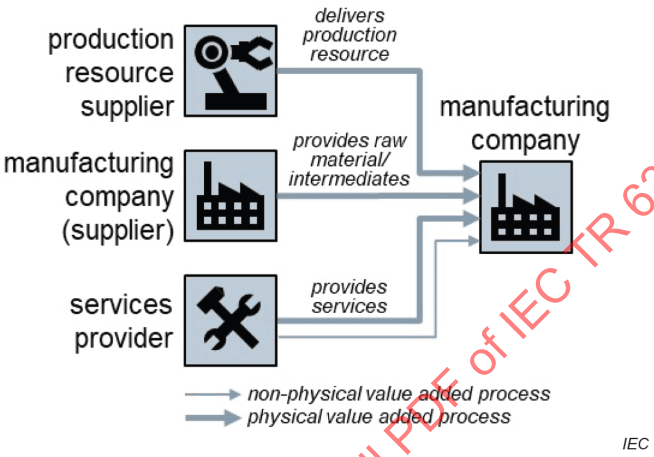

Figure 46 – Business context of "Service workflow management for production systems"

6.4.4.4 Technical perspective

Figure 47 illustrates the human and technical roles involved in the use case "Service workflow management for production systems".

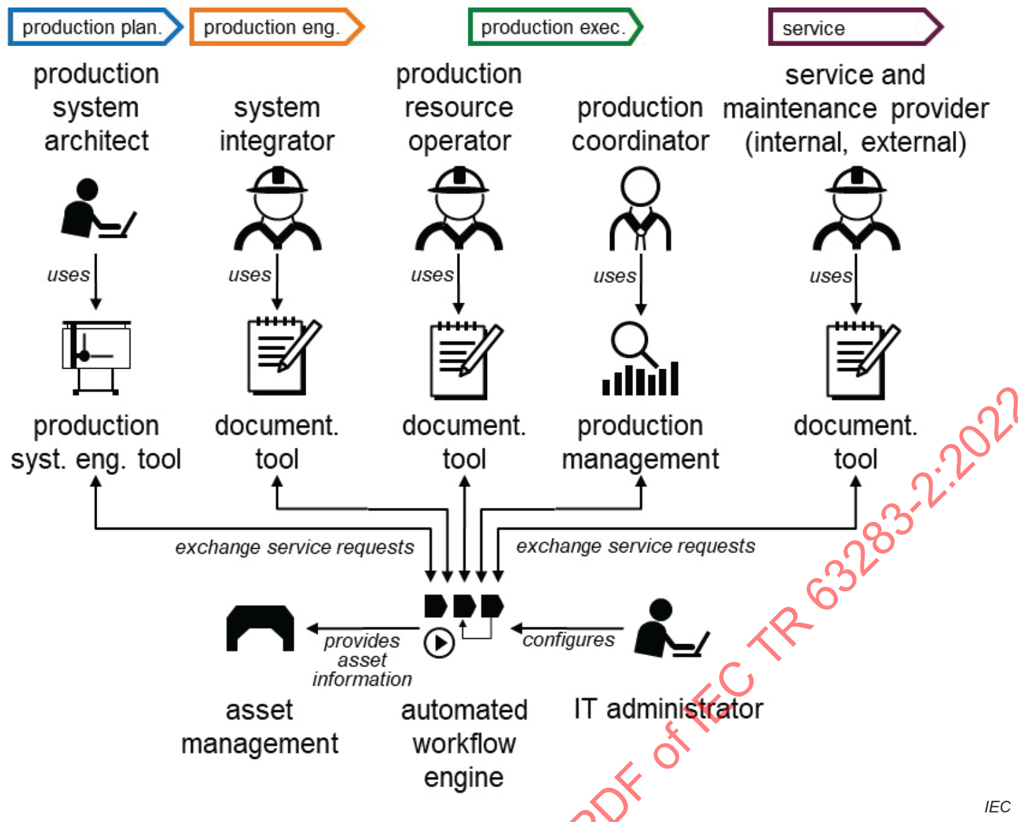

Figure 47 – Technical perspective of "Service workflow management for production systems"

6.4.4.5 Interaction of roles

The individual employees – specifically the production system architect, the system integrator, the production resource operator, the production coordinator and the service and maintenance provider – work with the tools they are familiar with in their usual roles in the various value added processes of a manufacturing company. The used tools – specifically the production system engineering tool, production management and documentation tool – are upgraded regarding service requests. Users can use these tools to receive and submit service requests based on their role in the company.

In this use case, the role of the service and maintenance provider also represents employees from external companies who receive and process service requests and deliver the corresponding results.

The workflow engine is responsible for the automated processing and monitoring of service requests. This includes, for example, receiving, forwarding, logging, tracking, monitoring or reminding. Important information about specific service requests can be managed by the asset management system. The installation of the workflow engine is an activity that does not differ in principle from the development of a software application, which is then integrated into the operation infrastructure.

The IT administrator configures the workflow engine regarding the following properties:

- Which user can see, create, forward and accept which service request. Not only the employees of the manufacturing company are considered, but also service and maintenance providers from external companies who provide services on behalf of the manufacturing company.

- Definition of general workflows according to the specifications of the manufacturing company. In the workflows, not only technical, but also business and legal aspects are considered.

6.4.4.6 Expected change and impact

The use case supposes a standardized and automated processing of service requests. Today such service requests are mostly processed manually, which leads to errors and inefficiencies in the processing.

Consequently, this will result in an overall improvement of the service processes and workflows of a manufacturing company.

6.4.4.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- Standardization of service requests including standardized interface to tools enabling the processing of service requests.
- Standardization of service processes and workflows
- Best practices for setup and execution of efficient and effective service processes and workflows

6.4.5 Successive improvement of production systems

6.4.5.1 Objective

A manufacturing company wants to successively improve the production system and production process.

6.4.5.2 Overview

In order to get benefits from a deployment of new technologies to improve manufacturing, it is very important to identify a performance achievement of the production system and production process due to the use of such technologies. This aspect is of importance when the manufacturing company targets on a continuously improvement process called Kaizen. Therefore, this use case provides performance achievement levels. These performance achievement levels include different points of view. Different stakeholders within a manufacturing company can clearly execute their own roles and deliver their appropriate result and the performance achievement levels guarantee that the contributions of the various stakeholder will result in an overall improvement. Thus, although under shrinkage of working populations, this use case also helps to empower collaborative intelligence, where a common target is set and various roles will participate and share their ideas.

This use case qualifies the value driven by improvement measures and thereby supports the optimization of manufacturing. The use case provides the manufacturing company with various performance achievement levels called kaizen levels for production systems and production processes. Each performance achievement level is characterized by a set of improvement measures and the result of each improvement measure can be assessed by improvement indicators. A manufacturing company can adapt the performance achievement levels, the improvement measures and the improvement indicators in a flexible way, for example using different visualization capabilities based on data analytics. This enables the manufacturing company to assess the investment for renewal or renovation, for example, current production resources, and to show that the measures really improve the production system and production process.

Using this use case, a manufacturing company and a production coordinator can visualize a cost performance against a targeted performance achievement level when the company invests into the production system. In addition, suppliers of production resources can deliver an accurate construction or implementation to match up the requirements for a targeted performance improvement of the manufacturing company or production coordinator. Furthermore, a manufacturing company or production coordinator can also obtain successive improvements, for example, in productivity, along to the evolution over the intermediate performance achievement levels toward the targeted performance achievement level. As a result, the optimization of a production system along its life cycle can be accelerated and thereby the production system itself will be optimized in a sustainable way.

6.4.5.3 Business context

Figure 48 illustrates the business roles involved in the use case "Successive improvement of production systems".

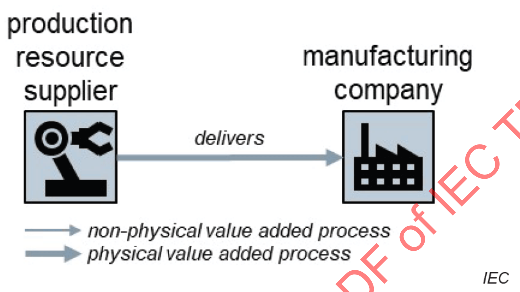

Figure 48 – Business context of "Successive improvement of production systems"

6.4.5.4 Technical perspective

Figure 49 illustrates the human and technical roles involved in the use case "Successive improvement of production systems".

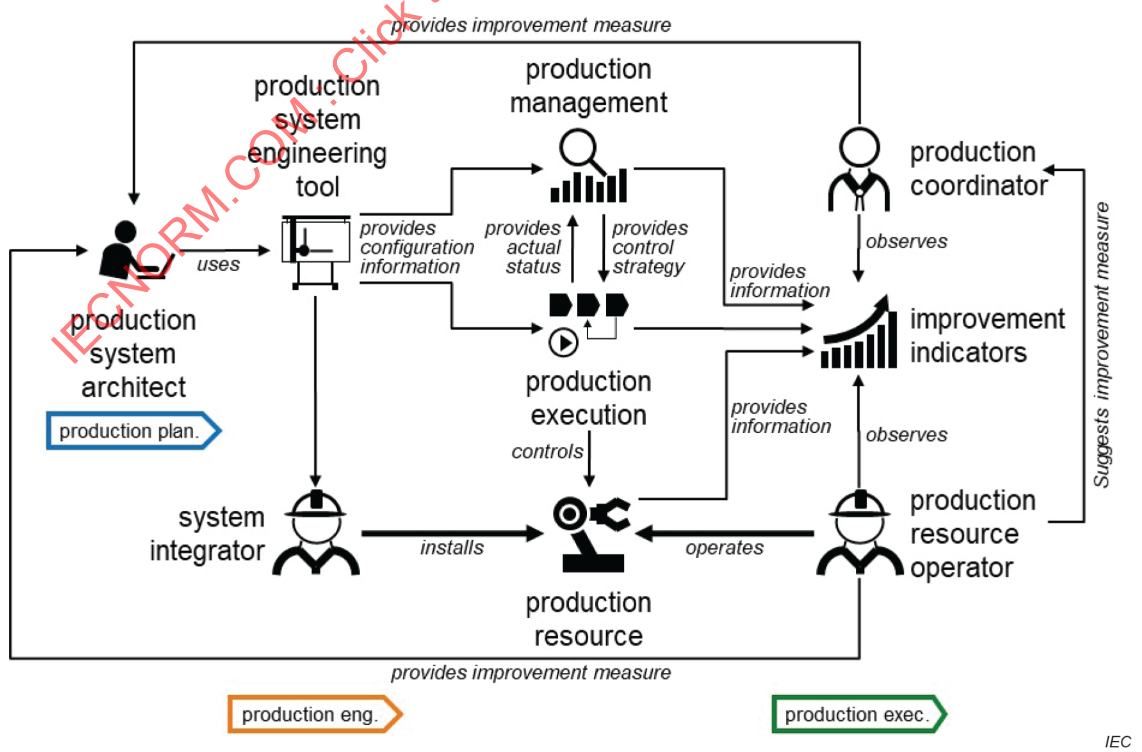

Figure 49 – Technical perspective of "Successive improvement of production systems"

6.4.5.5 Interaction of roles

The following activities are executed as part of an overarching, continuous improvement process. The example assumes that two interlinked improvement processes are taking place. One improvement process is driven by the production coordinator at the level of the entire production system and a further improvement process is driven by the production resource operator for a production resource:

- The production coordinator plans to improve the performance of the production system and production process according to the directions of the top management of the manufacturing company. The production resource operator plans to improve the performance of a production resource according to the direction of the production coordinator.
- The production coordinator evaluates the performance of the current installation of the production system and production process using an improvement indicators system. In the same way the production resource operator evaluates the performance of the current production resource.
- The production coordinator as well as the production resource operator study possible improvement measures using an improvement indicator evaluation to reveal the most effective improvement measure. In this step, the production coordinator can inquire improvement indicators of production resources or other sub-systems of the production system and can provide a production resource operator with requirements for a specific improvement of a production resource, so that the production resource operator suggests suitable improvement measures and associated improvement indicators of the production resource to the production coordinator.
- The production coordinator as well as the production resource operator will select a suitable improvement measure. The production coordinator or production resource operator can use simulation, see use case “Simulation in operation”, or even practical testing to evaluate the selected improvement measure. If the production resource operator selects an improvement measure with impact out of the scope of the production resource, the production resource operator will suggest the improvement measure to the production coordinator, who either accepts the improvement measure and initiates its implementation or rejects the improvement measure.
- The production coordinator as well as the production resource operator will provide the selected improvement measure to the production system architect so that the production system architect can plan the implementation of the improvement measure and can then guides the system integrator to install the improvement measure. The principles of these planning and installation activities are not specific for this use case.
- The production coordinator as well as the production resource operator check the result of the implementation of the improvement measure and enter a next cycle of the successive improvement of the production system.

The improvement indicator system is suitably integrated into the overall operation infrastructure. Especially the production management, production execution and production resources will provide performance information, which is evaluated and visualized by the improvement indicators system. The principles of these system integration activities are not specific for this use case.

6.4.5.6 Expected change and impact

The use case supposes that standardized performance achievement levels and improvement measures are provided to a manufacturing company which tangibly show the improvement of an installed measure of a successive improvement activity. Furthermore, the standardized performance achievement levels define a tangible achievement level of capabilities of a production system and production process and allow a manufacturing company to request these clear and reliable indications from a production resource supplier. Currently, there is no perspicuous measure to show an improvement achievement in the typical plan-do-check-action activities during the life cycle of a production system.

Consequently, the use case will result in a sustainable improvement of operation.

6.4.5.7 Recommendations for standardization

Standardized improvement process so that the improvement process can be executed on different levels within a manufacturing company, for example on an enterprise level and a shop floor level or on a production resource level

Standardization of improvement measures including their visualization by improvement indicators, impact and predicted tangible achievements

Collection and validation of best practices of possible performance achievement levels, improvement measures and improvement indicators

6.5 Use case cluster "Energy efficiency"

6.5.1 Design for energy efficiency

6.5.1.1 Objective

A manufacturing company wants to optimize energy consumption and/or energy costs and, therefore, requires for a production system designed for energy efficiency.

6.5.1.2 Overview

The design of a production system regarding energy efficiency does not differ in terms of general processes, methods, and tools from a "conventional" design of a production system. Therefore, this use case has structural similarities to the use case "Engineering of design for manufacturing and request/order management". In this special case, additional conditions and requirements regarding energy efficiency are considered in the design process. The installation and conversion measures in this use case do not differ fundamentally from "traditional" installation and conversion processes.

A basic distinction can be made between two basic measures to support energy optimization:

- Automation of processes, for example an automatic adaptation of a production step or an automatic switch to stand-by mode. Such automated processes can later be started automatically during the operation of the production system or can be initiated manually by the production coordinator.
- Targeted preparation of information, for example information about historical energy consumption, trends regarding future energy consumption or detailed information of important production resources regarding their energy consumption, in order to support the production coordinator in the own decisions.

Energy optimization can be structured in multiple layers. For example, a production resource could independently optimize its energy consumption, see, for example, the use case "Self-optimization of production resources".

It is also noted that the scope of this use case does not include electrical energy only, but also measures for a targeted recovery of energy, such as waste heat, which is then specifically fed back to the production process. The relevance of this use case is different regarding the various industries.

6.5.1.3 Business context

Figure 50 illustrates the business roles involved in the use case "Design for energy efficiency".

Figure 50 – Business context of "Design for energy efficiency"

6.5.1.4 Technical perspective

Figure 51 illustrates the human and technical roles involved in the use case "Design for energy efficiency".

