IMPULSE PAPER

The pathway to becoming a digital champion

Achieving data economy through digital transformation

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Purpose of this publication

To provide tangible guidance on how the digitalised production 2030 target vision can be achieved with the aid of the "CCM three-point fractal" and the recently introduced "data exchange framework".

Working hypothesis of the CCM project group of Plattform Industrie 4.0

"Multilateral data sharing offers enhanced opportunities for B2B data-driven business models and value creation for all stakeholders."

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Section 1: Target vision for achieving digitalised production by 2030

The 2030 Vision for Industrie 4.0[1] sets the objective of becoming more competitive, resilient and sustainable in order to tackle global challenges more effectively. A particular focus is placed on three key areas: autonomy, interoperability and sustainability.

1. **Autonomy** this aspect underpins the freedoms of all stakeholders on the market, including companies, employees, scientists and individuals. They should be able to take self-determined, independent decisions and to interact in fair competition within the Industrie 4.0 ecosystem. This includes shaping business models and decisions to make a purchase.

2. **Interoperability:** the flexible networking of different stakeholders to form agile value networks is a key aspect of Industrie 4.0. Ensuring the interoperability of all participants is a key factor when it comes to developing complex, decentrally organised structures. A high level of interoperability is required to ensure networking of operations and processes across companies and sectors. This helps manufacturers and customers to participate in digital value networks and to develop new business models.

3. **Sustainability:** economic, environmental and social sustainability are fundamental values of Industrie 4.0. These aspects are integrated into the development and implementation of Industrie 4.0 technologies, thus enabling substantial progress on sustainability initiatives. Greater sustainability helps to improve the prosperity and quality of life of all human beings.

1 Plattform Industrie 4.0 – Leitbild für Industrie 4.0 (plattform-i40.de)

By 2030, **digitalisation in the manufacturing industry** is well advanced, having transformed value creation, work and business success. Value chains have developed into flexible, agile and globally interlinked value networks. Companies are active participants in data ecosystems. They have enhanced their business relations and business models along entire value networks, transforming them into multilateral cooperation and competition models (Coopetition[2]).

Data are regarded as resources to be used as core elements in digital business models. Not only are data collected continuously during the product manufacturing process, but they are also generated, and then processed and/or stored automatically, throughout the subsequent product lifecycle by the products themselves. This ensures the desired transparency in the value networks with respect to resilience, flexibility and sustainability, while at the same time protecting the stakeholders' autonomy.

Products and production processes have merged and digital twins interact throughout the entire product lifecycle. The Asset Administration Shell (AAS)[3] concept has developed a proven track record in terms of the structuring, semantic interoperability and access to the content of the digital twin. Within the manufacturing industry, innovative methods are being used to help resolve complexities in the production and manufacturing processes. The properties and versatility of production facilities are mainly determined by software systems.

Risk-based cyber security is factored into the full lifecycle of the physical and digital assets and is regarded as a quality feature. Appropriate security updates ensure that the security systems remain resilient throughout the lifecycle.

Corporate cultures and the mindsets, beliefs and behavioural patterns of employees have adapted to reflect the changed boundary conditions and form the backbone of the manufacturing industry.

In the manufacturing arena, this is supported by the "Manufacturing-X" data space, within which data can be protected, managed and securely exchanged, thereby facilitating a seamless interchange with other data spaces. A federated, decentralised infrastructure based on Gaia-X principles ensures data autonomy and equal access to data. The building blocks are developed and operated in the context of cross-company collaborations. On the other hand, the products and services based on those building blocks are developed and supplied on a competitive basis.

The manufacturing industry in Germany has adapted successfully to the new technological challenges, and businesses have found their feet in the changed market environment and competitive situation. They have successfully completed their respective journey to become a digital champion. **Germany is playing a leading international role in core industries.**

Figure 1 (p. 6) shows an example illustration of a data ecosystem comprising two companies, a machine supplier and a factory operator, that are linked via a logistics process.

The production environment of a factory operator is presented diagrammatically at the bottom right. The logistical connection is shown at the bottom centre and the production environment of a machine supplier is presented diagrammatically at the bottom left. Each of the physical assets, such as robots and forklifts, has an Asset Administration Shell[4] (AAS), that is to say a digital twin from Industrie 4.0. This is shown in the next layer, above the factory operator's physical production environment. The respective data produced by the physical assets are received at the bottom interface of the corresponding AAS using the relevant proprietary protocol. Consolidation/transformation of the data into a semantically interoperable data format takes place in the respective AAS.

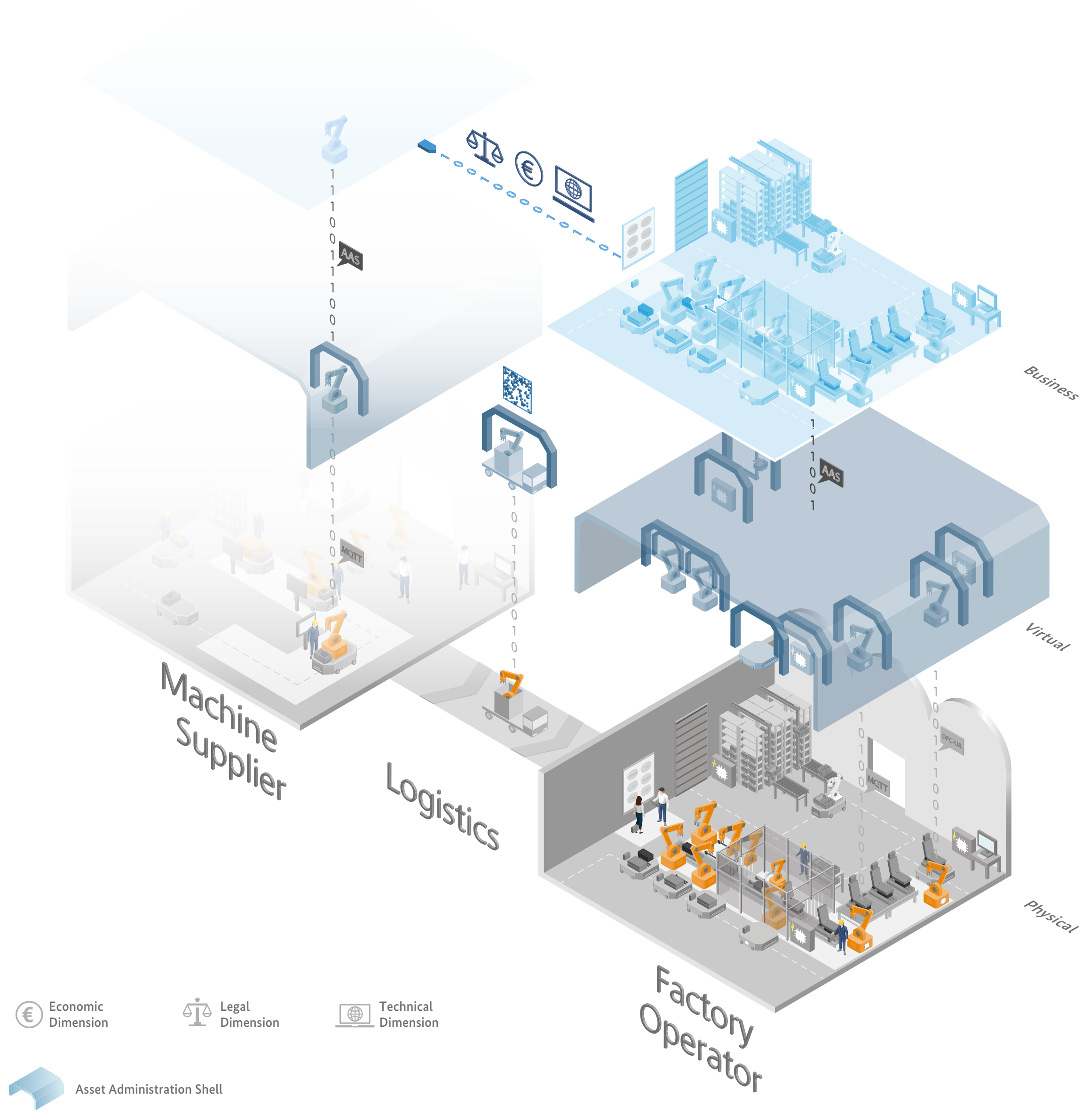
Communication with the business layer takes place via the top interface of the respective AAS using the AAS protocol. The business layer acts as the interface to the adjacent participants in the value network. Information is exchanged on the basis of economic criteria, taking into account the legal requirements, and semantically interoperable information models.

2 Coopetition – Wikipedia

3 Plattform Industrie 4.0 – What is the Asset Administration Shell from a technical perspective? (plattform-i40.de)

4 AAS-ReadingGuide_202201.pdf (plattform-i40.de)

Figure 1: Example illustration of the interrelationship between real layers and data layers, presented in the form of a wimmelpicture



Source: Plattform Industrie 4.0

Section 2: Data exchange – What's the current state of play?

One thing is clear from the target vision presented in section 1: The pathway to becoming a digital champion involves the use and mastery of data, which are regarded and managed by companies as a resource. Consequently, data present the same challenges as those presented by other resources such as energy and raw materials: Can I master everything relating to procurement or provision, production and processing, exchange, purchasing, sales, trading and quality assurance as well as the necessary safety and security processes?

When it comes to data as a resource, there is therefore a key focus on three fundamental capabilities:

1. Can I actually generate and supply all of the data that is necessary in order to become a digital champion?

2. Am I "connective" with external data partners, platforms and infrastructures?

3. Am I willing to share, exchange and trade data multilaterally, rather than bilaterally as I have done up to now, and what needs to be done in order to make that possible?

At present, bilateral interfaces between partner companies, and even within individual companies, are still standard industry practice. In the best-case scenarios this is achieved using APIs, but documents and information are often simply exchanged by email or file transfer.

Within industry that is the case, for example, when exchanging compliance documents, hazardous substance warnings or even requirements specifications. In terms of value chains (illustrated as a tier chain[5] in Figure 2 below) this takes place both upstream, i.e. from the supplier to the customer, as well as downstream, from the customer to the supplier.

In the example depicted in Figure 2 (p. 7), the OEM is sending its requirements along the tier chain to the raw materials producer (Tier n). Each supplier sequentially passes back its compliance documents and hazardous goods warnings to its immediate customer, which, in turn, packages, reformats and retransmits them in an appropriate manner, as requested by its own customer. Insofar as possible, the exchange takes place in a machine-readable format. However, the complexity and heterogeneity lead to greater effort and costs, and also restricts cooperation within the envisaged data ecosystem.

In the case of cross-company data exchanges, the following activities involve effort and costs on the supplier side:

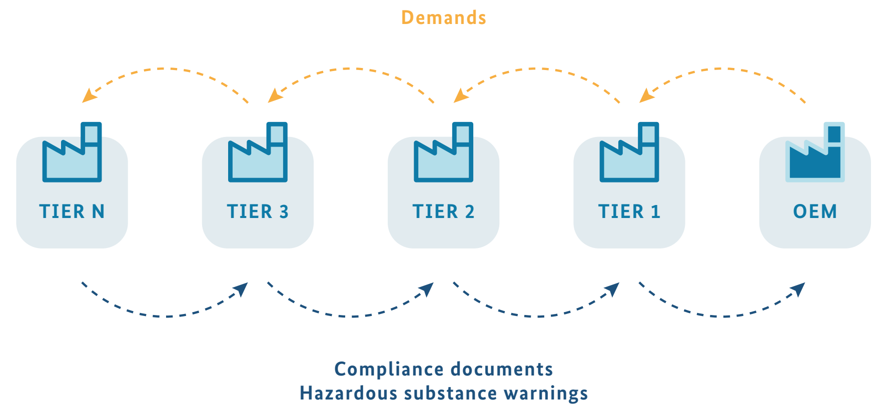
- provision of data and documents;

- formatting data and documents in the manner requested by the customer;

- delivery, or uploading the documents to the customer portal, or transmitting them via email;

5 Supply pyramid – [Wikipedia]

Figure 2: An example of an information exchange along a tier chain



Source: Plattform Industrie 4.0

- tamper-proof storage of the transfers made to the different customers;
- reviewing the shared information to confirm legal conformity (GDPR[6], competition law,[7] etc.).

On the customer side, effort and expenditure arises primarily in connection with:

- manual inspections and queries;
- correlating the received information with the customer's own batch sizes.

This customer-specific approach is – depending on the number of customer portals that have to be used – not only expensive and time consuming but also error-prone (impact on data quality).

Even within companies (e.g. between Development, Production, Sales and Aftersales or Finance), point-to-point relationships can entail considerable expenditure in terms of creating and maintaining the interfaces, while offering limited data quality.

In many cases, much of the data is not available centrally and instead remains at source (e.g. the application or database) without being used, or capable of use, in the downstream processes. A lack of uniform descriptions and semantics can often result in restrictions at their point of use.

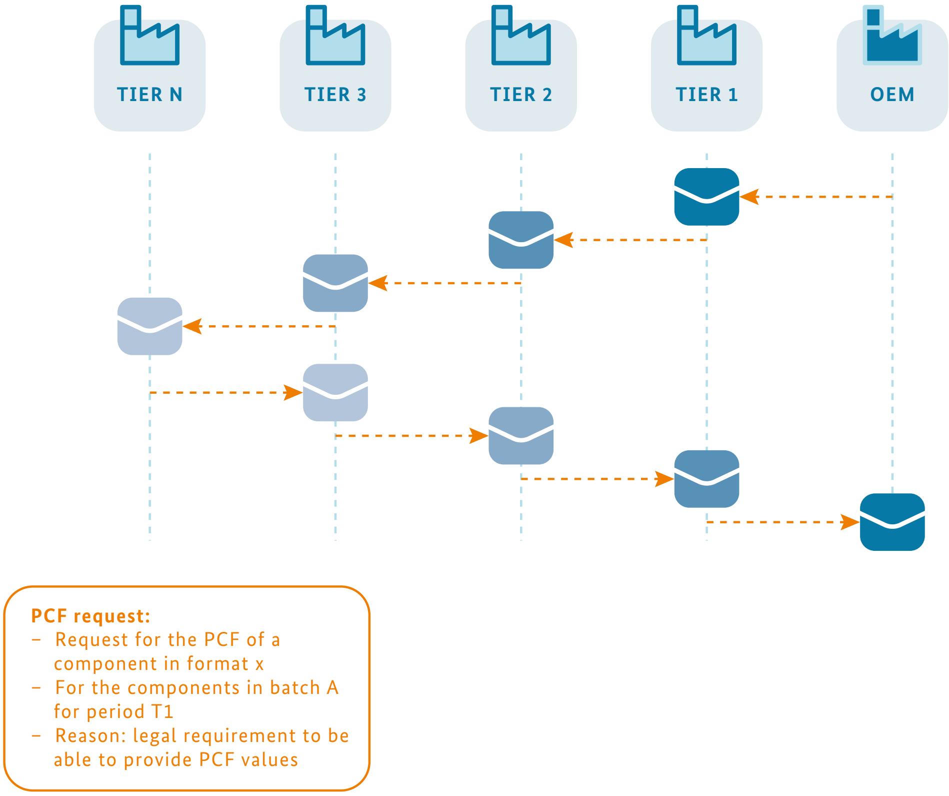
In many cases, for example, only local data models are available, but no information models at higher levels, such as domains (development, production, etc.) or industry levels (e.g. ACRIS Semantic Model[8] in the airport sector or the SID model[9] in the telecommunications sector). The semantics and the protection requirements of the data, as well as their currentness and reliability, are frequently not described or can only be accessed locally. A company-wide or cross-company overview is not available. Consequently, such data is unavailable for further use or can be made available only at great expense.

Data products and the associated data management systems (lifecycle management, quality management, availability, etc.) are available only in select cases, which presents further difficulties in terms of making the data available for cross-company data exchanges.

In both intra-company and cross-company data exchanges, individual point-to-point relationships between sources and sinks have the effect of significantly reducing the added value obtained from the data. Rather than being able to exploit the data, the point-to-point relationships within the company must be laboriously adapted in application-centric enterprise architectures, just to be able to respond to even simple requests from external partners. During exchanges with partners, the requests must be formulated in advance and, in each case, a new query must be agreed through a process of aligning the information model, the exchange formats and templates, and the exchange cycles.

