A European Common Digital Manufacturing Infrastructure and Data Space Pathway for Connected Factories 4.0 Data Value Chain Governance

Digital Europe EU Grant Agreement: 101083939

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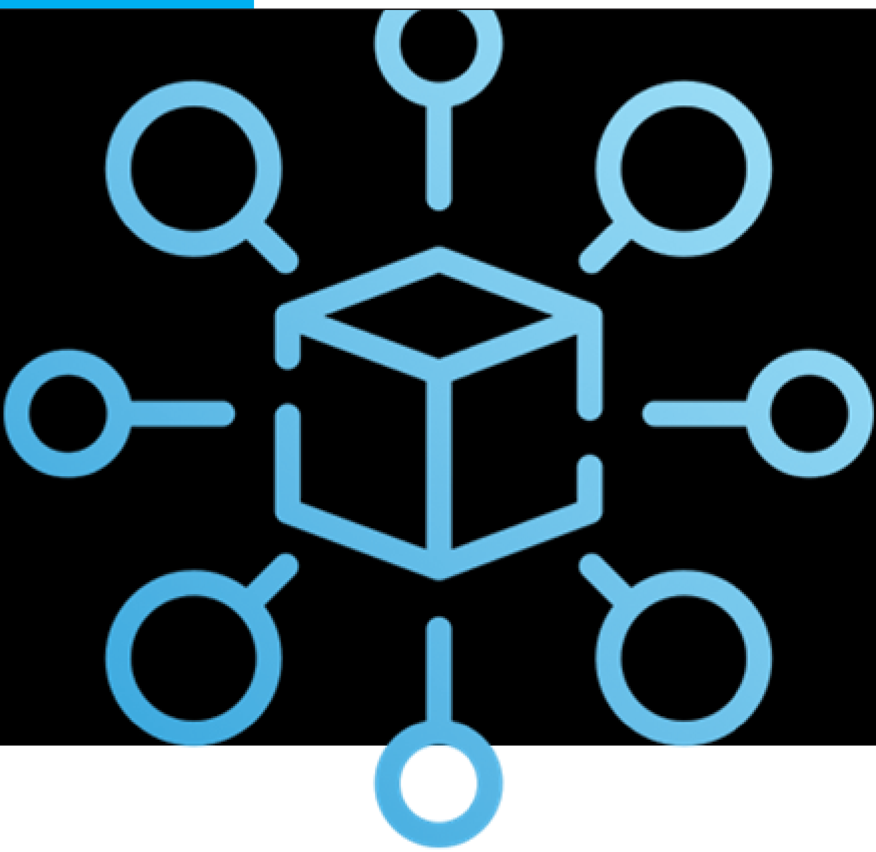

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Project Partners

Participant organisation name	Acronym
ASOCIACIÓN DE EMPRESAS TECNOLÓGICAS INNOVALIA	INNO
FONDAZIONE POLITECNICO DI MILANO	FPM
COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA
VDI TECHNOLOGIEZENTRUM GMBH	VDI TZI
BRAINPORT INDUSTRIES COOPERATIE UA	BPI
INDUSTRIE 4.0 OSTERREICH – DIE PLATTFORM FUR INTELLIGENTE PRODUKTION	PIA
CHALMERS TEKNISKA HOGSKOLA AB	CHALMERS
INTERNATIONAL DATA SPACES EV	IDSA
ENGINEERING - INGEGNERIA INFORMATICA SPA	ENG
UNPARALLEL INNOVATION LDA	UNPARALLEL
SOFTWARE QUALITY SYSTEMS SA	SQS
FIWARE FOUNDATION EV	FIWARE
IDC ITALIA SRL	IDC ITALIA
SIEMENS AKTIENGESELLSCHAFT	SIE

Executive Summary

D3.2 Business Model (BM) navigator and data space 4.0 maturity assessment model is the second deliverable at M12 of WP3 SUSTAINABILITY BUSINESS MODELS FOR DATA ECONOMY IN MANUFACTURING after D3.1 the Industrial Agreements catalogue.

Firstly, D3.2 analyses some embryonic Data Spaces in the Manufacturing domain currently present and described together with their development stage (Lead-in, Committed, Pilot, Live cases) and extracts commonalities and lessons learned during their implementation.

Moreover, D3.2 introduces the methods and tools to define a DS for Manufacturing Business Model and a Maturity Assessment Model. Several methods have been analyzed specifically coming from EU projects and EU tenders and a specific methodology selected.

Finally, D3.2 validates such methods and tools through a series of DS for Manufacturing Industrial Pilots coming from H2020, Horizon Europe and Digital Europe programs.

- In the Industrial Data Spaces category, we included cases especially focusing on high value FAIR data sharing, including standard common data models and semantic interoperability. The aim here is to have a highly decentralized pool of data, commonly described by standard models and ontologies and implementing Data Sovereignty rules between Data Providers and Data Consumers.
- In the Industrial Data Platforms category, we included cases where the underlying digital platform is playing a fundamental role, for instance when managing and governing a non-hierarchical network of suppliers or when aiming for demonstrating a worldwide certification of origin for a high-quality product.
- In the Sustainable Green Products category, we put cases specifically addressing green and circular economy challenges, using Digital Product Passports for critical raw materials tracking and tracing (Polymers, Magnets, Batteries)

D3.2 concludes its journey by listing some lessons learned and recommendations for the deployment actions SM4RTENANCE and UNDERPIN developed in the first wave call (Dynamic Assets Management and Predictive / Prescriptive Maintenance) and for the additional initiative to be funded in the Agile Supply Chain domain.

The document including the main results and confidential findings of the Maturity Model results will be provided upon request to secretary@digitalfactoryalliance.eu.