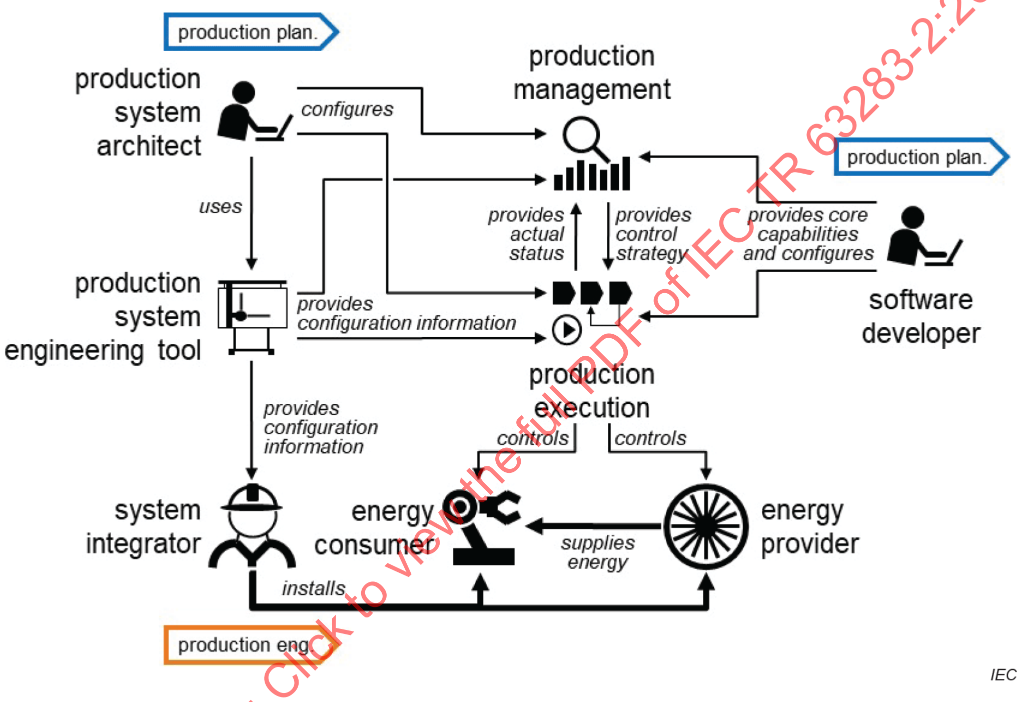

Figure 51 – Technical perspective of "Design for energy efficiency"

6.5.1.5 Interaction of roles

In this use case, the production resources of a production system assume a role as energy providers and/or energy providers.

The production system architect develops a concept for energy optimization: Considering the specific boundary conditions (for example, the company's production strategy, the capabilities of the production system or the market environment), the production system architect designs a suitable production system. Examples of such concepts are the conversion of a production systems regarding waste heat recovery or automated processes to put a production resource in a stand-by mode. The concept is based on creative decisions of the production system architect. The procedure does not differ fundamentally from the general activities for setting up or converting a production system.

The software developer develops automated optimization functions and preparation of information with regard to energy efficiency: After the concept has been developed, the software developer will use suitable optimization and data analysis algorithms to integrate them into production management and production execution with the aim to improve the existing production management and production execution and to offer improved decision support to the production coordinator with regard to energy efficiency. Thus, this is a “classical” software development task. The interplay between production management and production execution is identical to the basic interaction of production management and production execution in the context of automation of a production system.

The system integrator executes the installation and conversion work on the production system: The system integrator works according to the specifications of the production system architect. These activities are not specific to this use case and do not differ from the general activities for setting up or converting a production system.

6.5.1.6 Expected change and impact

The design of a production system regarding energy efficiency has already been practiced for a long time. But driven by the technological development of the mathematical optimization algorithms and the increasing dissemination of standards such as, for example, PROFIEnergy (both on the supplier side, where suppliers of components or production systems support such standards and on the user side, where operators of production use such standards consistently), further potentials can be tapped.

This results in optimizations that are better in terms of the resulting optimum as well as in a reduction of efforts for the creation of the optimization solution.

6.5.1.7 Recommendations for standardization

Standards such as for example PROFIEnergy already exist to support these objectives.

Standardization of capabilities of components and production resources with regard to energy efficiency (as a special case of the use case “Standardization of production technologies”): For example, components and production resources should provide energy efficiency KPIs, energy plan information for energy efficiency calculations or should provide the possibility to go into a standby mode with minimized energy consumption (including providing information about the activation time after switching in standby mode).

Targeted adaptation of general optimization methods and tools to the specific needs in production regarding optimization of energy efficiency. This can affect for example programming languages or function libraries. The task of standardization would first be to collect requirements and possible solution approaches.

Best practices about which processes should be automated regarding energy efficiency, considering an effort versus benefit assessment.

6.5.2 Optimization of energy

6.5.2.1 Objective

A production coordinator wants to optimize the operation of the production system according to specific KPIs related to energy efficiency, for example, energy consumption and/or energy costs.

6.5.2.2 Overview

This use case is an extension of the use case “Optimization of operations”, where specific attention is paid to the optimization of energy.

Here the task of the production coordinator is to operate a production system in an optimized way. On the one hand, the production coordinator complies with boundary conditions, such as a production plan, the contract regarding energy delivery (e.g. avoiding energy consumption peaks) or the availability of production resources, supplied material or intermediate products. Sometimes these boundary conditions change unexpectedly, for example in the case of a technical failure. On the other hand, within the framework of these boundary conditions, the production coordinator has certain degrees of freedom, which can be used to optimize the operation of the production system. The production coordinator has a knowledge of the technical context to make the decisions. Additionally, the production coordinator can be supported that some processes in production run automatically and that information about the production system is prepared in a suitable form for the purpose of decision support.

However, it is in the responsibility of the production coordinator to make appropriate creative decisions within a certain time window. Examples can include measures to avoid energy consumption peaks, manual adjustments of a production step or the targeted switching of a production resource into a stand-by or idle mode.

6.5.2.3 Business context

Figure 52 illustrates the business roles involved in the use case “Optimization of energy”.

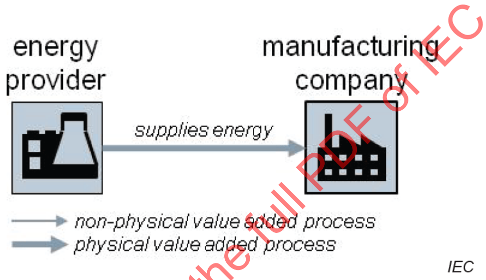

Figure 52 – Business context of “Optimization of energy”

6.5.2.4 Technical perspective

Figure 53 illustrates the human and technical roles involved in the use case “Optimization of energy”.

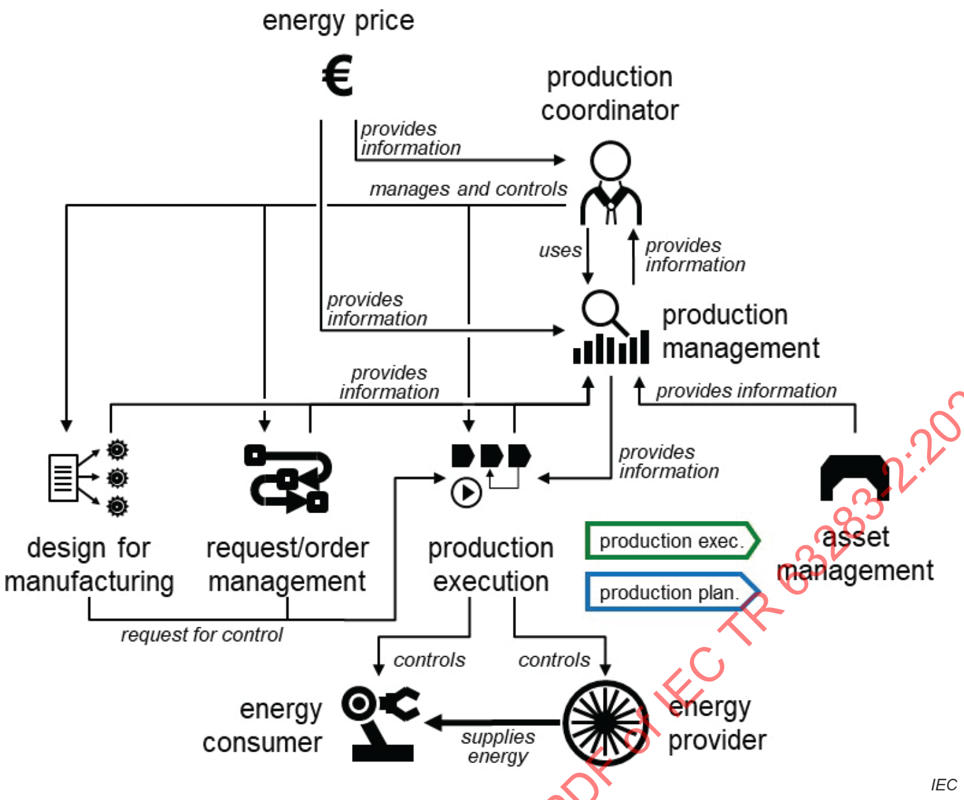

Figure 53 – Technical perspective of "Optimization of energy"

6.5.2.5 Interaction of roles

Structurally, the interaction of the roles involved is the same as for the use case "Optimization of operations", so that only the additions regarding energy optimization are described here.

The production coordinator considers the production resources of the production system as energy consumer and/or energy provider and considers the energy price offered by an energy provider assuming the business role energy provider. Based on the current energy price and the forecast energy demand, which is determines based on the current production plan, the production coordinator will take appropriate measures regarding the operation of the production system. For this purpose, the relevant information is prepared according to the actual situation in order to take appropriate decisions.

6.5.2.6 Expected change and impact

Optimization of the operation of a production system regarding energy efficiency has already been practiced for a long time. However, the more and better processes in production are automated and decision aids are made available for the production coordinator (see 6.5.1 Design for energy efficiency), the more the production coordinator is relieved of error prone routine work and can concentrate on creative activities.

Consequently, the use case will result in an improvement of energy efficiency.

6.5.2.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- Best practices of recommendations to a production coordinator supporting to implement measures to optimize energy efficiency.

- Proposals for a uniform presentation of information to support a production coordinator in implementing measures to optimize energy efficiency, for example, a uniform presentation of plans, history, and trends of energy consumption.

6.5.3 Design for participation in decentralized energy networks

6.5.3.1 Objective

A manufacturing company wants to optimize energy costs by aligning own energy demand and/or supply with energy prices offered to the market and, therefore, requires for a production system that can participate in decentralized energy networks (“Smart Grids”).

6.5.3.2 Overview

The background of this use case is that renewable energy and cost effectiveness drive the market to manage energy depending on availability. Since it is possible that the availability of renewable energies and the current request for energy do not correlate, improved flexibility of production systems regarding energy consumption will offer an effective lever here.

A decentralized energy network is a network of prosumers, who can assume both the role of an energy consumer and the role of an energy producer. It is the task of the operator of the decentralized energy system to control the prosumer by means of load management. Supply and demand are synchronized in such a way that network stability is ensured while also providing energy to the individual manufacturing companies according to the underlying energy contract.

In this use case, the production system is considered as a prosumer in a decentralized energy network, where the manufacturing company has signed an energy contract with an operator of a decentralized energy network. From the manufacturing company's point of view, this contract regulates the conditions under which the manufacturing company can consume energy from and provide energy to the decentralized energy network. An essential aspect of this contract will be the handling of energy peaks.

In addition to the contractual agreement between the manufacturing company and the operator of the decentralized energy network, there is a technical interface between these two parties to enable the synchronization of load management during the operation. This interface includes aspects such as measuring energy consumption, but also possibilities to control a prosumer by the operator of the decentralized energy network. Usually, the operator of the decentralized energy network specifies this interface. As part of this use case, the manufacturing company will upgrade the production system to implement this technical interface.

In this respect, this use case is an extension of the use case “Design for energy efficiency”, where in addition to optimizing the energy due to the volatility with respect to the orders of the manufacturing company, the volatility of the energy price will also be considered. This makes the underlying optimization problem more complex.

From the manufacturing company's point of view, this use case is not limited to a single location, but can be applied to multiple sites, as far as all sites participate in the same decentralized energy network.

6.5.3.3 Business context

Figure 54 illustrates the business roles involved in the use case “Design for participation in decentralized energy networks”.

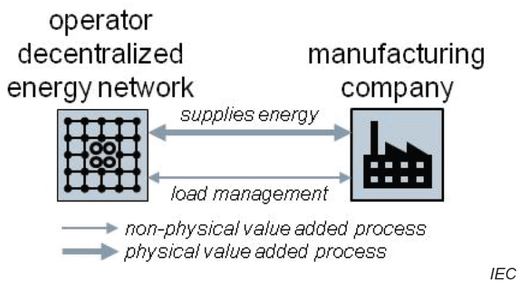

Figure 54 – Business context of "Design for participation in decentralized energy networks"

6.5.3.4 Technical perspective

Figure 55 illustrates the human and technical roles involved in the use case "Design for participation in decentralized energy networks".

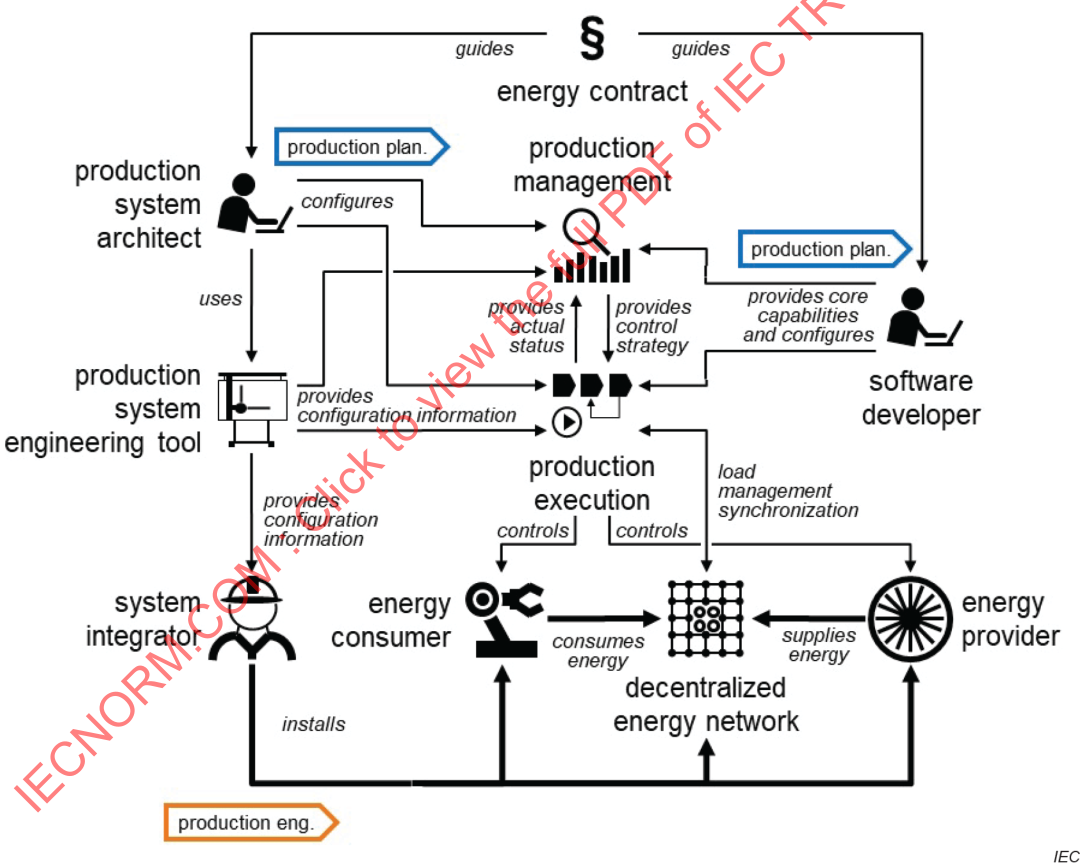

Figure 55 – Technical perspective of "Design for participation in decentralized energy networks"

6.5.3.5 Interaction of roles

Regarding the interaction of roles, this use case is structurally congruent with the use case "Design for energy efficiency". For this reason, only the supplements to the use case "Design for energy efficiency" are described here.

The production system architect and the software developer structure the production system logically in energy consumer and energy provider, which are then included in the load management synchronization. To do this, they design and implement concepts that the energy consumer and energy provider are operated in such a way that the overall business goals of the manufacturing company are optimized. Here, the required energy consumption for producing products is compared to the price that can be achieved by selling energy to the operator of the distributed energy network.

Regarding the underlying energy contract, the production system architect and software developer will typically come up with solutions where energy consumption peaks are avoided and energy is used at times when the energy price is low.

Regarding load management synchronization, the production system architect and the software developer will typically take precautions to ensure that a safe operation of the production system is guaranteed and that the satisfaction of the manufacturing company's customers is ensured.

6.5.3.6 Expected change and impact

In principle, the arguments for the use case “Design for energy efficiency” also apply to this use case. A design of a production system regarding participation in decentralized energy networks is already technically possible today, but to what extent this makes economic sense for a manufacturing company will depend on the availability of attractive energy contracts.

6.5.3.7 Recommendations for standardization

The driving force for the standards required for this use case will be primarily in the “Smart Grid Community”. These upcoming standards will be considered by manufacturing industries and adapted regarding specifics of business-to-business relations. Specifically, this includes:

- standardization of concepts and description of energy price;
- standardization of concepts of energy contracts;
- standardization of load management synchronization.

6.5.4 Participation in decentralized energy networks

6.5.4.1 Objective

A production coordinator wants to optimize the operation of the production system according to specific KPIs addressing the alignment of the own energy demand and/or supply with the energy prices offered to the market.