6 General Data Protection Regulation (GDPR) – dejure.org
7 Competition Law (Germany) – Wikipedia
8 ACRIS Semantic Model
9 Shared Information & Data Model | Software-Wiki | Fandom

Figure 3: Example of a carbon footprint query cascade



Source: Plattform Industrie 4.0

There is also the additional burden placed on the data sources, which increases with each additional interface. Even during internal data exchanges, 40 percent of the processing power is often attributed to the interfaces. Further increases in the number of requesting point-to-point interfaces can mean that scalability limits are reached rapidly.

The figures that follow show an illustrative example of the data flow involved in processing a subsequent query to obtain the PCF (Product Carbon Footprint[10]) value for a component used by an OEM. The example is based on the simplified assumption that, at each stage, only one tier x in the chain is queried, and that that tier also provides the appropriate answer. It shows the considerable administrative costs that are involved if, for example, the query is processed by email. In this example, any adaptations that may be necessary in the course of the lifecycle, whether requested by the partner or to ensure compliance with a regulatory requirement, have not been taken into consideration.

Figure 3 shows an example of a query received from the OEM seeking to ascertain the carbon footprint of a batch, A, in period T1, stemming from components supplied by the tier 1 supplier. The query is sent in a format, x, which is specific to the OEM. The answer is requested in a format prescribed by the OEM.

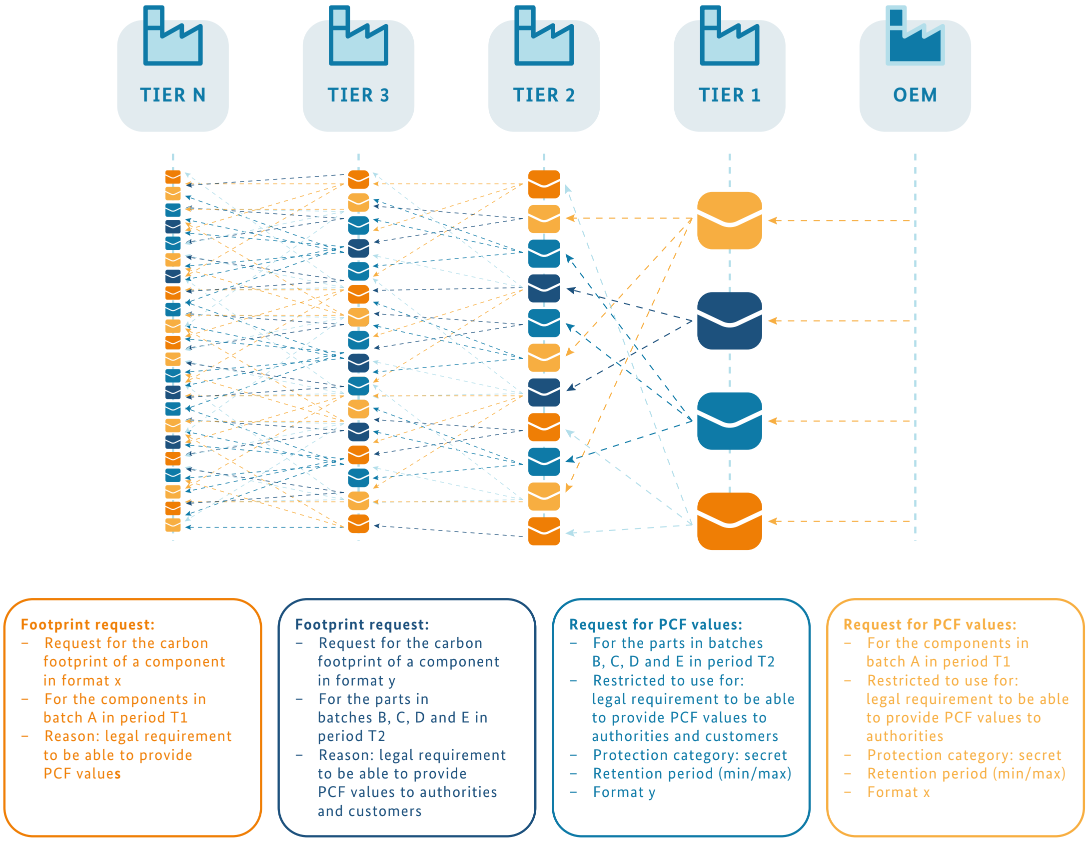
The tier 1 supplier bundles the data from all components in batch A that were supplied in the specified time period. To do so, it uses the raw data from its own company as well as from its suppliers and performs a transformation from its own company format, y, to the target format, x, of the OEM.

This query to the tier 1 supplier is not received from just one OEM but rather from different OEMs, for varying time periods and in various formats.

Similar queries are received by the other tier suppliers (represented here by the images for tier 2, 3 and n) from their respective customers in the tier chain (tiers 1, 2 and 3).

10 Carbon footprint – Wikipedia

Figure 4: An example illustrating the complexity of the query cascade for obtaining the PCF value



Source: Plattform Industrie 4.0

In this case too, the query to the tier n supplier is not received from just one tier 3 supplier but rather from different suppliers for varying time periods and batches, and in different formats.

A real-life example would involve a considerably more complex network, featuring numerous tier 1 and tier 2 suppliers, etc. Figure 4 is intended only as an example, to give an idea of the complexities involved in processing the query.

The query is sent by the OEM to four tier 1 suppliers. At the next level, each of those tier 1 suppliers sends it on to four tier 2 suppliers in turn. It is clear, even from this simple breakdown as far as level 2, that the degree of complexity to be overcome results in considerable effort, especially for the suppliers at the lower levels. This involves significant additional costs.

It is also clear that the data reconciliation along the chain from the lowest source to the sink can be comprehensibly and verifiably ensured (traceability) only by great effort.

However, exchanges involving multiple participants (multilateral exchange) along the value chain will be increasingly required:

- UFLPA (UYGHUR FORCED LABOR PREVENTION ACT)[11]
    - Prohibition on the importation of any goods, wares, articles, and merchandise mined, produced, or manufactured wholly or in part in the Xinjiang Uyghur Autonomous Region of the People's Republic of China, or produced by certain entities.
- *Lieferkettensorgfaltspflichtgesetz* (Law on Due Diligence Obligations in Supply Chains)[12]
- "Regulations" emerging from industry (consortial standards)
    - For the Catena-X[13] network, one format is defined for a given data exchange. Parties wishing to participate in the network must adopt that format.

There are also the legal framework conditions to consider, which must be clarified in each case in order to prevent, by way of example, breaches of the GDPR or competition law.

The three examples illustrate the challenges presented by advancing regulations, mechanisms and structures when it comes to implementing multilateral data exchanges. For stakeholders in the supply chain, key questions thus arise, such as:

- How can I benefit from data exchanges in an economic manner?
- How can I restrict and safeguard the purposes for which the exchanged data will be used?
- What do I need to do in order to comply with my legal obligations?
- How can I protect the security and authenticity of the exchanged data?
- How can all of the requirements be technically implemented and secured?

11 Uyghur Forced Labor Prevention Act | U.S. Customs and Border Protection (cbp.gov)

12 BMAS – Lieferkettengesetz (Federal Ministry of Labour and Social Affairs – Law on Supply Chains)

13 Catena-X Automotive Network | Catena-X

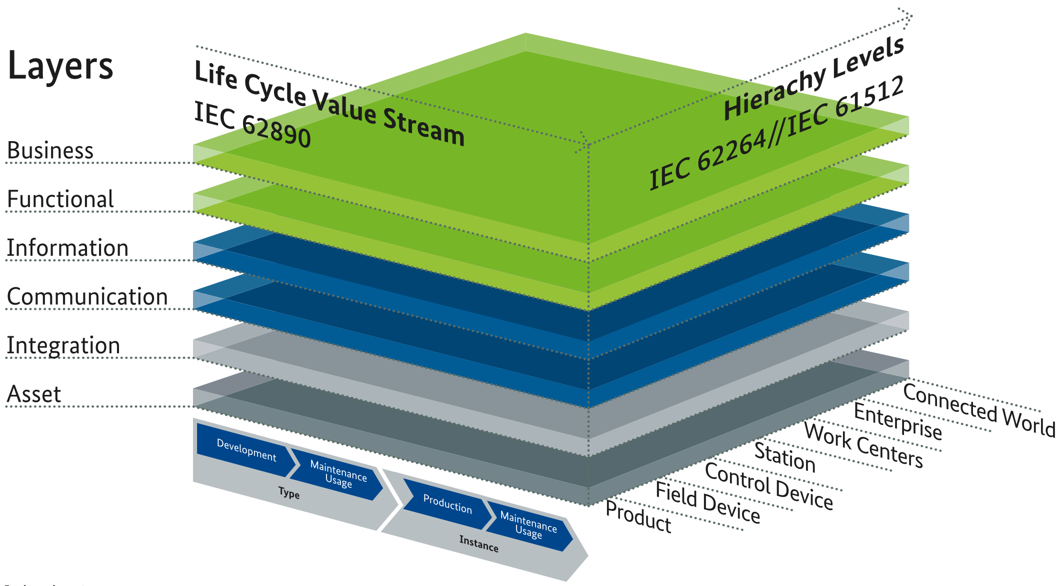
Section 3: Challenges encountered by companies during internal implementation of the target vision

3.1 Design layers from the business level to the asset level

The model of the design layers defined under the RAMI 4.0 reference architecture, which demonstrates, as illustrated in Figure 5, the implementation steps in ordered, manageable sections,[14] provides a fitting representation of the digital perspective on an intra-company implementation. Based on the business need, it is necessary for us to descend from the "business" layer to the "Asset" layer (physical factory) in order to collate the requirements. To implement those requirements, we must then climb back up the layers.

There are a variety of challenges that may be encountered on the journey towards the objective, depending on the scope and the level of digital maturity of the environment in question. It may comprise a single asset, e.g. a pump or production line, an entire factory, a process or just one process step. The RAMI 4.0 reference architecture model is available to help insure that everything is planned in a

Figure 5: RAMI 4.0 Reference architecture



Source: Plattform Industrie 4.0

14 Plattform Industrie 4.0 – RAMI 4.0 – A reference framework for digitalisation (plattform-i40.de)

structured manner and to facilitate the implementation management. It enables all of the necessary components to be separated into clear design layers and elements, thus enabling rapid decision-making and implementation. This also has the added advantage of ensuring that nothing has been forgotten.

How does RAMI 4.0 achieve that? RAMI 4.0 has been developed by the Plattform Industrie 4.0 working group "Reference architectures, standards and standardisation"[15], in the course of in-depth discussions between engineers and computer scientists across all disciplines. The result, i.e. that three completely different perspectives can be combined, or brought together in such a way that they can be collectively interconnected with each other, is just as profound. This is the critical success factor on the journey towards Industrie 4.0.

Perspective 1 (Life Cycle Value Stream) comprises the industrial processes. In this respect, RAMI differentiates between the development process and the production process. This perspective enables the appropriate processes or process steps to be precisely identified. RAMI is initially discussed in the context of discrete production processes, but may also be instantiated in process manufacturing, in conformity with the NAMUR[16] Recommendations and Standards. In some cases, this is regarded as the fourth RAMI perspective, because discrete manufacturing and process industries are being considered.

Perspective 2 (Hierarchy Levels) is the organisational perspective. Am I considering an individual product, a machine, a production line, or should I even move away from the shop floor and develop an entire factory, perhaps even a factory network? In this perspective also, I can and must decide on the focus to be given to the design tasks in question.

Perspective 3 (Layers) presents the perspective of the digital technologies and the digital business. It begins with the "Integration" layer, that is to say with the type of sensors, interfaces and outputs offered by the particular asset. The "Communication" layer addresses the networking requirements and the corresponding technologies and standards. The "Information" layer pools the design levels comprising information systems and the processed data. The "Functional" level deals with the logical clustering of functional units with business-capable units. In addition, the IT and technical capabilities are combined, in the form of an information model (e.g. the production information model), with the associated data that is required for the function. An example would be "customised contract manufacturing": What do I need to achieve all that? This is generally compiled in "capability maps", whereby the associated discipline is known as capability management. The highest layer is the "Business" layer. The business models envisaged for implementing the business strategy are finalised at this point. The business objects are also addressed under this perspective. At this point, recourse is made to the business capabilities of the "Functional" layer, or, if they are not yet available, then the following requirement is set: create for myself the business capability to provide "customised contract manufacturing".

How can this basic understanding of RAMI 4.0 assist me? In RAMI 4.0, I can find my bearings with respect to my own particular challenge. But much more importantly: I can move around in it and gradually work through all of the tasks I need to complete in order to overcome my challenge, without forgetting any important steps.

Some examples are set out below to demonstrate how this works. This is based on the assumption that the trigger for the change may emanate from either the business side or, on the other hand, from the production or technology side, or even from the factory itself. Accordingly, the "RAMI journey" begins either from the top, at the Business layer (section 3.1.1) or from the bottom, at the Asset layer (Section 3.1.2)

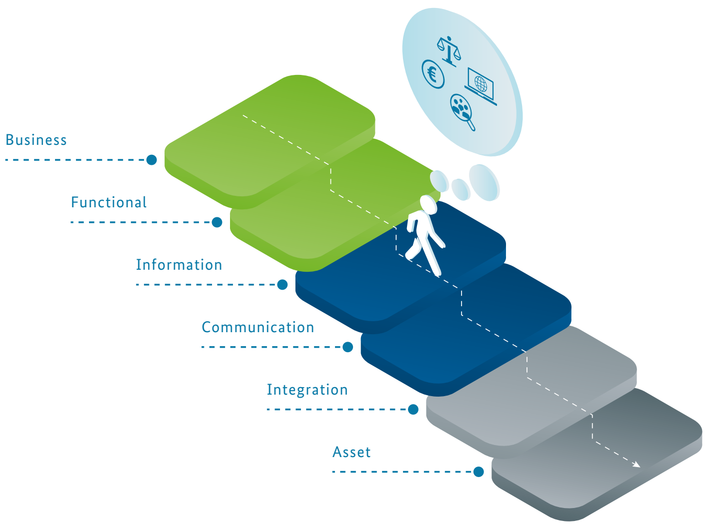
3.1.1 Descending the design levels, starting from the business strategies

Layer 6, Business: Comprises strategy, business models, organisation & business processes, business objects and all factory rules. If the introduction of new business models in the business layer means that new business capabilities are needed, for which data are a key factor, a determination will need to be made as to which data are required and in what form. Making that determination is a matter of deciding which data are particularly important from a strategic point of view, and which external relationships are relevant to the data. That includes, for example, market standards or the requirements of data ecosystems such as Catena-X or Manufacturing-X.

15 Plattform Industrie 4.0 – Working Group "Reference architectures, standards and standardisation" (plattform-i40.de)

16 NAMUR – Interessengemeinschaft Automatisierungstechnik der Prozessindustrie e.V. (User Association of Automation Technology in Process Industries)

Figure 6: RAMI journey, descending the design levels



Source: Plattform Industrie 4.0

Layer 5, Functions: The required business capabilities are described in this layer, that is to say the technical and IT requirements as well as the skills and data, in the sense of information, that are necessary to achieve those capabilities. In this layer it would be necessary to determine the point in the process at which obtaining the necessary and useful data would be desirable, as well as the function and algorithm that would be used to obtain it. Quality and originality serve as guiding principles, as does time in the sense of the required frequency, or even a need for real-time data. The determination could initially be made without regard to existing algorithms and will take account of where the actual data source is located or should be located. If the ability to use energy data from the production process is desired, that data can be obtained from measurements taken by the machinery, or by an energy management system, if one exists. Descending further, the standards to be followed, and/or any other requirements there may be in terms of syntax or semantics, are postulated from the strategy at this point. For example, is the temperature specified in Fahrenheit or Celsius? Or what signals should be used to specify whether the machine is running or not running – "1" and "0" or "on" and "off"? A strategic decision is made here regarding the standard to be followed, e.g. ECLASS[17], Umati[18] or the Asset Administration Shell, or whether the company wishes to develop its own standard for its important data because it has market power or wishes to attain it.