Keywords: Data Spaces Business Models, Maturity Models, DS for Manufacturing use cases, Dynamic Assets management and preventive / predictive maintenance

Disclaimer

Acknowledgement

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Abbreviations and Acronyms

Acronym	Meaning
CA	Consortium Agreement
CPPS	Cyber-Physical Production System
DoA	Description of Action
DS(s)	Data Space(s)
DVC(s)	Digital Value Chain(s)
EC	European Commission
GA	General Assembly
IA(s)	Industry Agreement(s)
IPR	Intellectual Property Regulations
KPI	Key Performance Indicator
TCC	Technical Coordination Committee
TF	Task Force
WP	Work Package

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N/A

1 Introduction

1.1 Motivation and Purpose of the document

D3.2 Business Model (BM) navigator and data space 4.0 maturity assessment model is the second deliverable at M12 of WP3 SUSTAINABILITY BUSINESS MODELS FOR DATA ECONOMY IN MANUFACTURING.

D3.2 mostly addresses two major goals: on the one side to conduct a through business model analysis of existing embryonic data spaces for manufacturing (and Green Manufacturing), on the other side to develop and validate a new data-driven method to measure and assess the maturity of Manufacturing enterprises with respect to Data Economy challenges.

1.2 Methodology

Being data Space 4.0 a preparatory action in Digital Europe, we are not conducting extensive validation and assessment campaigns (this will be in charge of the subsequent deployment actions), but we will illustrate the methods and the tools and conduct sample validations in a restrictive but significant number of industrial cases coming from our projects' ecosystem.

1.3 Structure of the Document

The structure of the D3.2 reflects the methodology just described in §1.2 and provides a set of methods and tools for Business Impact Assessment (T3.2), Maturity Assessment (T3.3) and validation cases in the two domains of DEP deployment actions: Dynamic Manufacturing Asset Management and Predictive Maintenance (T3.4) and Agile Manufacturing Supply Chain Management (T3.5).

Chapter 1 is the introduction and describes the motivation, the methodology and the structure of the document.

Chapter 2 provides the state of the art in terms of

i) Embryonic Data Spaces for Manufacturing by consulting the RADAR and extracting the most significant cases of Lead-in, Committed, Pilot and Live cases. Ten cases are analysed in detail in section §2.1.

ii) Future 2030 scenarios and Business Models respectively indicated by the Connected Factories CSA (§2.2) and the EC communication "Towards a common European Data Space" and its declination for private sector (§2.3)

iii) Business Matrices for Scenarios / Business Models (§2.4) and for Data Spaces / Business Models (§2.5) driving the subsequent chapters of the deliverable's analysis

iv) Data Space for Manufacturing Maturity Models both at the level of organizations participating in it (Connected Factories II) and at the level of data Space maturity in itself (working document in the DSSC – Data Space Support Center - about Maturity Models) in §2.6

Chapter 3 provides an overview of methods and tools for Business Modelling of the Data Space by analyzing in detail the stakeholders participating in a data Space (§3.1) and three main frameworks for Business Modelling (DSSC §3.2), Governance (DSSC §3.3) and Emerging Models (JRC §3.4)

Chapter 4 defines the DS4.0 methodology for Business Models Analysis which will be validated in a number of industrial cases in Chapter 6 through questionnaires, participative workshops and focused interviews.

Chapter 5 reports the data-oriented methodology (7Ps) adopted for measuring and assessing the Maturity levels of a series of industrial cases taken from our embryonic Data Spaces for Manufacturing and reported in synthesis in Chapter 7 and in detail in ANNEX III.

Chapter 8 draws some conclusions and describes how the Data Space 4.0 Business and Assessment models validation can prosecute in the two deployment actions in DEP.

In Appendix you could find the questionnaires used to conduct the analysis of Business Modelling ANNEX I and of Maturity Assessment ANNEX II.

2 Embryonic Data Spaces in Manufacturing

2.1 The IDSA Radar and Manufacturing / Supply Chain Data Spaces

International Data Spaces RADAR is a powerful platform facilitating the discovery and development of IDS-based solutions applied to real-life challenges. It introduces the concept of the "Data Spaces Radar," a unique tracking system that monitors companies developing data spaces based on the IDS standard. The radar provides a comprehensive overview of the adoption of IDS, categorizing companies by domain and solution maturity. The impact of the Data Spaces Radar is highlighted in three key aspects:

Inspiration and Learning: Companies can draw inspiration from the progress and success of others adopting the IDS standard. This encourages them to engage with the IDS framework, learn from how businesses are developing their data space solutions, and connect with experts who can assist in designing their own IDS adoption.

Connecting with Experts: The radar facilitates connections between companies and experts who can support them in adopting the IDS framework. This collaboration is crucial for designing effective and secure data space solutions.

Supporting Consortia: The Data Spaces Radar serves as a tool for experts to identify and support consortia that are ready to invest in implementing IDS solutions. These consortia are seen as the standard bearers of the future, representing new business opportunities in the evolving data economy.

In summary, the role of the Data Spaces Radar in tracking and promoting the adoption of the IDS standard, fostering inspiration, learning, collaboration with experts, and the development of consortia that exemplify the potential business opportunities in the data economy.