6.5.4.2 Overview

This use case is an extension of the use case "Optimization of energy", where in addition to optimizing the energy due to a volatility in the order situation, the volatility of the energy price also is considered with respect to an overall optimization. This makes the optimization task for production coordinators more complex, but the task itself does not change fundamentally.

For this reason, this use case only describes the differences to the use case “Optimization of energy”.

6.5.4.3 Business context

Figure 56 illustrates the business roles involved in the use case “Participation in decentralized energy networks”.

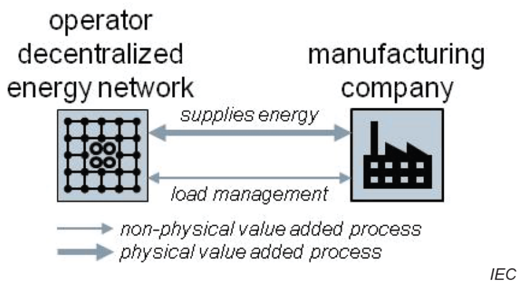

Figure 56 – Business context of "Participation in decentralized energy networks"

6.5.4.4 Technical perspective

Figure 57 illustrates the human and technical roles involved in the use case "Participation in decentralized energy networks".

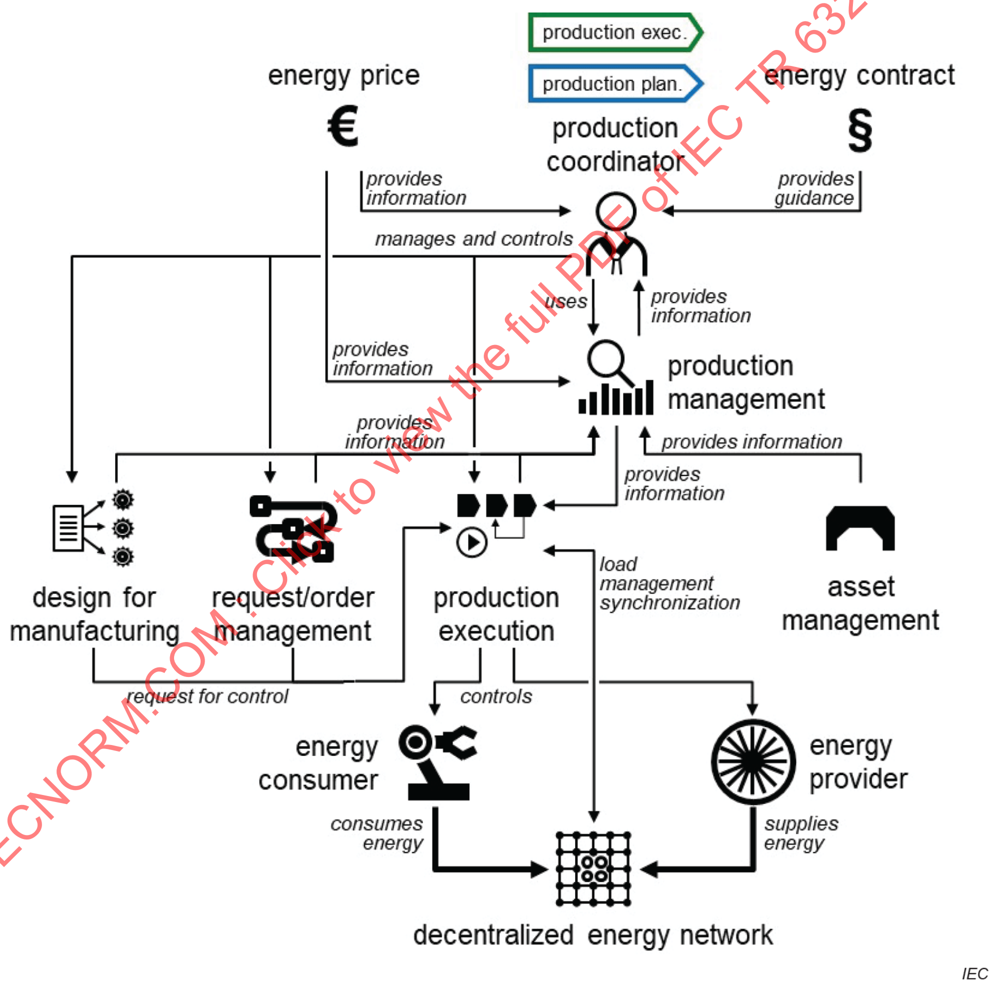

Figure 57 – Technical perspective of "Participation in decentralized energy networks"

6.5.4.5 Interaction of roles

In addition to the use case "Optimization of energy", the production coordinator takes the constraints of the energy contract into account and considers that the synchronization of load management can intervene in the control of the production system, which can require appropriate reactions.

6.5.4.6 Expected change and impact

See 6.5.2 Optimization of energy.

6.5.4.7 Recommendations for standardization

See 6.5.2 Optimization of energy and 6.5.3 Design for participation in decentralized energy networks.

6.6 Use case cluster “Design and engineering”

6.6.1 Seamless models

6.6.1.1 Objective

A manufacturing company has an interest in managing the increasing technical complexity of products and production systems to make balanced and secured decisions, to improve the workflows, and to reduce the total costs.

The manufacturing company has an interest in making the knowledge of key persons more transparent to secure business after retiring of the key persons.

6.6.1.2 Overview

The management of the increasing complexity from a technical point of view of products and production systems is a challenge. This includes a management of cross-references between information from different sources, which are semantically identical, in order to have overall consistent information. This applies both to information that represents an actual situation and to information that represents a predicted future situation.

Information structures are designed by different people. In the context of manufacturing industry, these are essentially the product developer and the production system architect. But there are also various disciplines involved within product design and production system design value added processes, all of which structure the information relevant to them from their perspective. This leads to redundancy and dependencies between the information. In addition, within a discipline, one considers the development of information over the time, for example, information about requirements, concepts, solutions and implementations, which results in dependencies between the information. In addition, superordinate restrictions are considered. This concerns information about externally delivered concepts (non-physical) or components (physical), which are integrated into the company's information structures. However, this also applies to the management of company-internal specifications, for example, the use of sample solutions or libraries.

However, the knowledge about the various cross-references between the information is very often in the minds of people today, especially the key people. One would like to make these cross-references more transparent and make this knowledge more accessible and actionable.

In order to manage the core interdependencies between these different information structures, the following aspects are formalized within an information structure – that is, a meta model needs to be described – and made accessible “externally”:

- relations between entities, for example, hierarchy or technological interactions;
- attributes of entities, for example, characteristics and properties;
- relationships between entities, relations and attributes.

Following the same principles, the interdependencies between different structures are formalized.

Following this procedure, in the case of changes in information due to the formalized meta-model hints on the impact of these changes are given. All in all, not all interdependencies need to be formalized. It is a design decision which relationships are formalized and which ones not.

It is assumed that the production coordinator, the operator production resource, the service and maintenance provider, and the purchaser will incorporate “their” information into these pre-designed structures, but do not conceptually design or extend them. The product developer or production system architect will be notified by them accordingly, see 6.3.3 Feedback loops.

6.6.1.3 Business context

Figure 58 illustrates the business roles involved in the use case “Seamless models”.

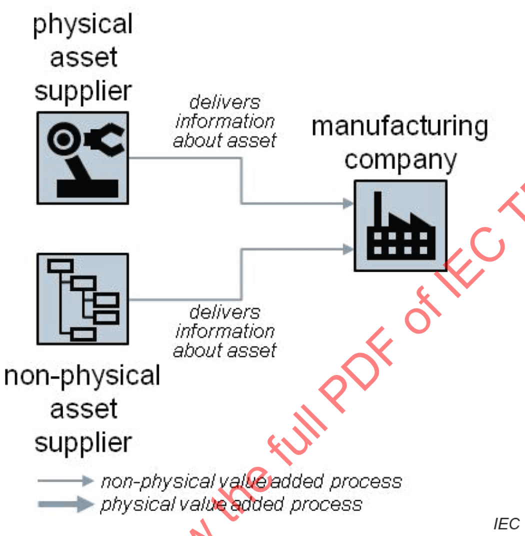

Figure 58 – Business context of “Seamless models”

6.6.1.4 Technical perspective

Figure 59 illustrates the human and technical roles involved in the use case “Seamless models”.

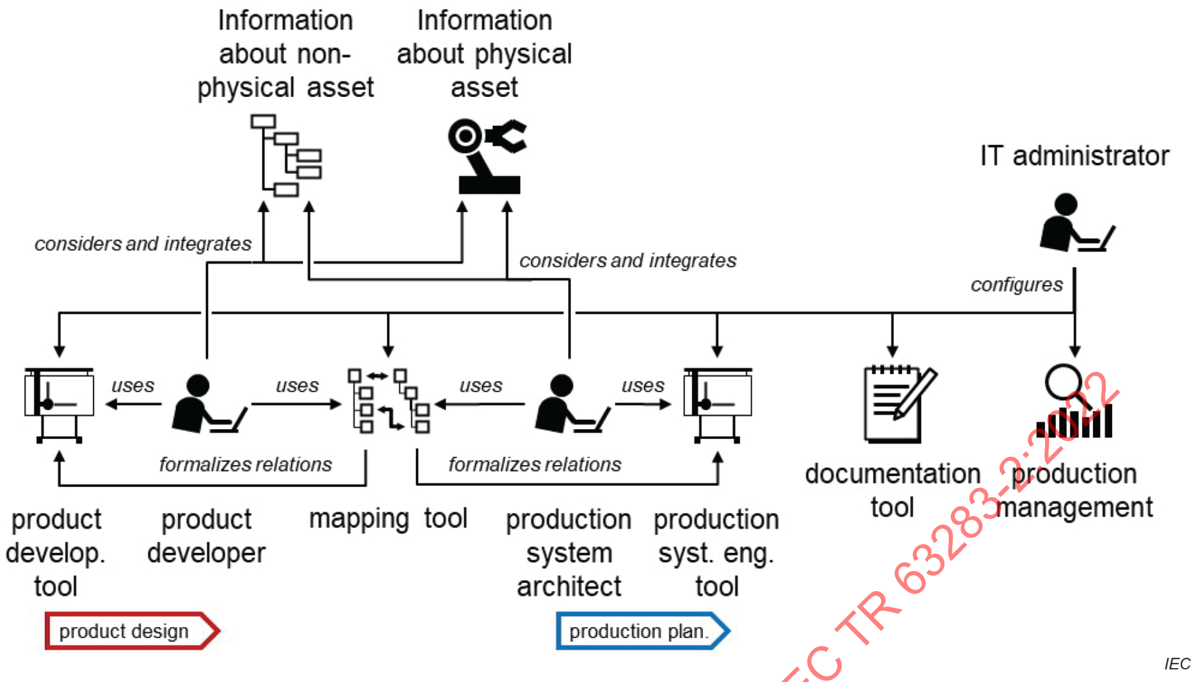

Figure 59 – Technical perspective of "Seamless models"

6.6.1.5 Interaction of roles

An overarching mapping tool within a manufacturing company that complies with a standard describes relationships and, thus, configures semantic interoperability within each engineering tool and between the different engineering tools.

The product developer uses the various tools in the following way:

- Information from external stakeholders, for examples engineering service providers, suppliers of raw materials and intermediates or customer requests, is suitably integrated in the meta model.
- Creative design decisions are documented in the product development tool – as far as possible – in a model, for example, via a relation that represents the relationship between a requirement and a chosen solution. This relation is then formalized in the meta model. This includes, for example, interdependencies resulting from the use of a sample solution or a template from a library. The product development tool provides appropriate capabilities to access the internal information model. In addition, the relationship between the product series and the production system is modeled in the meta model.
- Changes in the life cycle of the product series are also documented and can be referred to later, see 6.3.1 Administration of assets, and these life cycle-related relationships are also described in the meta model.
- The interdependencies are described not only with reference to the product series, but also with regard to the models of the later produced, delivered and then used physical products, including the constituents supplied and incorporated therein, and even – in coordination with the production system architect – the concrete production steps.

The production system architect uses the various tools in the following way:

- Information from external stakeholders, for examples engineering service providers, suppliers of production resources, components, auxiliaries, raw materials or intermediates, are suitably integrated in the meta model – in coordination with the product developer.

- Creative design decisions are documented in the production system engineering tool – as far as possible – in a model, for example, via a relation that represents the relationship between a requirement and a chosen solution. This relation is then formalized in the meta model. This includes, for example, interdependencies resulting from the use of a sample solution or a template from a library. The production system engineering tool provides appropriate capabilities to access the internal information model.
- Changes in the life cycle of the production system are also documented and can be referred to later, see 6.3.1 Administration of assets, and these life cycle-related relationships are also described in the meta model. And this also applies to the interdependencies that later result from maintenance, service or disposal.

The IT administrator integrates the mapping tool into the overall IT landscape of a manufacturing company, which comprises, for example, various documentation tools and the production management. This follows the same approach as described in the use case "Administration of assets". However, the content-related interdependencies are described by the product developer and production system architect.

6.6.1.6 Expected change and impact

The use case supposes a self-describing meta model for the relationships in information structures, which is created by a user – and not given by a tool. The engineering tools allow external access to their "internal" data models and publish changes in their internal data to the outside world. So far, information is stored in many independent data sources redundantly and knowledge about the relationships almost exclusively is in the minds of selected employees.

Consequently, the meta model can be evaluated universally to improve consistency of engineering data and can also be used to automate recurring, non-creative engineering activities to reduce engineering efforts.

6.6.1.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- Standardized and self-descriptive and thus universally evaluable meta models.
- Standardization of internal information models of engineering tools, for example, how design decisions are documented within a tool or how changes in internal data are published externally.

As a preliminary stage and intermediate step, general system models can be standardized. These standardized system models serve as a core for a common understanding and thus allow a simplified mapping, so that mapping does not need to start again and again on the "bits and bytes" level. This requires an agreement and description of the underlying core concepts. Such core models already exist in some areas, for example, properties and characteristics, see [8]. Other core models still should be developed and standardized, for example, life cycle or device.

6.6.2 Simulation in design and engineering

6.6.2.1 Objective

A product developer wants to simulate a model of the designed product to reduce risks resulting from product design and/or to speed-up the product design.

A production system architect wants to simulate a model of the designed production system to reduce risks resulting from production system engineering and/or to speed-up production system engineering.

6.6.2.2 Overview

It is not the purpose of this use case to explain the broad field of simulation in its details, but – without pretension to any completeness – to explain some important issues. This use case is supplemented by the use cases “Virtual commissioning of production systems” and “Simulation in operation”.

Simulation is a process of using computer-based modeling of a system to understand its behavior and predict the effect of changes. It is a powerful method for analyzing, designing, and operating complex systems, a cost-effective way of exploring new systems (as well designs as processes) without having to resort to expensive pilot programs or physical prototypes. Simulation can provide a high level of understanding of the system achievable.

Simulation has been used for a long time and is, therefore, not new at all. However, the application of simulation is always a trade-off between effort and benefits. There is an effort made in advance to create benefits on effects that can arise later, for example, a risk reduction or time or effort savings to eliminate design errors.

There are different goals and purposes to use simulation. In each case, a target-oriented, executable and purpose-based model is needed. Thus, there is not a single “model” that can be used for a every simulation. Basically, the following sorts of simulation can be distinguished:

- Steady-state simulation provide details of a system under a specific set of conditions. Simulation models can be run multiple times to develop cases for different operating ranges. Steady-state simulation can be applied in design and engineering for testing capabilities of a system and performing “what-if analysis” for system configuration and evaluation of new equipment and providing a base to aid in system improvements, de-bottlenecking, troubleshooting, and performance monitoring.
- Dynamic simulation predicts how system variables change with time when moving from one state condition to another and these values of variables are tracked over a transition period. Dynamic simulation can be applied in design and engineering for providing controllability analysis to design an easy to control system, testing control systems prior to implementation and planning startup procedure and enabling the operations staff to gain a better understanding of their operations through simulated training exercises, see also 6.6.3 Virtual commissioning of production systems and 6.6.5 Immersive training of production system personnel.

Typically, the creation of models is expensive. Therefore, one considers whether to reuse existing, for example generic models, instead of creating new models for each own purpose. But this is always trade-off between objectives, efforts and benefits. Typically, in the early stages of design and engineering, there are used quite abstract models – technical details are still not yet known – and theses models a successively refined during design and engineering.

It is purposeful, especially with regard to the use case “Virtual commissioning of production systems”, to conceptually separate, in particular for production systems, early in design and engineering between the model of the technological process, which is later replaced by a corresponding technical system, for example, production resources, and the control of the technological process, which is later typically implemented by a process control system.

