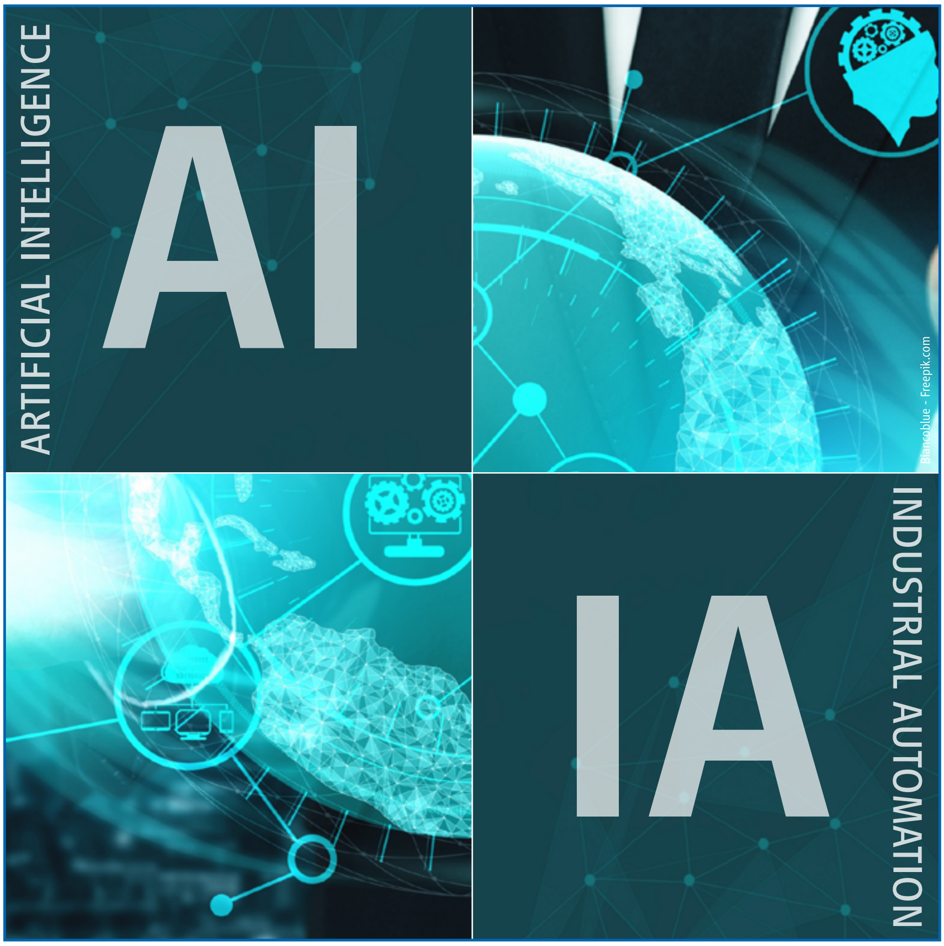
White Paper

AI in Industrial Automation



German Electrical and Electronic Manufacturers' Association

Die Elektroindustrie

Artificial Intelligence in Industrial Automation
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Content

Executive Summary

Digitizing industry will open-up potential additional cumulative value added of €425 billion in Germany alone. The sectors that will benefit most in the next five years are the automotive industry with an increase in revenue of €52.5 billion (13.6%), mechanical engineering (€32 billion or 13.2%), process industries (€30 billion or 8.1%), the electronics industry (€23.5 billion or 13%) and ICT (€15 billion or 13.4%). The distinction between manufacturing and services will become less important, and global manufacturing competition will also be digitally driven or based on ICT1.

The digitalization of industries supports the migration from Industry 3.0 with focus on automation to industry 4.0 where data-driven inter-company services break up conventional value chains. Networked production enables the new manufacturing scheme of "manufacturing as a service" making the customer co-designer of his new product with AI getting the key role in designing new products and production systems in near future. This has the potential to drive outsourcing and just in time supply chains to complete new levels with disruptive potential for product provisioning. Virtual factories could be designed with AI supporting assessment, validation and negotiation of production elements offered in a highly dynamic platform economy.

Germany enjoys an excellent reputation in AI research, for example in industrial AI applications in production areas. However, when it comes to developing innovative products and services from the research results and ultimately leading them to commercial success, other countries such as China or the USA are much more successful. If it is possible to combine the wealth of industrial experience of the German economy with the possibilities of data-driven AI methods to create an industrial AI, Germany could become a winner of the new AI technology, and could secure – and even expand – its competitiveness in the industrial sectors it already dominates (Bundesregierung, 2020).

The German platforms Industry 4.0 and learning systems already depict 50+ AI use cases across Germany. The majority however is focusing on long known facets of AI, i.e. machine learning to optimize machines and production lines based on shopfloor data. But the potential AI will get in the design and engineering stage for the automation of connected industries has not yet been analysed. This white¬paper introduces a new approach to understand the role of AI for systems engineering in an integrated picture of use cases showcasing connection and automation of different industries. The evolvement of digital twins will further help to develop upcoming use cases in the light of new data-based business models. AI will support collaborative manufacturing ecosystems in enabling systems engineering to negotiate and implement solutions with regards to best costs of production, trust levels, and also with regard to environmental costs, i.e. energy consumption, circular economy and green foot print.

This white paper is designed to share the experience of "First Movers" in the exploration and evaluation of new AI use cases for manufacturing with focus on collaborative engineering. The ZVEI AI workgroup analyses and supports the creation of new use cases and scenarios to answer questions related to KPIs, AI architectures, Business Models and ROIs for the different stake holders, i.e. chip producers, machine builders, integrators and OEMs to motivate further development and invest.

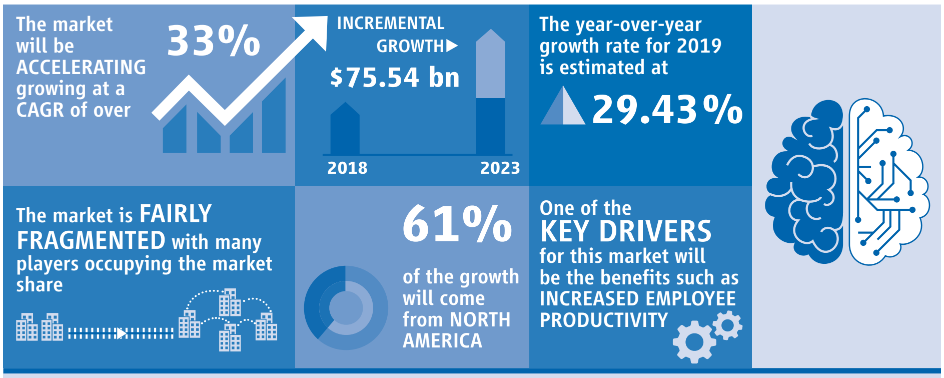
1 AI as Key Technology in Industrie 4.0

1.1. Business Value of AI

Artificial intelligence (AI) technologies are forecast to add US$15 trillion to the global economy by 2032.

The artificial intelligence market size will grow by $ 75.54 billion during 2019-2023. The market's growth momentum will accelerate during the forecast period because of the steady increase in year-over-year growth.
The market forecast takes end-users perspective and geography landscape (APAC, Europe, MEA, North America, and South America) into account as displayed in figure 1.

Figure 1



- AI and Machine Learning have the potential to create an additional **$2.6T** in value **by 2020** in Marketing and Sales, and up to **$2T** in manufacturing and supply chain planning.
- Gartner predicts the business value created by **AI** will reach **$3.9T** in **2022**.
- IDC predicts worldwide spending on cognitive and Artificial Intelligence systems will reach **$77.6B** in **2022**.

Source: ZVEI

The AI share in the manufacturing market is expected to grow at a CAGR of 39.7% from 2019 to 2027 to reach $27 billion by 2027.

Organizations are aggressively adopting AI-based solutions and services to reshape their business operations and increase profitability. The adoption of artificial intelligence technologies in the manufacturing industry is on the rise to create new opportunities & enhance operational capabilities by leveraging new technologies, fastening processes, and making organizations adaptable to changes in the future.

1.2. AI Facets and Impact on Industries

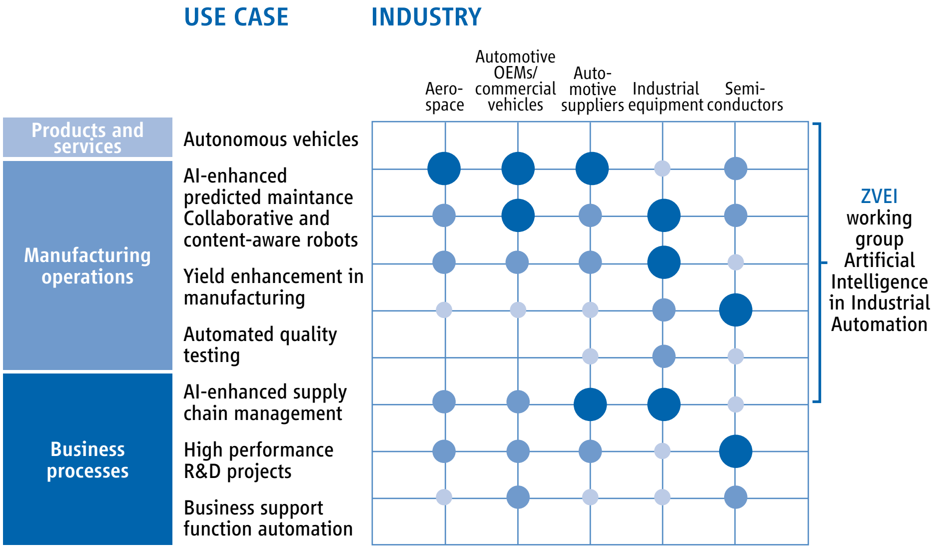
The Federal Government has oriented its strategy (Bundesregierung D., 2020) to the „weak“ approach which covers:

- Deduction systems, machine-based proofs: deduction of formal statements from logical expressions, systems to prove the correctness of hardware and software,
- Knowledge-based systems: methods to model and gather expertise; software to simulate human expertise and to support experts (previously designated "expert systems"),
- Pattern analysis and pattern recognition: inductive analytical processes in general, machine learning in particular,
- Robotics: autonomous control of robotic systems, i.e. autonomous systems,
- Smart multimodal human-machine interaction: analysis and "understanding" of language (in conjunction with linguistics), images, gestures and other forms of human interaction.

The most commonly used AI technology across industries is Machine Learning. This is inarguably due to its wide-ranging applicability, making it relevant for a variety of use-cases across the value chain depicted in figure 2.

While companies historically have primarily used internal data for supervised Machine Learning, many have begun exploring the possibility of combining internal and external datasets as well as internal and external data science-related competencies in order to produce even deeper insights.

Figure 2



Source: ZVEI

Artificial General Intelligence (AGI)

While focussing on today's activities on weak or narrow Artificial Intelligence, this paper will also provide a vision of the future, when AI no longer acts only reactively, but also of its own accord, intelligently and flexibly. Not only providing the solution but also understanding the underlying system, recognizing patterns independently and drawing new conclusions. This kind of AI is comparable to human cognitive skills and referred as Artificial General Intelligence.

The properties of artificial general intelligence include, among others, knowledge-based presentations, communication in natural languages, the use of strategies, the evaluation of irregularities and acting. AGI systems can recognize and react to hazards, they support cognitive research, math-oriented intelligence and decision-making. Today there are no commercial solutions available, except for the Project Debater from IBM (IBM Research, 2021), which was integrated into Watson in 2020.