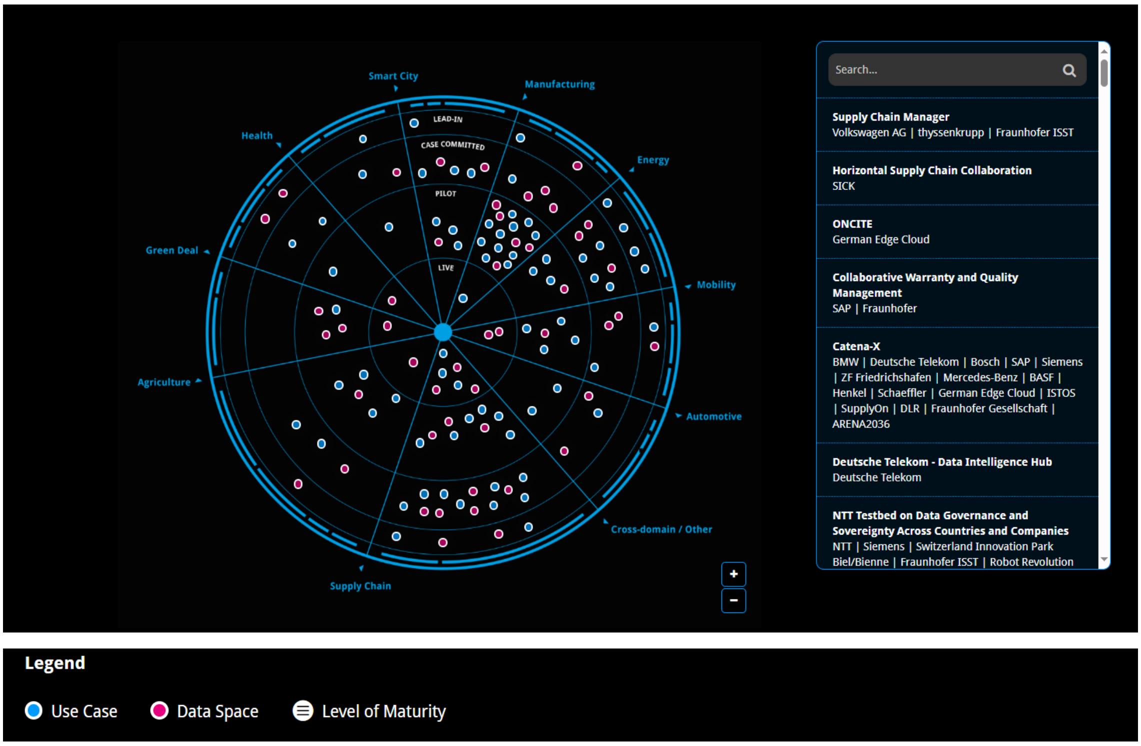


Figure 1. The Data Space Radar

The Radar focuses on use cases where two or more organizations collaborate to share data in a sovereign manner. The RADAR covers a spectrum of use cases, from the early stages of shaping ideas to the full implementation of operational data spaces. It spans across different industries and functional domains, aligning with specific business goals for sovereign data sharing.

These use cases are categorized based on levels of maturity within the Data Space ecosystem, encompassing various stages:

1. Lead In: Organizations or consortia are in the initial phase of shaping an IDS-based use case. Identification of opportunities and challenges for sovereign data sharing is underway.
2. Case Committed: The scope of the use case, value creation, and roles of participating organizations have been identified. An approach for realizing the use case has been defined.
3. Pilot: Implementation of the IDS-based solution has taken place. Initial prototypes have been tested in a use case pilot.
4. Live: The use case is in a live operational state. Data flows in a sovereign way between participating parties within the Data Space ecosystem.

Below it is a detailed description of each level of maturity identifying for each level the features and the status:

LEVEL 1. Lead-in

Description: Initial stage with a general overview of the use case or data space project.

Features:

- Consortium formation.

- Defined vision and domain.
- Lack of detailed preparation.

Status: Preliminary phase without extensive technical groundwork.

LEVEL 2. Case Committed

Description: A more mature stage with a well-defined technical architecture.

Features:

- Clearly documented business cases.
- Accessible roadmap.
- Project planning and management in place.
- Allocated budget, and activities initiated.

Status: Comprehensive groundwork laid, moving beyond initial planning.

LEVEL 3. Pilot

Description: Technical solutions actively in use, with ongoing trials.

Features:

- Interoperability and data sharing trials addressing business challenges.
- Approaching a live stage, but not yet market-ready.

Status: Active experimentation, testing, and validation in progress.

LEVEL 4. Live

Description: Mature stage where sovereign data exchange is in full operation.

Features:

- Functional technology within the data space.
- Participants can access it as a service.
- Demonstrated improvement in processes or issue resolution.
- High accessibility and adoption within a network.

Status: Fully operational, offering tangible benefits and solutions.

The IDSA data space radar is a graphic representation that considers a visual representation with a horizontal timeline or a vertical progression bar. Each maturity level can be represented as a distinct phase, progressing from left to right or bottom to top. Use distinct colors or markers for each level to enhance clarity. Additionally, you can include brief descriptors and key features associated with each level to provide a quick reference guide.

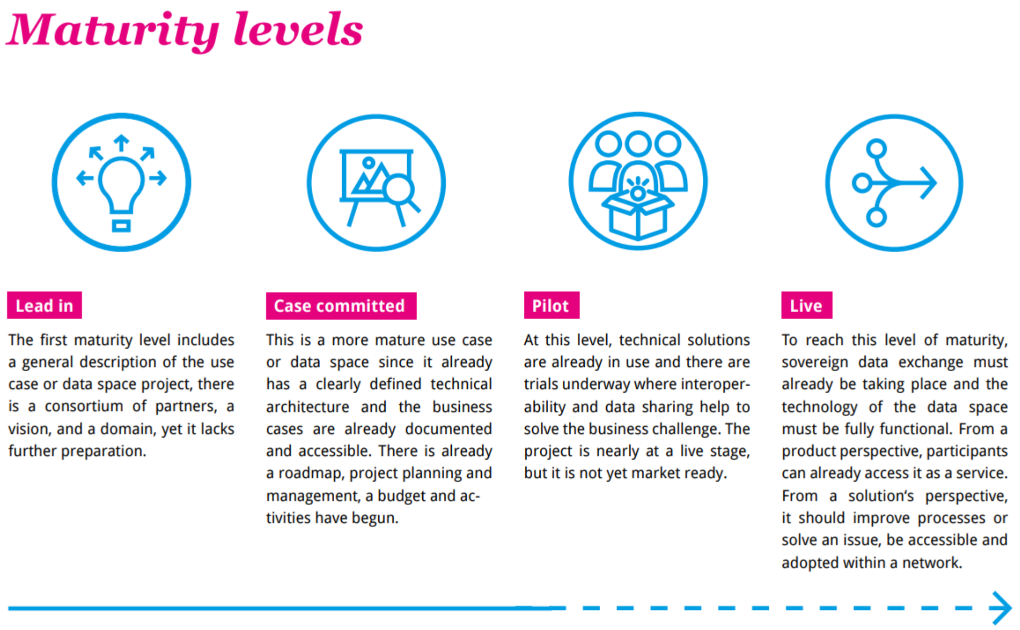


Figure 2. Maturity Levels

2.1.1 Lead In cases (2 examples)

1. Logistics and Product Life Cycle Management
2. UCIMU "Data Space Committee"
   Various Italian Companies associated to UCIMU-SISTEMI PER PRODURRE

Logistics and Product Life Cycle Management

Consortium members: Fraunhofer Institutes IML, ISST, IOSB, FIT, AISEC, IAIS

CHALLENGE

Data exchange as a basic requirement for collaborative condition monitoring.