To model such a technological process, the intended physical process is represented by means of a reproducible, mathematical form. Typically, this is based on configuration of prebuilt entities in a sequential modular flow sheeting environment and modeling is done in terms of equations through an equation-oriented package. To achieve high fidelity simulation environments comprehensive physical and thermodynamic property databases are used.

It is possible to abort a simulation at a certain point in time, to save the current state and to reinitialize it at a later point. Also, it is possible to overwrite the simulation model input and output signals in order to test faulty states. A simulation run can be accelerated or decelerated in relation to real time. In this way, for example, intermediate states that are irrelevant for the test can be accelerated.

6.6.2.3 Business context

Figure 60 illustrates the business roles involved in the use case "Simulation in design and engineering".

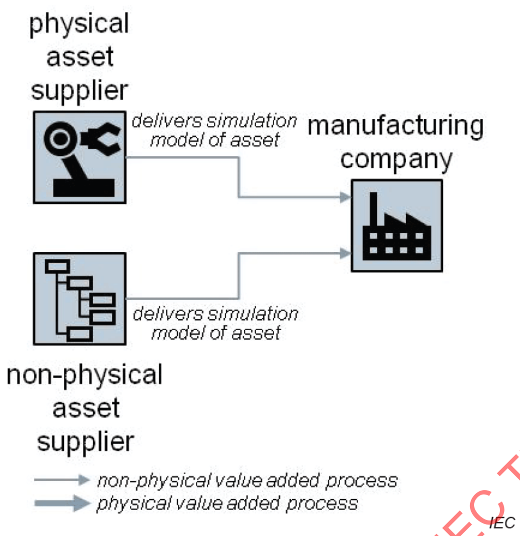

Figure 60 – Business context of "Simulation in design and engineering"

6.6.2.4 Technical perspective

Figure 61 illustrates the human and technical roles involved in the use case "Simulation in design and engineering".

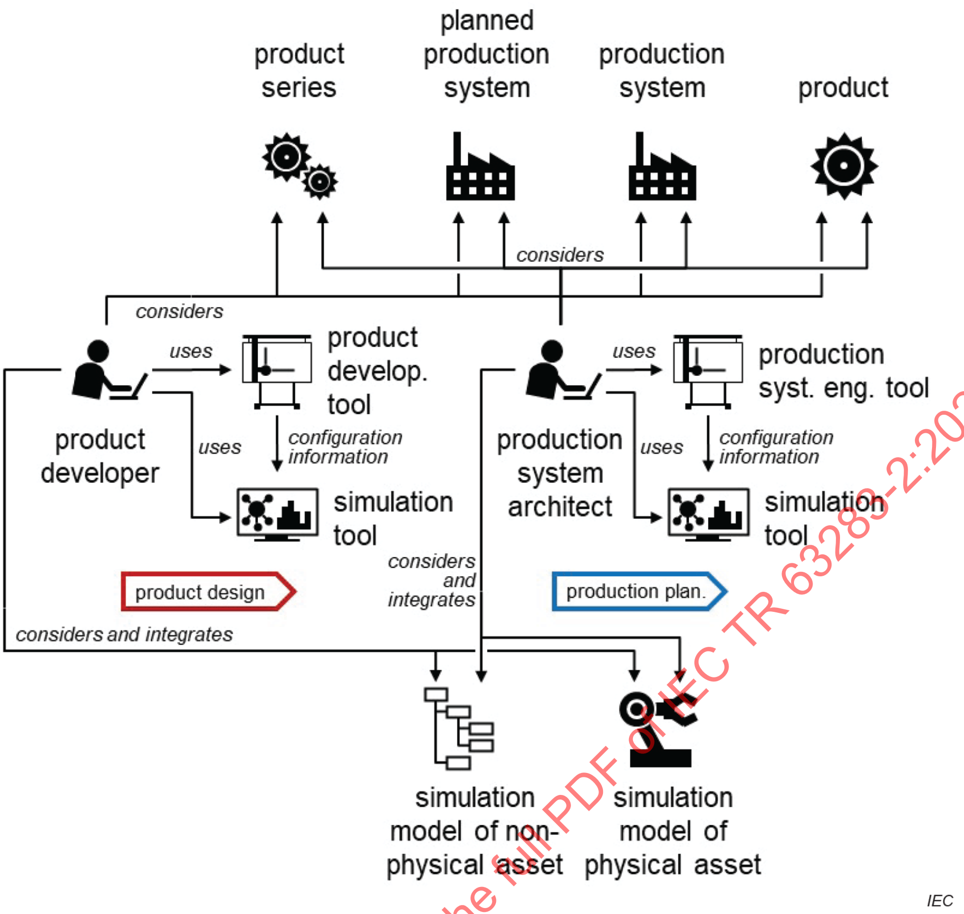

Figure 61 – Technical perspective of "Simulation in design and engineering"

6.6.2.5 Interaction of roles

The product developer considers the results of the design activities and designs in a creative step which properties of the design artifact are secured by a simulation. The product developer uses a product development tool to execute the development activities.

The product developer considers the available simulation models regarding the specific problem and integrates these models into a simulation tool. The product developer adds further models that are needed to perform the intended simulation. These further models are developed by the product developer.

The product developer uses the product development tool to generate an overall configuration of the simulation – as far as the product development tool offers such capabilities – in order to minimize the effort required to create the simulation.

After these preparations, the product developer carries out the actual simulation runs and interprets the result of the simulation runs regarding whether the design artifact solves the problem. The product developer will then decide, for example, to make changes to the design artifact, or to change the problem or to change the simulation model.

The production system architect works in the same way as the product developer using the production system engineering and simulation tool.

6.6.2.6 Expected change and impact

In principle, simulation is already used nowadays in design and engineering. Simulation is in a field of “tension” between the capabilities of available simulation tools, the skills of the human actors in using of simulation, the effort to create an adequate simulation model, the quality or reliability of the used models, the costs for the required computing capabilities on one side, and on the other side the benefits provided by a simulation. Here, the development of technologies, tools and models can result in a “tipping point”, where suddenly in a concrete application area a simulation can be created and carried out economically. In addition, models are increasingly being supplied in a standardized manner, which, on the one hand, reduces the cost of model building from the user's point of view and, on the other hand, improves the quality of the models used. In addition, the available models are increasingly better aligned and can, therefore, be reused more easily. This helps gaining benefits from simulation easier.

Consequently, the use case will result in an improvement of design and engineering by securing design decisions at an early stage.

6.6.2.7 Recommendations for standardization

Standardized models: This concerns the structure with respect to interconnect models, the generation of the entire simulation model from the individual sub models (here is distinguished between rather loosely coupled black-box sub models and rather strongly coupled white-box sub models), the description of the content of sub models (particularly important in the case of white-box sub models) and the requirements for a runtime environment to execute the individual sub models (particularly important in the case of black-box sub models).

Standardization of specific purposes of models (for example, 3-dimensional models) and, based on this, standardization of certain abstraction levels of modeling, so that corresponding models can also be provided by suppliers of assets. However, this is a complex field of “tension” because the purposes can be very different, and some simulation tool provider offer for specific purposes solutions with corresponding unique selling points on the market.

6.6.3 Virtual commissioning of production systems

6.6.3.1 Objective

A production system architect wants to validate process control software early to reduce risks in and time needed for commissioning.

A manufacturing company wants to train operators of the production systems to early improve the ramp up of a production system from handover to operational mode.

6.6.3.2 Overview

This use case is a special case of the use case “Simulation in design and engineering” with focus on the later engineering phases and the commissioning of the production system. In contrast to the use case “Simulation in design and engineering”, however, here the simulation does not exclusively use entities of the virtual world but in combination with already existing physical parts of the production system. The physical process control system of the production system is coupled with a simulation in a factory acceptance test prior to a site acceptance test.

One of the challenges of creating process control software is that it can only be tested after complete installation of mechanical and electrical engineering and the process control system. Today, this results that many errors in the process control software are only found on the construction site and debugging is executed under massive time pressure. In order to be able to test the process control software earlier, the process control system is built up physically, but not coupled with the not yet physically existing technological process, but with a dynamic simulation simulating the technological process. The main purpose is to ensure that actual control system software will operate properly.

The minimal setup for the simulation is the connection to the control system on an input/output level and reacting on outputs of the process control system and providing input to the process control system. However, this also means that the technological process in terms of its behavior in real time is adequately represented by the simulation model.

The use of a simulated process also offers advantages in terms of safety. In case the automation system fails, no damage can occur to persons, the environment, the production system or the produced product. Conversely, simulating the technological process offers the possibility to determine the damage resulting from a failure of the automation system without hazard. It is also possible to set the simulation to a defined initial state and a sequence in which a fault has been identified and corrected can be simulated again.

Such a setup can then gradually evolve with the construction of the physical production system, so that successively parts of the simulation of the technological process are replaced by the real physical system that realizes the technological process.

Another application area of this setup is the use for training the operator of the production system. The operators are trained, especially regarding the handling of emergencies and disturbances, see use case “Immersive training of production system personnel”.

Models used in early engineering phases often form basis for models of the control system validation and training simulation. For more information about virtual commissioning see for example [9].

Data quality from other simulation models or data sources that provide an input have direct implication to the output and trust of the simulation model. The ISO 8000 series Data Quality addresses this aspect in more detail, see [10].

6.6.3.3 Business context

Figure 62 illustrates the business roles involved in the use case “Virtual commissioning of production systems”.

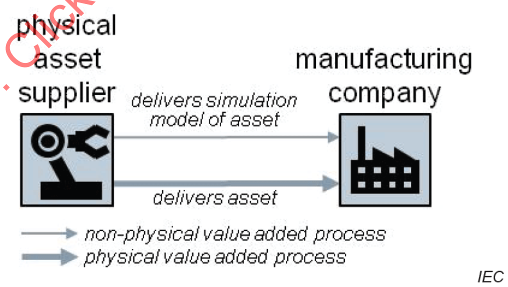

Figure 62 – Business context of “Virtual commissioning of production systems”

6.6.3.4 Technical perspective

Figure 63 illustrates the human and technical roles involved in the use case “Virtual commissioning of production systems”.

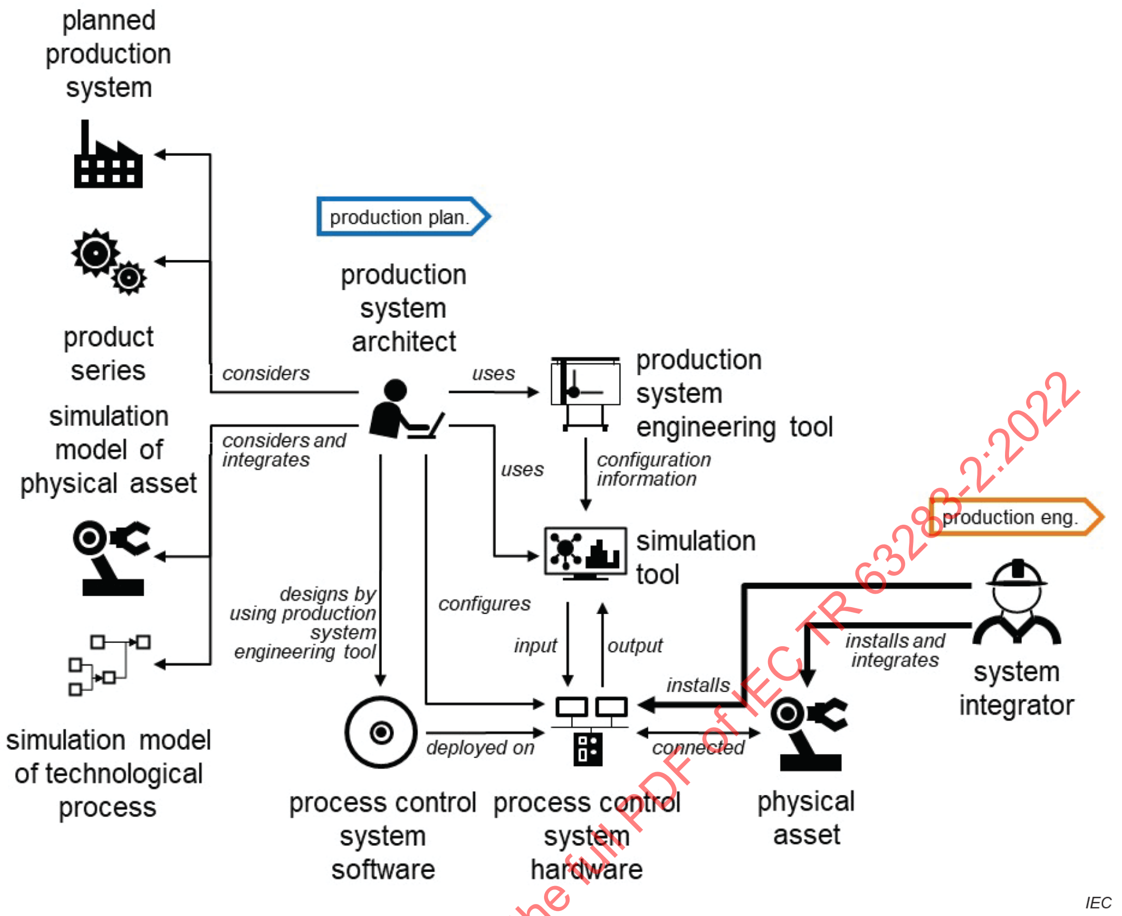

Figure 63 – Technical perspective of "Virtual commissioning of production systems"

6.6.3.5 Interaction of roles

The production system architect designs process control software: For this purpose, the production system architect considers the product series and the planned production system with respect to the requirements. For doing this the production system architect uses the production system engineering tool.

The production system architect considers available simulation models: The production system architect considers available simulation models of physical assets and technological processes with respect to the purpose of validation of the process control software and integrates these models into the simulation tool. The production system architect adds further models that are needed to perform the intended simulation. These models are developed by the production system architect.

The production system architect configures the process control system and system integrator installs the process control system according to this configuration.

The production system architect configures the interface between simulation tool and process control system and system integrator installs the interface according to this configuration.

The production system architect uses the production system engineering tool to generate an overall configuration of the simulation – as far as the production system engineering tool offers such capabilities – in order to minimize the effort required to create the simulation and manually extends the result by further required information.

Having these preparations completed the production system architect can validate the process control software.

Subsequently, the system integrator builds up the production system successively, and the production system architect replaces the corresponding simulation models with the parts of the production system that are already physically erected. The production system architect uses the production system engineering tool for these activities.

6.6.3.6 Expected change and impact

In principle, the arguments for the use case “Simulation in design and engineering” also apply to this use case. In addition, the use case supposes that today's asset-specific models are subject to more uniformity and can therefore be easily interconnected for simulation.

6.6.3.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- Standardization of simulation models for production resources, specifically for the purpose of validating process control software.
- Standardization of the input/output interface between a simulation and a process control system.

There are further stages conceivable that a process control system is not physically built, but only runs virtually on a generic computing infrastructure. This requires a standardization of process control systems regarding their structure and runtime capabilities.

6.6.4 Optimization in design and engineering through machine learning

6.6.4.1 Objective

A product developer and/or a production system architect want to be supported in the execution of non-creative activities.

A manufacturing company has an interest in making the knowledge of key persons more transparent to secure business after retiring of the key persons.

6.6.4.2 Overview

The product developer and/or production system architect execute creative activities during design and engineering and evaluate the outcome of their work to determine the extent to which their creative design decision will serve their intended purpose. They revise their decision and make a new decision. Over time, patterns of goal-oriented and less-targeted solutions will be created, and these labeled solutions are collected in the context of this use case. This collection is used to generate “suitable” suggestions to the product developer and/or production system architect to support the decision making.

This use case is quite generic and postulates that machine learning methods are used to create a suitable model for generating suggestions for design decisions. In practice, there are already various, sometimes quite specific, applications implemented. Overall, there is currently a dynamic environment in which such approaches are evolving technologically.

The use case is conceptually identical to the use case “Optimization of operation through machine learning”, except that the application here is in the value added processes of design and engineering. The use case “Self-optimization of production resources” is also comparable, but in this use case it is assumed that the collection of the training data for machine learning and the training of the model is driven by the same company and therefore the contractual agreement regarding usage of data is easier to design.

The application of machine learning is an extension of software engineering life cycle regarding verification and validation as well as change control regarding the manufacturing environment. Both require traceability of all entities such as reference input training data sets, data ingestion to digital workflows, algorithms creating models and any output in form of digital decision workflows, whether safety critical or not.

6.6.4.3 Business context

Figure 64 illustrates the business roles involved in the use case "Optimization in design and engineering through machine learning".

Figure 64 – Business context of "Optimization in design and engineering through machine learning"

6.6.4.4 Technical perspective

Figure 65 illustrates the human and technical roles involved in the use case "Optimization in design and engineering through machine learning".