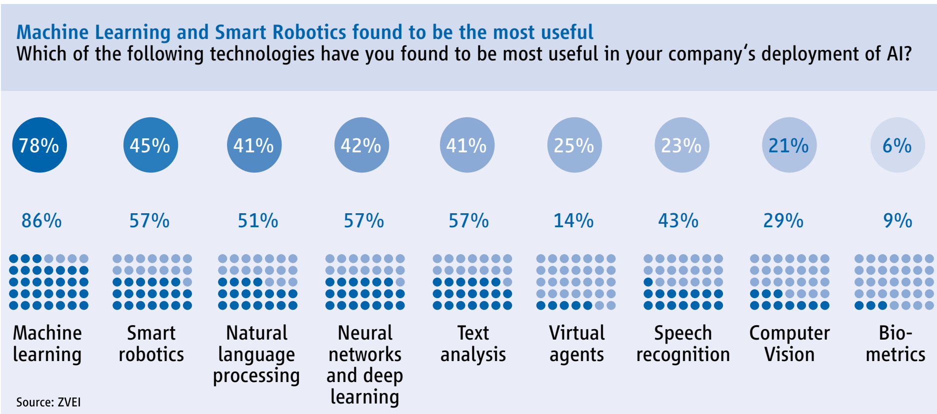
Research work is done in the field of systems with cognitive synergy, which allows to combine different kinds of memory and their related learning methods to generate AGI. One promising project is CogPrime (Ben Goertzel, 2014). Further work on self-reflecting systems in the context of AGI addresses the skill of drawing own and new conclusions. One pertinent example, inspired by Kurt Gödel's self-referential formulas (Gödel, 1931), is the Gödel Machine, which employs a proof searcher — parallel to its regular problem solving duties – to find a self-rewrite of which it can prove that it will be beneficial (Schmidhuber, 2012).

In section 3.3 we describe a high-level scenario, using above skills in the context of innovative product development and systems engineering.

1.3. Landscape of AI and Focus for Manufacturing

Of the different types of Machine Learning, the most common is supervised Machine Learning, where software is fed with structured data to find patterns and to understand and interpret new observations. Machine Learning and Smart Robotics have been found most useful in companies' deployment of AI. A technology brake down is displayed in figure 3.

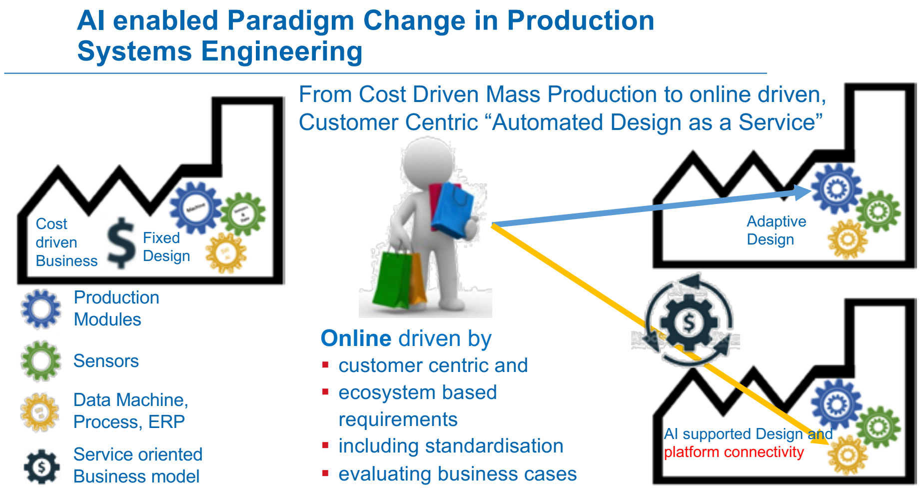
Figure 3



1.4. Potential for automation and systems engineering during its life cycle

Data-driven inter-company services break up conventional value chains. Networked production enables the new manufacturing scheme of "manufacturing as a service" making the customer co-designer of his new product. This results in bringing together design, production and use of products at regional locations, as shown in Figure 4.

Figure 4



Source: ZVEI

On the left side we see the automation and production scheme to serve mass production at lowest costs. Once designed the production is rigid and does not allows adaptivity. In the middle we see the paradigm shift towards customization, with the customer starting to act as co-designer of his product. On the right side the digital twins of assets, machines and services are depicted which will further enable new types of service-oriented cost models which takes the common value [1] in ecosystems into account - opposed to existing cost models which more focus on "private" value of key suppliers. First new formats for auction-based selling of services and diverse goods based on the work of Wilson and Milgrom – awarded with the Nobel Prize for economy 2020 (The Royal Swedisch Academy of Sciences, 2020) – are discussed and adopted for systems engineering in chapter 4.

As regional enterprises may be connected to serve the local customers' demands, offshoring of mass-production from low wage countries to a close-by location is reached. High environmental costs related to excessive energy consumption and logistic efforts for shipment are saved.

Connected Modular Smart Factories enable customer demand driven mass-customization at reduced environmental, design and manufacturing costs. Networked production needs trusted networks and business models assuring data sovereignty in manufacturing ecosystems. The current GAIA-X initiative is working towards development and provision of trusted cloud-based infrastructures for manufacturing industries and thus leverages "digital" as enabler of sustainability.

First movers in R&D and Industry are already driving the future as will be showcased in next chapters. Artificial intelligence, integrating existing infrastructures, digital twins and further resources for data, allow computers to independently design advanced products, corresponding production processes and production lines. In this context digital twins cover exiting assets as well as no longer existing (historical) assets. This approach breaks with traditional paradigms and opens-up extraordinary possibilities also for the acceptance of new solutions in industry and society.

[1] a common value can be uncertain beforehand but, in the end, is the same for everyone.

2 Landscape of Applications and Scenarios related to Production

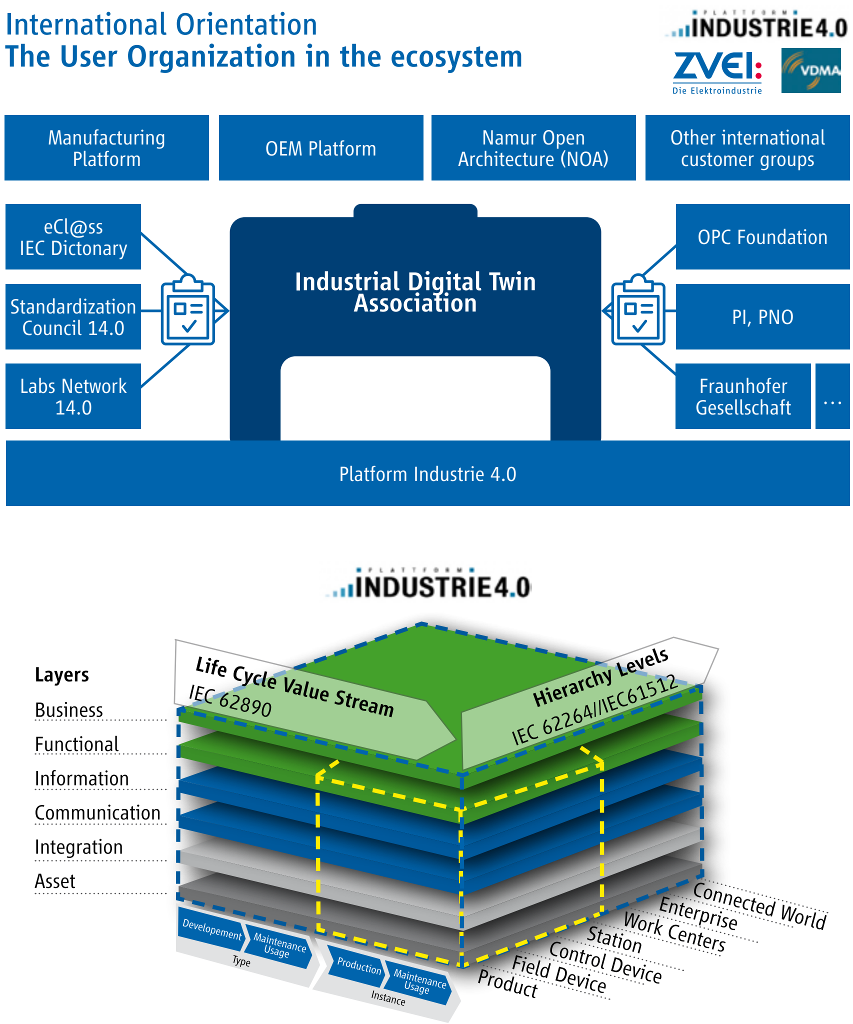
The Map on AI (Plattform Lernende Systeme, 2021), initiated by the Federal Ministry of Education and Research (BMBF) in cooperation with the Federal Ministry of Economical Affairs and Energy (BMWi) provides an overview on applications using AI, research institutions and transfer activities in Germany.

If we take the RAMI4.0 model depicted in figure 5 as a reference the characteristics of most of the 50+ AI use cases can be mapped into the "orange box", covering the operation of machines and systems. Data are used to optimize processes. This follows the first wave of digitizing industries by sensor integration into existing machines, called "brown field" optimisation.

The role of AI in left part of the RAMI4.0 model is not yet investigated and will be fuelled by parallel evolution of digital twins and wireless connectivity. The "blue box" focuses on the engineering part to enable new AI use cases in the range of networked production and federation of AI services based on trusted infrastructures. As outlined in chapter 3 this system boundary will also embrace the "digital aftermath" of assets, as data are still available long after disposal of the physical asset.

Figure 5

AI Use Case Mapping to RAMI 4.0 Domains: Development Path



Source: ZVEI

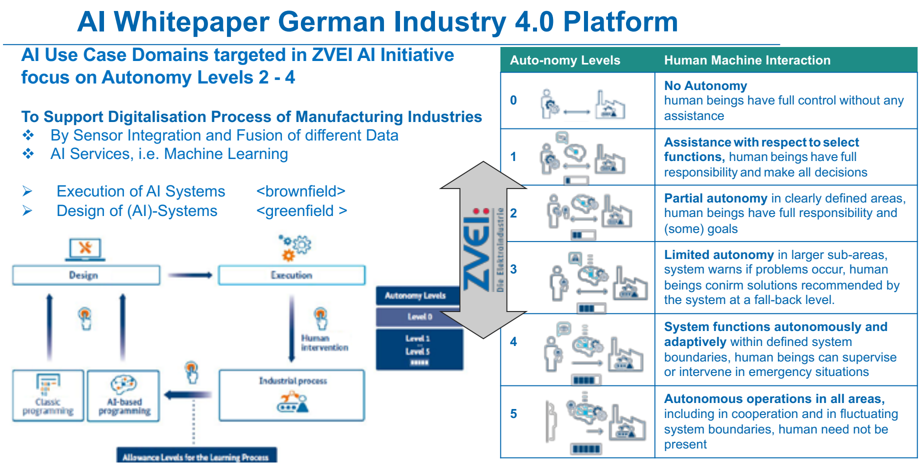
2.1. Industrial AI-Applications classified by autonomy levels

The latest AI Whitepaper from German Industry 4.0 Platform has defined 5 levels of autonomy, in levels zero to five see figure 6. For those autonomy levels [2] we describe the functionality of AI and the impact AI has for systems engineering. In chapter 2.3 we map the published industry 4.0 application scenarios to the autonomy levels and discuss the role of AI.

The picture on the left side in figure 6 symbolically shows autonomy level dependent differences in the design stage of AI systems, i.e. AI architecture, learning mode, pre training and also in the execution stage in the industrial process. We will differentiate this approach in detail (Figure 7,Figure 8).

This ZVEI whitepaper will focus on AI use cases in autonomy levels 1-4 highlighting the role of AI for design, engineering, its impact on standardisation and acceptance of systems.

Figure 6



Source: ZVEI

[2] Autonomy levels are not equal to automation levels, the autonomy levels are defined assuming AI is used, automation (in production) is one of the results on all levels, (Plattform Industrie 4.0, 2020), but autonomy also applies on automated system engineering (Figure 6).