Layer 4, Information: Whether travelling upwards or downwards, the "Information" level of the RAMI journey presents particular challenges. Because the application and architecture of the IT systems are determined at this point, it is necessary to take decisions regarding the form in which the data "requested" by the business layer are actually to be implemented as concrete data in an application or microservice. The tension arises partly because using standard software entails standard data formats, which are usually incompatible with the required data. In such cases, it is often wise to use the standard data "as is" in the business function as well. Secondly, it is often the case that the raw data from the lower levels are also unready for use in the required form, and hence a decision must be taken at this stage regarding how to adapt the raw data. Hence, a further important decision must be taken here: Where should the data from the business model be stored? In our own data centre (on premises), in a cloud, distributed within Europe, USA or globally?

Layer 3, Communication: As of this point, we now know which data are important and valuable from a business perspective, where the data sources are and what format the data should have. It is now time for the data to actually be obtained. Access to specific data flows is structured using communications protocols. What protocols should be used to communicate temperature and power consumption?

17 Home Page – ECLASS
18 Umati – Wikipedia

While MQTT[19], OPC-UA[20] or IO-Link could be used, for example, it is also possible that elements of the Asset Administration Shell could be tapped as early as this stage. Here, it is a question of determining what is already present and what is missing.

Layer 2, Integration: If something is missing, this may be due to inadequate networking, or no networking at all. The data source is simply not integrated into a data network and cannot communicate the required useful data – a connection is required. Whether it's an Ethernet, WLAN, Time-Sensitive Networks (TSN)[21] or 5G, it makes no difference what type of network is used, provided that the requirements in terms of time and data volumes – as determined on the basis of the strategic business model described above – are fulfilled.

Layer 1, Assets: It may be the case, however, that the physical asset, sensor or machinery simply does not generate the necessary data — the twenty-year-old pump, the large press or the old oven in the heat treatment facility. In such cases, the challenge is to elicit data from those assets. Today, this is often possible with highly retrofittable sensor packages that can measure parameters such as temperature, electricity, gas or fluid flow rates, vibrations or speed. All of the assets in the factory must be given the ability to talk, in other words they must "talk data".

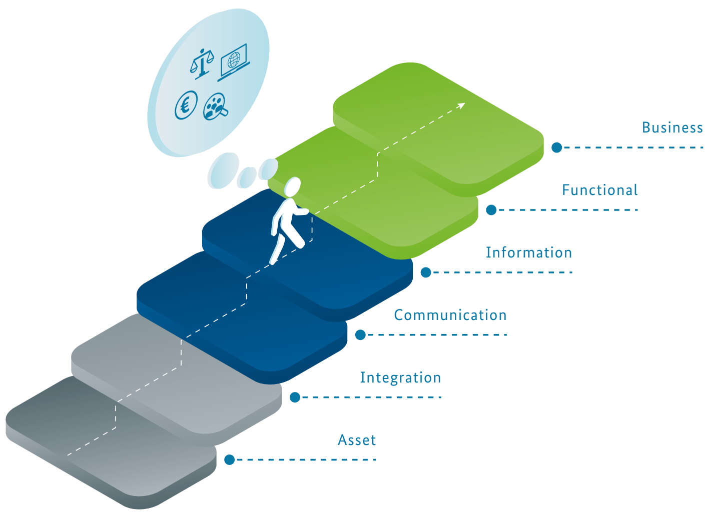
3.1.2 Ascending the design levels, starting from the assets

This perspective is helpful if, for example, data requirements are placed on a company, such as to specify energy consumption or the carbon footprint.

Layer 1, Assets: Today, the physical asset, sensor or machine usually generates data and communicates this by some method. But there may be some assets that do not do that, such as the twenty-year-old pump, the large press or the old oven in the heat treatment facility. In such cases, the challenge is therefore to elicit data from those assets. Today, this is often possible with highly retrofittable sensor packages that measure temperature; electricity, gas or fluid flow rates; vibrations; speed; and so forth. All of the assets in the factory must be given the ability to talk, in other words they must "talk data".

Layer 2, Integration: If an asset emits data, it must be integrated into a network in order that the data can be accessed remotely from the asset. The type of network that is used, such as an Ethernet, WLAN, TSN or 5G, does not matter, provided that the requirements in terms of time and data volumes are fulfilled. Figure 8 (p. 16) uses a Y-Switch to provide an illustrative example of how a data stream might be processed and further aggregated. In this example, the control data can be separated from other data.

Figure 7: RAMI journey, ascending the design levels



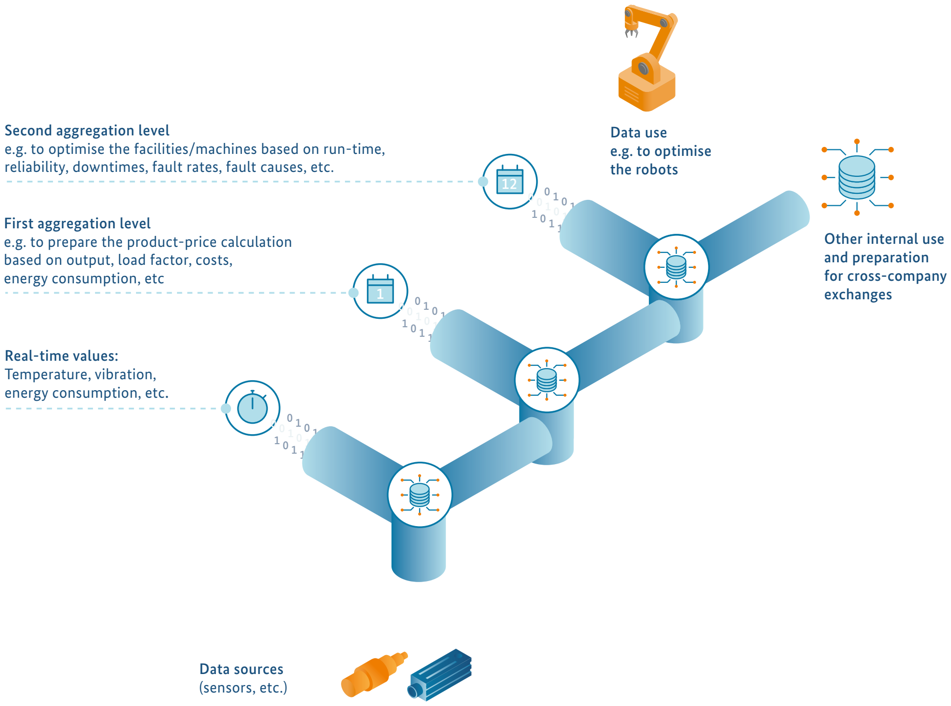
Source: Plattform Industrie 4.0

19 MQTT – Wikipedia

20 OPC Unified Architecture – Wikipedia

21 Time-Sensitive Networking – Wikipedia

Figure 8: Y-switch – Application-specific aggregation of the data streams



Source: Plattform Industrie 4.0

Alongside processing and use of the real-time values, two additional aggregation levels for preprocessing and reduction of the data flows are presented, e.g. an hourly or daily aggregation.

A Y-architecture for the process industry is described in the NAMUR Open Architecture (NOA[22]) concept. From the highly available and specially protected system components, data for monitoring and optimising (M+O) are diverted to the system-specific M+O (first level of aggregation). Forwarding to a central M+O takes place in a subsequent step (with production planning, HMI, simulation and advanced analytics).

Layer 3, Communication: Once the asset “talks” and has been connected to the network, it is time to organise access to the relevant data. What protocols should be used to communicate temperature and power consumption? While MQTT, OPC-UA or IO-Link can be used, for example, it is also possible that elements of the Asset Administration Shell could be tapped as early as this stage.

Layer 4, Information: This is potentially the most important and difficult section, particularly in the light of subsequent data sharing, syntax and, above all, semantics. At this point, it is a question of specifying the meaning of the data in sufficient detail and thus making it combinable with other data. Formats and standards play a role here. Standards such as Umati and a standardised Asset Administration Shell provide syntactical and semantic assistance in this regard. One question is where the data are to be stored – in an in-house data centre (on premises), in the Edge or in a cloud? In what environment will the data be stored, e.g. in a data lake, data mesh or in a classical database?

Layer 5, Functions: In this layer, the functionalities are logically and digitally mapped; in other words the object generated by the data or the way in which the data are used is defined. If the machine has an overheat protection system, for example, this can be simulated here as an algorithm using the limit values and the actual data. This is the algorithm layer, an important layer that depends on abundant data. In particular, the business capabilities are defined here and described in the summary of their technical and IT

22 https://www.beuth.de/de/technische-regel/namur-ne-175/329955409

data components. As such, the business capabilities defined here constitute the necessary building blocks for business layer 6.

Layer 6 "Organisation and business processes" contains all of the rules of the factory or data ecosystem, such as Catena-X, which can provide frameworks or objectives for the other layers. In this layer, the business capabilities are combined with business models and the necessary processes are developed.

3.2 The production facility of the future – physical vs. virtual

The target vision set out in section 1 emphasises that for every physical asset there is a corresponding digital twin throughout the entire product lifecycle. In the context of Industrie 4.0, the AAS is regarded as a digital twin.

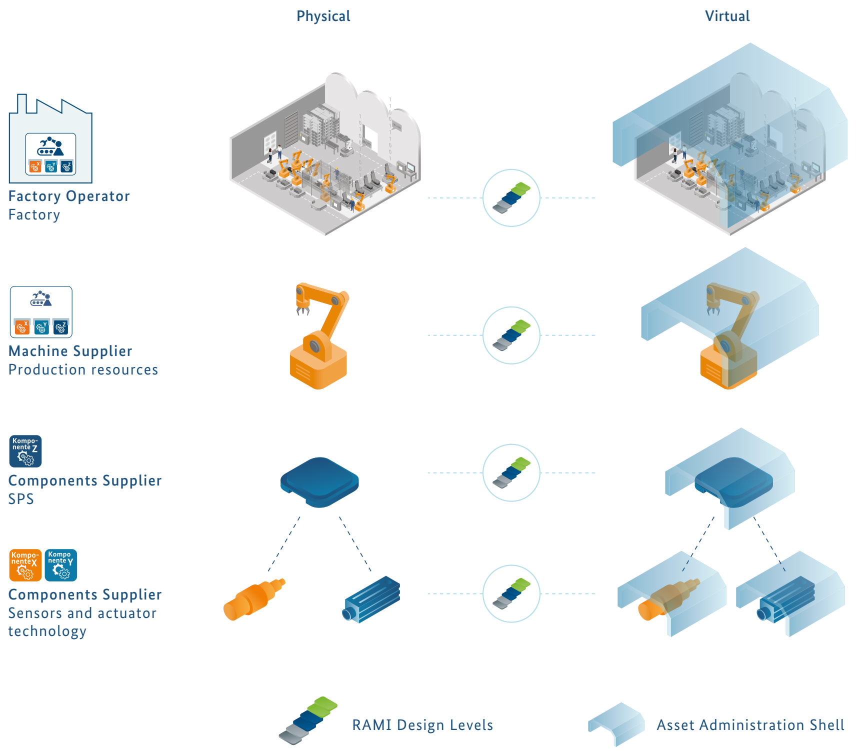
The Asset AAS concept has been developed to facilitate the structuring, semantic interoperability and access to content of the digital twin.

A factory or company can therefore be regarded as a network of physical assets, each of which is represented virtually by a digital twin. Based on the example of a machine in a company, Figure 10 illustrates the interaction between physical and virtual assets, in this case the AAS.

In the light of this example, it can therefore be seen that requirements governing the interaction between the physical and virtual world are:

- The physical asset and the respective AAS are inseparably linked to each other.
- The physical asset and the associated AAS continuously synchronise themselves.

Figure 9: Physical and virtual world



Source: Plattform Industrie 4.0

In the virtual representation of the production facility, a logical, **hierarchical "tree structure"** emerges, in which the individual application objects (AAS) must be managed by means of a suitable applications-integration system.

This gives rise to some **key questions:**

1. How should the machine supplier take ownership of the physical asset and the associated AAS for the components?

2. How is the AAS to be integrated into this logical tree structure, taking into account the technical and legal framework conditions?

3. How should the factory operator take ownership of the production facility?

4. How can a search for the "correct" AAS be performed within this structure? (e.g. by creating a catalogue, or similar)

5. As a factory operator, how can I access – by way of example – the AAS for the orange-coloured components?

3.3 The logistics of the future – physical vs. virtual

Advancements in digitalisation are impacting not only production facilities but also the entire logistics sector. The integration of digital technologies is playing a decisive role in the process of supply chain optimisation. The use of innovative solutions such as digital twins enables physical processes to be mapped to the digital world in a detailed and precise fashion, which makes it possible for goods deliveries to be monitored and controlled efficiently.

Implementing Asset Administration Shells enables companies to collect and analyse (real-time) data across the entire supply process. In addition to improving transparency, this also enables faster responses to any changes or problems in the supply chain. Furthermore, digitalisation makes it easier to identify bottlenecks, optimise inventories and shorten delivery times. Interlinking production facilities and logistics opens up fresh opportunities to improve efficiency while simultaneously reducing costs.

3.3.1 The basic requirement: unique serial numbers

The successful creation of a digital twin fundamentally depends on the allocation of unique serial numbers. Relying solely on the product number from the ERP system will not suffice. Instead, it is of vital importance that there is a unique serial number issued directly by the production unit. The serial number serves as a unique identifier, accompanying the product throughout its entire journey along the supply chain.

Accordingly, a unique serial number serves not only as a basis for identifying and tracing a physical product, it is also a vital prerequisite for creating a precisely matching digital twin that is capable of providing useful information. Linking the serial number to the corresponding digital data produces a unique digital representation of the physical object. That digital counterpart enables real-time access to comprehensive information spanning the product's entire lifecycle.

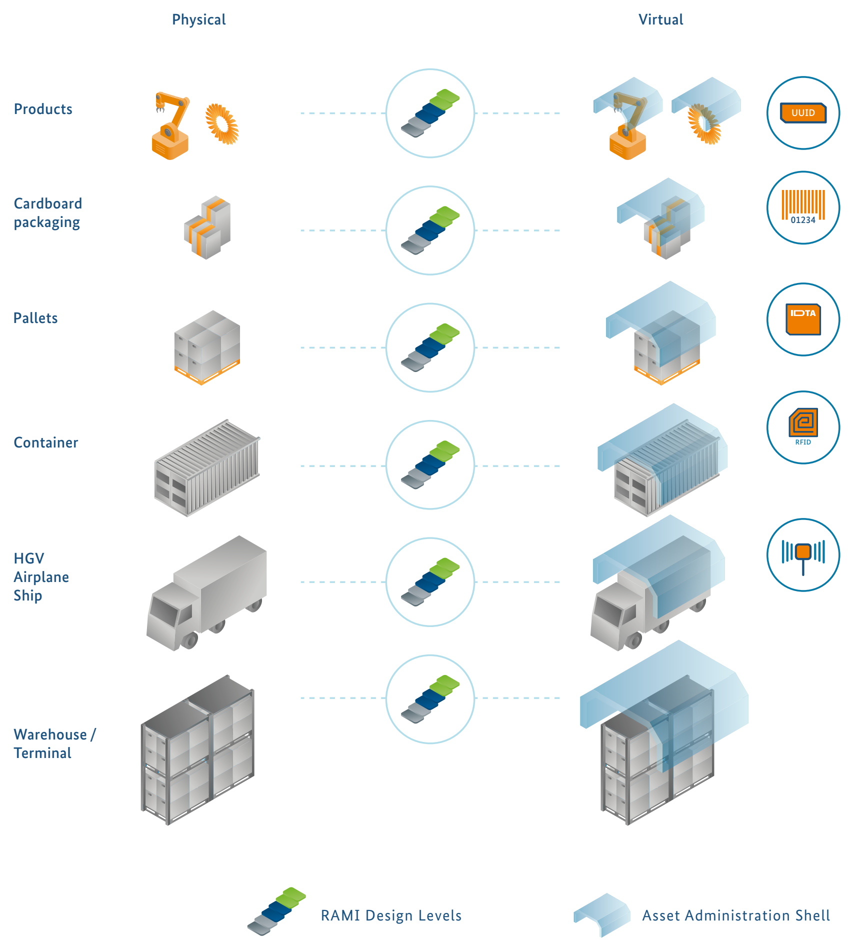
The digital twin thus acts as a virtual equivalent for the physical product, enabling its behaviour, performance and state to be monitored continuously during the logistics process. Sensors and IoT devices that are linked using the unique serial number continuously collect data, which are then fed into the digital twin.