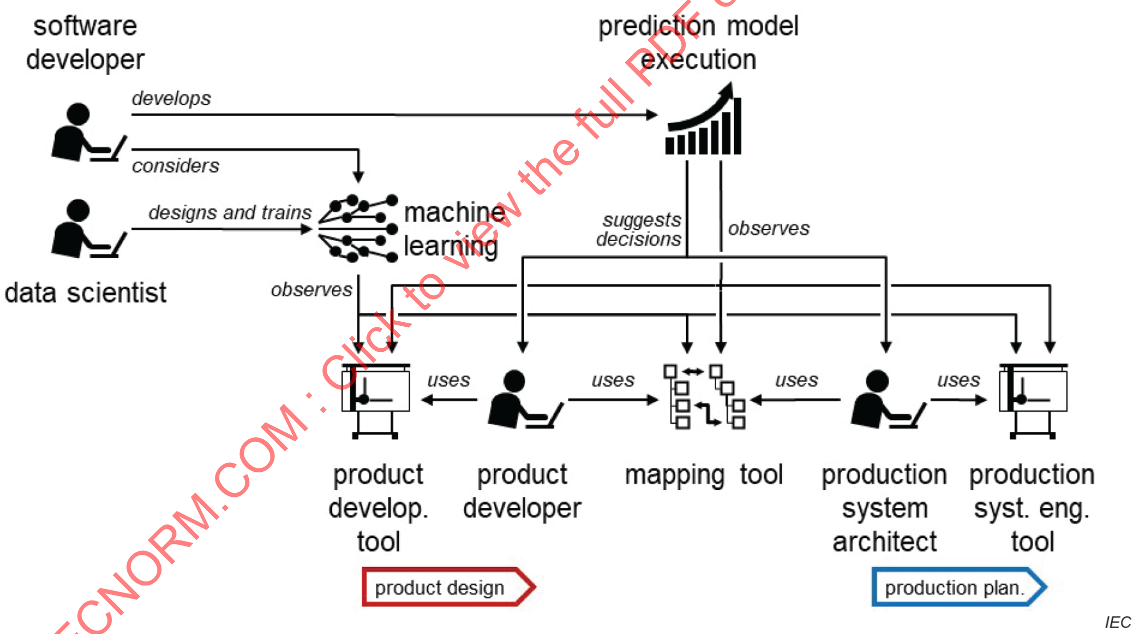

Figure 65 – Technical perspective of "Optimization in design and engineering through machine learning"

6.6.4.5 Interaction of roles

The data scientist develops and trains a prediction model: Using data mining and machine learning methods, the data scientist prepares and trains a prediction model on the basis of initially available data until a maturity of the prediction model is achieved, that the prediction model can be used for an optimization of design and engineering value added processes.

The software developer develops a prediction model execution and integrates it: The software developer uses the prediction model provided by the data scientist and integrates an execution of this prediction model in the context of an engineering tool landscape of a manufacturing company, especially consisting of a product development tool, a production system engineering tool and a mapping tool. An IT administrator can be involved, but this is not illustrated in the graphical representation of the technical perspective.

The prediction model is executed while the engineering tools are used along the entire life cycle of the product series and production system: The execution of the prediction model performs the following tasks:

- suggestions of design decisions to the product developer and/or the production system architect;
- collection of data about the usage of the engineering tools by the product developer and/or the production system architect.

The data scientist optimizes the prediction model: Based on the data provided from the usage of the engineering tools by the product developer and/or the production system architect and the reaction of the prediction model execution, the data scientist optimizes the prediction model. At some point in time, the data scientist provides the software developer an update of the prediction model from which the software developer, in turn, generates an update of the prediction model execution.

The software developer provides an update of the prediction model execution: The integration of such an update is feedback-free, without affecting the work of the users of the engineering tools.

6.6.4.6 Expected change and impact

The use case supposes the application of machine learning, which in today’s practice is not widely used. However, the challenge is that the data available for learning is representative and that meaningful and actionable suggestions are generated for the product developer and/or the production system architect.

The value proposition behind this use case is the reduction of the effort for the prediction model design and especially the prediction model maintenance along the entire life cycle of the product series respective production system.

6.6.4.7 Recommendations for standardization

The workflows and mechanisms related to machine learning should be standardized. This concerns the initial modeling, the generation of a prediction model execution from a model as well as the incremental improvement of a created prediction model. Nevertheless, the subject is currently evolving in a dynamic environment.

6.6.5 Immersive training of production system personnel

6.6.5.1 Objective

A manufacturing company wants to train production system operators and service and maintenance providers before or while the production system is constructed so that dangerous and complex training scenarios can be executed in a virtual and therefore safe environment.

6.6.5.2 Overview

In this use case virtual reality is a simulated experience that is like the real world. Currently standard virtual reality systems use either virtual reality headsets or multi-projected environments to generate especially realistic images that simulate a user's physical presence in a virtual environment. A person using virtual reality equipment can move around in the artificial world and interact with virtual features or items.

This technology is available in principle, but the effort required to use the technology to train production system operators or service and maintenance providers is often still too high from an economic point of view. This affects decreasingly the physical equipment required, but more the project-specific engineering effort to configure a virtual reality environment.

The essential levers to reduce this engineering effort have already been explained in the use cases “Seamless models” and “Simulation in design and engineering”. Nevertheless, the main challenges of this use case can be summarized as follows:

- Reduction of the effort to create suitable models: On the one hand, this concerns the virtual reality model of a production system for existing virtual reality platforms. On the other hand, this concerns the simulation model of the production system, see also use case “Simulation in design and engineering”.
- Reduction of the effort to integrate and combine different models: This concerns the virtual reality model and the simulation model as well as the virtual reality model and engineering data of the production system.
- Creation of a simulation model of the production system, which is accurate enough for training purposes, for example by using co-simulation to simulate critical production system resources.
- Reduction of the effort for creating training scenarios including the authoring methods to provide the appropriate data for a training scenario.
- Development of suitable methods for virtual collaboration in the area of training production system operators or service and maintenance providers.

It can be observed in the market that this technology is increasingly being used in practice, especially in the context of large investments, for example, the engineering and erection of large production systems.

6.6.5.3 Business context

Figure 66 illustrates the business roles involved in the use case “Immersive training of production system personnel”.

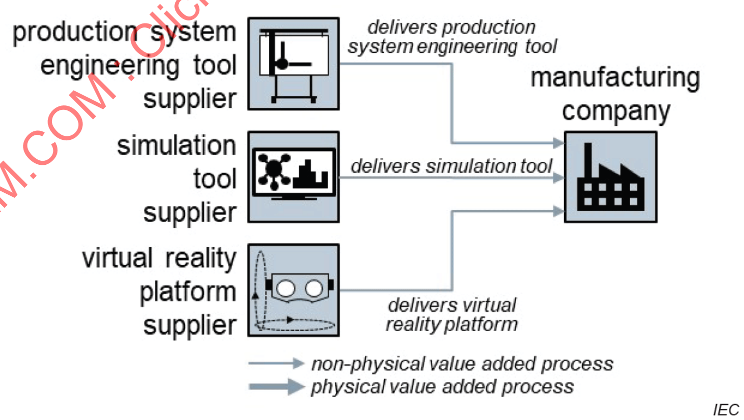

Figure 66 – Business context of “Immersive training of production system personnel”

6.6.5.4 Technical perspective

Figure 67 illustrates the human and technical roles involved in the use case “Immersive training of production system personnel”.

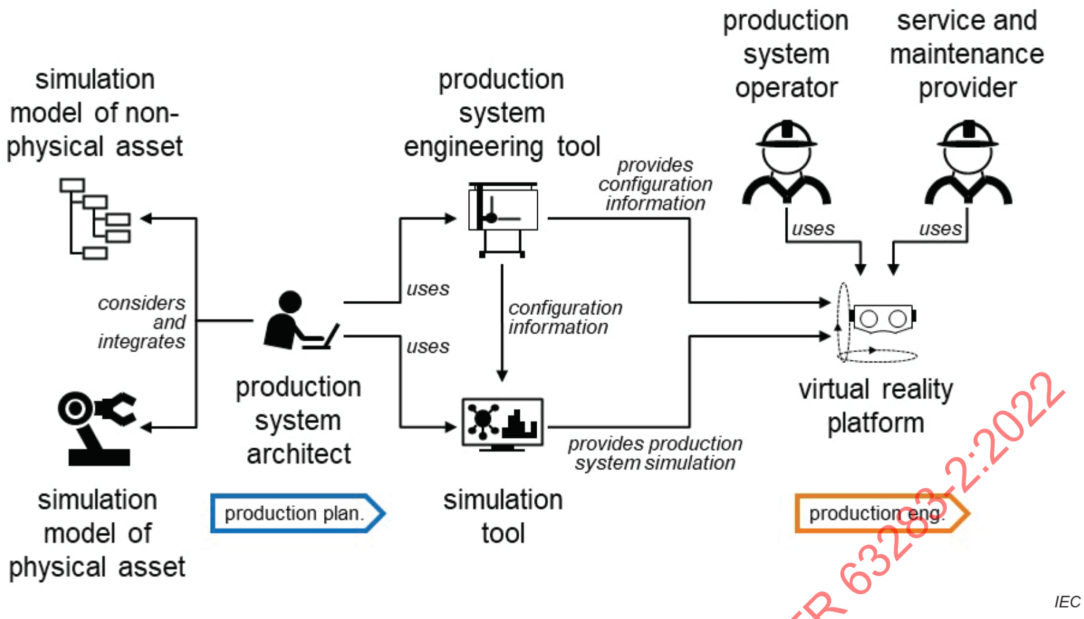

Figure 67 – Technical perspective of "Immersive training of production system personnel"

6.6.5.5 Interaction of roles

The production system architect considers the available simulation models to be used for an immersive training of the production system personnel, for example, simulation models of production resources provided by the production resource supplier, and integrates these models into simulation tools. The production system architect adds further models that are needed to perform the intended simulation. These further models are developed and integrated by the production system architect, see also 6.6.2 Simulation in design and engineering. In many cases a production system simulation is already available from the virtual commissioning of the production system and can be reused, see 6.6.3 Virtual commissioning of production systems.

The production system architect uses the production system engineering tool and selects appropriate engineering data of the production system, for example, the process and instrumentation diagram, to create an overall configuration of a simulation of the production system behavior – as far as the production system engineering tool offers such capabilities – in order to minimize the effort required to create the simulation.

After these preparations, the production system architect initiates the configuration of the virtual reality platform based on engineering information of the production system and the specific simulation model. Especially a 3D model of the production system can be used to create a virtual reality model of the production system. The production system architect combines the virtual reality model and simulation model to get an immersive training environment especially for production system operators. The production system architect combines the virtual reality model and other engineering data of the production system to provide service and maintenance providers information on the various equipment of the production system.

The production system architect also provides appropriate training scenarios specific to the production system operator and service and maintenance provider respectively. On this basis, production system operators can use the virtual reality platform to be trained how to start up, operate and shut down the production system. In addition, service and maintenance providers can use the virtual reality platform to be trained how to execute maintenance operations on production system equipment.

6.6.5.6 Expected change and impact

See use cases "Seamless models" and "Simulation in design and engineering".

6.6.5.7 Recommendations for standardization

See use cases "Seamless models" and "Simulation in design and engineering".

Methods, best practices, recommendations, and guidelines how to use virtual reality for the training of production system operators and service and maintenance providers.

6.6.6 Co-creation in design

6.6.6.1 Objective

A manufacturing company wants to offer products that meet customer and market expectations, i.e. designing the right product, and wants to increase productivity and reflect the value of customers in the design process, i.e. designing the product right.

The manufacturing company wants to involve suitable competencies, to use appropriate components, and to apply best technologies in the overall design process; in addition, sometimes a manufacturing company wants to integrate non-business stakeholders in the overall design process, for example a community, to achieve a requirement converge to a realizable design of product more effectively.

6.6.6.2 Overview

Co-creation is a management initiative bringing together different parties to jointly develop a mutually valued outcome. From a manufacturing companies perspective co-creation brings blend of ideas from customers and other external stakeholders which gives many new ideas to the organization. Co-created value typically arises in form of personalized, unique experiences for the customer. As a result, a manufacturing company can improve its customer loyalty with the potential for ongoing revenue. This also results in learning for the manufacturing company regarding the optimization of existing products and the development and market launch of new products.

The focus of this use case is on the early phases of the design process, both for the product and for the production system. The use case is complementary to the use cases "Manufacturing of individualized products" and "Outsourcing of production", which focus on the manufacturing of a developed product.

Regarding the application of co-design, a manufacturing company needs to balance the following possible conflicting interests:

- joint creation of value and aligned shared objectives;
- reliable elicitation of customer or market requirements;
- taking achievable requirements as the core of co-creation rather than the design department within the enterprise;
- keeping the design of the product and all related information under control;
- involvement of suitable competencies, usage of appropriate components, application of best technologies, and controlling of schedule, quality, and cost;
- satisfying laws, regulations, rules, and specifications related to the co-designed products.

To be able to use co-design, a manufacturing company needs the following capabilities:

- clear understanding of the own core competencies focused not only on technology, but also on domain know-how and market and business understanding;
- ability to assess the potential and impact of new methods, for example, hackathons, for the creation of ideas and elicitation of customer requirements;
- ability to assess an appropriate degree of openness and the required features of a collaboration platform to attract and integrate the best suitable external stakeholders;

- flexible use of services delivered by novel business stakeholder, for example marketplaces, distinguished specialists, or freelancer;
- ability to maintain stable communication between external stakeholders and customers and compatibility with the interfaces, protocols, or other basic requirements to support the product and production system architecture;
- modular functions or models that can be invoked by stakeholders Including systematic simulation and verification capabilities;
- ability to access the production capabilities of the manufacturing company.

Depending on a concrete application there is a high investment for the installation and operation of a suitable collaboration platform.

Overall, this use case addresses less technical challenges because there are no major barriers from a technical point of view, but rather the challenges in terms of strategy and the design and management of the design processes. In addition, cultural differences are also considered in co-design as well as changes in the customs and expectations of future generations.

6.6.6.3 Business context

Figure 68 illustrates the business roles involved in the use case “Co-creation in design”.

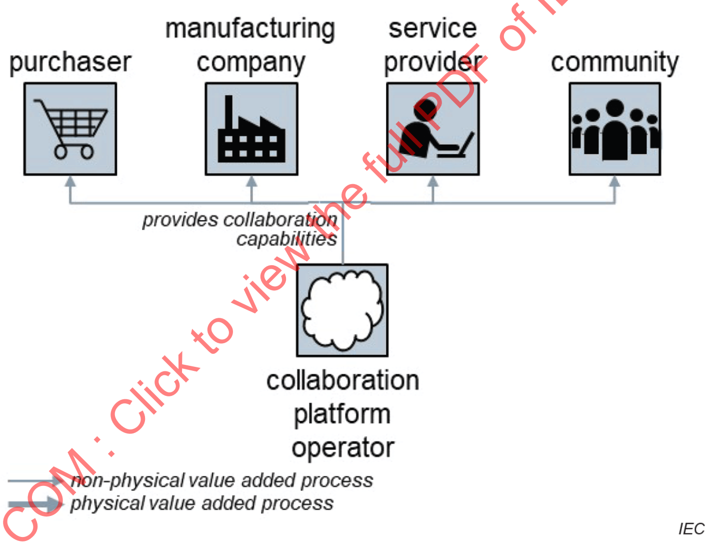

Figure 68 – Business context of “Co-creation in design”

6.6.6.4 Technical perspective

Figure 69 illustrates the human and technical roles involved in the use case “Co-creation in design”.