2.2. AI impact on selected key I4.0-Scenarios for system engineering

The German Platform Industry 4.0 (PI4.0) has published 11+ key industry 4.0 application and technology scenarios related to different value streams in manufacturing. More than 50 AI use cases have been analysed by expert groups from DIN/DKE-SVCI4.0, IEC-TC65 being referred to different viewpoints of the industrial internet reference architecture (IIRA). The analysis revealed that there is a gap for engineering.

The AI potential in the selected scenarios is listed below with reference to the autonomy levels (AL). Six application scenarios will be discussed and one new technology scenario will be scoped.

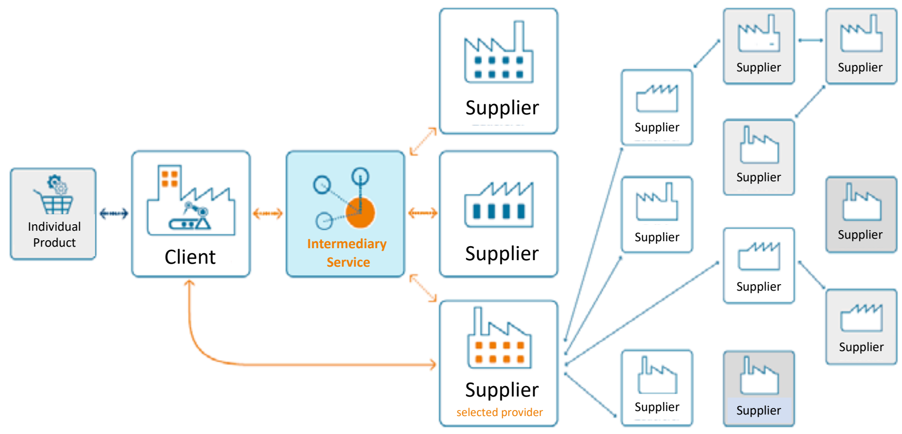
Industry 4.0 Application and Technology Scenarios as Published by PI4.0

Order-Controlled Production (OCP):

At its core, the "order-controlled production" scenario deals with how a company can automatically place orders to integrate the capacities and capabilities of other companies into its own production to produce individualised products across factory boundaries.

AI Potential:

- The analysis and selection of suitable suppliers and their functions in the value chain with the aim of finding the most economic offer matching the requirements
- The automated selection and negotiation with the potential suppliers offering production capabilities.



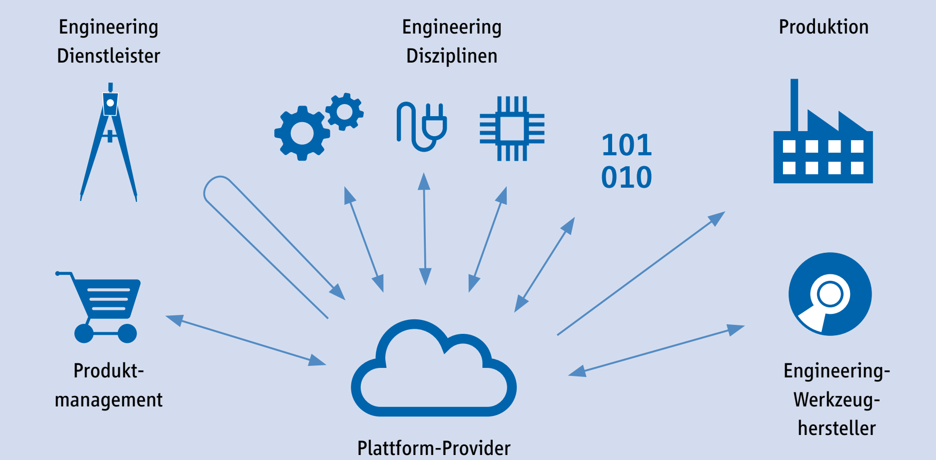
Source: ZVEI

Smart Product Development for Smart Production (SP2):

Digital twins of future products and sensor equipped components enable new forms of collaboration in engineering processes and the automation of engineering activities. Digital twins and sensor data are provided during the manufacturing process. The digital twin will be adapted to the actual process step. One product may have different digital twins responding to customer requirements.

AI Potential:

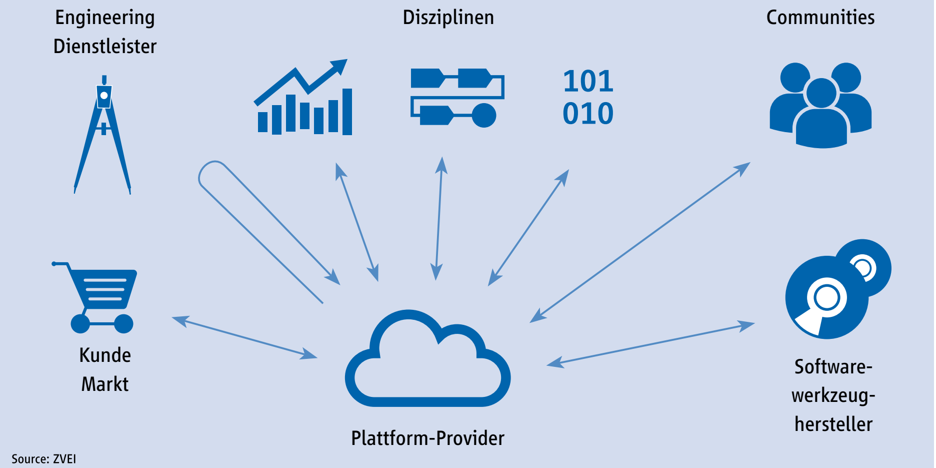
- AI Potential for platform provider: Complete Lifecycle in value chain.
- AI supported engineering tools and engineering and simulation (modelling) services.



Source: ZVEI

Innovative Product development (IPD):
The core of this application scenario are processes for innovative product development based on intelligent networking and collaboration between a wide range of actors. This is made possible by Internet-based collaboration providing shared tools, services and data.

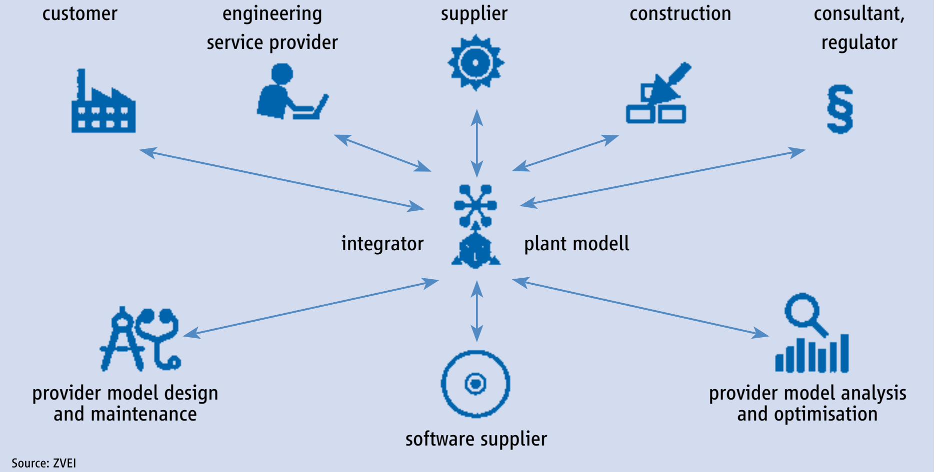
AI Potential:
- Complete Lifecycle in value chain.
- Customer centric product design in virtual world



Source: ZVEI

Seamless and Dynamic Engineering of Plants (SDP):
This scenario describes how an integrating plant model is created and used starting from an initial engineering process for setting up a system, which is maintained and kept consistent throughout the lifecycle of the realized plant in permanently interrelated processes between engineering, operation and service of the plant. This model also includes boundary conditions, context information, possible variants of the plant, conceivable and made engineering decisions as well as the potential and real effects, etc. of such decisions. (VDI - GMA technical committee 6.12, 2018). While IPD and SP2 are focussing on the product, SDP focus on a plant, which is typically tied to a location.

AI Potential:
- supporting the system engineering process, and the model creation
- During the life cycle of the plant using monitoring data and further context information to make engineering decisions.



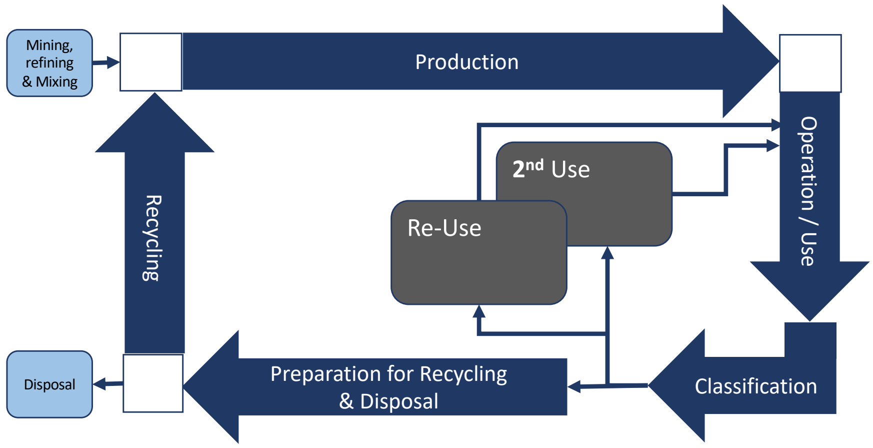
Source: ZVEI

Circular Economy (CRE):

The application scenario „circular economy" describes how industrial processes can learn from nature to use resources avoiding waste – allowing re-use, 2nd-use and recycling of products from the „cradle to the grave". Reducing the overall footprint and considering life cycle assessment.

AI Potential:

- Preparation and validation of Life Cycle Assessment Design of products and systems for "re-usability" of components contributing to "green footprint" of production.
- Supporting the classification process. AI helps to predicting the State of Function (SoF) and State of Health (SoH)



Source: ZVEI

Mobile Controlled Production – 5G for Digital Factories (MCP):

This is the first technology scenario published 2019. (Grotepass, 2019) The whitepaper discusses the enabling potential 5G offers for use cases in production and logistics. Substituting cables will lead to new design and engineering solutions in production and logistics deploying smart edge and cloud services using wireless connectivity.

Work in Progress at 5G-ACIA (5G-ACIA, 2021) reveals how network components will become assets with their services being described by administration shells (AAS). They can be treated as industry 4.0 components, featuring vendor independency and easy integration into sensors, machines and also into end 2 end applications.

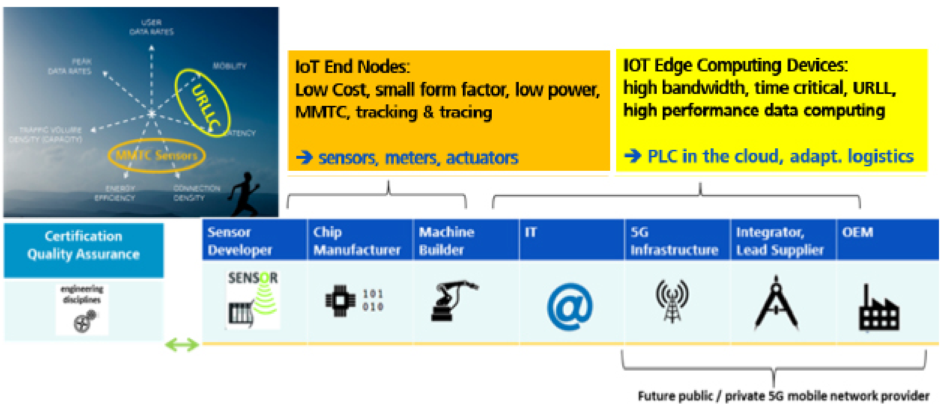
Actors in the value chain may need different types of network features (quality of service parameters) and solutions:

AI Potential:

Finding an optimal strategy for network slicing supporting industrial production and system engineering

Supporting intelligent applications for the IPv6 network (ETSI, 2020), like

- private line service,
- home broadband business
- intelligent antenna activation for indoor application optimisation
- self-healing and prediction,
- network resource arrangement and management
- IPv6 intelligent security,
- etc.