3.3.2 Hardware and software enablement along the entire supply chain

The challenge lies not only in physically affixing the serial number but also in ensuring that it can be tracked and digitally documented during its journey along the supply chain. Meeting that challenge requires a twin upgrade encompassing both the hardware and the software. Installing printers capable of affixing the serial numbers is just as important as integrating local software solutions that can ensure the availability of those serial numbers.

The structural adaptations extend to all levels of a company, from the sensors to the machines and production lines and ultimately to the entire production plant. To ensure consistency, the physical object must be mapped to the virtual level for each layer on which products are undergoing preparation for transport or being transported (see figure). In that respect,

Figure 10: Physical and virtual logistics levels



Source: Plattform Industrie 4.0

technologies such as RFID (Radio Frequency Identification) or DMC (Data Matrix Code) can assist with the collection of information on the relevant process step. To maintain interoperability and consistency across the entire system, it is necessary to ensure that the design layers described in sections 3.1 and 3.2 are passed through for each iteration.

3.4 Connectivity (a solution approach)

In section 3 of the second publication[23] of the PG CCM, providing connectivity was identified as a core principle, in a technical, legal and economic context.

The following section sets out a solution-oriented approach for establishing connectivity from the perspective of potential data space participants.

3.4.1 Solution approach: A data mesh approach for building a data-centric architecture

Intra-company data exchanges present similar challenges to those encountered during cross-company exchanges of data (see section 2). In this respect also, questions arise concerning the availability of the data and the definition of the data sets (digital twin, certificates), as well as how the data are to be integrated into the systems and distributed or made available to the users.

23 Plattform Industrie 4.0 – Multilateral data sharing in industry (plattform-i40.de)

As previously mentioned, many companies are still largely conducting data exchanges manually or via point-to-point interfaces. Information models, master data management and data governance are often absent. However, there are some pioneers enabling cross-domain and cross-border data availability within companies by putting into effect a "data first strategy" and setting up data-centric (as opposed to application-centric) architectures.

This involves publishing data in a data hub on the basis of the "need to share" principle and mapping them to domain-specific information models. Access to the data is enabled on the basis of the "need to know" principle using an attribute-based access control method.

Even internally within companies, it is important to ensure that data are used for specific traceable purposes and are not simply passed on automatically. Data governance and data classification are therefore of crucial importance. Alongside general protection classes, meta information on the use (e.g. project, installation space) and the source (e.g. trust level, accuracy, actuality) is brought into play. This means that each use of the data is tracked and documented in a continuous data lineage.

Such effective data governance establishes a foundation that enables both intra-company and cross-company use of the data, while at the same time ensuring compliance with data protection requirements (country-specific legal provisions) and competition law, and safeguarding the data autonomy of the data producer and data controller.[24]

This applies not only in large corporate groups but also in medium-sized enterprises. Among other benefits, adopting this approach facilitates a cross-domain collaboration (e.g. between engineering, production and sales).

Drivers of that approach include projects for putting into effect the GDPR, or requirements to ensure traceability from the engineering stage to the point of use.

Another important driver underpinning this approach within companies is the increasing use of machine learning and artificial intelligence, which requires extensive data availability.

Data-centric approaches within companies are driven forward in order to lay the foundations for regulated data exchanges to take place in the course of intra-company collaborations as well as when collaborating with business partners in the ecosystem. In doing so, companies use data-centric domain architectures as a basis for creating a company data mesh. The domains (e.g. development, production – or even smaller units within a domain) are the producers of data products for the purposes of the data mesh concept.

On this basis, companies meet their internal requirements for data availability and collaboration between different business units.

The data mesh production approach releases the data from its traditional confinement in the application's data silo and elevates the data to a product level. This means that data producers will need to consider the requirements placed on their data by consumers outside of their domains, as well as the purposes for which the data will be used, and they must also provide appropriate availability and lifecycle management.

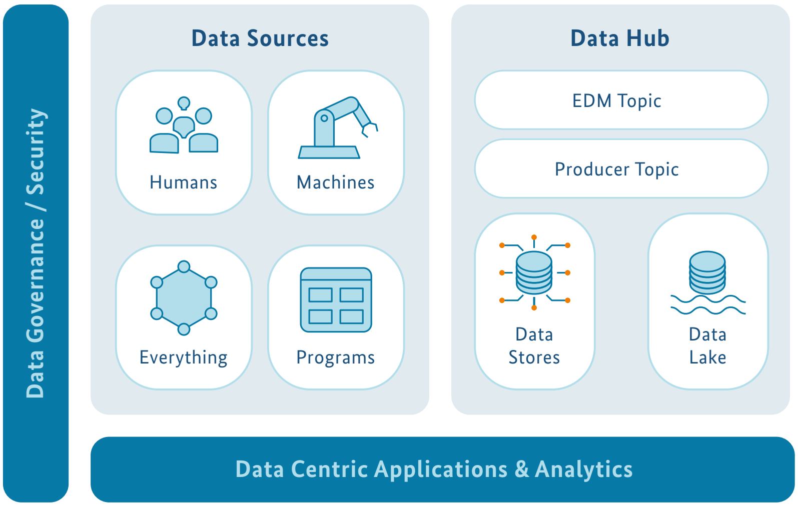
Companies proceeding in this manner will be able to make more extensive use of their own data and generate greater added value.

However, it is also important for them to prepare themselves so that they can achieve greater consistency in their collaborations between OEMs and partners, while at the same time ensuring both compliance with the legal and economic framework conditions and continuous traceability. Figure 11 (p. 21) illustrates a data mesh based on a data-centric architecture. This data mesh essentially consists of a data hub and central data governance capabilities.

In this respect, the hub and governance capabilities are multi-client capable and should be regarded as operating in a technologically hybrid environment encompassing Edge, a data centre and a hybrid cloud environment. The data hub consists of streaming components (e.g. for mapping the Y-architecture), data storage devices, data lakes and data stores (data warehouses). All data sources and data consumers are linked to the data hub. Access to and protection of the data hub, as well as the traceability of the data streams (data lineage) are handled by the multi-client capable data-governance capabilities. This includes attribute-based access control and policy-based access control (ABAC/PBAC), data and metadata catalogues, and encryption and access components.

24 See section 4.2 in Plattform Industrie 4.0 – Multilateral data sharing in industry (plattform-i40.de)

Figure 11: An architectural vision for a data mesh based on a data-centric architecture



Source: Plattform Industrie 4.0

Thanks to these core elements, every domain has the capability to expand its data mesh within this technological and governance framework. Uniform onboarding and description rules serve to simplify the control and operation mechanisms. Data sources are connected directly to the hub as producers, together with their data models. Transformation to the mesh's domain information model takes place within the hub. This means that every domain manages its own data mesh. Legal and contractual permissibility (e.g. GDPR compliance) is ensured through metadata.

As clients, the domains can describe their own information models and make them available in the data catalogue. "Subscription" to the data products then takes place either as a stream in the case of domain information topics, or as APIs or micro-UIs in the case of micro services.

Even in evolving application landscapes, adopting this solution approach will make it possible to incrementally effect a seamless transformation to a data-centric architecture. The division into domains or subdomains promotes and accelerates the transformation and provision of new data products. Using the data hub as a "data virtualisation layer" relieves old source systems from the burden of responding to requests (in the sense of the Y-architecture) and enhances data quality if provision of the information does not take place separately for analytical purposes and day-to-day use but is instead based on the same data products.

In the context of inter-company collaborations, an intra-company data mesh can also offer the advantage that dedicated information streams for exchanging data with partners and customers can be created, operated and monitored in the same manner. The data product owner for the external data products is then once again responsible solely for its own information models and data products.

Data Mesh

A data mesh is a concept for changing the way in which data are exchanged and passed on between companies. Contrary to traditional, centralised approaches in which data are collected in a central data repository and distributed from there, a data mesh requires a decentralised data architecture.

In the case of a data mesh, data are regarded as discrete, autonomous units that are administered by the respective companies or domain owners. The data units are enriched with metadata to describe their significance, context and relationships with other data. By using standardised interfaces and protocols, companies can share and link their data with other companies, without the need for a central data repository.

A data mesh makes the process of data sharing more agile, scalable and flexible. Companies can monitor their data more effectively and make better decisions as to whom they wish to share their data with. Using metadata enables other companies to identify, understand and access the available data in order to expand their knowledge or drive forward innovations.

A data mesh promotes the notion that data are to be regarded as a product. Data products are generated by domain experts who best understand their data sources. This leads to an enhanced quality of the data, thus increasing the data's value to the company.

A data mesh can also help to facilitate collaborations between companies, as it establishes a common data infrastructure that serves as a basis for companies to collaborate and learn from each other. It promotes the interoperability of data, enabling companies to concentrate on their respective core competencies, while simultaneously benefiting from data shared by other parties.

In sum, a data mesh facilitates information sharing with other companies by establishing a decentralised and networked data architecture that enables efficient sharing and linking of data. It offers a more flexible and collaborative environment for tapping the full potential from the data and driving forward innovations.

Section 4: Cornerstones of a Manufacturing-X data space

When it comes to establishing a common data space, it cannot be assumed that all participants will have the same level of maturity. While a few individual participants will already be pursuing a “data first strategy”, many will first need to address their internal company data governance in order to be able to provide the data. In that respect, the RAMI 4.0 layers outlined in section 3 help to establish a holistic view of the company data for the purposes of assessing the data’s relevance in terms of the legal, technical and economic risks and the added value. In turn, that assessment is based on the company’s own contextual circumstances, and it will need to be taken into account when designing a data space.

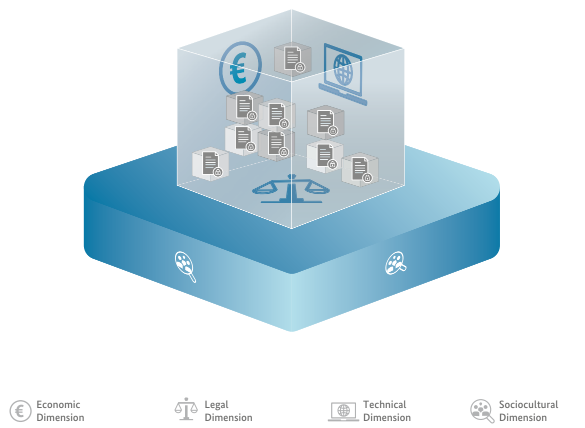
4.1 Four interconnected dimensions (3 + 1)

To ensure the scalability of a data space, it is vital that the requirements of as many participants as possible are harmonised at a common level. In that respect, it is important to take account of the potential participants’ sociocultural backgrounds alongside the three dimensions of the data exchange framework (legal, technical and economic). This results in four interconnected dimensions which serve as cornerstones for coordinating the setup of a data space.

None of the dimensions can generate added value on their own without taking into account the requirements of the other dimensions.

If, for example, the provision of data is aimed at enhancing business processes (added-value driven), the basic decision-making criteria will be based on economic motives (economic dimension).

Figure 12: A data exchange framework with a sociocultural dimension as a basis

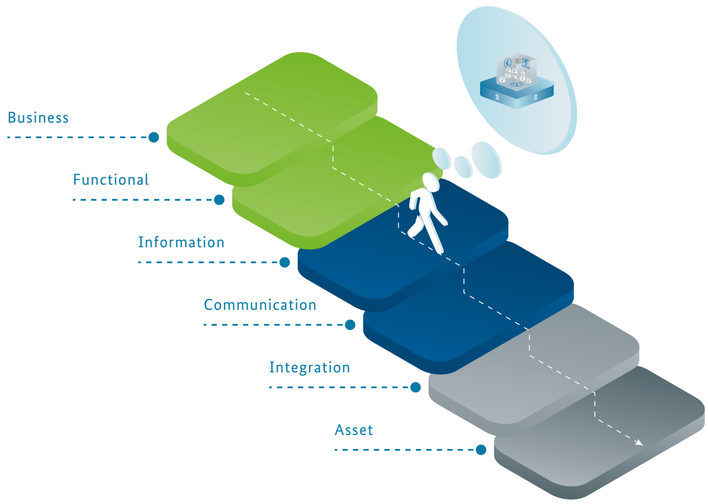


Source: Plattform Industrie 4.0

At the same time, however, it will be important to ensure that providing the data does not entail any legal ramifications (legal dimension) and that the data can be processed in a high-quality and tamper-free manner (technical dimension). Otherwise, the risks will outweigh the added value that a participant is hoping to obtain.

The risk and added value assessment depends on a very wide range of factors (e.g. degree of digital maturity, company culture/internal opinion leader, confidence in the main actors, market position/power relations) and directly impacts the decision on whether to participate in the data space. These influencing factors as a whole form the basis for the collaboration and can be regarded as a sociocultural dimension.

Figure 13: Influence of the four dimensions on all design levels



Source: Plattform Industrie 4.0

4.2 Influence of the four dimensions on the design levels

Although many companies have yet to adopt the RAMI model and different approaches are being taken, companies will need to tackle decisions relating to the design-levels model outlined in section 3 independently, in order to be able to provide data for business purposes. Even if a company has not previously adopted a data strategy, doing so is vital for the purposes of conducting a sound assessment of the costs and benefits associated with providing data to external parties.

The following figure shows an example of the impact that the four interconnected dimensions (from Figure 14) can have on the individual design levels, even at the intra-company level. At each level, all four dimensions must be considered in order to be able to assess the expected added value in the light of the legal requirements, technical possibilities and the degree of sociocultural acceptance. If a company is unable to appropriately assess the risks and added value in respect of its own data, it will not be able to make a well-informed decision as to whether or not to participate in a data space.

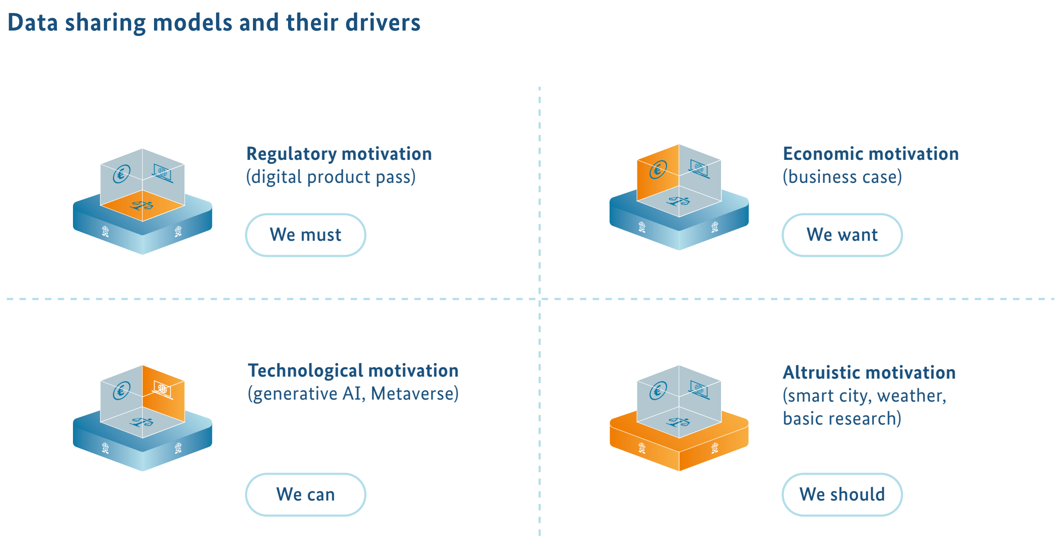
Even if, for a given design level, the discussions often focus on individual dimensions (e.g. economics of business processes), all of the dimensions must be taken into account at each level (e.g. no unlawful business processes), as otherwise they have the potential to inhibit adoption of the data space.

However, the approach used to address the individual levels will depend primarily on the company's own requirements and will be influenced – to varying degrees – by the four dimensions, irrespective of the motivation. Regardless of the order in which the decisions are taken (top-down/bottom-up), they will have a direct impact on the connectivity of a data space.