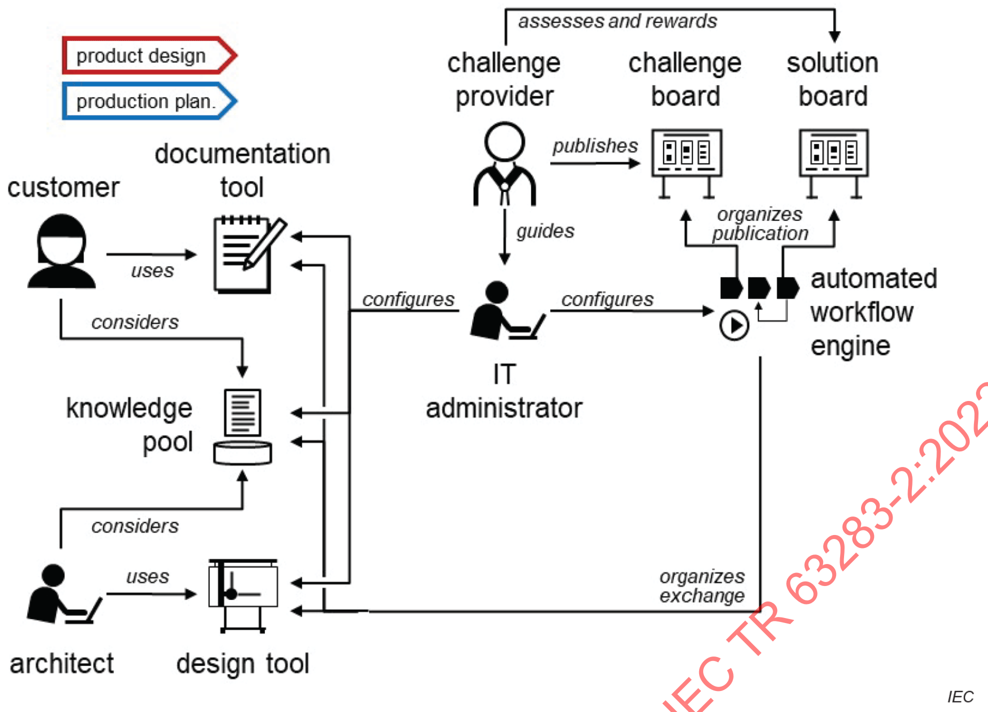

Figure 69 – Technical perspective of "Co-creation in design"

6.6.6.5 Interaction of roles

From a technical point of view this use case is based on the operation of a collaboration platform. The collaboration platform is an IT infrastructure that enables employees from different companies to work together by sharing information in a well-defined way in the form of knowledge pools and by processing information using tools. The collaboration platform provides capabilities to create and structure information content, to configure the processes of sharing and exchange of information, and to manage and control the overall processes via an automated workflow engine. Typically, the individual employee who works with the collaboration platform is very free to design the own way of working. The employee also has the greatest possible control over which of the own information is made accessible to which employee in which form and how and when this information is made available.

A challenge provider publishes a problem to be solved in the form of a challenge.

- This challenge is published on a challenge board. In addition to the challenge, the rules associated with solving the challenge are defined, such as the success criteria for the acceptance of a solution and the rules regarding a reward for solving a challenge. However, the challenge provider also specifies which employee who works with the collaboration platform can see which challenge and proposed solutions and can also specify an overall procedure to be followed when solving the challenge. The possibilities for designing such a set of rules to solve a challenge are very diverse and the challenge provider needs to give conscious thought to the design of this set of rules.
- There are two different types of challenges. On the one hand, a challenge provider can formulate business challenges about market needs, such as how to increase the market acceptance of a product or asking for ideas for new product features. Typically, such challenges are formulated by a product manager. On the other hand, a challenge provider can also formulate a technical challenge for which a technical solution is requested. Such challenges are often formulated by a product developer, software developer, production system architect, cyber security architect, production coordinator or cyber security coordinator.
- If proposals for solutions for the formulated challenge have been published via the solution board, the challenge provider will evaluate the proposals and reward the employee, who proposed the solution, accordingly.

The formulated challenges are perceived by a community in the form of employees who work with the collaboration platform. These challenges are taken up on their own initiative.

- This community can be divided into two groups. On the one hand, there are employees who act in the role of a customer and are therefore able to formulate a challenge or requirement more precisely. Sometimes, it is necessary to judge whether the challenge or requirement can be achieved. On the other hand, there are employees acting in the role of architects who formulate concrete solutions for challenges or requirements.
- The community can use a knowledge pool that is made available by the collaboration platform. The employees work with suitable tools that also are made available by the collaboration platform. Employees in the role of customers typically use documentation tools, while employees in the role of architects typically use design tools.
- The members of the community are free to use the provided knowledge pool and tools. They can also decide on their own to whom and in what form they will provide the information they have elaborated. After all, they decide when and in what form they publish a solution on the solution board.

The IT administrator is responsible for the configuration of the collaboration platform. This includes the administration of basic access rights, the administration of basic structures such as the knowledge pool structuring, the administration of usage rights with regard to the tools provided by the collaboration platform, and the configuration of the basic processes, but also the implementation of the rules defined by the challenge provider with the means made available by the collaboration platform.

6.6.6.6 Expected change and impact

This use case supposes that external stakeholders are involved in the early phases of the design processes. The possibilities and areas of application are very diverse, and the general principle of the use case is often already being implemented, while rarely to the full extent as described in the use case.

From an overall perspective an incremental further penetration of this use case is to be expected, which will also be strongly influenced by the individual customer segments. Those companies that specifically implement this use case will have a competitive advantage by improving their innovative strength.

6.6.6.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- Standardized description of requirements, concepts, and solutions used as basis for collaboration in the early phases of the design process between various stakeholders from different legal entities
- Standardized structure of and tagging entities in libraries and knowledge pools of requirements, concepts, and solutions
- Standardization of usage conditions and usage rights for information and especially models
- Best practices for collaboration in the early phases of the design process with external stakeholder

6.7 Use case cluster “Product and production services”

6.7.1 Value-based services for production resources

6.7.1.1 Objective

A value-based service provider offers value-based services to a manufacturing company to improve the usage of a production resource.

The manufacturing company wants to optimize the usage of the production resources and decides to which extend taking advantage of offerings of value-based services for the optimization.

6.7.1.2 Overview

This use case generally describes the underlying mechanisms for offering value-based services, but not the specific content offered as a value-based service. The use cases “Update and functional scalability of production resources”, “Condition monitoring of production resources”, “Self-optimization of production resources”, “Benchmarking of production resources” and “Production resource as-a-service” are special cases that all follow the mechanisms of this use case, but describe different value-based services in terms of the specific content.

This use case is characterized by the fact that it can be implemented differently from a business perspective, see some examples described in [11]. It is important to note that in a specific business implementation, several business roles can be implemented by the same company, for example both the offering of the production resource and the offering of the value-based service. An analysis of such examples, which are today already observable on the market, shows that this results in business model innovations in accordance with the definition of the St. Gallen business model navigator, see [12]. But the consideration of the business perspective is out-of-scope of this document.

Often, the production resource supplier is the driver for this use case. On the one hand, the production resource supplier usually has the best understanding of the capabilities of the own production resources. The production resource supplier incorporates suitable competence for the provision of value-based services, for example, from the field of data analytics. On the other hand, the production resource supplier wants to retain the access to the own customers and, therefore, avoid third-party vendors offering value-based services for the own production resources. In addition, the market for new production resources is declining and therefore the production resource supplier tries to generate new sources of revenue from services for the installed base.

From the point of view of a production resource supplier it is important to define a suitable market segmentation. Not necessarily each of the customers will be interested in such value-based services, because information is exchanged for the benefits of such services, which is worth for a customer to be not divulged but protected.

Also important is the strategic positioning of the production resource supplier regarding the role of the computing and connectivity infrastructure operator (“IIoT-platform”). The infrastructure can either be operated by the production resource supplier, which was often the case in the past, or by an independent operator – especially here currently a great momentum in the market can be observed – but also a manufacturing company – in particular If this is a large company – can force the production resource supplier to implement the value-based service in the manufacturing company's infrastructure.

Typical examples of value-based services include providing remote access to a production resource, offering a mobile operation capability of a production resource, providing diagnostic capabilities, including ordering spare parts, offering and selling technology parameters for the production resource for the purpose of optimizing the use of the production resource, optimizing the placement of tools in a tool magazine or condition monitoring as described in the use case “Condition monitoring of production resources”.

For these use case, the production resource supplier, the supplier of value-based and the manufacturing company agree in advance in terms of data access and data usage based on a legal contract.

6.7.1.3 Business context

Figure 70 illustrates the business roles involved in the use case "Value-based services for production resources".

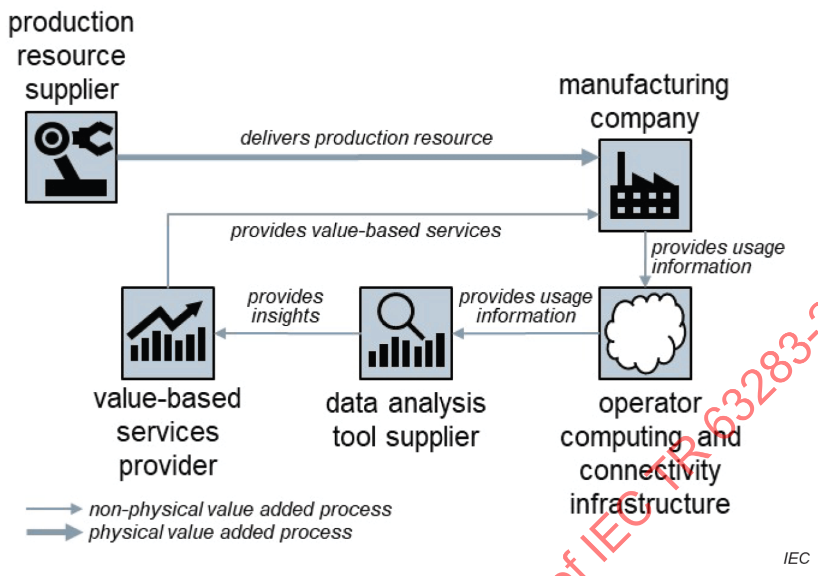

Figure 70 – Business context of "Value-based services for production resources"

6.7.1.4 Technical perspective

Figure 71 illustrates the human and technical roles involved in the use case "Value-based services for production resources".

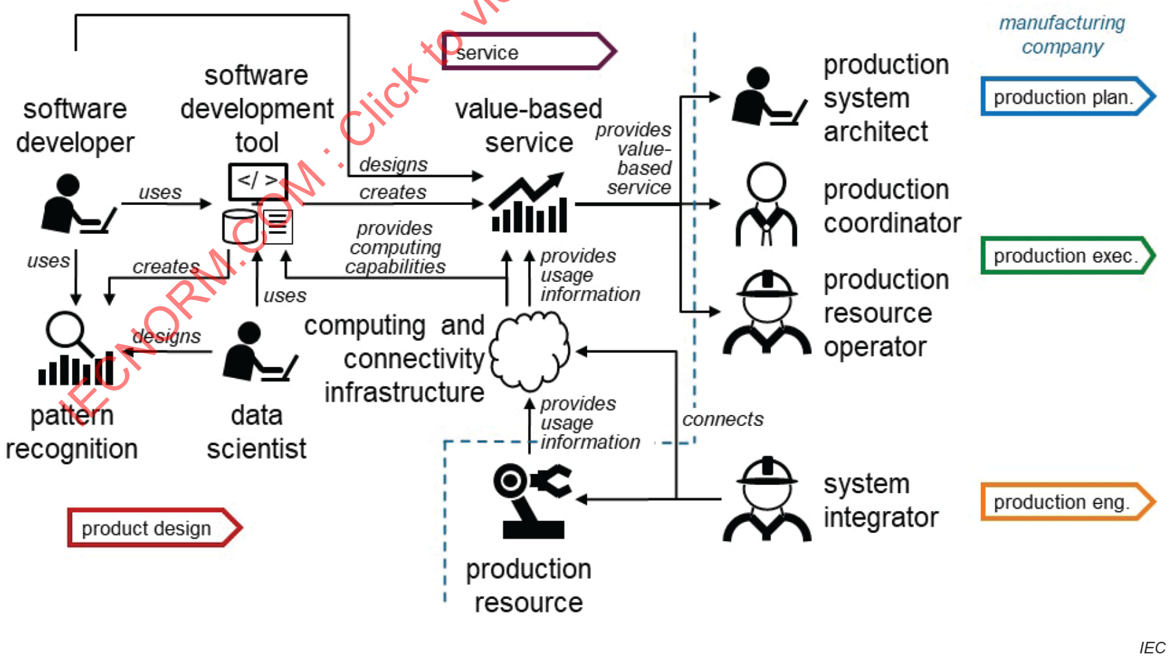

Figure 71 – Technical perspective of "Value-based services for production resources"

6.7.1.5 Interaction of roles

In this use case, the computing and connectivity infrastructure (“IIoT-platform”) will be provided with corresponding capabilities. The computing and connectivity infrastructure is an important technical enabler for this use case, but here the use case is considered from the perspective of the provider of value-based services.

The data scientist develops needed pattern recognition capabilities: The result of this activity are software applications capsulizing certain pattern recognition capabilities, which can be used by a software developer to create a software application. This activity can be executed as an independent business role, which will be purchased by the software developer developing the value-based service.

The software developer develops value-based service: This activity includes the development as well as the test. The result of this activity is a software application. Typically, well-founded know-how of the technological context of the underlying the production resource is the basis for the development. Therefore, this activity is typically not executed as an independent business role. In most cases, the production resource supplier performs this role, but sometimes also the computing and connectivity infrastructure operator, especially when it comes to more basic functions such as payment or more generic value-based services such as visualizations.

The system integrator connects production resource to the computing and connectivity infrastructure: This is an activity as it is done today in the erection of production systems. Typically, this will be done by the owner of the production resource. Mostly this is the manufacturing company today. For as-a-service business models, see 6.7.3 Production resource as-a-service, this can also be the production resource supplier or an independent financial services provider. From a technical point of view, the connection depends on the capabilities of the computing and connectivity infrastructure.

The software developer deploys and tests the value-based service: This is a development and commissioning task that is basically identical to the development and commissioning of control systems of production systems.

Execution of value-based service: Based on the usage information provided by the production resource, using the computing and connectivity infrastructure, the value-based service is executed or made available to the manufacturing company. According to the legal contract concluded between the provider of value-based service and the manufacturing company, billing also takes place. It is quite conceivable that the manufacturing company can be offered certain value-based services based on a freemium model.

Based on the feedback of the manufacturing company with respect to the value-based service, the software developer improves the value-based service. Again, this is a typical software development activity. At some point in time, the software developer provides an update of the value-based service, which then will be provided to the manufacturing company according to the legal contract between the provider of the value-based services and the manufacturing company.

Based on feedback of the software developer, who has developed the value-based service, the data scientist will improve the pattern recognition capabilities, and, at some point in time, provide an update of the pattern recognition capabilities.

6.7.1.6 Expected change and impact

The use case supposes the connection of production resources to a computing and connectivity infrastructure. In principle, this use case can already be implemented today and there are already numerous implementations on the market. However, the development of the computing and connectivity infrastructure as new offerings to the market have the effect that cost for the required connectivity capabilities are declining, so that value-based services can be implemented more cost-effective.

Consequently, the use case enables a production resource supplier to offer (new) value-based services.

6.7.1.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- Standardization of the connectivity of production resources to a computing and connectivity infrastructure: In addition to the semantic aspects already described in the use case “Standardization of production technologies”, the aspect of cyber security should also be taken into consideration, which should also be based on appropriate standards.
- Standardization of the mechanisms how the provision of usage information of a production resource is released or made visible, including the underlying access rights and release concept.
- Standardization of the capabilities of a computing infrastructure regarding a runtime environment for value-based services.
- Standardization of the business processes for offering value-based services, such as deployment, update (see 6.3.4 Update and functional scalability of production resources) or the contractual management and billing.

6.7.2 Benchmarking of production resources

6.7.2.1 Objective

A production resource supplier has an interest in selling value-based services, in this use case benchmarking services, to a manufacturing company to generate additional revenue streams.

The manufacturing company wants to optimize the usage of the production resources and decides to which extend taking advantage of a benchmarking offerings of a production resource supplier.

6.7.2.2 Overview

This is a special case of the use case “Value-based services for production resources”. Therefore, only the differences to the use case “Value-based services for production resources” are explained in the description.

Although typically the individual context, in which a production resource is used, is different, manufacturing companies have an interest in learning from others, especially outside of their own industry. They want to know how their usage of the production resources is related compared to a cross-company usage in order to get hints for optimizing efficiency and effectiveness. This use cases can also be applied in-house if, for example, a manufacturing company operates a large fleet of similar production resources.

The production resource supplier anonymizes the information provided by the various production resources and relates the information from the considered production resource to the anonymized information from the other production resources.

The use case stands and falls by how representative the usage information provided by the connected production resources is. Note that not every manufacturing company is willing to provide usage information from the own production resources to third-parties, or the manufacturing company determines what information will be provided.

This is an example of a “classical” subscription-based value-based service, where typically registration is as easy as possible from a manufacturing company's point of view. There can be different layers of detail – depending on the contract concluded between production resource supplier and manufacturing company – regarding the provided benchmarking information.

6.7.2.3 Business context

Figure 72 illustrates the business roles involved in the use case "Benchmarking of production resources".