Source: ZVEI

2.3. Description of new AI enabled collaboration Use Cases from Industry

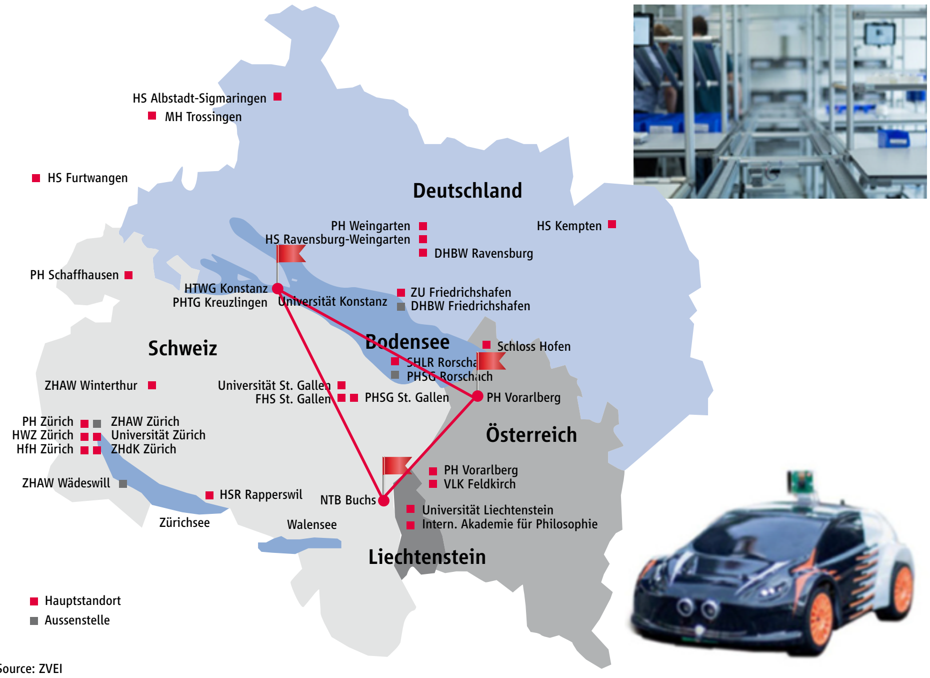
AI has the potential to leverage automation to a new level automation+ as it facilitates automated collaborative engineering between different stakeholders along the value chain across different industries.

New service-based business cases evolve encompassing value chain and manufacturing ecosystem partners.

Application Domain

Networked Production

In a common, standardised automation concept a cyber-physical system (CPS) of a car is produced allowing the manufacturing of customer dependent variants in the networked model factory.



Source: ZVEI

Owner: LNI40

Short Description: Collaborative Engineering Potential & service-based business I4Production, www.LNI40.de

The aim is to develop and simulate an international
networked process land map 4.0 based on three networked
topic related factories in three countries (Germany, Austria, Switzerland).

Modular use of networking, intelligent actuators and
Sensor technology and big data as a basis. The reprogramming in Operation is carried out by modularization and networking, not by reprogramming.

Features:
Networked Engineering and Rapid Prototyping

AI potential:
For network management of an international process land map of production facilities.

Autonomy levels: 2-4

Owner: Trumpf

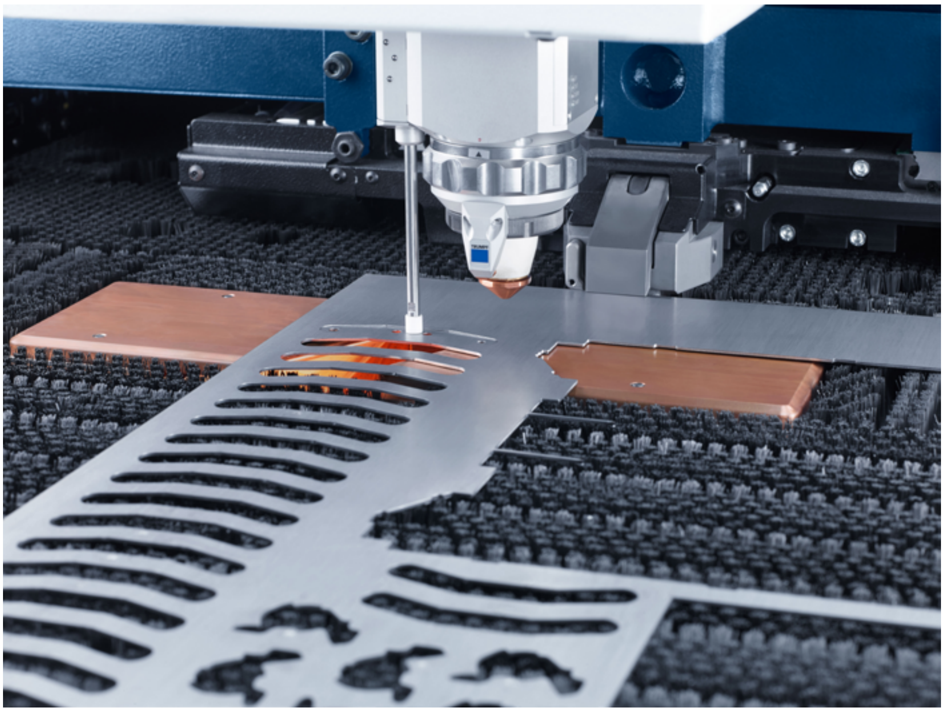
Short Description: Laser Cutting Machine with new cost model “pay by part”

Application Domain

New and disruptive production opportunities for companies in the sheet metal processing industry

Manufacturing as a Service Customers can use a TRUMPF full-service laser machine without having to buy or lease any equipment

Munich Re acts as business enabler, relayr provides IoT infrastructure



Source: TRUMPF Group

Trumpf and Muenchener Re (insurance company) have founded an Alliance to compensate for unforeseen risks from the manufacturing ecosystem effecting production.

AI potential: Risk Assessment and cost modelling

Owner: Trumpf

Short Description: Sorting Guide

Support the worker at the manual removal process at a 2D-Laser cutting machine. A computer vision system recognizes which part was grasped by the operator. All necessary intralogistics information is provided just for that specific sheet metal part.

For the AI photos of the whole sheet are provided in combination with the part taken by the operator.

Level 2-3. Not the „muscle” work is replaced but “brain” work

Hugh potential for engineering tasks (understanding how costumers are actually using the equipment) and further optimization of the productivity with an learning computer vision approach.

Owner: plus10 GmbH

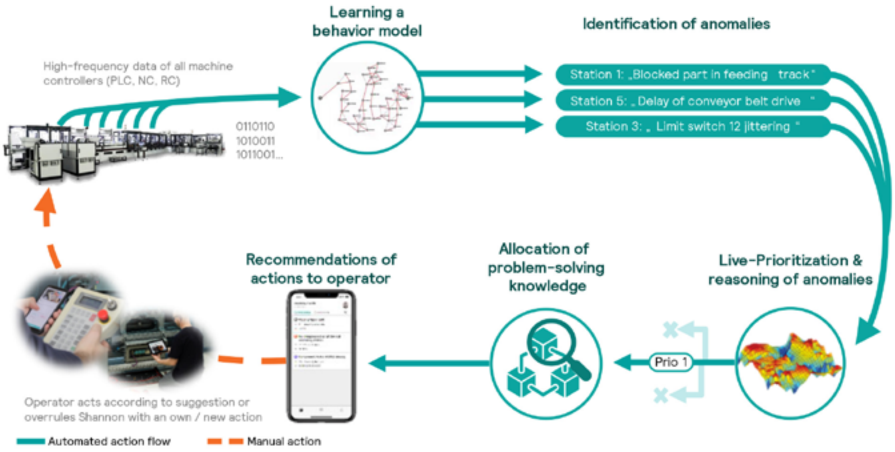
Short Description: Shannon® - Real-time solution recommender

Application Domain

Networked Production

Engineering and re-design based on AI analysed behaviour of the manufacturing system

Ramp-up support of new manufacturing equipment



Source: ZVEI

Illustration of Shannon® - Real-time solution recommender

Technical breakdowns of fully automated manufacturing lines require technical expertise and know-how to immediately detect the dedicated root-causes.

Based on high frequency data, a behaviour model can be implicitly trained to describe ongoing actions in automated production networks and allocate situational root-causes in case of technical problems.

Shannon® is currently used for ramp-up support of new manufacturing equipment to learn quickly from occurring problems, suggested root-causes and solve them immediately.

AI Potential for Engineering:

The industrial engineering department is involved in an additional feedback loop for receiving aggregated facts about the real-world manufacturing system behaviour during operations. Based on these quantitative feedback loops, the engineering departments can re-design and optimize manufacturing concepts as well as product designs to make them more efficient and effectivein terms of producibility.

2.4. Description of new AI enabled automation Use Cases from R&D

AI enabled new engineering and automation paradigms

Owner: SmartFactory-KL

Production as a Service and GAIA-X compliant architecture

Production Level 4 as demonstrator contains four innovations:

- a module exchange with automated release,
- self-learning AI methods based on deep neural networks,
- a Gaia-X system architecture

Source: SmartFactory-KL / A. Sell

Production Level 4 stands for “shared production” on a scalable trusted architecture. This use case is part of the BMBF funded R&D project SMARTMA-X under the umbrella of GAIA-X. Different production facilities across Europe may be interconnected to serve individual customer needs.

AI Potential for Engineering:

AI services (i.e. machine learning) provided from suppliers on shared data

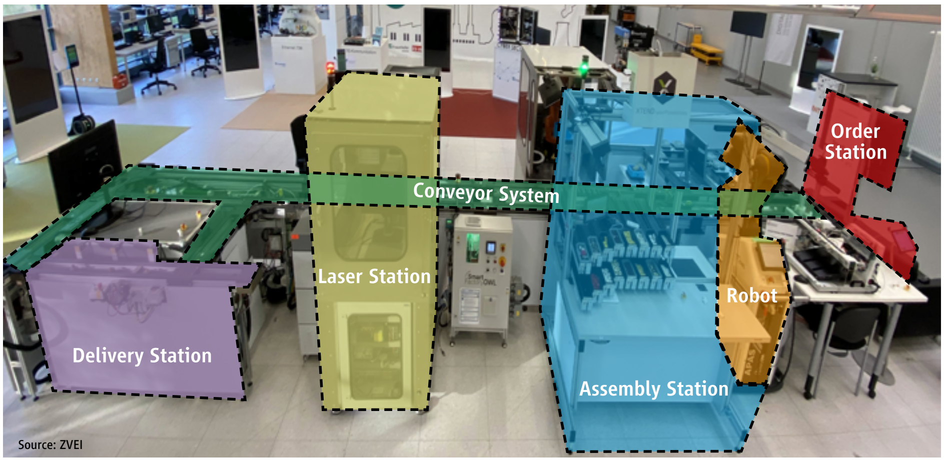
AI supported engineering and orchestration of different production facilities across Europe

https://www.elektroniknet.de/automation/smartfactory-kl-erarbeitet-shared-production.182372.2.html

Owner: SmartFactory-OWL KI Reallabor

The KI Reallabor is also funded by BMBF under the umbrella of GAIA-X. AI "Hackatons" are organized to address SME building up AI Marketplace for SME needs

An approach to achieve consistency in engineering is based on a data model that underlies all trades. Each domain can write into this model with its specific engineering tools, or extract existing data from this model.



Owner: SmartFactoryOWL

AIM (agile IT management) is an IT start-up at SmartFactoryOWL which offers cus-tom-fit solutions in Predictive Analytics, Machine Vision and Intelligent Document Management and enables customers to leverage AI & Machine Learning for industrial applications and real added value.
Fraunhofer IOSB-INA in Lemgo is a leading research institution in the field of intelli-gent automation. Research and transfer activities include technologies in intelligent networking, interoperability, data analysis and monitoring, cybersecurity as well as the user-oriented design of technical systems.