In this respect, it is important to keep in mind that it will only be possible to implement use cases for which there is agreement between the participants, vis-à-vis the relevant layers of the design-layers model, as to the minimum requirements for all four dimensions.

The weighting of the individual dimensions will also vary depending on the use case and the underlying motivation. This will become evident if different data sharing models are compared according to their initial motivation.

Figure 14: Initial motivation as a driver for data sharing models

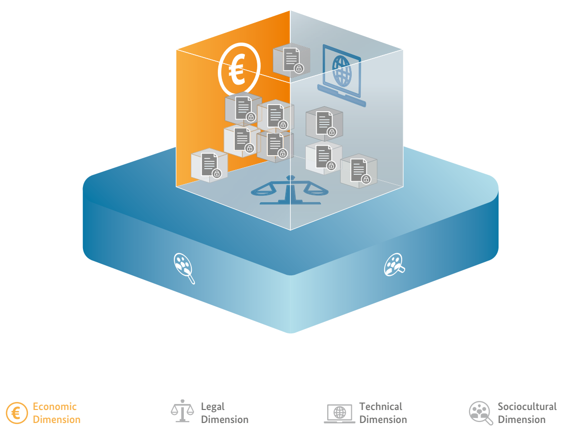


Source: Plattform Industrie 4.0

4.2.1 Economically motivated data sharing ("we want")

In cases of economically motivated data sharing, all dimensions will have a similarly high level of importance, while the sociocultural dimension will be a decisive success factor. Assessing the economic success and the legal risk will depend heavily on the individual background circumstances and the participants' individual levels of digitalisation.

Figure 15: Economically motivated data sharing



Source: Plattform Industrie 4.0

Economically motivated, multilateral data sharing is unavoidable when it comes to tapping additional efficiencies and/or market potential in the production industry, and it contributes to the working hypothesis of the CCM project group of Plattform Industrie 4.0:

> **"Multilateral data sharing offers enhanced opportunities for B2B data-driven business models and value creation for all stakeholders."**

4.2.2 Technically motivated data sharing ("we can")

In cases involving technically motivated data sharing, the technical dimension will be of primary importance. The primary motivating factor for such data spaces will often be to ensure that experiences with new technologies can be gained swiftly in order that they can be used subsequently in an effective and targeted manner. Even if it is clear that the technical dimension is the primary focus in such cases, the financial expense must compare favourably with the expected added value. At the same time, the planned use cases will need to be realisable under the applicable law and there should be a sufficient number of potential participants meeting the basic sociocultural requirements for connectivity. Neglecting one of the four interconnected dimensions in this case would increase the risk that the data space could not be scaled up to accommodate new participants in addition to the initiators and would have to be discontinued due to a lack of further development funds.

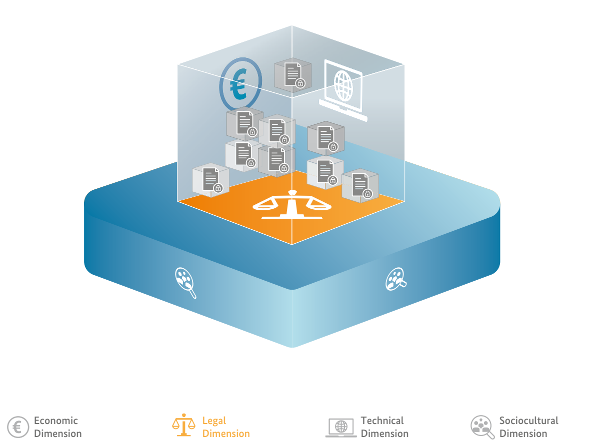
Figure 16: Technically motivated data sharing

Source: Plattform Industrie 4.0

4.2.3 Regulatory data sharing ("we must")

If the motivation for sharing data is rooted in regulatory requirements, the legal dimension will be of primary importance and will influence the other dimensions accordingly. Breaching the requirements will entail legal consequences. At the same time, those requirements must not have the effect of placing the companies concerned under excessive economic stress and they must be technically feasible and socially acceptable. Current examples of regulatory data sharing requirements can be found in connection with the digital product pass or carbon reporting.

Figure 17: Legally motivated data sharing



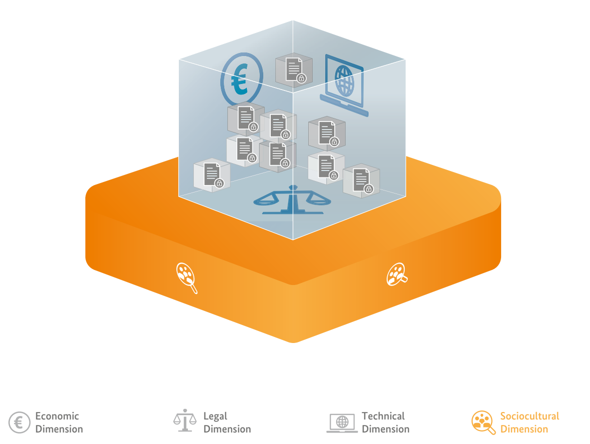
Source: Plattform Industrie 4.0

4.2.4 Altruistic data sharing ("we should")

As altruism precludes at least direct economic and legal motives, it therefore follows that altruistic data sharing is primarily concerned with the sociocultural dimension. The interests of driving common technological progress will often be a factor in this regard. At the same time, however, laws will obviously need to be complied with and financial expenditure will need to be kept in check. In some areas of basic research, for example, this is already being practised through the use of anonymised data.

Further examples of data sharing models can be found in a ZVEI publication.[25]

Figure 18: Altruistically motivated data sharing



Source: Plattform Industrie 4.0

25 Data Sharing Models in the Electro and Digital Industry (Update) (zvei.org)

4.3 Examples of design challenges associated with the four dimensions (e.g. Manufacturing-X)

As every company gives its own interpretation to the four dimensions in the context of the internal design layers, the different approaches will need to be aligned in the interests of creating a collaborative data space. In the interests of fulfilling the different perspectives, it is advisable to coordinate with the anticipated participants on a series of basic building blocks that will span the dimensions. They will need to be compatible with the participants' current maturity levels and must, in aggregate, cater sufficiently to all four dimensions in order to ensure lasting motivation for the participants. Even if individual building blocks could clearly be allocated to one of the four dimensions, their interconnectedness means that they should nevertheless be considered and agreed in the context of the other dimensions. Otherwise, initial margins of interpretation and neglect of individual dimensions will give rise to subsequent scaling difficulties, by the adaptation phase at the latest.

4.3.1 Economic dimension (motivation)

From the perspective of the economic dimension, the aim is to identify and realise added value and benefits, with a view to offering participants a concrete financial incentive to participate in a data space. The expected added value, such as new business models and services, improved customer loyalty and greater efficiencies, must be relevant for all participants and must, in the context of the applicable law, be realisable at manageable costs. Accordingly, the potential implications for the other dimensions must be considered even when addressing the economic dimension.

Example building blocks and their design requirements

Cost savings

In order to generate cost savings from a data space, it will first be necessary to ensure connectivity. However, the necessary level of investment will vary significantly among the potential participants according to their different levels of maturity (technical dimension). This may have the effect of delaying the expected returns on investment and hence, although all participants should follow one data strategy, participating in a data space may rapidly exceed the company's internal planning horizon (sociocultural dimension). Furthermore, different participants have different framework conditions (legal dimension) and savings potentials, depending on their role in the process chain. This will need to be reconciled with the required investment level beforehand.

Time savings

Even time savings, e.g. those realised through automation potential, differ based on the different working methods and time efficiencies (technical dimension). When it comes to efficiencies spanning departments, companies or value chains in particular, the individual working methods must be adjusted to match the collective aims. Carrying out that adjustment will require all participants to implement appropriate change management, which must be supported by the employees (sociocultural dimension). To be able to demonstrate concrete successes for all participants in a short space of time and justify further investments, the planned application scenarios will therefore need to be aligned as closely as possible to the current realities of the potential participants.

Quality improvement

Holistic data-based learning along a wide range of supply chains holds great potential for identifying and avoiding sources of error. At the same time, the sources of error may lie within the area of responsibility of individual stakeholders, who will in turn wish to protect themselves against potential ramifications (legal dimension). Depending on the individual error culture, these are either admitted or covered up before they are remedied (sociocultural dimension). To actually be in a position to tap the potential of such a data-based quality improvement, the participants will need to agree on how to guarantee an appropriate quality level for the data. The amount of effort required in that regard must be in proportion to the capabilities of all participants.

Organisational structures and incentive schemes for digital ecosystems

Digital ecosystems require not only that the participants have connectivity but also that they collaborate in a coordinated manner, while also working to further develop and maintain the common infrastructures. In view of the necessary expertise and technical requirements (technical dimension) only a few participants will be able to play an active role, and they will need to engage service providers or rely on participants with suitable resources. However, those parties will invest their resources in line with their own self-interests, which will rapidly lead to an imbalanced representation of interests (sociocultural dimension). To ensure that equal participation remains possible, it will therefore be necessary – even in the case of decentralised data spaces – for the rights, obligations and compensation entitlements of the operators to be clearly defined and reviewed regularly by independent service providers (legal dimension). To ensure a durable ecosystem, the associated costs must be factored in.

4.3.2 Legal dimension (compliance)

In terms of the legal dimension, there are two fundamental questions to be answered: Is it permissible for the data to be shared and how are the legal framework conditions governing such data sharing to be structured?

At present, it is only possible to provide a partial answer to the first question concerning the legal permissibility. A legal entitlement may be curtailed or precluded by both legislative and contractual constraints, or even prohibitions.

In terms of a legislative prohibition, the requirements under the General Data Protection Regulation ("GDPR") must be considered first of all. Under the GDPR, personal data processing (e.g. storage, transfer or alteration of the data) is prohibited unless authorised; in other words, processing is prohibited except in those cases where it is expressly permitted by law. In that respect, the fact that large amounts of machine data feature unwanted but almost unavoidable personal references raises difficulties. Data protection authorities have yet to issue any reliable guidelines on how personal data protection requirements should be addressed when sharing data. This means that parties involved in data sharing currently have to trust that data protection authorities will not prosecute any associated violations of the GDPR in view of the low impact on the persons concerned.

In addition to the GDPR, it is also necessary to comply with the provisions of antitrust law, which prohibit direct, and in some cases indirect, sharing of competition-related information between competitors.

Contractual restrictions on data sharing may arise out of contracts with third parties, who will generally be the data providers. For example, data sharing may be precluded under the terms of a confidentiality agreement. A "data licence" typically contains detailed provisions governing the extent to which the relevant data can be used. It is emphasised, however, that contractual restrictions apply only to the parties to the relevant contract. Unlike in the cases of copyrighted software or a patented technology, for example, use of the data is not generally prohibited if a usage licence has not been obtained. This impedes the protection of data confidentiality. When dealing with persons who are not subject to any contractual restrictions, the party who shared the data has no right to prohibit the use and transfer of that data.

The above-mentioned legislative restrictions are not necessarily set aside by legislative requirements to share data (see the section on "Regulatory data sharing"); by way of example, the requirements laid down in the GDPR are not overridden by carbon footprint regulations. Instead, the participants must ensure that the prescribed outcome is achieved in a manner that does not violate the prohibitions.

If it is concluded that the planned data sharing is permissible (or that a potential violation is so inconsequential that the possibility of a prosecution by the competent authorities can be disregarded), it will be necessary to develop the legal framework conditions on data sharing that are to apply between the parties.

Who is to share what data with whom, for what purpose, and in exchange for what consideration? For example, the essential contractual provisions of a "data licence" can be briefly summarised.

Defining the responsibilities will also be key factor. Who is responsible for deciding that the relevant data can be shared? Who is responsible for ensuring that the data content is correct and are not manipulated in any other way? Who is responsible for deciding that the data can be used for the envisaged purposes and for ensuring that they are suitable for that purpose?

In this respect, an initial check will usually be carried out – just as for any contractual arrangement governing a life-related situation – to determine who is best able to manage which risks. That does not mean, however, that the relevant person will be willing to accept that responsibility. This is because responsibility frequently entails legal questions as to liability. In other words: if responsibility for managing a given risk is accepted, who is to pay compensation for the losses or damage arising if that risk should crystallise. The responsible person concerned will therefore try to exclude as much liability as possible for the ensuing losses or damage. However, doing so will generate mistrust that undermines willingness to participate in a data sharing arrangement.

A data licence could be a bilateral arrangement, but it could also be developed as a set of usage rules governing use of a data space that would apply to all participants, or as another arrangement between multiple parties. Combinations may also be considered that take the form of general principles that apply to all participants, while allowing them the freedom, vis-à-vis a specific data sharing process, to specify the applicable rules in further detail for individual areas.

Even when considering only the legal dimensions, the weighting given to the individual contractual aspects will depend on the use case and the underlying motivation. For example, in cases involving a regulatory or altruistic motivation, the question as to the consideration to be given in exchange will not really arise. In the regulatory domain, questions as to responsibility, accuracy of the data and their suitability for the envisaged purpose are also mostly subject to mandatory rules. However, the situation is different in relation to economically motivated data sharing. In this regard, while the legal framework is also subject to the applicable law, it can be deviated from to a significant extent through contractual provisions. For example, German law provides for unlimited liability in cases of culpably caused losses or damage. However, except in a few mandatory cases (wilful damage, product liability, etc.), such liability can be contractually limited or even completely excluded.

It is clear, however, that contractual provisions allocating risks will always lead to conflicts between the parties. That is why it is so important to minimise the conceivable risks from the outset. For example, the technology can be designed in a way that ensures data immutability. Risks of loss or damage can, to a certain extent, be spread across all parties participating in the data sharing arrangement by taking out insurance cover for the relevant risks. At the present time, due to the large number of different motivations for sharing data, it is apparent only that there are still a large number of contractual arrangements catering to those motivations.

4.3.3 Technical dimension (reliability)

From the perspective of the technical dimension, the aim is to establish a fair and transparent playing field for all participants. This includes clear responsibilities and independent traceability of relevant actions, in order that relevant rights can be asserted in cases of dispute. Similarly, the economic interests (e.g. intellectual property and competitive knowledge) must be protected, and compliance with the participants' legal requirements (e.g. prevention of data misuse or GDPR compliance) must be ensured.

Example building blocks and their design requirements

Standards

Technical standards are an essential requirement for data spaces because they facilitate the interpretation of information and serve as a basis for matching data supply with data demand. However, it is not possible for data from all of the source systems to be rapidly converted into the required data formats. The process of converting the data so that they conform to the standards can therefore be cost-intensive and will require – depending on the company's level of IT maturity – the involvement of external service providers. That impacts on the economic dimension and can adversely affect the economic viability. Participant confidence in an accurate data transfer process is of vital importance for the sociocultural dimension, while the legal dimension requires traceability and verifiable data authenticity. Implementation of the standards must therefore factor in the translation processes and thus requires a balanced consideration of all dimensions and careful planning.

Data sovereignty

Data sovereignty – in other words control and ownership of the data – is a key concept in the context of data spaces, determining who has access to the data and the permissible uses. However, achieving full data autonomy can present challenges, especially for companies that are unable to act as co-operators of the data space. This is because realising data sovereignty does not lie fully within the sphere of control of such companies. From the perspective of the legal dimension, this means that the companies have to rely on the processes and mechanisms of the data space operator for the purposes of ensuring compliance with data protection laws and regulations and protecting data integrity. In terms of the sociocultural dimension, the lack of full control over the data management system can undermine confidence in the data autonomy. From an economic perspective it could, however, make sense for control over data autonomy to be assigned to third parties, especially in cases where developing and operating such functionality for the purposes of ensuring compliance with data protection legislation would involve high levels of cost. In that regard, however, it must be ensured that the risks of third-party error are either excluded or legally protected against. To enable equal participation, data autonomy will thus also need to be shaped in a way that takes account of the other dimensions.