SUCCESS

Use of the IDS infrastructure to build up a common database that allows valid analysis processes.

BENEFITS

The exchange of machine data makes it possible to carry out condition analyses that an individual company would not have been able to do due to the lack of data.

UCIMU "Data Space Committee"

Consortium members: Various Italian Companies associated to UCIMU-SISTEMI PER PRODURRE

SUCCESS

Our Data Space aims to manage the ownership of data exchanged among Machine Tools manufacturers and users, in order to set up effective implementations of predictive maintenance and other value-added services.

UCIMU initiative develops a proof of concept improving predictive maintenance is at the core of their data space activity covering aspects of how it works, why it works, and what the benefits of data space. Before going on the industrial implementation of the overall concept.

BENEFITS

Transparent access to all relevant machines related data. Secure, robust and efficient communication between OEM and customers. Simplified provision of trusted services for machine tools operation. Interoperability and data sovereignty for all involved parties

2.1.2 Committed cases (3 examples)

Case committed

1. EuProGigant - European Production Giganet
2. aiXia
3. ManuSpace

EuProGigant - European Production Giganet

Consortium members: Pilotfabrik Industrie 4.0 | TU Wien | Concircle Österreich | craftworks | Stark Spannsysteme | A1 Digital International | WFL Millturn Technologies | Plasser & Theurer | Export von Bahnbaumaschinen | Gesellschaft m.b.H. | EIT Manufacturing East | PTW TU Darmstadt | IGH Infotec | Gebrüder Heller Maschinenfabrik | Software AG | Brinkhaus | EIT Manufacturing Central

CHALLENGE

EuProGigant encompasses four thematic working groups working on industry-relevant, cross-company related use cases:

1. CO2e footprint in production engineering & manufacturing: how can estimations on energy use and CO2 footprint be created and used in the design phase by using portable data and interoperable software tools?
2. Component matching: how can Gaia-X principles be instrumentalized to manufacture and assemble with optimal resource use and minimal waste?
3. Mobile processing machines: how does the EuProGigant/Gaia-X concept work when the machine comes to the part instead of the other way around? How can large data volumes be synchronised for the autonomous planning of maintenance processes on track infrastructure?
4. Validation platform: how can small companies monitor machines and assemblies without having to compile a large database?

SUCCESS

EuProGigant focuses on the Gaia-X Federation Services. EuProGigant demonstrates that an ecosystem based on Gaia-X mechanisms enables digital sovereignty, transparency and fosters interoperability to ensure a secure data and service portability. EuProGigant connects multiple edge systems, platforms and cloud services. The EuProGigant demonstrator powered by deltaDAO and Ocean protocol is based on a distributed ledger technology - try it out: https://euprogigant.portal.minimal-gaia-x.eu/.

BENEFITS

The EuProGigant business value is defined as increasing the value creation speed through dynamic, decentralized datadriven business models. The European Production Giganet allows you to choose your business partners you trust, own your data and manage the cross-company connectivity easily.

COMPONENTS

Currently EuProGigant does not use any IDS components. EuProGigant focuses on the Gaia-X Federation Services and might use the Eclipse Dataspace Connector.

aiXia

Consortium members: aiXia" which will be led by LANTEK (digital services) together with the companies LIS SOLUTIONS | S.L. (data analytics and ai services) | INGETEAM, S.A.(energy) | GOIZPER S.COOP. (machine-tool industry) | MONDRAGON ASSEMBLY S.COOP. (manufacturing) | UBIKARE ZAINKETAK, S.L. (healthcare) | EROSKI S.COOP (retail) | The technology coordinator is IKERLAN (a leading knowledge transfer center providing competitive value to companies)

SUCCESS

Seeks to promote and research the necessary technologies for the definition of a reference architecture, operational models, adoption of standards and developments for a data space based on the common technical framework proposed by DSBA members, extending its main services to favor the development of artificial intelligence with guarantees of traceability, security, and governance of the data and services.

BENEFITS

Aims to provide the country with a reliable data space that enables companies to offer new concepts of high-added value services based on data sharing, through the servitization of collaborative artificial intelligence for the productization and monetization of their data and industry knowledge in new business models.

COMPONENTS

Will develop new services in the field of artificial intelligence and will explore current IDS components implementations (focusing on Connectors, Metadatabroker, and IdentityProviders) in order to select one of them to rely on.

ManuSpace

Consortium: Irish Manufacturing Research |ServBlock | NEXA EAM | Ingeniero Solutions | Unison Process Solutions | ishare | Fiware

SUCCESS

By utilizing the ManuSpace dataspace, manufacturers can not only reduce the cost to the patient but more importantly reduce the time it takes to get these life-saving medicines to the people that need them. Through interoperable data sharing, we can ensure that contract manufacturing capacity is maximized. In turn, ManuSpace can help alleviate drug shortage problems for some of the most vulnerable in society.

BENEFITS

As more and more, pharmaceutical and biotechnology companies choose to outsource their manufacturing projects - companies must evaluate the performance of its Contract Manufacturing Organizations (CMOs) and determine whether it meets industry and regulatory standards.

Companies outsource business activities to external partners for a variety of reasons – cost, flexibility, time to market, and core competence. This outsourcing leads to an increased risk of non-compliance to Good Manufacturing Practice (GMP) procedures which in turn is a risk to the brand reputation of the company.

Data integrity is critical in the pharmaceutical industry to make sure that the end products meet all the required quality standards. Enabling the digitisation and automation of cross-organisational business processes integral to pharmaceutical manufacturing will help improve supply chain security and help reduce the time to patient

COMPONENTS

i4Trust project

2.1.3 Pilot cases (3 examples)

Metal Domain Data Space - Market 4.0

Consortium members: Tecnalia | Ekin | Engineering | Exkal | Gepro Systems | Gizelis | Goialde | Intrasoft | Kleemann |LMS Lab of the University of Patras | Prima Industrie | Rico | TNO

CHALLENGE

Selecting the most suitable new manufacturing equipment is a time-consuming challenge for many customers. There's no easy way to digest all available information about options, so customers must browse the internet, attend trade shows and talk to multiple experts in order to reach an informed decision. We wondered if data spaces could help integrate and streamline this process. We focused specifically on the metal domain.