AI Methods being deployed in Use Case:
Major data processing / science tools like pandas, scikit, Tensorflow and glue com-ponents are used to automate the AI lifecycle and integrate AI building blocks in IoT environments. A machine learning model is used to learn (and predict) the behaviour of the pneumatic system – but actually only as means for the purpose of detecting differences in air flow. In fact, a major part of the work is done by signal correlations and classical statistical tests.

Use Case Autonomy Level: 0-4

3 Classification Scheme for Use Case Mapping

To further analyse the impact and business value of Artificial Intelligence used in systems engineering we need to develop a classification scheme. This scheme may become a landscape to locate scenarios and to draft change stories and roadmaps leading to future systems engineering scenarios using cognitive skills.

The RAMI 4.0 Architecture Model as seen above is a first model, which can be used to locate use cases. But there are two aspects which the RAMI 4.0 model in the current version does not consider.

The first aspect is the option to use historical data of assets and systems, which no longer exist due to their end of life. In the terminology of RAMI 4.0, those data cannot be assigned – neither to the type nor to the instance. Therefor we need to extend the life cycle axis by a third term, which describes the "digital aftermath" of assets, meaning that the asset no longer exists, but its data (for instance as digital twin) continue to be accessible. This aspect came up in the context of a proposal for a location architecture for mobility, with the aim of locating the effective variables when creating the life cycle assessment, published in the NPM's main roadmap for sustainable mobility (Nationale Plattform Mobilität - Arbeitsgruppe 6, 2020).

The second is related to the described autonomy levels which can be added as additional perspectives on slices of the Rami 4.0 model (from product to connected world), as shown in figure 8.

As a first approach we need a simple classification scheme, which allows:
- to locate use cases with reference to their autonomy level and lifecycle,
- to point out their characteristic features and further potential to provide even more benefit in the lifecycle.

In the following section we develop a proposal for such a classification scheme and its relation to RAMI 4.0.

3.1. Description of classification scheme

Perspective: Life Cycle
The life cycle should include the entire spectrum: the extraction of raw materials, operating materials and auxiliary materials, production, operation, different reuse cases, reconfigurations, recycling and disposal. The life cycle and the material chains for production according to IEC 62890 as well as the aspects of life cycle assessment (according to ISO 14040 and 14044) should be compliant and useable, data in all phases should be accessible and kept. AI based tools should be enabled to use actual and historical data for ongoing learning.

Figure 7

Source: ZVEI

Adopting the differentiation into „type" and „instance" for RAMI 4.0 we add a third phase of „digital aftermath" (or „afterlife" or "after-effects") to the life cycle axis. The „type" relates to the design of the product and the production, e.g. locates the ISO 14006 Eco-Design there. The future use, re-use, readiness for reconfiguration and recycling are part of the design and are already defined as part of the "type". The second phase describes the production as well as the primary and secondary use (re-use) and executed reconfigurations. The asset is a real part and can be identified as instance e.g. with a digital nameplate, its data during its life time can be stored in a digital life record [3].

[3] See work of Michael Rudschuck (VDE DKE) on digital nameplates and digital life records

The decision about further utilization has to be made for each asset once or more during its life. For this classification it is necessary to know the state of products, of their components and materials with regards to their functionality (State of Function, SoF) and general constitution (State of Health, SoH). At the end, the result of the classification will be "end of life". That is why the third phase is introduced for the purpose of tracking remaining components and materials of an asset after its end of life. The information will be adjusted, the digital life record of the asset kept, to ensure that the historical data of an asset can be used by AI tools and other documenting tools in future.

Perspective: Autonomy Levels

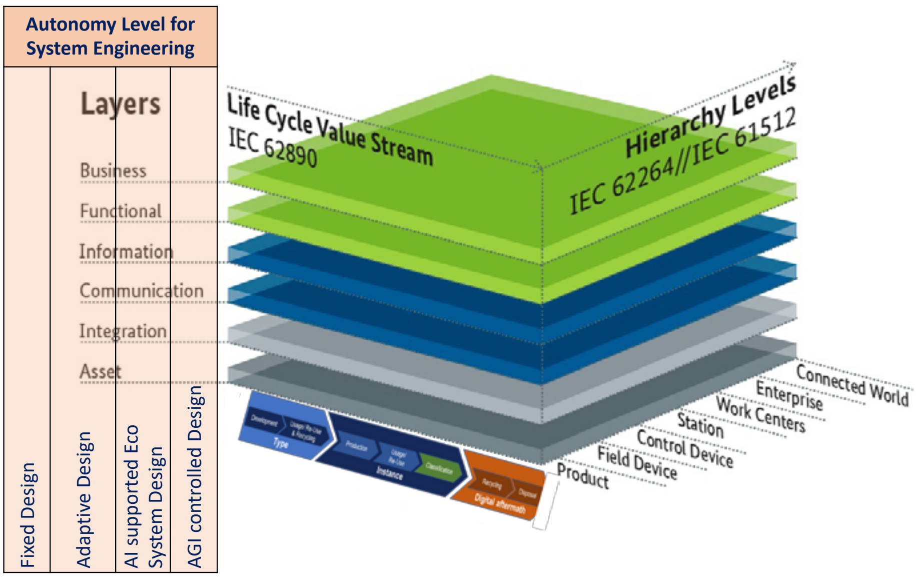
Coming back to the RAMI 4.0 Model we have noticed that we need autonomy levels as new perspectives as described in figure 8 and further differentiated in following table.

Autonomy Level	Autonomy Level for System Engineering	System Design From Fixed to AI supported, Ecosystem Design	
0-2	**Fixed Design** Brownfield optimization of existing production lines	**Product from catalog, mass production** **Impact for design of production line entities:** • New machines • Updating existing machines • Sensor Integration • Digitalisation • Programmed software algorithms	**AI/ML facets**: Rule-based, traditional programming
3	**Adaptive Design** Intermediate stage: Customization of existing, trusted design	**Customer acts as Co-designer of Products** **Impact for design on production line entities:** • Machines are adaptive • Sensors are customized • Sensors (cameras) have AI chip integrated with pre-configured AI algorithms. Data remain on premise • Machine learning onsite at process owner	**AI/ML facets**: Rule-based or supervised for neural networks
4	**AI supported Ecosystem Design** Future stage based on new platforms supporting eco systems	**AI supports customer ecosystem as Co-designer for design of production line entities:** AI analyses production capabilities, standards and proposes best matching connection of facilities • Production Modules / lines get interconnected from different locations and enterprises • Sensors are customized, data may be fused • All available Data of the ecosystem are shared for AI services • Including social networks • Domain Expert knowledge is added in expert databases for data crafting	**AI/ML facets**: Rule-based or supervised or unsupervised learning for neural networks or re-enforcement
5+	**Artificial general intelligence (AGI) controlled Design** Human centred AI definition and approach to be developed in Europe	AGI designs collaborative manufacturing Ecosystems and business. Human interaction • By defining the design intention • In dialogue with AGI 	**AI/ML facets**: AGI in combination with new type of human centred interaction

Source: ZVEI

We chose to overlay the dimension of RAMI 4.0 interoperability layers with the autonomy levels as visualised in the following picture.

Figure 8



Source: ZVEI

Focusing on systems engineering we will describe the role of AI mainly on the business and functional sublayers for the “type-phase” of the life cycle, while the involved data space for AI will use data on all interoperability layers and hierarchy levels.

In this paper we focus our classification scheme on systems engineering and we are mapping relevant scenarios to the view plane shown in Figure 9.

Figure 9

Autonomy Level	Autonomy Level for System Engineering	Development, Usage/ Re-Use & Recycling — Type	Production, Usage/ Re-Use, Classification — Instance	Recycling, Disposal — Digital aftermath
5	AGI controlled Eco System Design			
4	AI supported Eco System Design			
3	Adaptive Design			
0-2	Fixed Design			

Source: ZVEI

For each use case or scenario, we can evaluate its location within the scheme and then describe within its box :

- the impact on the process of standardisation
- the role of AI
- and how acceptance will be achieved.

In a second step we can describe what needs to be established to reach the next higher level of autonomy.

3.2. Classifying scenarios and selected use cases into the scheme

For the briefly described scenarios we will use the scheme to classify the engineering relevant scenarios and describe main arguments for classification.

OCP – Order-Controlled-Production:

AI will enable to transform traditional, sequential value aggregation chains to value creation in ecosystems. With AI a fully automated order-controlled production including automated matching and auction can be implemented as described in chapter 4. Regarding the autonomy levels, the scenario is by itself a perfect candidate for the AGI controlled engineering covering the phase “Instance (production)” of the life cycle. It still will work on the next lower level, but as it requires access to an ecosystem by its nature it will not work on lower levels. With AGI, this scenario will merge into a new complex scenario of automated system engineering (CESE) combining the scenarios OCP, SP2, IDP and SDP (see section 3.3) covering the complete life cycle.

SP2 – Smart Product Development for Smart Production:

A Smart Product Development for a Smart Production will be supported by AI in

- evaluating methodological requirements of the production and user systems
- drawing conclusions about the product design.
- Including customers‘ experiences with similar products can already be used.

- Determining the corresponding production steps and compare the producibility and price with the available or externally usable production capacities.

These tasks, addressing the phase "Typ" of the life cycle, are possible with the capabilities of AI described for the level "Adaptive Design".

In the case of a "lot 1" production the ability of the AI in combination with an ecosystem (level 4) may be used to derive the manufacturing processes that are necessary only once without dedicated work preparation.

Like OCP this scenario will end up on level 5 in new more complex scenario combining OCP, SP2, IPD and SDP.

IPD – Innovative Product Development:

Complex activities in product development, related to the phase "Typ", are automated using AI. Depending on the level of autonomy of the design out of others the following tasks can be supported:

- Starting with level "Fixed Design" for example the documentation of development projects, the use of standards, certification and information for users.

- "Adaptive Design" expands the solution horizon in engineering processes through targeted knowledge extraction from diverse sources of knowledge. Solution principles of other domains, such as chemistry, biology or social sciences can be used as well as knowledge offers from service providers, institutes and collaborative knowledge exchanges.

- Moving up to the level of "AI supported Ecosystem Design" creative processes are stimulated by AI. Simultaneous text, voice and video translation or virtualization capabilities simplify the interactions in the processes between users and providers. The customer becomes a co-designer of the product that he later uses.

With AGI this sketched scenario will end up in new more complex scenario combining OCP, SP2, IDP and SDP which will be described in section 3.3

SDP – Seamless and Dynamic engineering of Plants:

While the scenarios IPD and SP2 are focusing on the product development and therefor are applicable primarily on the phase "Type" of the life cycle, the scenario SDP covers the complete life cycle. During the "Type"-phase development und the aspect of reuse is of importance. As the scenario deals with the construction of a plant, AI on the level "Adaptive Design" can already contributes supporting the system engineering process and the model creation. In the production phase, production systems can scan the digital twin of a product using AI methods and derive the necessary processes for production. This is also possible with the capabilities of AI described for the level "Adaptive Design".

The higher level "AI supported ecosystem" is required supporting the complete life cycle of the plant, especially, if aside monitoring data further context information is used to make engineering decisions.

With AGI this scenario also will end up in the new more complex scenario mentioned above.

CRE – Circular Economy:
Circular Economy means that the reusability of the materials used has to be considered right from the start of a product's life cycle. The focus is on:

- Reuse of used but functional components, products in the primary cycle (re-use), if full functionality is given, or in secondary use scenarios, if a limited function is given that is sufficient for alternative use (2nd use).

- Repair or reconditioning of damaged or no longer fully functional components with the aim of restoring full functionality.

- Re-use of raw materials and materials after processing (recycling)

- Processing of raw materials and materials so that higher quality products are created (upcycling).