Data reliability

Ensuring data reliability within data spaces is a multi-faceted endeavour. Technical aspects, particularly the proper functioning of identity and access management (IAM) systems, are of vital importance. Within data spaces, their functionality should be controlled independently to prevent misuse and raise confidence among the participants. At the same time, sociocultural aspects, such as transparent data practices, are of vital importance in order to build further trust among the users and take account of their perceptions regarding data security and reliability. In addition, the legal dimension can and should contribute towards increasing data reliability, through clearly defined and assessable guidelines governing collection and use of the data. From an economic perspective, a balance must also be struck between the granularity of the technical monitoring and the legal provisions governing data reliability, in order to control costs while at the same time ensuring a minimum level of reliability. Rather than operating in isolation, these different dimensions mutually influence each other and jointly contribute towards ensuring data reliability, particularly within data spaces that manage a large variety of data from different sources and in various formats.

Secure data exchange

At a first glance, ensuring a secure data exchange would also appear to be a mainly technical matter. However, if consideration is given to the different levels of IT maturity among the potential participants, it will quickly become clear that not all participants have the capacity to holistically implement appropriate security standards. To counteract that critical limitation, data spaces should facilitate the involvement of qualified service providers such as data custodians. Companies can thus decide whether to completely secure the connectivity for a data space themselves or cover parts of the requirements by engaging appropriate service providers under bilateral service contracts. In cases where the results of a data analysis are paramount, federated learning can also be used so that the sharing of sensitive data is significantly reduced. In this respect, however, the procedure for dealing with the consequences of defective code will need to be clarified, including from a legal perspective. Furthermore, many companies will not have the capability to make an appropriate and independent assessment of the risks. Provision should therefore be made for independent audits and certification of the information processing operations, in order to minimise the risks and counteract concerns about participation (sociocultural dimension).

4.3.4 Sociocultural dimension (human factor)

Willingness to participate in a data space is based on confidence that doing so will bring mutual added value for the participants. Such confidence depends on a blend of quantifiable risk and the subjective reputation of the data space. In this respect, the subjective reputation relates mainly to the initiators and is independent of individual experiences or the decision-maker's background.

Example building blocks and their design requirements

Independent guarantees and control mechanisms

Independent guarantees and control mechanisms, such as external audits, are of vital importance for ensuring confidence in a common data space. In an interconnected world in which data are shared between different organisations and countries, these facilitate objective reviews of data security, compliance and data protection measures (technical dimension). They create transparency and credibility by ensuring compliance with the applicable standards and regulations (legal dimension). To guarantee independence, the corresponding service providers should not have any self-interest in the data space or its contents. The costs associated with the use of independent, external service providers must therefore be appropriately budgeted for, similarly to the costs of the operating model (economic dimension). Without appropriate audits and informative certificates, participants that lack expertise will be reliant on the subjective reputation of the data space when it comes to assessing the technical and legal risks for themselves. Building the necessary trust will therefore be difficult, even where decentralised approaches are adopted. Alternatively, appropriate contractual guarantees may be negotiated in order to reduce the quantifiable risks for the participants. However, such guarantees must precisely define the rights and obligations of all participants and are therefore only partially suitable for a dynamic, multilateral collaboration environment. Independent guarantees and control mechanisms thus serve as cornerstones underpinning the stability and success of a common data space and must be coordinated appropriately, taking into account the four dimensions.

Company cultures

Decisions on whether or not to participate in a data space largely depend on the company culture. The different general conditions in which the companies operate form and shape their culture, as they have a corresponding impact on priorities and planning horizons. For example, a company operating in a highly regulated sector may be inclined to exercise caution and prioritise data protection, whereas a startup in an innovation-driven environment might be more flexible and have a greater risk appetite. However, both companies would be precluded from participating if the requirements for the data space differed too greatly from the requirements of the business environment. Value systems may also vary considerably. Different countries and regions have different cultural norms and business ethics. For example, while some companies regard employee cost savings as attractive, others are hesitant to engage in such cost savings because they value social responsibility or they wish to pursue a more distinctive business strategy. The diversity of the value systems that can be found in different countries and regions has a direct impact on how those companies rate the added value that they can expect to gain from participating in the data space.

Power dynamics in the value network

Power dynamics in the value network and the associated experiences of the participants are also decisive factors underlying motivation to participate. If the initiators of a data space hold a position of power, this may encourage other companies in the value network to join a data space. However, such a decision to join is not rooted in self-motivation since, in cases of uncertainty, a refusal could have critical adverse consequences for smaller companies. Although, in that context, it can be assumed that the participants are fulfilling their obligations, this is inconsistent with the notion of an equal, multilateral collaboration. If there is no personal added value that extends beyond mere necessity ("must-do") then companies will limit their involvement to that which is necessary and will gratefully seize upon alternative cooperation models if the opportunity should arise. True cooperation requires an equal footing Hence, a common data space should go some way towards counteracting existing power dynamics, while ensuring added value for all participants. The full potential of a multilateral collaboration can be realised only if as many participants as possible are making an active contribution and generating mutual added value.

System confidence

Confidence in a system that extends beyond technical aspects to include the community, the government and other societal institutions significantly increases willingness to participate in a data space. If people or companies have confidence in the stability and integrity of such social structures, they will be more inclined to share their data and information. That confidence stems from the perception that their data will be handled in an ethical and legally compliant manner. A high degree of confidence in the social and political systems creates an atmosphere of trust and cooperation, thus facilitating participation in a data space. On the other hand, a lack of confidence in those systems can significantly limit willingness to share data because the participants have concerns about misuse or infringements of their rights. In this respect, it is important to note that the company's own assessment will depend significantly on the decision-maker's prior experiences. This aspect assumes even greater prominence if, for example, international cooperation is involved, since confidence in third-party systems cannot automatically be taken for granted. To address that issue, it is essential to offer a range of verification mechanisms that are appropriate to the capabilities and requirements of the potential participants in the context of the four dimensions.

4.4 Data space connectivity (solution approach)

In section 3 of the second publication[26] of the PG CCM, providing connectivity was identified as a core principle, in a technical, legal and economic context. When connecting to a data space, participants should face as few hurdles as possible and costs must be kept to a minimum.

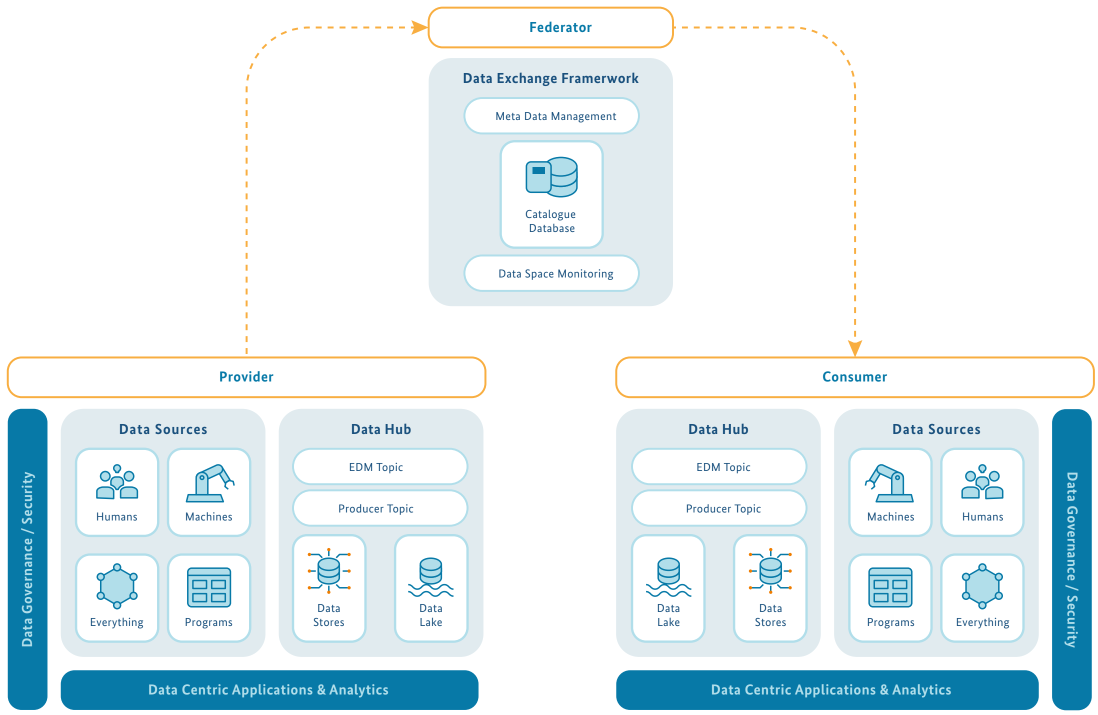
This is currently being tested in a variety of data space projects such as Catena-X. Data sharing within the project takes place on the basis of a standardised connector (EDC/Eclipse Dataspace Connector[27]), standardised data models based on the Asset Administration Shell and their component models for realising use cases. These building blocks are prerequisites for cross-company data sharing. KITS[28] (toolboxes) and services such as "EDC as a service" are provided to facilitate access for companies. In that regard, Catena-X also develops open-source solutions in the Eclipse Foundation (Tractus-X[29]).

4.4.1 Solution approach: collaboration via a federator

Federators provide essential services for data spaces. Under the Gaia-X[30] concept, a federator is a service that forms the technical basis for developing and operating a Gaia-X federation. Gaia-X federations are associations of companies and organisations that jointly develop and operate an ecosystem facilitating the safe and autonomous exchange of data and services.

Participants in the data space thus have certainty regarding the partners they are dealing with and their data exchanges with those partners will benefit from contractual protections. They will also be able to access a catalogue of all available resources such as data, services and infrastructure. The actual data exchange can then take place between the data provider and the data consumer, independently of the federator.

Figure 19: Federator-assisted collaboration in a data space



Source: Plattform Industrie 4.0

26 Plattform Industrie 4.0 – Multilateral data sharing in industry (plattform-i40.de)
27 Eclipse Dataspace Connector (EDC): central components of Catena-X | Catena-X
28 Catena-X Developer KITs | Catena-X
29 Eclipse Tractus-X | projects.eclipse.org
30 Gaia-X Conceptual Model – Gaia-X Architecture Document – 22.10 Release

4.4.2 Solution approach: complexity reduction with the example of a data intermediary

As Figure 4 illustrates, complexity rises sharply as the tier chain grows in size. To counteract that effect, the role of a data intermediary is introduced, as clearly defined and described in the Data Governance Act (DGA),[31] which has been adopted as part of the EU's data strategy.

A data intermediary is an organisation or company that acts as an intermediary between different parties in order to facilitate exchanges or transfers of data. A data intermediary collects, organises and supplies data in order to make it available for other parties. This can take place in various contexts, such as transmission of carbon footprint data along the supply chain.

In this regard, a data intermediary acts as a contract data processor, to which any intra-company tasks are outsourced.

On the other hand, the following services, among others, are not to be regarded as data intermediation services: Services comprising shared use of data, without establishing a commercial relationship between data holders and data users (see Article 2 (11)(a) of the DGA), services used in a closed group, and services that focus on the intermediation of copyright-protected content (Article 2 (11)(b) of the DGA).[32]

The data are usually then stored in a formatted and structured format and made available to other partners, by means of either direct access to the data or the provision of reports, analyses or other derivative information.

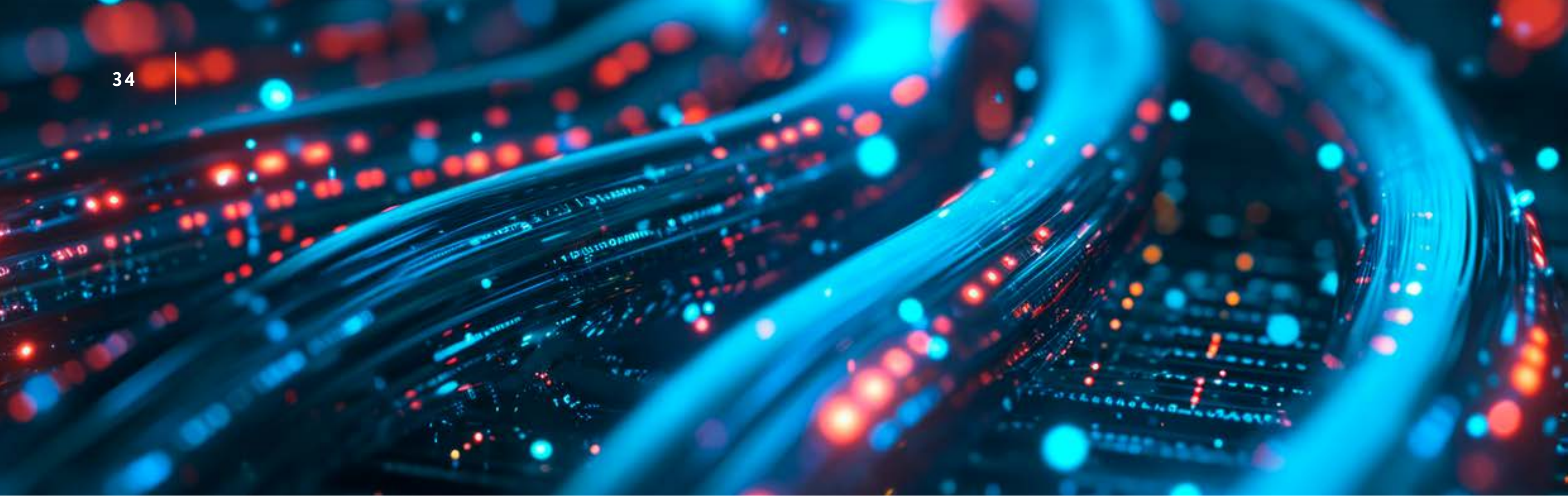
Data intermediaries play an important role in the collation and integration of data from different organisations. In that respect, they can help to:

- facilitate data exchanges while at the same time ensuring compliance with data protection guidelines and legal requirements;
- ensure the quality of the data;
- reduce complexity in tier chains in which data are made available to large numbers of partners;
- increase connectivity;
- build confidence.

It is important to note, however, that the use of data intermediaries may also entail data-protection and data-security risks, especially in cases involving sensitive or personal data.

31 The European Data Governance Act (DGA) (european-data-governance-act.com)

32 Data trusts, data intermediation services and Gaia-X (gaia-x-hub.de)



Section 5: Collaborative data sharing as a success factor

Collaborative data sharing refers to the practice of sharing data across multiple organisations, teams, or individuals aiming at achieving a common goal. Through shared data use, organisations can enhance communication, avoid duplicated work, and promote transparency. The success of a collaborative data sharing depends not only on the level of trust and agreement between the participants but also on effective use, management and protection of the shared data.

5.1 Minimum viable collaboration

Multilateral data sharing is a complex endeavour that requires careful coordination of the various stakeholders, roles, requirements, and perspectives:

Collaboration between *at least three* companies (triple fractal), and

the fulfilment of the following three conditions:

1. all collaboration partners benefit;
2. data supply matches data demand; and
3. the benefits outweigh the efforts for all participants.

Further, it requires the well-orchestrated interplay and scaling of the four interconnected dimensions:

1. the economic benefit and hence the underlying motivation for the partners;
2. the legal requirements that must be observed;
3. the technical implementation that meets the requirements; and
4. consideration of the sociocultural dimension (company culture, etc.).

The minimum viable collaboration (MVC) approach was developed to organise and master the complexities of collaborations aimed at multilateral data sharing. This systematic approach allows for a step-by-step definition of the multilateral collaboration, ensuring that all stakeholders are involved – from the initial vision and their individual business models and added value to the implementation strategy – and the individual goals are aligned.

A key element of the MVC approach involves the early preparation of concrete examples in the design phase. In accordance with the “fail fast to iterate early” principle, the aim is to test the collaboration concept against reality at an early stage, with the aid of concrete example scenarios. The resulting rapid feedback facilitates a steep learning curve, catalysing convergence towards a profitable business model. The key advantage of this approach lies in the ability to differentiate the relevant from the irrelevant at an early stage to allocate resources purposefully, ideally from the outset.

MVC is based on developing application-specific minimal scenarios, which are then gradually refined with the aid of the following three questions:

- Does the data supply match the data demand?
- Do all participants obtain a fair benefit?
- Is it possible to achieve consensus on a suitable implementation strategy?

By focusing on those questions, superficial requirements can be identified and eliminated early, thus ensuring an efficient and target-oriented project implementation.