SUCCESS

The MARKET 4.0 Metal Domain Data Space is based on the IDS Reference Architecture Model (RAM). It describes a robust and efficient solution for linking the inventories of different equipment manufacturers to a MARKET 4.0 service that analyses the customer's requirements and returns the most suitable equipment options for a certain metal domain manufacturing process. The connection is made through IDS connectors and the inventories and services include essential IDS modules (i.e., clearing house, metadata broker) that guarantee a trusted data exchange.

BENEFITS

The MARKET 4.0 Metal Domain Data Space makes the selection of manufacturing equipment simpler and more efficient, getting to a better result in less time. It is flexible and offers two solutions:

Connecting equipment manufacturer repositories with a single IDS connector. The equipment manufacturers do not require knowledge of the IDS RAM. Only the connector owner needs to have it.

Connecting one service with multiple data providers via IDS connectors. The benefit of this is that the data provider controls the data flow and is independent of the connector provider.

COMPONENTS

IDS Connector; IDS Clearing House; IDS Metadata Broker; Special Applications; Central IDS compliant platform;

Qu4lity project, Mondragon assembly Egokia

Multi Stage Zero Defect Manufacturing Railway Axles Production Line

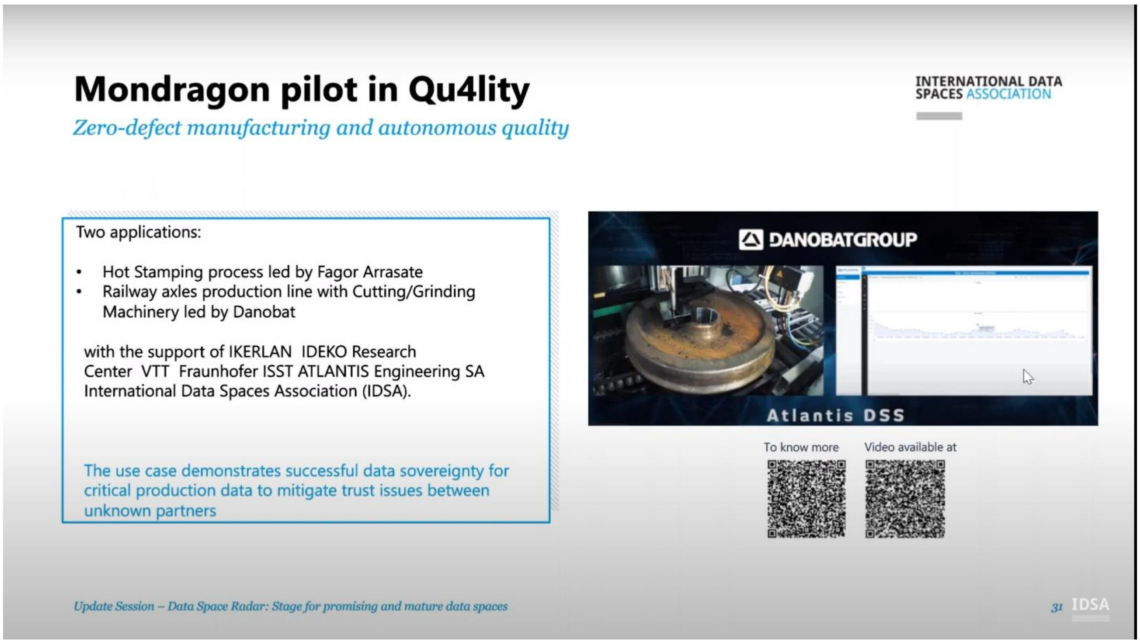


Figure 3. Qu4lity project

Consortium: MONDRAGON ASSEMBLY - an international firm specializing in the development of automatization and assembly solutions for various sectors. It operates 6 production plants around the world and is part of the largest cooperative group in the world | IKERLAN Technical research center and member of IDSA | IDEKO Research | Fraunhofer ISST | VTT | ATLANTIS | Engineering |IDSA

CHALLENGE

EGOKIA solution allows collaborative learning and knowledge sharing between geographically distributed plants, integrating headquarters in Basque Country and domain experts. Thanks to the data space, data, and AI assets can be securely shared throughout different corporate sites and a new knowledge-based economy emerges.

SUCCESS

Deploys an architecture based on IDSA connectors, linking Mondragon Assembly's data and AI platforms from different corporate sites. With this new reliable data space, we extend the lifecycle of artificial intelligence models, enhance their capabilities, and facilitate trusted access and use of its assets by EGOKIA participants.