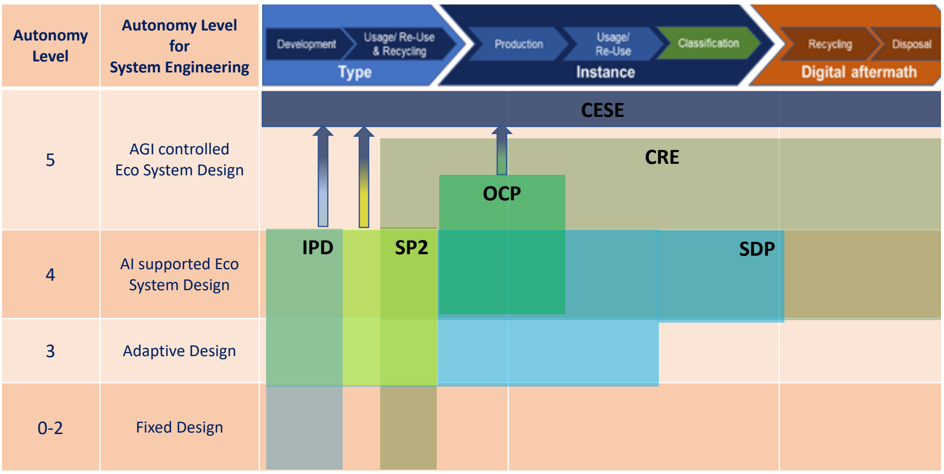
AI is required to open-up new possibilities for automating the processes of product design and use as well as recycling and subsequent disposal.
For each product and each component, the decision about further recycling, i.e. a classification, has to be made once or several times in the life cycle. It is necessary at all time to know the condition of products, of their components and materials with regard to their functionality (State of Function, SoF) and general condition (State of Health, SoH).

The use of AI can significantly increase the quality of the condition determination and, moreover, predict a critical condition that would require classification. This can be done on the level of "Fixed or Adaptive Design" (Level 1,2). With AI supported Design or AGI (level 3,4) the classification can be started and carried out fully automatically at the right time. (Nationale Plattform Mobilität - Arbeitsgruppe 6, 2020).

Circular economy as scenario will have AI based sub-scenarios on all levels. The knowledge on Life Cycle Assessment provided by an AGI will have an impact on the new scenario of automated system engineering, as this knowledge will be used for the design and system engineering.

The following figure is summarising the above discussion on the agglomerated new scenario at level 5

Figure 10



Source: ZVEI

3.3. Future scenario (Collaborative Ecosystem System Engineering – Description of AGI Controlled Design)

Systems engineering and production processes are characterized by a high degree of agility, in which the specification, the prototype implementation and the compliance with norms, standards and guidelines and their design of production lines are closely interlinked. If in the future system engineering and production should be established by an AGI controlled design with limited human interaction, we have to think of a scenario (CESE), which is a combination of the following scenarios:

- IPD: the innovative product development based on intelligent networking and collaboration between a wide range of actors (in future cases replaces by software agents),
- SP2: Smart Product Development for Smart Production enabling the design of a network for the engineering processes and automation of engineering,
- OCP: automatically placing orders to integrate the capacities and capabilities of other companies into the production.
- SDP: Using an integrating plant model for setting up a production system, which is maintained and kept consistent throughout the lifecycle of the realized plant.

The human centric aspect of AI in this new scenario of automated system engineering then consists of describing the new product as a kind of SCRUM storyline. This storyline contains the desired functionalities and properties (appearance, shape, size, material, ...), whereby the description may be even incomplete. While designing the product the human can already communicate with the AGI system asking for support. Triggered by the story line the complete system engineering process is initiated with all facets of above scenarios.

A fundamental property of the AGI system is the ability to merge the different types of restricted knowledge (e.g. declarative, procedural, sensitive) obtained with different learning methods. This ability is also called cognitive synergy as described in section 1.2 and was first described in terms of software in the "CogPrime" project (Ben Goertzel, 2014).

The system is able to continuously expand its expert knowledge to independently create Industry 4.0-compliant descriptions [4] for new products and their required production capabilities. AGI also handles the standardisation process deciding whether current standards are to be used or expanded or which new ones needs to be established. In the latter case the adjustment process is done automatically. Also included is the automatic negotiation, placement of orders to integrate capacities and capabilities of other companies into the production, as well as the monitoring of the execution, as described in the OCP scenario. We will cover special aspects of the related auction in section 4.1.

Since the underlying General Artificial Intelligence merges different types of knowledge with different learning methods (cognitive synergy), the types of content creation are also different and can come from different sources. Among others, the following sources can be used to generate knowledge in the context of system engineering:

- Databases
  Design data
  Data from installed and past machines and production lines
  Environmental data (room climate, weather, ...)
- Social networks

[4] like the Industry 4.0 asset administration shell and future extension

- Any unstructured data (including documents with texts and images (laws, ordinances, ...)

- Verbal information (Human input)
  Dialogue with experts, whereby the system speaks and debates directly with the experts using natural language processing (NLP) (e.g. based on a future version of the Watson Project Debater (IBM Research, 2021))

This requires a content management that links knowledge in a meta-representation, which itself is a semantic (neural) network that builds up a semantic memory over time. References to external knowledge or to the acquisition of knowledge with external methods are stored. Both, this semantic memory and the cognitive synergy are central entities of the AGI system.

3.4. Impact on standardization and certification - Link to IDiS

The consensus-based norms and standardization processes may also be replaced by automated AI-supported decision-making processes. Norms and standards are no longer static documents but rather „digital norms". They describe the current level of knowledge of the technical and regulatory framework, that is necessary for sustainable functioning in a global ecosystem. The „digital norms (standards)" are constantly being adapted to new knowledge that is learned from the installed products, production systems and environmental influences that change over time. Furthermore, certifications and their processes will also be changed by AGI. This includes new approaches for acceptance. The Initiative Digitale Standards — IDiS (DIN|DKE, 2021) is working on those topics, focussing on a roadmap for digital norms. AGI as the highest level is also considered.

4 Trends – the next level for cross industry business automation

4.1. Automated matching and auction for cross industry business automation

As introduced above in section 3.3 the agglomerated scenario of automated system engineering and production contains various aspects of using AI. The main process steps are:

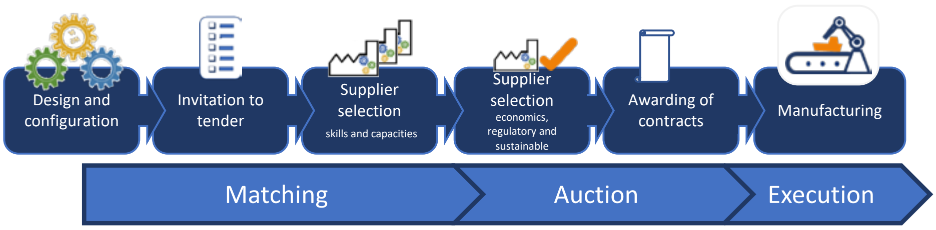
- Matching (finding the appropriate partners (suppliers)):
  (1) design and configuration
  (2) invitation to tender
  (3) supplier selection based on skills and capacities

- Auction (awarding the appropriate partners / suppliers):
  (4) supplier selection based on economics, regulatory and sustainable reasons
  (5) awarding of contracts

- Execution:
  (6) manufacturing.

The system engineering planning deals with the first steps while step 4 and 6 represent the production. In the following section we want to focus on the aspects of matching and automated auction for new types of ecosystems. The underlying scientific disciplines matching theory and auctions theory are both strands of the field market design.

Figure 11



Source: ZVEI

The Ecosystem

Before we start with the matching and auction processes it is important to have the following joint understanding:

- Ecosystems of the future will be a combination of de-centralized, edge-driven, dynamic and trusted networks rather than one central platform. Those networks will adapt to the different value chains. They respond to the requirements of the order, of standardization, of environmental regulations, of business and more.
- Those networks can be described as relationship markets, where you care with whom you are dealing in the sense of a matching market [5].
- Suppliers decide on responding to the requirements, while clients decide on accepting offers. Both consider and respond to business aspects as well as standardisation and environmental regulations, differences in legal spaces, ethical requirements and more.

[5] Matching markets are markets in which you can't just choose what you want, you also have to be chosen. (Roth, 2012). An example are labour markets, which are two-sided matching markets, where both sides have preferences. This example is close to our more complex scenario. Like in labour markets potential candidates not just accept any job offer, suppliers will not response to every client request.

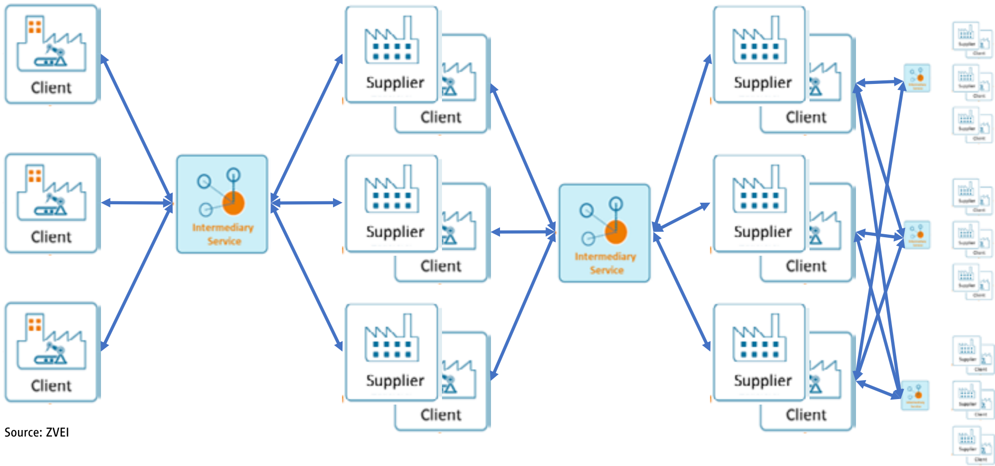
Matching and Auction — the Intermediary Service

Jointly the matching and auction arrange the collaborative network in the sense of an intermediary, who is bringing the partners together and is manging the negotiations. Therefor we call the related service "Intermediary Service", which includes both Matching and Auction.

The prerequisites for such an Intermediary Service are diverse and complex. They require a complete description of all aspects of the tender (technical, functional, business conditions including engineering requirements for production, standardisation and more) as well as the comparable information by the suppliers. In addition: general market information as well as legal frame conditions will be included. All this must happen in a standardised way, which ensures that the syntax, semantics as well as model descriptions are interpretable by all parties. We assume that this will be achieved within a more general version of the Industry 4.0 administration shell (Plattform Industrie 4.0, 2019) in future, which no longer is focussed on assets only. Further we assume AGI will help to provide all information and to generate the needed descriptions.

The Intermediary Service itself could be one central resource integrating all different sub-tasks and roles or distributed, both located at different nodes of the network and divided into different tasks as shown in fig 11.

Figure 12



Source: ZVEI

Looking at the service itself we can divide it into five sub-tasks:

1. Requestor Service (Requirements Elicitation and Ecosystem Aggregator)

The role of the demanding investigator (requestor) uses AI to analyze the production requirements of the customer-specific product. This includes production form, size, material requirements and more. As part of the service an extended system engineering in the sense of the scenario IPD is included. It uses the client-provided design data (form, size – CAx), material requirements and will, if not provided, generate the required standards and a description of the engineering requirement for production using AI.

2. The Service Description

The Service Descriptor delivers the information of the suppliers' offered production capabilities and capacities in a format that allows the possible match between supplier and customer. This role can be taken by the supplier itself or could be an additional service provided by a third party.

3. Matching Service

The Matching Service compares above information to the suppliers and thus finds possible matches between suitable potential suppliers and their functions in the value chain and the product requirements. Generally, this problem is part of the matching theory and can be described with mathematical functions. But the more complex the value chains are, the more important will be the use of AGI the find the appropriate matches.