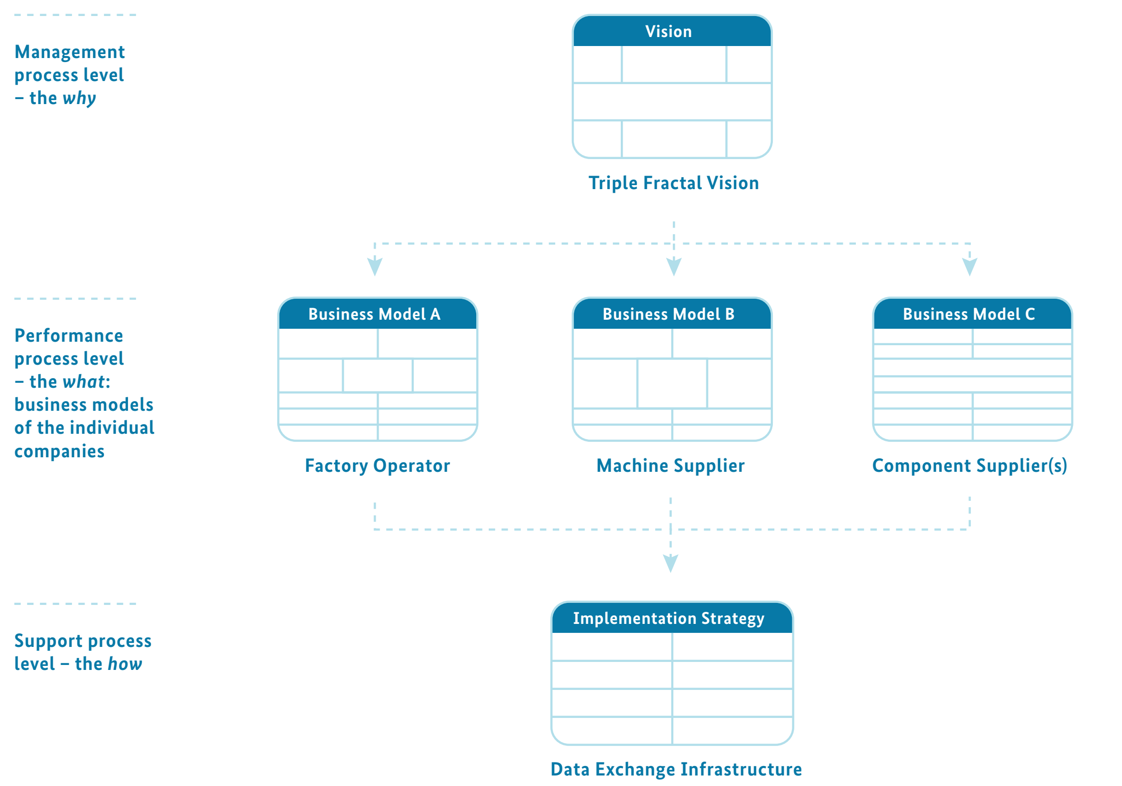
5.1.1 The canvas-structured MVC design

To give structure to the MVC approach, we pursue a hierarchical multi-canvas approach, which subdivides the complexities of multi-lateral exchange projects into manageable segments (the interconnection and the individual canvases are shown in large format in the appendix). Some of the segments can be handled individually by involved stakeholders, while others are specially designed for harmonising the different stakeholder-specific inputs, typically in the form of an iterative adjustment process. If the hierarchical canvas can be fully filled out, this means that the interests, resources, and framework conditions of the partners are sufficiently aligned to exclude any major obstacles to a successful implementation, at least in conceptual terms. Otherwise, any incompatibilities that cannot be resolved as part of the continuous, iterative adjustment process will have been discovered at an early stage. In that scenario, while the project may have failed, an unnecessary waste of resources has nevertheless been avoided.

More specifically, the multi-canvas approach to MVC design enables the partners to communicate at different levels – from the management level to the performance level and ultimately the support process level. Figure 20 illustrates multilateral data sharing, using the triple fractal as an example.

The first canvas captures the common vision at the management level (the "why"), whereas the performance level, in this context the desired business model (the "what"), is defined individually by each partner. To provide optimal support during the process of defining the performance level and the specific added value, two role-specific canvases have been created that distinguish between data providers and data consumers. The fourth canvas defines the necessary infrastructure requirements at the process level (the "how") for the entire triple fractal.

Figure 20: Value proposition canvases for collaborative data sharing



Source: Plattform Industrie 4.0

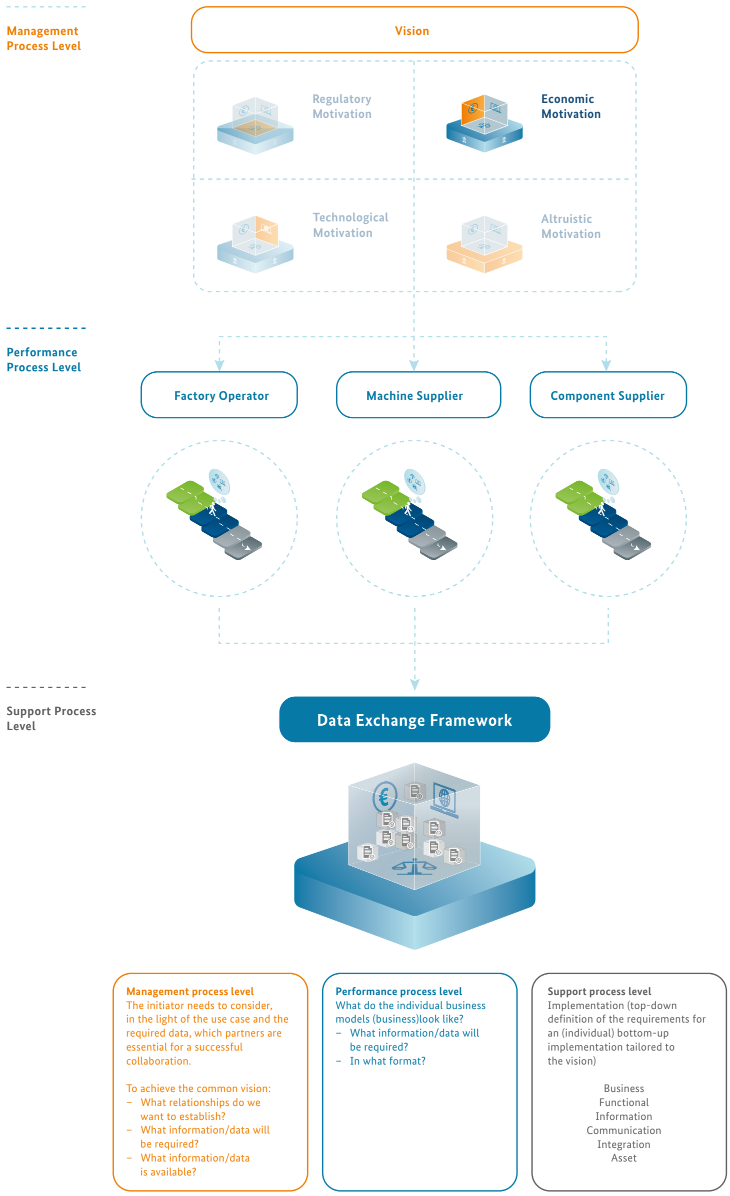
To ensure that the conditions attached to the overall vision for the triple fractal and the individual business models of the partners both converge in the implementation, some segments overlap across two to three canvases. In this respect, the conditions are derived from the originally formulated, partner-specific data-exchange requirements (e.g. legal and technical) at the performance process level. Those requirements must be gradually transferred to a final description of the data exchange infrastructure that is acceptable and applicable to all parties.

5.1.2 The MVC approach in the context of the RAMI model

The MVC approach pursues and supports a top-down strategy, which is also reflected at the levels of the Industrie 4.0 (RAMI) reference architecture model (see Figure 21):

Management process level: A use case is defined by taking the factors motivating the initiators as a starting point and applying one of the four data sharing models. In doing so,

Figure 21: Top-down strategy



Source: Plattform Industrie 4.0

the associated overall vision and the relevant partners are defined. Once the partners have been identified, joint discussions can take place to identify the information and data that are relevant and available. In addition to the common KPIs, all partners will have their own individual KPIs. They may, for example, describe reciprocal services that are to be defined more precisely at the performance process level.

Performance process level: At this level, the partners define individual business models/ added values and set out detailed specifications for the desired KPIs, based on the overall use case. Each partner derives the necessary requirements for the information/data (data set and data policy) and for legal protection from its own objectives. This is equivalent to descending the design levels of the RAMI staircase.

Support process level: The use case describes the roles and responsibilities of the individual partners. At the performance process level, detailed specifications are set out for a successful implementation. At the support process level, an initial check must then be performed to ascertain whether the requirements of the individual partners are compatible with each other. If that is not the case, the partners need to engage in negotiations and adjustments until an agreement is reached.

The result will be the common definition and description of the overall data exchange framework. During the implementation process, each partner must independently work through levels 1 to 6 (assets, integration, communication, information, functional, business) from top to bottom, using the overall plan as a basis. The data exchange framework thus forms the interface between the collective responsibilities and the individual responsibilities of the partners involved in the collaboration.

If it should be identified at the support process level that, although the partners are able to reach an agreement, there are some partners who are struggling with the bottom-to-top implementation, there is the possibility of providing mutual assistance, or of engaging external service providers.

5.1.3 In summary

MVC focuses on establishing definitions and detailed specifications for use cases and visions that are common to all participants, while ensuring that all parties can benefit (equally) from the outcome. In this respect, it is important to ensure that the legal and technical challenges associated with the implementation are in proportion to the economic added value. In other words, the benefits must always outweigh the implementation costs for all participants. This targeted, efficient, and effective approach forms a sound basis for a successful collaboration and improves confidence that there is a need for multilateral data sharing and the lever that it offers.

Precise target definitions: For a successful collaboration, it is of fundamental importance that all participants have a clear and common understanding of the project's objectives, added values and challenges. In this respect, the role assumed by each of the partners for the purpose of achieving those objectives must be specifically defined.

Resource identification: It is vital to determine which resources are necessary to achieve the desired objectives. These could include time, money, human resources or specific tools and technologies.

Implementing the decision-making processes: A transparent, clearly defined and coordinated decision-making process is of vital importance to ensure that all partners are working towards the same objectives.

Defining communications channels: Establishing clear and efficient communications channels is of vital importance. These ensure that all partners are kept continuously up-to-date, that they can jointly address any emerging issues at an early stage and that they are pursuing the same objectives in an aligned manner.

Planning for continuous improvement: The MVC design is not a one-off act; instead, it facilitates and supports a continuous improvement process. As the most important cornerstones and requirements are presented in a transparent and tangible manner, adjustments/ improvements and their consequences are easier to communicate, negotiate and put into effect. In that respect, it is important to provide regular evaluations, improvements and progressive enhancements in order to ensure that the collaboration continuously fulfils its objectives and requirements.

By focusing on those key elements, MVC provides a robust foundation for a successful collaboration, paving the way for future growth and further development.

5.2 Examples of minimum viable collaborations

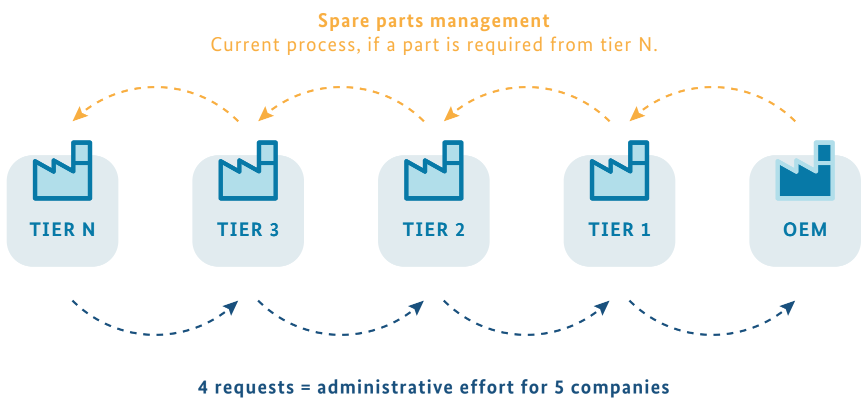
Value chain optimisation presents companies with enormous opportunities. In addition to generating global added value, closer collaboration and increased transparency, it also creates individual benefits for each partner. It is essential to consider the individual conditions and needs of all partners and find a common denominator. In the following, we consider three specific examples that illustrate the potential of strengthened partnerships that go beyond bilateral collaborations.

5.2.1 MVC spare parts management

In current value chains, relations are mainly based on numerous parallel chains of bilateral relationships. The component supplier delivers its parts to the machine manufacturer, which installs the components in its machine and then sells it to the factory operator. During the machine's operation, the factory operator normally contacts the machine manufacturer directly in the event of any problems, faults, or requests for spare parts. The machine manufacturer is pleased to accept that role because close contact with customers strengthens its own competitive position.

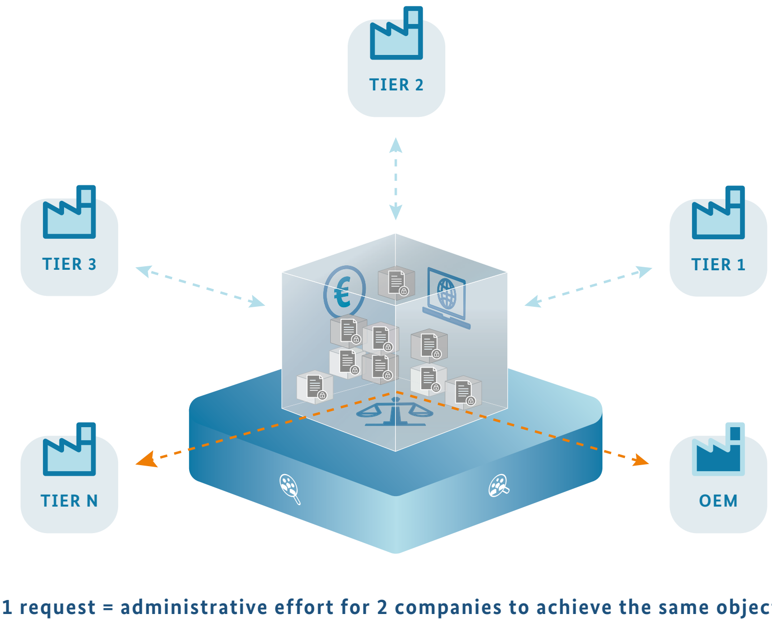
However, this involves a complicated process. If a defect is discovered, the factory operator contacts the machine manufacturer. If the machine manufacturer identifies that a subcomponent is defective, it contacts the relevant component supplier, which in turn contacts the subcomponent supplier. Why? This is generally because the machine manufacturer does not know the identity of the subcomponent supplier and the associated contact person. This means all companies, from the OEM to tier 3 of the value chain, must be involved in the process of ordering and supplying the spare part, which results in administrative effort and costs for all companies concerned (see Figure 22 – Current process). Furthermore, this can also lead to delays at every stage, protracting the entire process from identification of the fault to the delivery of the spare part. Not only does this lead to higher costs but it also increases the time required to remedy the fault. In extreme cases, the duration of complete failures is prolonged, halting the entire production process. In addition, there is the administrative effort required on the part of all the affected companies to consider.

Figure 22: Spare parts management; current process



Source: Plattform Industrie 4.0

Figure 23: Spare parts management; optimised process



Source: Plattform Industrie 4.0

A transparent approach could help to provide a remedy here. In a well-networked value chain, the relevant (sub-)component supplier could be contacted directly when necessary. This would save time and costs and increase efficiency (see Figure 23 – Optimised process). In that respect, it is essential that all participating companies are kept informed regarding the current ordering and exchange processes, in order to maintain quality standards and prevent the formation of parallel structures. If the OEM orders a defective subcomponent directly from the tier 3 supplier, it is crucial, for example, that the tier 1 and tier 2 suppliers whose products the subcomponents are installed into are notified of the defects. It is only that way that the tier 1 supplier, for example, can identify that problems with the subcomponent are occurring frequently. This is an essential information that enables the tier 1 supplier to improve its own long-term product quality.