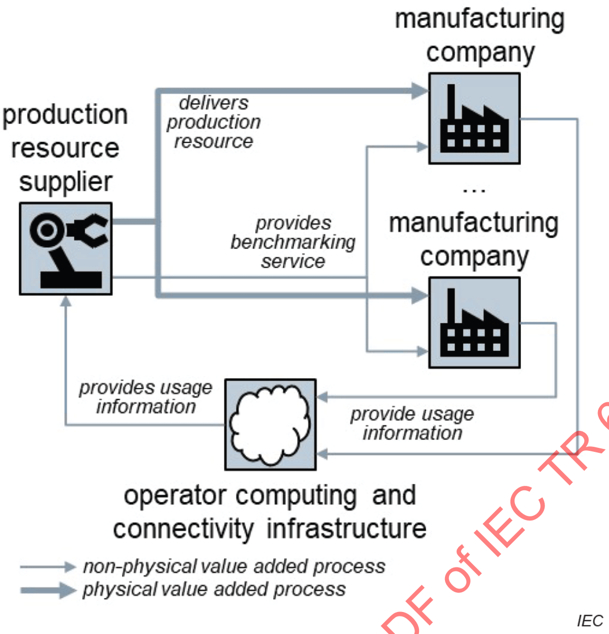

Figure 72 – Business context of "Benchmarking of production resources"

6.7.2.4 Technical perspective

Figure 73 illustrates the human and technical roles involved in the use case "Benchmarking of production resources".

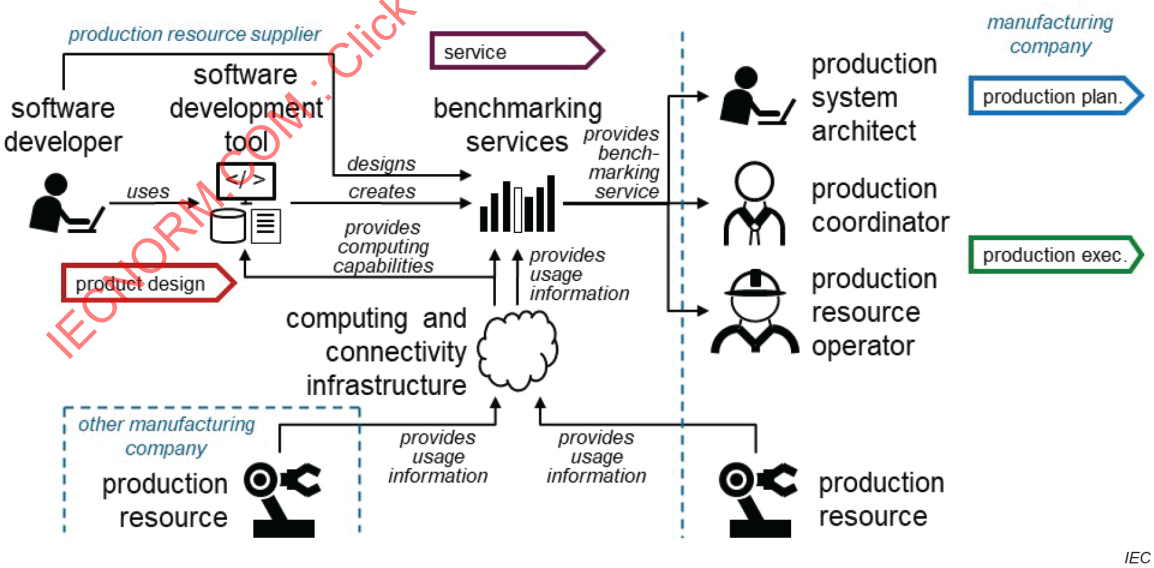

Figure 73 – Technical perspective of "Benchmarking of production resources"

6.7.2.5 Interaction of roles

The value-based services according to the use case "Value-based services for production resources" are the benchmarking services. Typically, benchmarking services do not require as much pattern recognition capabilities as other value-based services, such as dedicated condition monitoring services.

When developing the benchmarking service by the software developer, the various contracts with different manufacturing companies are considered. The processing of the usage information of the production resources connected to the computing and connectivity infrastructure complies with the agreed terms of use in the corresponding contract.

This use case is an example, where the computing and connectivity infrastructure is usually determined by the production resource supplier. The production resource suppler ensures that the various production resources are connected to this infrastructure via suitable connectivity capabilities. This can be done by connecting a production resource directly to this infrastructure, or by connectivity to another computing and connectivity infrastructure, for example, operated by the manufacturing company.

6.7.2.6 Expected change and impact

See use case "Value-based services for production resources". The use case describes an effect that can be achieved if as many production resources as possible are connected to a computing and connectivity infrastructure.

Consequently, the use case scales the better, the easier it is to connect production resources to a computing and connectivity infrastructure.

6.7.2.7 Recommendations for standardization

Standardized key performance indicators (KPIs) of production resources, which can be considered as a special case of the use case "Standardization of production technologies" should be considered. It is even possible to define standardized visualization entities for KPIs.

6.7.3 Production resource as-a-service

6.7.3.1 Objective

A production resource supplier has an interest in selling value-based services, for example, production resource as-a-service, to a manufacturing company to generate additional revenue streams.

The manufacturing company wants to optimize the usage of the production resources and decides to which extend taking advantage of a production resource as-a-service offering of a production resource supplier.

6.7.3.2 Overview

This is a special case of the use case "Value-based services for production resources". Therefore, only the differences to the use case "Value-based services for production resources" are explained in the description.

If a production resource is offered as a service, the production resource is no longer sold to the manufacturing company as a physical product, but the production resource is made available to the manufacturing company and the manufacturing company pays for the concrete usage. Typically, on the one hand a performance of the production resource is guaranteed and on the other hand the manufacturing company assures a certain utilization of the production resource. Various models are conceivable, even that both parties benefit from realized savings (performance contracting). From a business perspective, there is usually a shift in risk between the parties.

These models are also becoming increasingly popular in the manufacturing industries; in particular, this is observed on the market in the auxiliary processes of a manufacturing company, such as the provision of compressed air or power supply.

On the one hand, systematic monitoring of the production resources offered as-a-service, which are usually installed in different locations, is important in order to be able to remotely monitor to what extent the use of the production resources by the manufacturing company is compliant to the contract, on the other hand, to ensure the guaranteed performance of the production resource and, for example, to be able to optimize the maintenance work, see 6.4.1 Optimization of operations.

As-a-service models can be offered not only by the production resource supplier, but also by third party companies, for example financing service providers. By using a computing and connectivity infrastructure, they can improve the efficiency of their internal business processes, for example, because they no longer need so many on-site inspections, and therefore the number of such as-a-service contracts can be increased without additional costs for additional employees.

Consideration of data usage and storage are key for production resource as a service business models to avoid any intellectual property or regulatory infringements. In contrast to the use cases "Value-based services for production resources" and "Benchmarking of production resources", in this use case the production resource user and production resource owner are different legal entities.

6.7.3.3 Business context

Figure 74 illustrates the business roles involved in the use case "Production resource as-a-service".

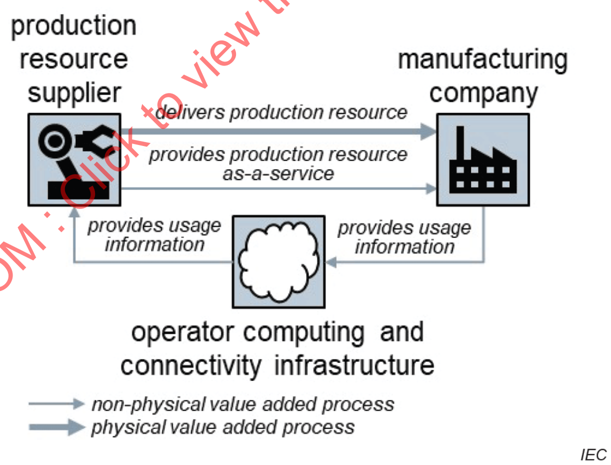

Figure 74 – Business context of "Production resource as-a-service"

6.7.3.4 Technical perspective

Figure 75 illustrates the human and technical roles involved in the use case "Production resource as-a-service".

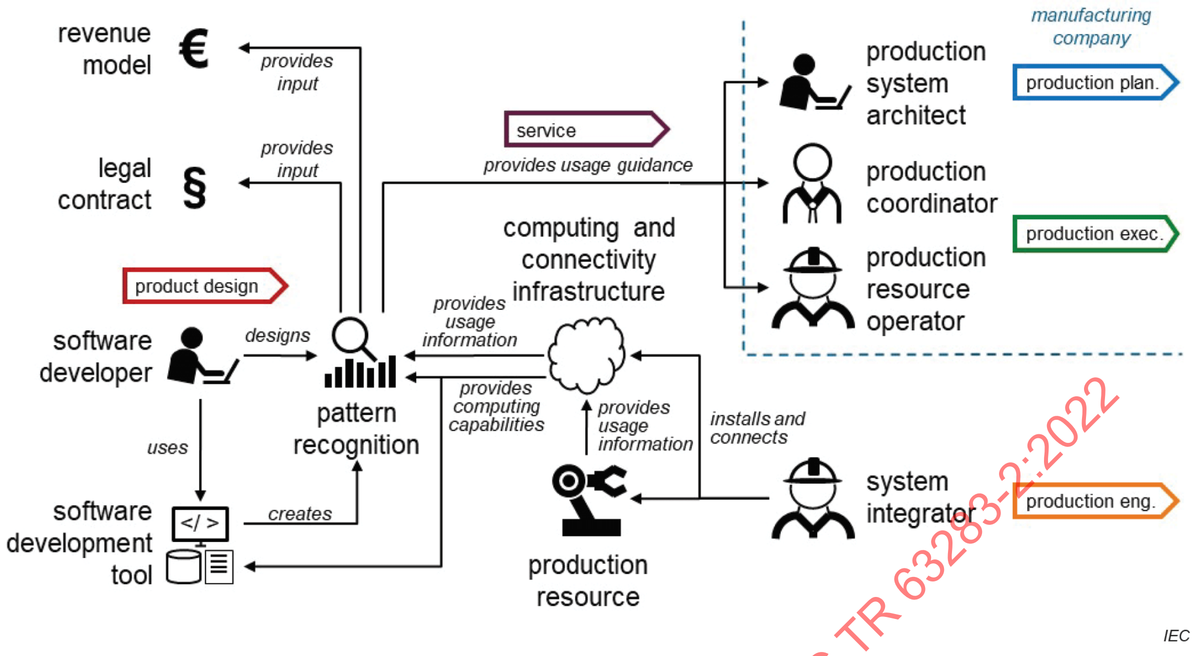

Figure 75 – Technical perspective of "Production resource as-a-service"

6.7.3.5 Interaction of roles

The value-based service according to the use case "Value-based services for production resources" is here the as-a-service business model for a production resource. In addition to the technical aspects, business aspects are of central importance in this use case, regarding the control of business risks. However, this document only highlights the technical perspective. The technical pattern recognition capabilities provide basic information that are evaluated from a business perspective, especially with respect to the contract design and the revenue model.

The connection of the production resource in this use case is typically paid by the production resource supplier.

The computing and connectivity infrastructure in this use case is usually determined by the production resource supplier.

Based on the analysis of the usage information of the production resource, the production resource provider will provide the manufacturing company – depending on the contract – information regarding a technical use of the production resource, but also document non-compliant use of the production resource by the manufacturing company as basis for the own claim management against the manufacturing company.

6.7.3.6 Expected change and impact

See use case "Value-based services for production resources". Today the use case often is implemented based on specific connectivity solutions developed by the production resource supplier.

6.7.3.7 Recommendations for standardization

Standard and/or sample contracts for as-a-service models for production resources should be considered.

6.8 Use case cluster “IT-infrastructure and software”

6.8.1 Device configuration

6.8.1.1 Objective

A manufacturing company wants to avoid a vendor lock-in of supplier of devices and to master the increasing complexity arising from IT through a flexible deployment of software applications to the various devices or to a generic computing infrastructure.

A software application supplier wants to offer software applications, which can be flexibly deployed to devices or to a generic computing infrastructure.

6.8.1.2 Overview

The market observes an increasing connectivity of the various devices and production resources as well as an increasing number of software applications and data-driven services (based on software applications) used in manufacturing industries. This leads to increased complexity of the underlying IT systems, for example, in connection with cyber security. Therefore, the challenge for the user is to master this complexity. To leverage this, the use case considers the decoupling of software applications and devices that provide computing capabilities, so that software applications can be offered independently of a specific device and the user of a software application can deploy the software application arbitrarily on a device.

In this context, the hard-real-time applications in the context of the operation of a production system are not considered, but rather less time-critical analysis and evaluation applications. The use case also addresses scenarios where an additional device – an edge device – is integrated close to the technological process, such as in a production resource, in order to be able to execute evaluations of process information efficiently. For example, a preliminary analysis and information compression is made for large volumes of data collected from the field on site. But often it is also of interest to not unnecessarily spread information from production resources, but to keep the information local under the own control.

In the context of this use case, often one wants to be able to flexibly adapt a software application using agile software development methods, for example by using methods of machine learning. This also applies to the update of functions, the deployment of new versions, as well as the temporary execution of software applications, because it is used only for a limited time period.

This use case distinguishes between devices and a computing infrastructure. The computing infrastructure is a classic IT computing infrastructure that can be flexibly up- or down-scaled from the user's perspective, depending on the computing capacities required – a cloud computing infrastructure. Regarding the devices in the field, there is usually no such universal computing infrastructure today. In this respect, the use case transfers the concept of a universal IT computing infrastructure to “edge” devices by providing an additional IT infrastructure – parallel to the existing process control system – in the “edge”.

There are two sorts of software applications that run on the computing infrastructure:

- function blocks, which are used by a software developer to build a larger software application, but the software application will later not be used by the software developer;
- ready-to-use software applications, which a user selects from a store according to the own specific needs and then uses the software application.

Regarding the configuration of the devices, the use case “Plug-and-Produce for Adaptable Factories” according to [13] is a specific example.

6.8.1.3 Business context

Figure 76 illustrates the business roles involved in the use case “Device configuration”.

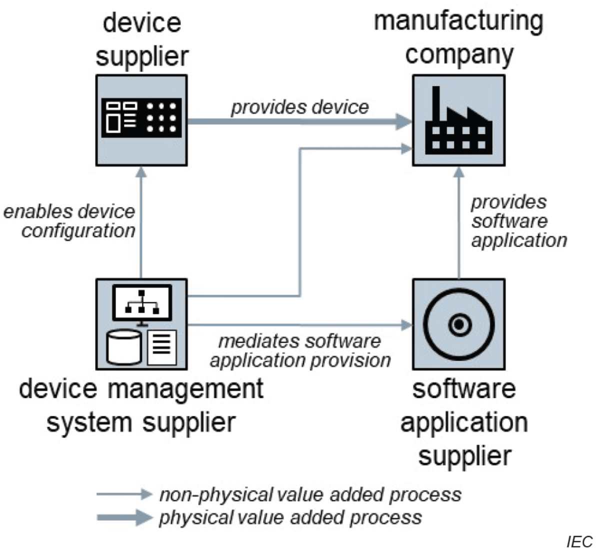

Figure 76 – Business context of "Device configuration"

6.8.1.4 Technical perspective

Figure 77 illustrates the human and technical roles involved in the use case "Device configuration".

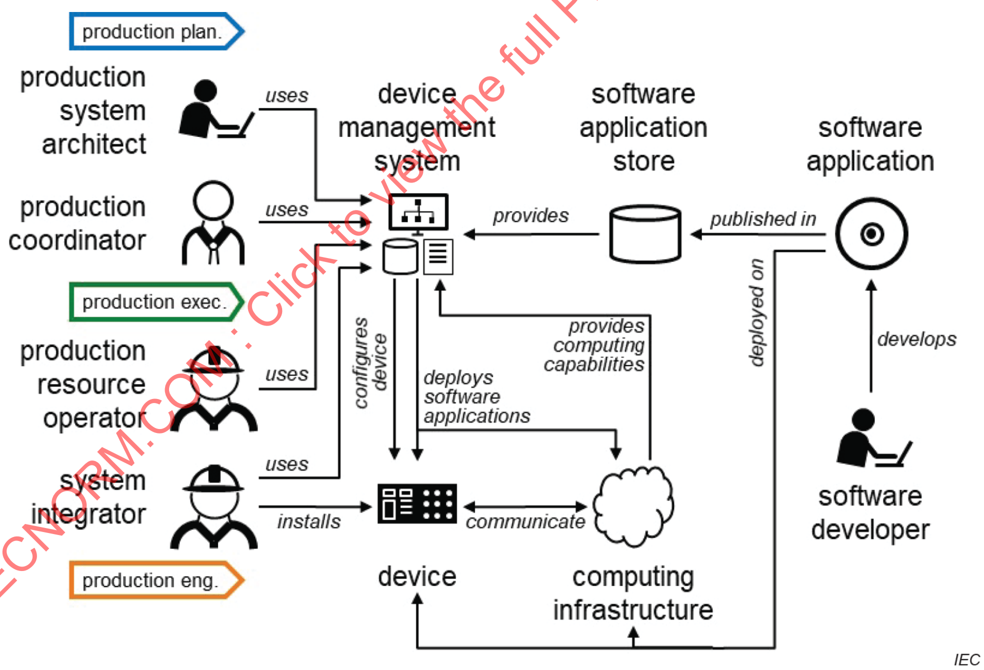

Figure 77 – Technical perspective of "Device configuration"

6.8.1.5 Interaction of roles

The software developer develops a software application and publishes the software application in a software application store: The creation of the software application is based on traditional software engineering processes, methods and tools. The software developer defines which specific requirements are assured by a computing capability so that the software application can be deployed on it. A software application is self-contained, which means it can be deployed as a unit and then used.