4. The Auction Service

The Auction Service negotiates for the customer with the potential suppliers, supported by automated auction, resulting in the contractual framework for the delivery of the production network. This framework could then finally be used for an automated execution and order fulfillment control of the production. (This will be done with the help of AI in combination of blockchain technologies for smart contracts.) While the matching service compares technical features and ensures the technical feasibility the auction can introduce additional values and parameters to the negotiation. So aside the price (which will be the simple case for an auction), the following aspects can have an impact on the awarding:

- Economical footprint, compliance meeting objectives of Life Cycle Assessment
- General ethical and compliance aspects
- Laws and other legal aspects
- Time of delivery

- Further contractual terms and conditions (T&Cs)
- Optimum of minimal efforts of
  - Design
  - Production
  - Standardisation
  - Logistics

Further the format of the auction, the auctioned object and uncertainty are three aspects, which have a major impact on the outcome and have to be clearly understood and selected. The format can be open or closed, it could allow one or many bids during an auction, the auction process could be starting with initial minimal bids (English auction [6]) or initial highest bids (Dutch auction [7]), can have different rules on what price the winner pays – their own bid or the second-highest bid. The definition of the price will include the mentioned above aspects and will be challenging, why AI may play an important role.
The auctioned object is in our case a combination of objects and services, with a structure of tasks, dependencies and very flexible. The auction process may handle the complete bundled combination as unique object or may be separated into sub-processes for several objects, which then may be provided by different suppliers. In our case the value of the bundle auction will follow rules defined to achieve the best result for the customer.
Finally: Uncertainty describes the different understanding information bidders may have about the objects values as well as the fact that there are common values (which are of interests for all) and private values which apply to single parties and may or may not be known by others.
The objective of the auction process for all is to learn more about each other's estimated values during bidding process.

5. Ecosystem control (contract award and settlement)

Above tasks require an exchange of data from the various partners in the ecosystem. Sharing this data is linked to trust between the partners. The foundation for this trust is established through unique identities. To avoid abuse at this point it is important to establish a high standard of administration and control in the cooperation. This requires a high degree of automation and transparency of the communication processes and contracting, as well as an associated rights management. It is precisely this task that assumes the role of ecosystem control. This control is focused on three tasks, which can be taken by different entities:

- Client Protection: Providing a secure area of trust protecting the client's data and IP.
- Contract Management: ensuring the contract awarding and monitoring off fulfillment
- Supplier Protection: Providing a secure area of trust protecting the supplier's data and IP.

[6] The English Auction starts with an initial lowest bid that stepwise will be increased in the competition with other customers to get the auctioned object.

[7] The Dutch Auction starts with an initial highest bid that stepwise will be decremented in the competition with other suppliers to get the order from the customer.

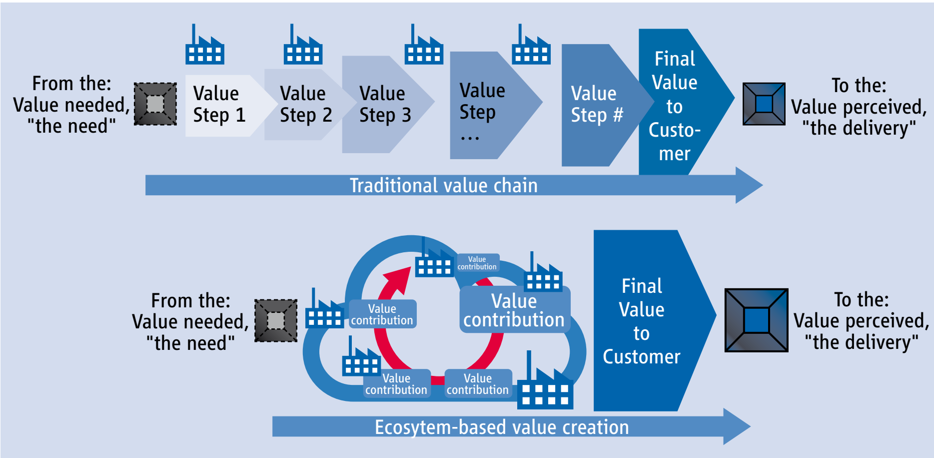
4.2. AI Ecosystem for SMEs arsing in near future – services and their business models

While section 4.1 deals with the agglomerated future scenario of an automated system engineering and production, SMEs as well as large enterprises today are faced with the need to change their business models and behaviour. This is recommended as they want to benefit from new technologies (robotics, IoT, 4G/5G, MPN, AI, Cloud, VR/AR, Digital Twins, etc.) already available.

Using external sources offered "as a service" (aaS) for the main industrial processes such as design, modelling, production, maintenance, allows the dynamic and flexible creation of multiple industrial ecosystems that bring the industry into the next level on its way to the automated system engineering and production.

Transformational and disruptive collaborative manufacturing ecosystems will show the transformation of the value creation, value distribution and value delivery to customers, moving ahead from the "traditional value chain", based on the sequential value aggregation, to the "ecosystem-based value creation" proposing the optimal cooperative value aggregation (figure 13).

Figure 13



Source: ZVEI

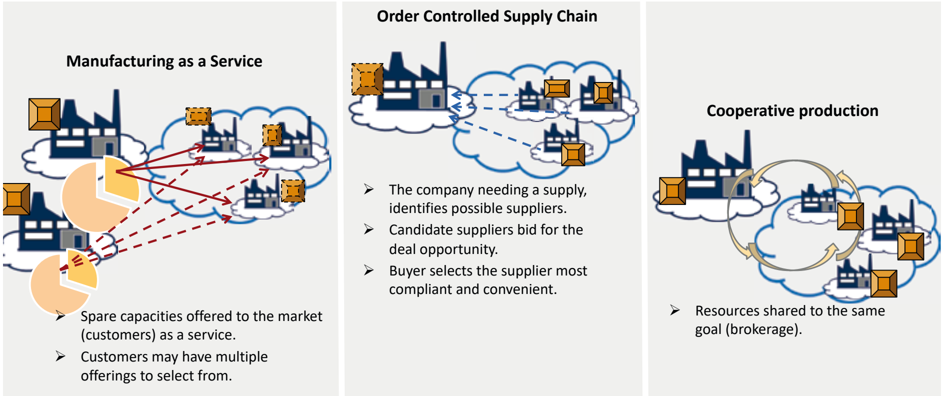
For the industrial context multiple arrangements and models can be considered, but for the SMEs we will focus on the ones that can be implemented in short term using available solutions and providers already available in the market (figure 13):

1. Manufacturing or Production as a Service (MaaS or PaaS): This is the service the supplier in the scenario OCP needs to implement for being able to offer to the market manufacturing capacity. The motivation is to offer unused spare capacities to increase the overall efficiency. Aside manufacturing this approach is applicable to other sharable capacities: Design, modeling, testing, maintenance, etc.

2. Order Controlled Supply Chain: for the flexible and accurate supply (purchasing) of the production needs. This is a first step on the way to the ordered controlled Production (OCP). Supplies are used as offered but the supply chain is automatically created and controlled by AI.

3. Cooperative production or manufacturing: where multiple-plant-capacities are managed jointly to optimize the overall productivity and efficiency. The same approach is applicable to other industrial processes: Design, modelling, testing, maintenance, etc.

Figure 14



Source: ZVEI

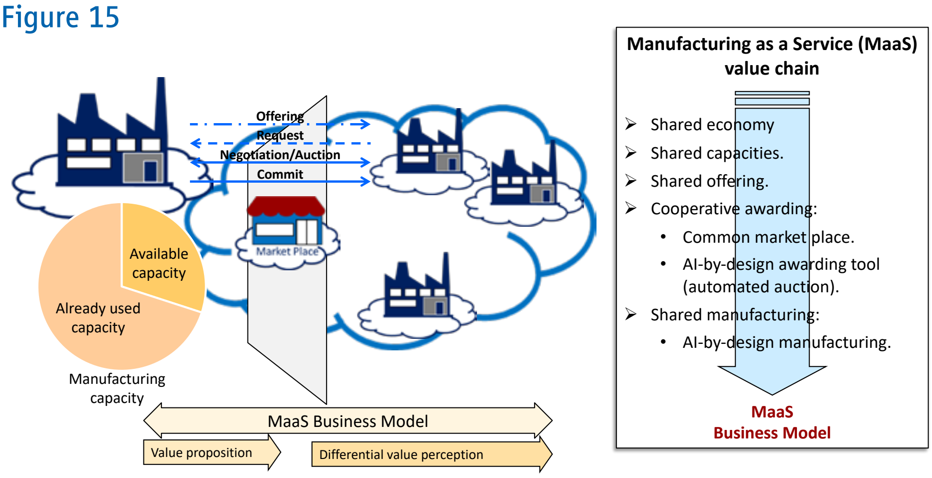
The needed operation and control of the related business as well as the resources/capacity brokerage requires an intermediary service as described, which today most likely will be implemented as "Marketplace" by a Service Provider. As we will introduce later the complexity of the Business Model may range from very simple and rigid to very complex and flexible, therefore already today the application of AI solutions and algorithms will emerge as the right solution. AI is mainly used to validate Business Models and to predict the effects on the efficiency.

Introducing the Business Model for Manufacturing as a Service (MaaS)

The MaaS ecosystem builds a business relationship between partners, where we have the partner offering its extra or spare capacities to the market for others (peers or customers) needing those capacities applying for their own production. This is a flexible way of building or increasing production capacity without the need of strong Capex investment.
The configuration of the offering can be simple or complex, searching for more or less efficiencies and results from our production capacity. For instance, provider could consider the possibility of reducing its own production activity to release more capacity to the market because the high demand will represent more benefits from him.
Rationales, dimensions, boundary conditions and algorithms defining the capacity to be offered to the market may require the support of a sophisticated system correlated with the features and capacities of the production plant. For this system the concurrence of AI solutions will become fundamental to design an appropriate offer.

The commercial relation looks simple: releasing the offer triggers requests from potential customers. They decide, if the offer matches their needs, and start the negotiation process which ends in a commitment and contractual agreement. (Figure 15). The offer may be placed on a marketplace or directly accessible at the providing party.

Figure 15



Source: ZVEI

However, the offering may be unique or multiple. It may consist of one or more types of production capacities (in the sense of a service portfolio), with different specifications, flexibilities and SLAs.

The flexibilities in the service offering, the flexibilities in the commercial conditions and the concurrence of multiple customers competing for the same resources will require sophistication on the decision process and supportive tools. When the complexity increases, AI implementations will be a promising approach (Figure 16).

An automated auction may be chosen by the provider to determine the customers, which will be awarded, automated negotiation may be included. Both require secure and trusted entities (platforms), giving confidence and confidentiality to all parties. Those entities or platforms are today provided by marketplaces.