However, to create a transparent process of that nature, it is vital that the companies trust each other. They must be willing to openly share relevant data and information without this disadvantaging individual companies. In that way, all participants can benefit from optimised processes and higher product quality. A common agreement that takes into account the respective framework conditions is necessary in order to clarify the requirements for transparency and the exchange of information.

5.2.2 MVC – Collaborative Condition Monitoring – solutions provider business model

Optimisation along the value chain and adaptation of business models are key elements for ensuring the future competitiveness of companies. In the context of Collaborative Condition Monitoring this means improving the performance of machines in the business, identifying faults more rapidly and taking proactive measures. Business innovation models can make a key difference in that respect.

An example is the transformation of a machine manufacturer from a simple supplier to a solutions provider. Traditionally, the machine manufacturer would sell its machines to the factory operator, which then held the exclusive rights to the operational and machine data. However, to successfully implement Collaborative Condition Monitoring, data must be exchanged between factory operators, machine manufacturers and components suppliers, for each party to benefit from the other's data and expertise. At present, this requires complex negotiations between the relevant companies to make proper provision for the respective economic, legal, and technical framework conditions.

Whereas the factory operator owns the machine data, it is the machine manufacturer that possesses in-depth knowledge of the machine and its optimal use, while the component supplier knows best about its own parts. A coordinated data exchange process can help to prevent malfunctions, speed up repair processes and optimise performance.

But how can this ideal situation be achieved with minimal complexity? One approach involves the machine manufacturer selling its service rather than the physical machine. According to this model, it is the machine manufacturer that owns the machine and the data instead of the factory operator. The same overall service can thus be simplified and, in most cases, even optimised. On the one hand, it reduces the legal and technical requirements since the factory operator is now purchasing only the service and can therefore no longer refuse access to the data. This significantly reduces the level of complexity. On the other hand, it simplifies the data exchange process and produces clear definitions of key points of interest. It thus enables clear separations according to core competencies, such as:

- **Factory operator:** Efficient production without malfunctions
- **Machine manufacturer:** Control over machine-specific factors, operation and optimisation of its machines based on the operating data
- **Components manufacturer:** Product optimisation and expansion of services

A solutions business thus provides a win-win situation for all participants and minimises complexity, while simultaneously optimising the machine's performance.

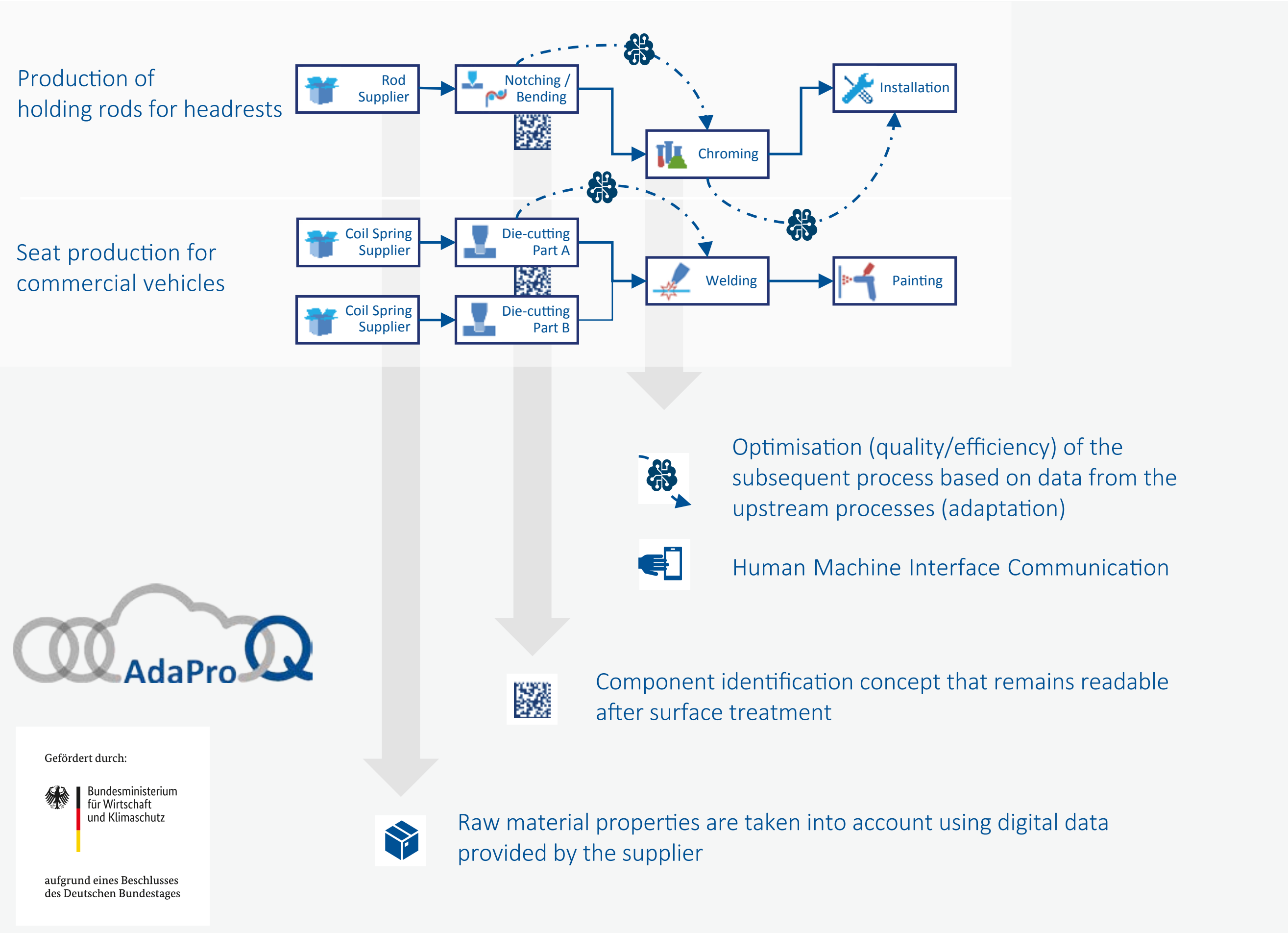
5.2.3 AdaProQ

AdaProQ[33] – short for Adaptive Process Chains for Increasing Production Quality and Efficiency – is a digital transformation project sponsored by the German Federal Ministry for Economic Affairs and Climate Action with thirteen consortium partners. "With AdaProQ, we're taking the next step towards Production 4.0 in unison with strong partners from the automobile and automotive supply industry", explains Jens Öhlenschläger, spokesperson for the management board of Grammer AG (consortium leader). "Together, we are working on viable solutions for the digitally networked, adaptive production chain of the future. Supported by partners and funded by the German Federal Ministry for Economic Affairs and Climate Action, the project is creating a win-win situation for all involved. The initial results are enabling us to build up joint expertise for multilateral data sharing, from which the entire industry in Germany will benefit."

The following example based on a use case from AdaProQ illustrates how a business case can emerge from adaptive process chains if the digital processes and structures are shared in the partners' manufacturing and supply chains. This requires the creation of digital product/machine twin data, clear identification of quality control components and optimal collaboration between humans and machines (human-machine interface) within a self-regulating framework.

33 About AdaProQ: | The AdaProQ digital transformation project is a partnership between the Fraunhofer Institute for Machine Tools and Forming Technology, partners from the automotive industry and Grammer AG. The project has a budget of 19.1 million euros, with the funding provided by the German Federal Ministry for Economic Affairs and Climate Action averaging more than 50 percent across all partners. The aim is to create a generic methodology framework for adaptive process chains in order to increase production quality and efficiency in the German automotive industry. In addition to Grammer AG, the following companies are part of the team: Gestamp Autotech Engineering Deutschland GmbH, Batix Software GmbH, Eichsfelder Schraubenwerk GmbH, Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V, Fraunhofer Institute for Machine Tools and Forming Technology (IWU), KAP Surface Holding GmbH, Merantix Labs GmbH, Promess Gesellschaft für Montage- und Prüfsysteme mbH, OptWare GmbH, Schütz + Licht Prüftechnik GmbH, Senodis Technologies GmbH, Siemens AG, Volkswagen AG. Learn more: www.adaproq.de

Figure 24: Process chains in AdaProQ



Source: Plattform Industrie 4.0

Digital twins

Using the AAS as a basis, material data are initially exchanged within the context of the use case and are then used for optimising the subsequent process (to start setting up a digital product twin). With the available machine twin data and known simulative behavioural states (digital simulation data) it is now possible, with the aid of AI models, to use the material data to perform a real-time analysis of the machine's behaviour from as early as stage one.

However, having digital twins at this first stage alone is only half the business case. It is also always necessary to durably identify the specific component during each subsequent process step.

Durable component marking

Unless there is clear component identification, it will not be possible to allocate production data to a specific component. Configuring the process on the basis of prior production stages is possible only in the case of serial processes (e.g. subsequent networked operations). Without specific allocation, it is not possible to provide a general (cross-company) response or to record component or module-specific values.

In order to set up a digital "red thread" network, data/information must be allocated to specific components. At best, former paper-based approaches are suitable for special parts or complete batches. In particular, the assignment of measurements requires that products are marked in a way that is permanent and digitalisable in order that production and application conditions can be allocated appropriately.

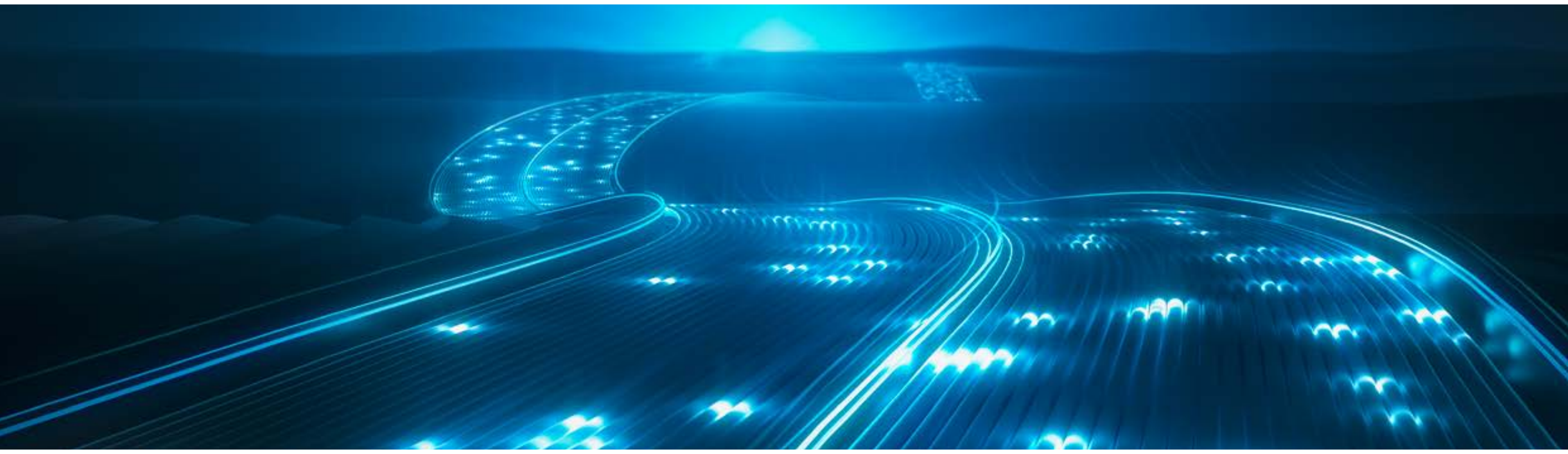
In this respect, marking the components in a manner that is permanent and durable throughout the process but without limiting the usability and scope for further processing is a key element for ensuring that components operating under the most adverse conditions and/or that have been in use for many years can be identified again. Otherwise, the corresponding component-related data would be of no value.

In the use case, this was achieved by means of a specific laser marking directly in the first process step. By using specific settings, it is possible to ensure that the markings remain fully intact after the chroming process.

Business Case

The durable markings make it possible to access the component-specific digital product twin data directly during the subsequent chroming process step and the chroming process can then be optimised, e.g. in terms of energy performance, with the aid of the digital behavioural data. This optimisation can even make it possible for the chromer to guarantee an optimum chrome thickness, which, in turn, creates a win-win scenario in terms of the subsequent installation and use of the component.

The example demonstrates that if the companies have a high level of confidence about sharing their data, and they are all willing to openly share their relevant data and information in a way that does not disadvantage any individual company, then the notch-bend supplier, the chromer, the subsequent fitter and even the end user can benefit from optimised processes and a higher product quality.



Section 6: Conclusion – the pathway to becoming a digital champion

Section 1 highlights specific elements of the "Target vision for achieving digitalised production by 2030". The strategic goal is for German companies to act as digital champions in this rapidly approaching future world. In terms of the postulated fundamental capabilities, it is clear that the use and mastery of data will play a vital role across the board, especially in multilateral contexts.

Section 2 outlines today's current practices. Data exchanges generally take place bilaterally in a format that is as machine-readable as possible. However, the complexity and diversity of the data lead to high levels of cost and effort and also restrict the scope for collaboration in the desired data-sharing ecosystem. Data exchanges between companies involve effort and costs, on both the supplier side and the customer side. The individual processing required for different customer portals is time-consuming, expensive, and prone to error. Within individual companies, point-to-point connections require high levels of effort at the interfaces and provide limited data quality. In many cases, data is not available centrally and remains at the source without wider use. Local data models often lack overarching structures, while semantics and protection requirements are unclear, and there is only limited access to data products and their management systems. At many points, data that will be needed in the future is either unavailable or available only in an unusable form. At present, data is not generally managed as a business resource.

Section 3 sets out solution approaches that can be pursued in an ordered and structured manner, for the necessary intra-company measures to be put into effect step by step. As a lead structure for addressing the question of "How can I get Data Space-ready?", RAMI 4.0 – the Industrie 4.0 reference architecture of the Plattform Industrie 4.0 – is introduced. With its six design levels, the necessary implementation steps are subdivided into ordered, manageable sections. Examples are provided such as: how should I proceed if the "data requirement" comes from the business area? I should start at the business layer and descend the RAMI levels step by step. What approach should I follow if the trigger is located within the technology or on the shopfloor? In that case, I should begin at the bottom RAMI level and ascend step by step. To that end, we consider the Y-model to be a useful aid for sorting control data and potential business data. Lastly, we set out the specific impact this can have on production or logistics.

All of these examples clearly show that sharing and consolidating data with the aid of interoperable information models lays the foundation for achieving connectivity in a way that companies will find easy to implement.

We have thus set out the first part of the framework conditions for multilateral data sharing.

Section 4 sets out the necessary context for achieving the data mastery outlined in section 3, emphasising that three-plus-one dimensions must always be considered for each design task and for each decision: *1. economic, 2. legal, 3. technical, and 4.,* as the underlying basis for everything, *the sociocultural context in companies and society.*

Guiding themes related to these dimensions are:

1. **Technical:** local/global architectures, collaborative engineering, standards, security

2. **Legal:** legal issues, IP, data protection, regulatory, sovereignty (digital, European)

3. **Economic:** driving forces, business models, it must make economic sense

4. **Sociocultural:** only those who can carry along the people within the company and in society will become digital champions.

In sum, **section 4** emphasises that there can be four very different driving forces that open the pathway to becoming a digital champion: economic, technological, but also regulatory and altruistic. "Connectivity" to a data space such as Catena-X or Manufacturing-X is demonstrated with the aid of two solution approaches.

In **section 5,** three examples are presented to demonstrate how collaborative data sharing can serve as an economic success model:

1. Minimal Viable Collaboration (MVC) as an underlying model,

2. MVC applied to spare parts management, and

3. AdaproQ as an implementation.

With the aid of examples, it is thus shown that the objectives, action requirements and solution approaches set out in sections 1 to 4 are already being successfully pursued and addressed, and that some enterprises are already on the pathway to becoming digital champions.

Conclusion: For those who share the objectives of Plattform Industrie 4.0, with its elements of autonomy, interoperability, and sustainability, and who seek to implement the strategy "We want to become digital champions by 2030" (*"Dort wollen wir 2030 digitale Champions sein"*), this paper will serve as a concise and helpful guide for determining and focussing on individual action requirements and for designing and implementing step-by-step solutions.

Read it, act and become a champion!

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