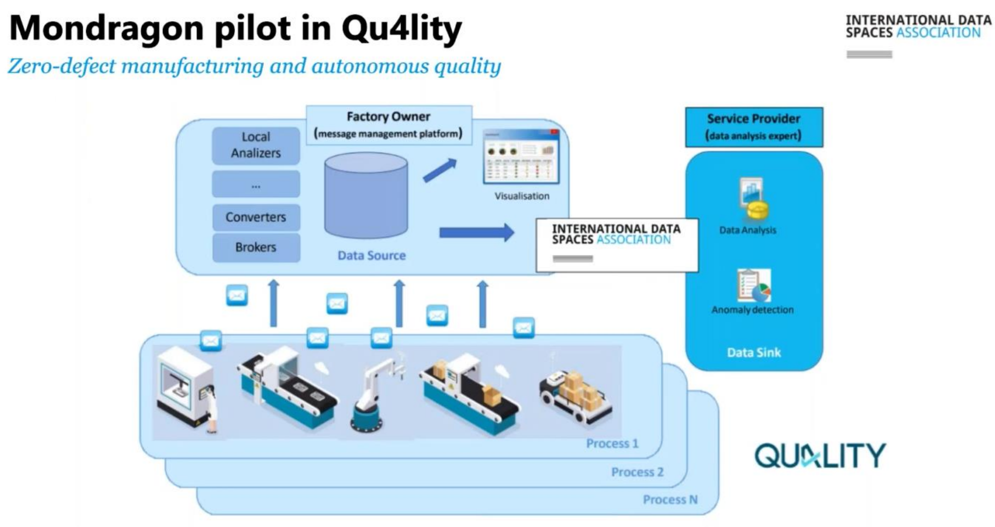


Figure 4. Pilot in Qu4lity project

BENEFITS

1. NEW BUSINESS MODEL: A new business model based on AI services and a knowledge-based economy.
2. RELIABLE AI SOLUTIONS: A "standardized", flexible, and secure solution to break data silos to share and complete AI assets and processes between trusted organizations and production plants. Measurable benefits can be listed as: Up to 30% quality on models thanks to the application of federated learning techniques, reduce inversion and time to market on IA-based solutions or lower communications loads.
3. STANDARIZED DATA SPACE – The organization is ready to take part in the knowledge economy with other entities, domain experts, and technology providers.

COMPONENTS

Data Space connectors 8.0.2 Metadata Broker 5.0.3 Identity Provider 1.6.0

FA3ST ecosystem for I4.0-compliant and data-sovereign digital twins

Consortium members: Fraunhofer IOSB

CHALLENGE

Due to the advancing digitalization of industrial value chain, increasingly large amounts of data are being generated in industry. Sharing data with partners in this domain, opens up new application and value propositions. This requires that the data can be interpreted across system and company boundaries, generally referred to as interoperability. The Platform Industry 4.0 proposes the Asset Administration Shell (AAS) specification for the digital representation of all assets. Additionally, the data security and data sovereignty challenges, which arise in such use-cases, are addressed by the IDS ecosystem. Digital twins are increasingly used in industry along the entire value chain. The dissemination of digital twins requires the integrability of their data and services across company boundaries. The Industry 4.0 platform proposes the Asset Administration Shell (AAS) specification for the digital representation of all assets.

SUCCESS

By combining the AAS with the IDS, interoperability across company borders is created. Product and production data is represented in AAS digital twins and shared via IDS Connectors.

BENEFITS

The AAS can describe all kinds of products and production equipment while linking data elements to semantic descriptions. The sharing of such data enables use-cases like the Platform Industry Collaborative Condition Monitoring use-case or the automotive network Catena-X.

COMPONENTS

IDS Connector; Eclipse Dataspace Connector 0.0.1-milestone-4; EDC Extension for AAS 1.0.0

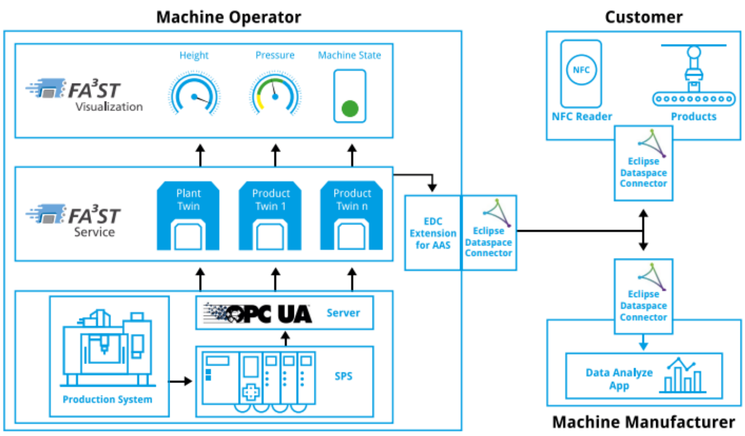


Figure 5. FA3ST ecosystem

2.1.4 Live cases (2 examples)

1. CATENA X
2. SCSN

Live

CATENA X

Consortium members: Acatech, BMW Group, Daimler AG & Mercedes-Benz, Volkswagen AG, Deutsche Telekom AG, Capgemini, Robert Bosch GmbH, IBM, BASF,SAP SE, SIEMENS AG, … up to 170 members .. (*see the complete list here*)

MISSION & CHALLENGE

The mission of the CATENA X initiative is to revolutionize the automotive industry by spearheading a comprehensive digitization effort of the entire value chain. Committed partners within the automotive sector aim to establish a unified standard for secure and sovereign data sharing, fostering increased value and streamlined processes. The core mission revolves around creating the industry's first data-driven value chain, offering end-to-end solutions that unlock new use cases and enhance overall operational efficiency. The challenges are:

1. Standardization and Interoperability: One of the primary challenges is to establish and maintain a universal standard for data sharing across the entire automotive value chain. Ensuring interoperability among diverse systems and technologies is crucial to the success of the initiative.
2. Data Sovereignty and Security: Guaranteeing sovereignty on all levels – data, services, identity, and operations – presents a complex challenge. The initiative must address concerns related to data ownership, security, and compliance with evolving regulations to build trust among stakeholders.
3. Digital Identity and Parts Relationships: Developing and managing unique digital identities and fostering trusted relationships between various components in the value chain (such as unique parts relationships) require robust technological solutions and adherence to industry best practices.
4. Integrated Solution Approach: Integrating business, technology, and legal aspects poses a challenge as it demands a cohesive strategy that aligns these diverse domains. Balancing the integration of these elements while ensuring they complement each other is essential for the initiative's success.
5. Open-Source Collaboration: Relying on open-source collaboration and software development is pivotal for the initiative. However, managing diverse contributions, ensuring code quality, and fostering a collaborative community present ongoing challenges that need to be navigated effectively.
6. User Control and App Integration: Empowering users to maintain control over their data and choose applications that suit their needs requires user-friendly interfaces and transparent processes. Striking the right balance between user control and standardized integration is a continuous challenge.
7. Transparent Development Practices: Ensuring transparent open-source development of business-relevant Kits (Knowledge and Information Transfer) and tested releases is crucial. This involves establishing clear development practices, documentation, and quality assurance processes to maintain credibility and reliability.