The software application store provides software applications to the device management system. In this context, a version management for software applications is needed.

The system integrator installs and integrates a device into the production system: This includes the setup of the communication with other devices and the computing infrastructure. It is conceivable that according to [13], this is done automatically. The device publishes, which computing capabilities will be assured. For the configuration of the device, the system integrator uses the device management system. In the case of an exchange of a device by a new device the configuration information of the old device is automatically provided to the new device. However, if the new device provides other computing capabilities, further actions can be needed. When removing a device, the software applications running on it is deployed elsewhere. Again, certain automatisms are conceivable.

This use case assumes that the required computing infrastructure is available.

The device management system will be used by different human roles:

- The production system architect (here in the role of a software developer): This role develops some software application to be used later during operation of the production system based on the integration of various software applications provided in a software application store to a superordinate software application.
- The production coordinator, the production resource operator or the system integrator: These roles select some software application from the software application store and use the software application to support their daily work.

The device and computing infrastructure offer computing capabilities for execution of software applications: The software applications will be deployed to the computing capabilities of the devices or computing infrastructure. The devices or the computing infrastructure assure certain computing capabilities, while the software applications require specific computing capabilities. The device management system will guide the deployment process.

6.8.1.6 Expected change and impact

The use case supposes a separation of software development and runtime environment. This is already the case in classical IT, but the landscape of devices used in manufacturing industries is still quite heterogeneous. The heterogeneity also applies to the underlying programming paradigms for the devices, for example the programming of programmable logic controllers is typically based on specific programming languages.

Consequently, the use case will reduce the technical system integration efforts and enables the economical implementation of high value automation, process management and decision support functions.

6.8.1.7 Recommendations for standardization

Standardized runtime environment for the devices, including standardization of the computing capabilities offered by a device and required by a software application.

Standardized software development paradigm in the sense that the following aspects are standardized:

- characteristics of a software application (according to this use case);
- process how to create a software application;
- features which should be offered by an associated software development environment.

Standardized processes for handling software applications, such as deployment, update or deletion.

6.8.2 Information extraction from production systems

6.8.2.1 Objective

A manufacturing company wants to collect information of a production system in a side-effect free and easy way in order to analyze and process this information using a generic computing infrastructure.

6.8.2.2 Overview

In this use case, the focus is on the enhancement of existing production systems as a baseline for the efficient and flexible application of new technologies and software applications to optimize a production system or the business processes in which the production system is integrated. The concept is developed and implemented especially in the context of the NAMUR Open Architecture, see [14].

The overarching goals are to enable, in addition to existing systems, a simple integration of fast-paced IT components from the field level to the enterprise management level in a standardized manner in order to achieve a significant improvement in costs by means of open and integrative approaches for the additionally required sensors without jeopardizing the availability and security of the existing system and thus reducing the complexity, in particular, for the operator of a production system.

Conceptually, a distinction is made in

- Real-time communication for safe and reliable production system operation: The core tasks are performing measurement and control tasks, overarching process control, process data acquisition, and the human-machine interface for the operator of the production system.
- A monitoring and optimization function as a basis for the agile development of innovative solutions, such as the execution of monitoring and optimization tasks, for example dispatching or advanced process control, or the collection of add-on sensor data as an enabler for additional applications, for example advanced analytics.

This use case addresses the concept of monitoring and optimization functions while ensuring the existing real-time communication. It also is the basis for the realization of future-oriented cross-production system applications such as simulation of value networks and is therefore also an enabler for the use case "Optimization of operations".

Examples of relatively easy-to-implement applications are the extraction and evaluation of configuration data regarding device life cycle management and optimization or the extraction and evaluation of operational data for a customized monitoring and diagnosis of devices and production resources.

Examples of more advanced applications are:

- optimization of production processes to improve quality or yield;
- improved operation of production systems to reduce energy or materials;
- improved maintenance to reduce maintenance costs and unplanned downtime;
- improving hazard management regarding the protection of people, environment and production system.

6.8.2.3 Business context

Figure 78 illustrates the business roles involved in the use case "Information extraction from production systems".

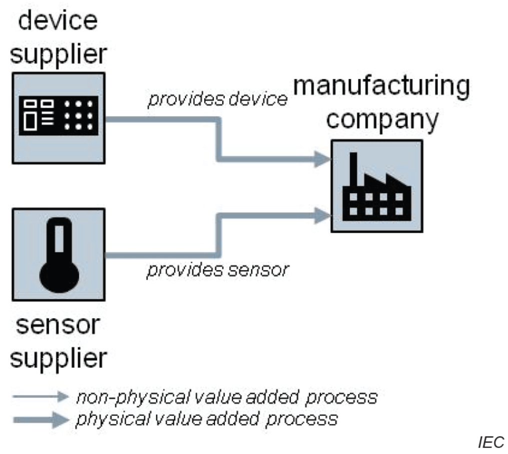

Figure 78 – Business context of "Information extraction from production systems"

6.8.2.4 Technical perspective

Figure 79 illustrates the human and technical roles involved in the use case "Information extraction from production systems".

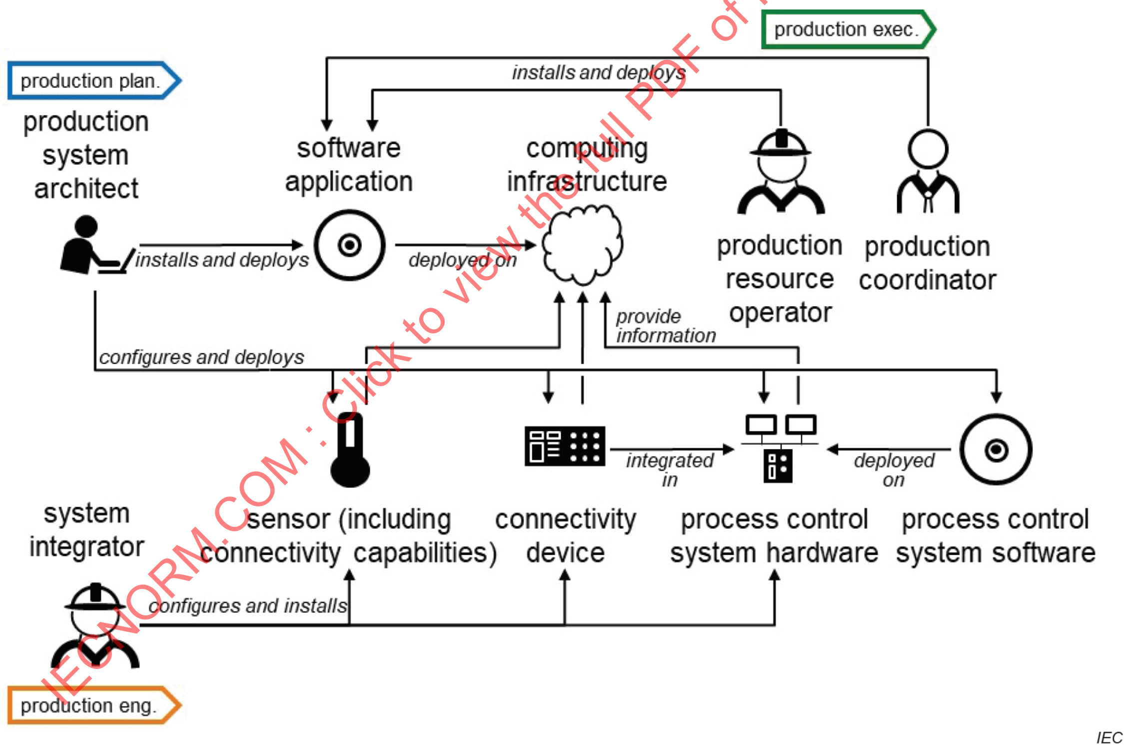

Figure 79 – Technical perspective of "Information extraction from production systems"

6.8.2.5 Interaction of roles

In principle, various options are conceivable as to how the additional information is recorded and transmitted:

- An additional sensor is installed, which in addition to the data acquisition capabilities also includes connectivity capabilities so that the information can be transmitted to the computing infrastructure.
- An additional connectivity device is installed via which information from the process control system hardware can be extracted and transmitted to the computing infrastructure.

- Additional process control system software is installed on the process control system hardware, which uses the installed process control system to read certain information about the production system and transmit it to the computing infrastructure using the existing process control system.

The system integrator installs the additionally required physical entities, for example, the additional sensor or the additional connectivity device, and from a system-technical point of view also configures these entities.

This use case assumes that the required computing infrastructure is available.

From the application perspective, the production system architect configures the additionally installed physical entities or configures and deploys the additional process control system software.

Either the production system architect, but possibly also the production coordinator or the production resource operator, deploy suitable software application for analyzing the additionally transmitted information on the computing infrastructure, so that based on the analysis results suitable decisions for optimizing the production system or the business processes in which the production system is integrated, can be taken.

6.8.2.6 Expected change and impact

The use case supposes a standardized minimally invasive upgrade of an existing production system in order to get easy access to information of the production system.

Consequently, the use case enables the integration of additional monitoring and optimization of both the production system and the business processes in which the production system is integrated.

6.8.2.7 Recommendations for standardization

Following recommendations for standardization have been identified:

- Standardization of the overall architecture regarding a communication between the existing production system and the extension of the collection and transmission of additional information about the production system.
- Standardization of the information model for the additionally recorded and transmitted information about the production system.

6.8.3 Rule-driven software applications

6.8.3.1 Objective

A manufacturing company wants to avoid lock-in effects from a software application supplier and wants to minimize the dependencies on the supplier for maintenance of the software application over the life cycle.

A software application supplier wants to make the own software application as flexible as possible so that it can be used in as many application scenarios as possible.

6.8.3.2 Overview

Software applications (including engineering tools) can be better designed with respect to the maintenance throughout their life cycle by consistently separating generic application logic from application-specific information and logic. As a result, tasks that the software application supplier has performed in the past can now be performed by the user of the software application. However, this requires enough preparation of the information to be provided by the software application user about its semantics.

Although not exhaustive, the following examples are intended to illustrate this:

- Macros: An engineering tool provides the ability for a user to define a macro (like scripts in office applications). A user then has the option of providing suitable data to this macro and then executing it instead of possibly having to carry out numerous manual operations.
- Bulk engineering: The user of an engineering tool creates table entries and the engineering tool performs a certain operation for each table entry. The table entries are available in a format specified by the engineering tool supplier. In addition, the engineering tool offers the possibility of defining macros and the user specifies how the macro is applied to the individual table entries.
- Data-driven analysis: A software application reads a stream of information from various sensors, each piece of information in the stream being organized for example according to the schema [entity name, attribute name, data type, value]. A user specifies which entity names and attribute names to look at and a condition for the value. The software application filters now all information from the stream, which meet these conditions.

Especially in engineering, this concept can be applied regarding the automation of engineering in order to automate frequently annoying and error-prone routine tasks in engineering.

The advantages of this approach are that less highly specific or highly customized software applications are used and instead more generic software applications can be used flexibly in multiple application scenarios. This increases the quality of the software applications and reduces the maintenance of the software applications over their life cycles.

This means that the focus is more on information, such as product resources or products – and less on the software application that processes this information –, which is the basis for improving the overall consistency of the data and information considered and workflows can be made more efficient.

When introducing this concept, the following aspects are considered:

- Generic use of standardized properties in order to allow the definition of self-describing information models. For example, an algorithm that checks whether a required capability to produce a product can be fulfilled by a production resource does not need to know all capability describing properties. The algorithm only needs to know how to find and how to compare the capability properties required for the product and offered by the production resource. To achieve this level of abstraction standardized properties are used; additional attributes of properties can be used as well, for example classifications.
- According to the separation of information and software application, different skills are necessary for the development and use of software applications. Responsibility of preparing information can be taken over even by the user of the software application. Nevertheless, the preparation of information requires experience and is critical as well as customizing of software applications, but programming skills are not necessary.
- The definition of properties in information models can follow certain rules. There can be used meta-models to describe the searching and interpretation strategy for information.
- Algorithm respective rules are implemented in software applications in a way that they do not require a large set of mandatory to provided properties. Properties that could be optional are not required to exist. On the other side, implementations do not need to take in account every existing property. These both concepts will allow that for example production resources with different levels of property support can be integrated easily and coexistent into a production system.

6.8.3.3 Business context

Figure 80 illustrates the business roles involved in the use case “Rule-driven software applications”.

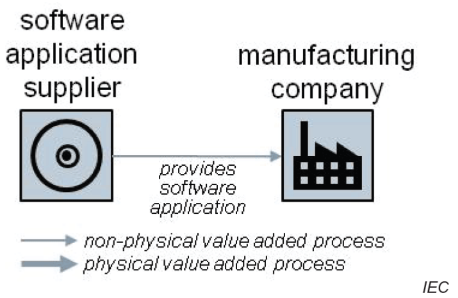

Figure 80 – Business context of "Rule-driven software applications"

6.8.3.4 Technical perspective

Figure 81 illustrates the human and technical roles involved in the use case "Rule-driven software applications".

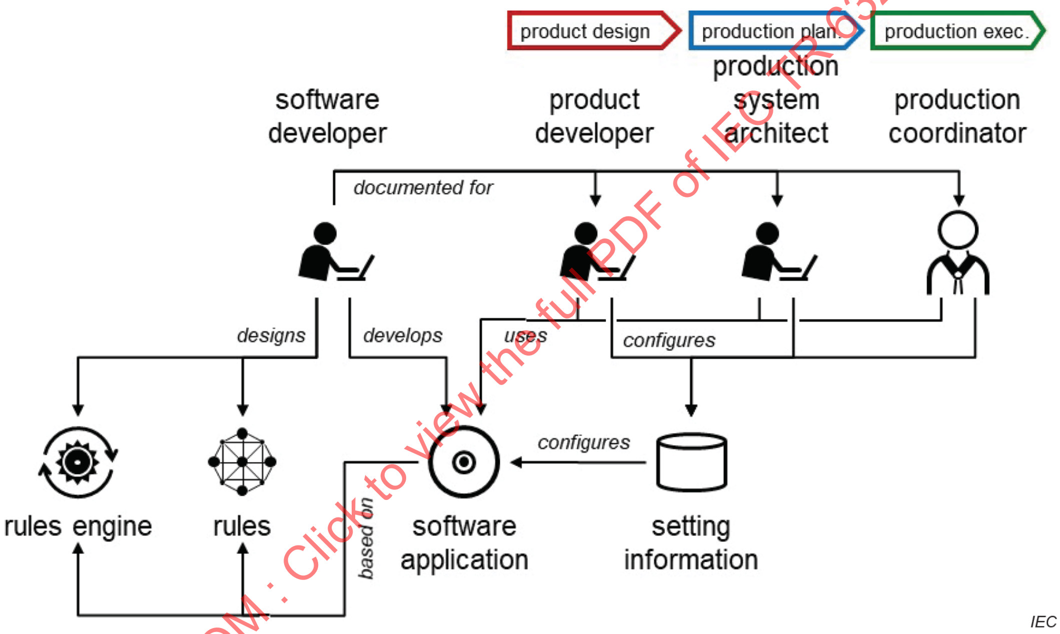

Figure 81 – Technical perspective of "Rule-driven software applications"

6.8.3.5 Interaction of roles

The software developer develops a software application based on the paradigm that a set of rules is processed by a rule's engine. The software application is designed so that the rules can later be changed as part of a customizing of the software application by another software developer who has not necessarily developed the software application. This also applies to the addition and deletion of rules. Overall, this is a classic software development task.

In addition, the software developer develops a possibility for configuring the rules in the sense that the user of the software application can define with which parameters the individual rules are to be executed.

The user of the software application – in this context due to the need for structured information processing, a product developer, a production system architect, or possibly a production coordinator – uses the ability to configure the rules via the settings of the software application and thereby controls the software application according to the intended purpose.