Figure 16

	Flexibilities in the commercial conditions		
Concurrence	**None**	**Some**	**Many**
Many commitments in the concurrence	Mid-difficult auction/negotiation	Complex auction/negotiation	Complex auction/negotiation
Some commitments in the concurrence	Easy auction/negotation	Mid-difficult auction/negotiation	Complex auction/negotiation
No commitments in the concurrence	Auctionable simple	Auctionable complexity medium	Auctionable complexity high

Introducing the Business Model for Order Controlled Supply Chain

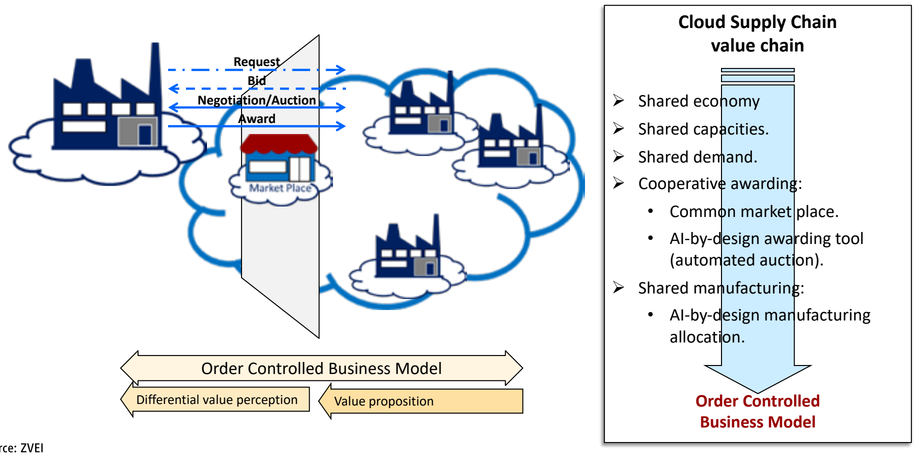
A strong supply chain is a success factor for sustainable competitive enterprises. Among the factors building that strength and resilience we see purchasing and supplier selection as one of the key levers to be managed (Figure 17).

Figure 17

Compared to MaaS, the Order Controlled Supply Chain builds similar ecosystem for a business relationship between partners, where we have the partner presenting to the market a supply need. The need, defined with the reference specifications, is presented to candidate suppliers that will deliver their proposals.

Bilateral commercial relation between parties looks simple: the release of the request, triggers proposals and bids and value proposals from candidate suppliers (maybe offering MaaS), flowed by the negotiation and finally the awarding and setting of commitments between the parties (Figure 18).

Figure 18



Source: ZVEI

The configuration of the requested need may be simple or complex, where Digital Twins may help the concretion and avoid misunderstandings.

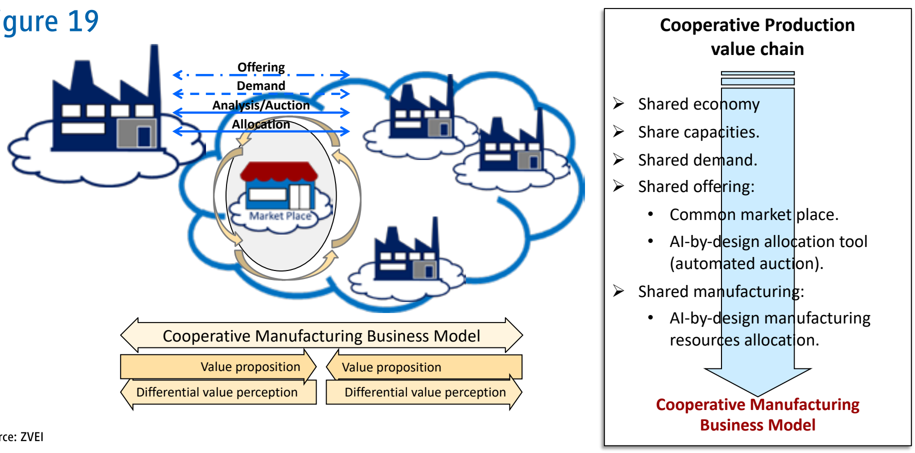
The Order Controlled Supply Chain business model requires the decision and resolution of the concurrence of multiple suppliers, which requires an analysis of the bids, analysis of the conditions, homogenization of bids, comparison and finally decision.
To achieve the optimal result, selecting the optimal supplier or optimal mix of suppliers, automated auctions or automated negotiation run by AI based marketplaces will be able to consider the many parameters in the game to achieve decisions giving parties the confidence, security and confidentiality they need.

Introducing the Business Model for Cooperative Manufacturing

Industrial Cooperative Manufacturing will take productivity, flexibility, efficiency and profitability to the optimal level, building ecosystem of resources to be shared and operated to achieve optimal results from the flexible aggregation and operation of all of them as a unique resource for the same goal. The resulting network of independent plants builds a unique and jointly used production plant (aggregation possibilities are many: plants of the same firm, plants from different firms, portions of plants, etc.).

The commercial relation that is created is multilateral among parties and very circular, where all parties share the available offerings and share the needs, which triggers the analysis and negotiations for the final optimal allocation of resources to the cooperating parties (Figure 19).

Figure 19



Source: ZVEI

The resolution and optimal decision on the allocation of resources has to be made based on the set of requirements to be fulfilled and targets to achieve, which will require the balance of multiple dimensions and factors. AI based marketplaces will optimize this brokerage function giving the parties the confidence and security they need.

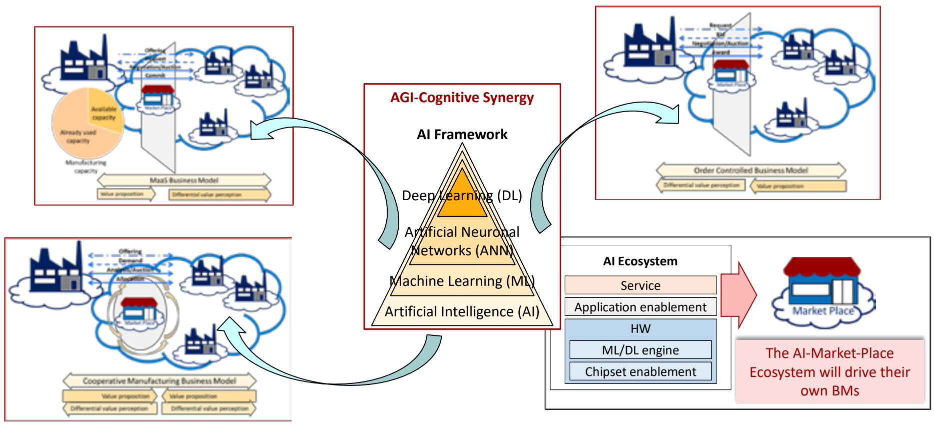
The complex map of value proposition, sharing and distribution will be optimally interpreted and decoded by the proper marketplace.

Industrial Automation Marketplaces build on AI ecosystems

AI application to the Marketplace will be a disruption in the supply chain management and in general in the value chain. The Marketplace has been addressed as a key component of the ecosystems, to orchestrate relations (value proposals, value analysis, value contributions and value distribution) and brokering resources and capacities to achieve optimal results.

XaaS offerings and the increase of complexity of the procurement configuration models will increase accuracy in the decisions and maximize results. AI technologies, with the incremental sophistication of functions and algorithms (basic AI, Machine Learning, Neuronal Networks and Deep Learning, AGI) will solve the complex equations (Figure 20). The cloudification of the marketplaces will facilitate enterprises to access the capacities needed.

Figure 20



Source: ZVEI

Marketplaces may become very complex as well, having to orchestrate and broker complex scenarios. For this the cooperation of multiple partners will be needed to achieve the expected and eventually specialized solutions in their own ecosystems. The necessary chipsets, the required HW, SW storage and computing capacities need to be engaged to deliver to customers the required applications and services serving the business models in place for the optimal business results and satisfactions.

By design, marketplaces may run on cloud and offered by a third party to all ecosystem members as a service, running for each of them their tailored algorithms to make their optimal decision.

4.3. Recommendations for Action for the efficient SME targeted AI Roadmap

Industry 4.0, automated industry, circular economy are transformational factors bringing productive benefits to the enterprises, the customers and the society. This transformational guidance applies to LEs (Large Enterprises) and SMEs (Small and Medium Enterprises), although solutions will need to be adapted to the particular needs of each enterprise. Consequently, the range of diversity will increase in the case of SMEs' solutions.

In all cases automation and cooperation will come effective with the application on AI solutions to deal with production requirements.

Progressing in the disruption of AI into core processes brings challenges such as risk of the early adoption, lack of staff and skills in the organization, eventual extra cost and investment at the early stages.

While LEs may have the budgetary muscle for a faster adoption, SMEs will need to make detailed transformation journey, adapted to their particular goals and in all cases to allow the short-term return on the effort they are putting on it.

SME targeted AI roadmap

Education and training in AI for the employees will be the first step. Access to testbeds and data in shared environments as second step will allow to roll out AI based applications for SMEs.

Initiatives by federal, National or European governments support by offering services, with focus on training, dissemination of cutting-edge technologies and testing new business cases in a safe environment. (Bundesminsiterium für Wirtschaft und Energie (BMWi), 2021) (European Commision, 2021).

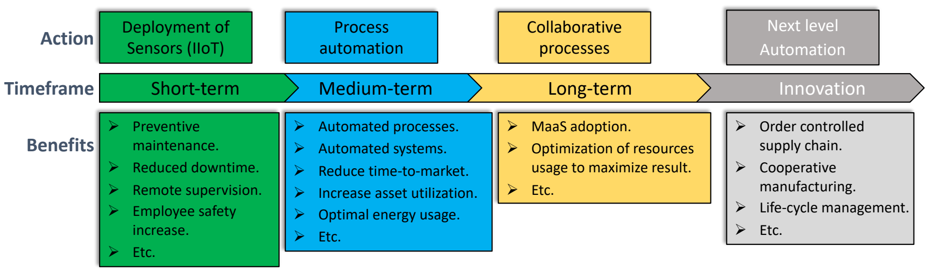
Digital Innovation Hubs (DIH) will enable SMEs to take benefit from AI developments in vertical industries, i.e. for manufacturing business. These DIH are based on local initiatives with a network of stakeholders coming from academia, research, large industry and SMEs. SMEs may connect to one of the public funded regional Industry 4.0 competence centres to learn about AI use cases. Our AI work group is willing to act as intermediary to support the matchmaking.

Figure 21

Source: ZVEI

Recommended innovation for SMEs, as the tentative roadmap that Figure 22 illustrates, should be a staged process and smooth transformation, adoptions and adaptions, as per the needs and priorities of each enterprise.

Figure 22



Source: ZVEI

Scope of innovation

The objectives for innovation in using AI for system engineering will focus on implementing prototypes of intermediary services on different marketplaces for the three business cases discussed. The intermediary services have to support:

- Access to data by connecting to networks of autonomous, sensor-based and spatially distributed production resources and components (drives, machines, robots, conveyor and storage systems, operating equipment) including their planning and control systems with economic data and processes (e.g. during order processing)
- First concepts for matching and auction

For the implementation of those prototypes a cooperation with the GAIA-X initiative and link to GAIA-X use cases in the manufacturing and Industry 4.0 domain (GAIA-X, 2021) will help to find the appropriate platform for the intermediary service. The Digital Twin Association (Industrial Digital Twin Association, 2021) will provide the required description of the resources of the network and may be interested in further develop the concept of the Industry 4.0 admin shell, enabling to use the admin shell on the business level especially for matching and auction purposes.

The following topics leading to concept for the marketplaces are independent of the above technical implementation and should be addressed in the context of creating organizations:
- Governance (risk, policy, standards and architecture management as well as their compliance)
- Business (strategy, demand, financing, accounting, procurement process and customer relationships)
- Management (operation of the overall environment)
- Security (identity management as well as application, information and infrastructure security)
- Safety
- Acceptance

To shape business models according to the industrial needs, as well as to tailor and train the AI algorithms for a prosperous application of those, the collaboration of all kinds of domain experts is necessary.

Scope of research

With AI or AGI the industrial processes themself will be more efficient and eventually simpler, but will require much-more complex systems supporting them. To get to the automated-AI-future-designed point requires a lot of design, testing and implementation and will require research on top of the detailed industrial process knowledge and AI knowledge.

In the future matching and auction, as well as the execution (see Figure 11) will be managed by AGI in a distributed network. The question, if acceptance by the users and the society will be reached, depends on the trust based on evidence that the solutions have proven to be secure, trusted by and beneficial for the humans. There is still a lot of research required as well on technical aspect as on social aspects and especially on the role of acceptance. The impact AGI unfolds strongly depends on the intention used during development process. How intention maybe controlled for AGI is also the subject of research.

It is important that we start to design this future now with our common and recognized European values of human centered AI.

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