The CATENA X initiative acknowledges these challenges and commits to overcoming them, thereby creating a transformative impact on the automotive industry through a digitized, standardized, and secure value chain.

SUCCESS

The success of the CATENA X initiative lies in its unwavering commitment to overcoming the challenges posed by the digital transformation of the automotive industry. By addressing issues related to data sovereignty, security, and interoperability, the initiative aims to bring about a transformative impact. The envisioned success involves the creation of a digitized, standardized, and secure value chain, marking a paradigm shift in how the automotive industry operates. CATENA X recognizes that success hinges on the active collaboration of all stakeholders across the automotive value chain. The initiative is committed to fostering multilateral collaboration, ensuring that every participant, from production to logistics, plays a pivotal role in the collective success of the digital transformation.

Standards in the CATENA X Data Ecosystem:

Central to the success of the CATENA X initiative is the establishment of common standards within its data ecosystem. The growing CATENA X ecosystem serves as a catalyst for integrating vast amounts of data collaboratively. This collaborative approach enables stakeholders to harness the power of data for collective advancements, driving innovation and efficiency across the entire value chain.

Recognizing the inherent complexity of the vision, CATENA X acknowledges that companies involved in different stages of the automotive value chain operate with their own IT systems. To ensure seamless communication and processing of data across these varied systems, the initiative emphasizes the need for a universal language – common standards. These standards serve as a bridge, facilitating the smooth exchange of complex data volumes, promoting interoperability, and allowing stakeholders to leverage the full potential of the digital transformation.

In essence, the success of CATENA X is not just the realization of a digitized, standardized, and secure value chain but also the establishment of a collaborative ecosystem where data becomes a unifying force, propelling the entire automotive industry into a new era of innovation and efficiency. Through a commitment to common standards and multilateral collaboration, CATENA X paves the way for a future where the automotive industry thrives in the digital landscape.

BENEFITS

1. End-to-End Value Chains: By participating in Catena-X, you gain access to end-to-end value chains that unlock new and innovative use cases, fostering advancements in the industry.
2. Integrated Solution Approach: Our approach integrates business, technology, and legal considerations, building upon the industry's core elements: digital identities, unique parts relationships, and trusted business partners.
3. Digital Identity Empowerment: Catena-X empowers you with a unique digital identity, facilitating the establishment of distinctive parts relationships and connections with trusted business partners. We assure sovereignty across all levels – be it data, services, identity, or operations.
4. Data Control and App Selection: Your benefit lies in maintaining control over your data and the ability to choose applications tailored to your specific needs. Our reliance on open-source collaboration and software development ensures flexibility and adaptability.
5. Open-Source Development: Participate in the transparent open-source development of business-relevant Knowledge and Innovation Transfer (KIT) components and tested releases. This collaborative approach ensures a robust and evolving ecosystem for the industry.

COMPONENTS

Eclipse Dataspace Connector, Dynamic Attribute Provisioning System (DAPS), Marketplace, Portal, Semantic hub and other components (*More information about Catena X components and architecture can be fine here*).

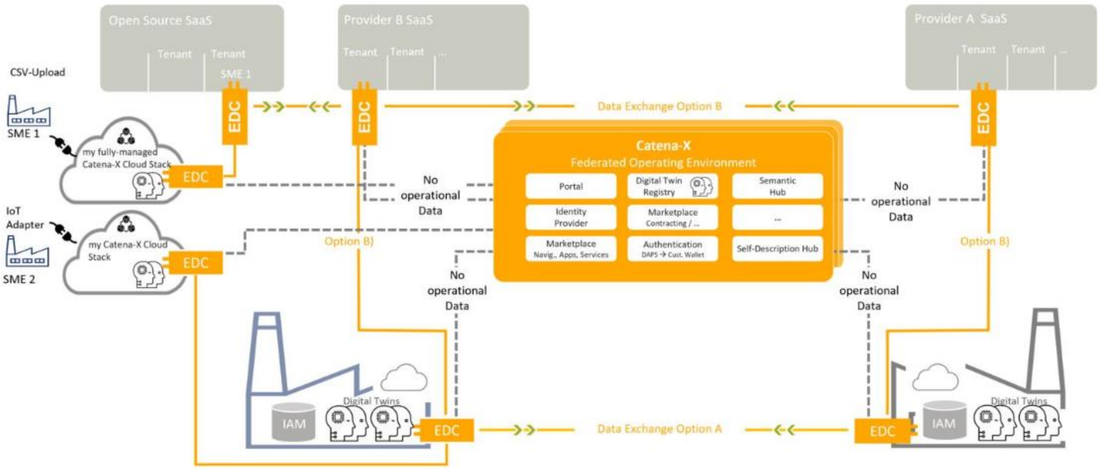


Figure 6. Catena-X Live Case

SCSN – Connect once – communicate with everyone

Consortium members: TNO |Isah | ECI Gatewise | Ketenlink | EDI4Steel | Supply drive | exact | tradecloud |Glovia

MISSION & CHALLENGE

The Smart Connected Supplier Network (SCSN) is a groundbreaking initiative spearheaded by manufacturing companies and their suppliers, designed to revolutionize communication across factories and ensure seamless interoperability within an open data ecosystem. At the core of SCSN's mission is the optimization of data exchange in the intricate web of supply chains within the manufacturing industry.

The challenges addressed by SCSN are particularly pronounced in small and medium-sized enterprises (SMEs) that play a pivotal role in these supply chains. In many cases, the success of these chains hinges on the efficient sharing of large volumes of data. However, the current process of data exchange is far from optimal, as the reception and transmission of data are predominantly manual tasks. This manual intervention is especially prevalent in SMEs, where data received from customers must be meticulously read, interpreted, and subsequently entered into their own Enterprise Resource Planning (ERP) systems.

SUCCESS

SCSN is a data standard that makes information exchange in the supply chain more efficient, allowing companies to share data more easily, quickly and reliably.

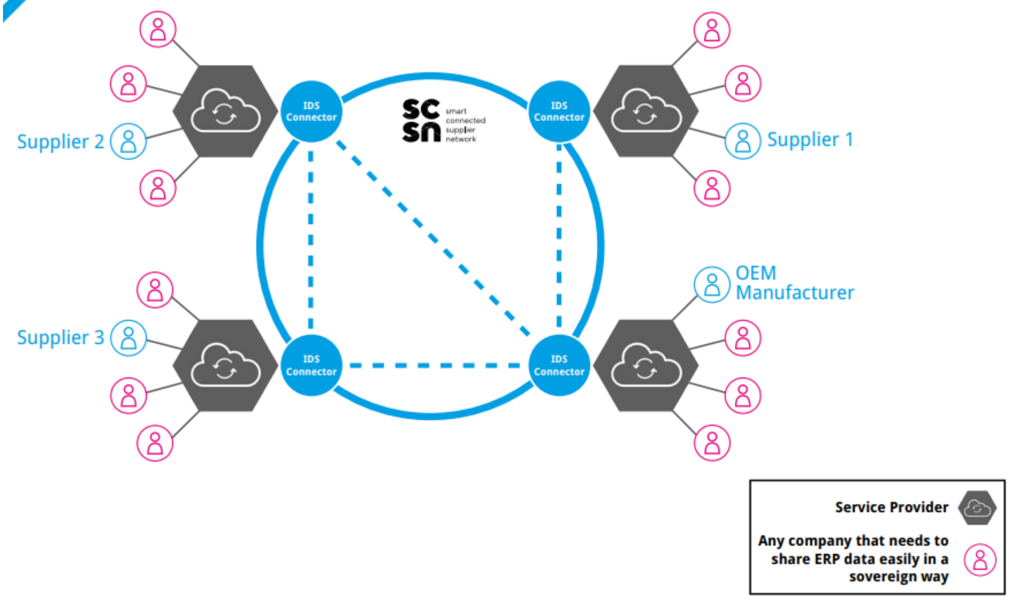


Figure 7. SCSN Live Case

BENEFITS

SCSN allows fast, secure and interoperable data sharing within the high-tech supply chain between companies. This results in increased supplier chain productivity. A company only needs to be registered once with an SCSN service provider, then share data with all other connected companies. COMPONENTS: IDS Identity Provider (Certificate Authority, DAPS, ParIS); IDS Metadata Broker; IDS Clearing House ; IDS Connectors and Data Apps.

2.2 Connected Factories 2030 Scenarios

The CF1 project (https://www.connectedfactories.eu) developed pathways that support manufacturing companies when navigating through the digital opportunities and challenges, i.e. the transformation of European Manufacturing Industry towards 2030. The CF1 pathways focus on Smart Factory, Smart Product and Smart Supply Chain scenarios and are divided to five steps that describe the development (maturity).

2.2.1 Smart Autonomous Factories of the Future

This pathway focuses on digitalisation within the so-called 'Automation Pyramid'.

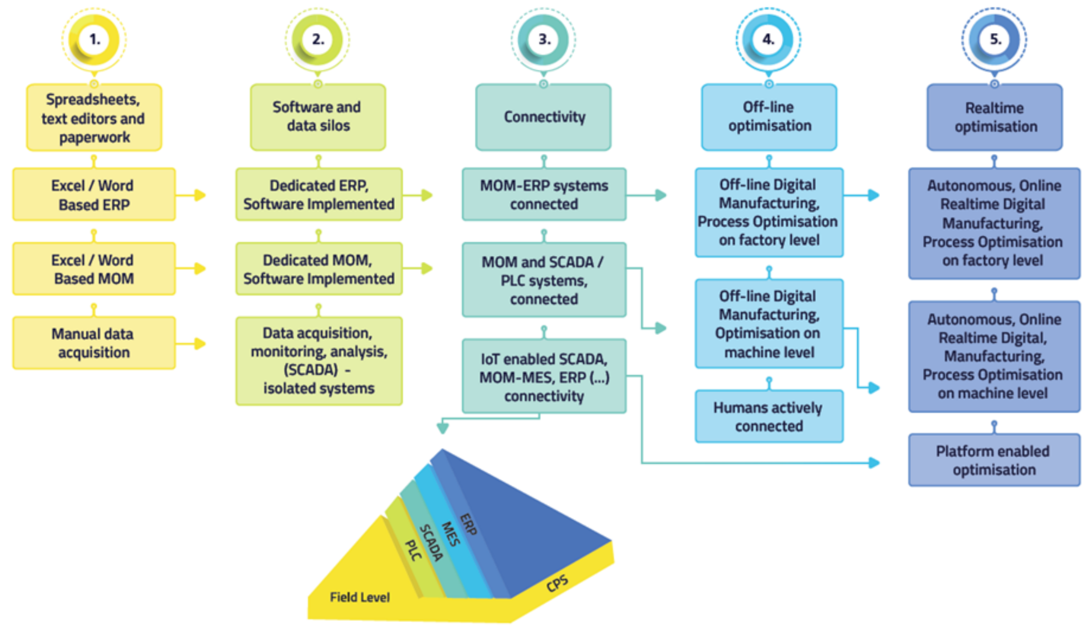


Figure 8. Smart Autonomous Factories Pathway

In this pathway, Level 1 reflects a situation that is still a reality in many manufacturing companies: data acquisition on the shop floor is done predominantly manually, while spreadsheets and text editors are used to do ERP and MOM including scheduling.

Level 2 involves the implementation of dedicated digital tools for doing ERP and MOM, while Supervisory Control and Data Acquisition solutions are implemented on shop floor level, connected to sensors and actuators and other field devices via PLCs or industrial PC's.

Level 3 focusses on the company internal connection of ERP, MOM and SCADA-PLC levels. This connectivity will increase the awareness of Enterprise Resource Planning about the status and condition of manufacturing operations, such as possible delays due to break-down or maintenance. This level includes the introduction of Industrial connectivity approaches, such as the use of Industrial IoT, RFID, other wireless technologies or identification methods.

In level 3 and beyond, the concept of Cyber-Physical systems is relevant, leading to a less hierarchical interpretation of the Automation Pyramid.

Level 4 focuses on the implementation of more advanced optimisation approaches, either on factory level or on machine level. Another achievement in this level is the inclusion of humans in the digital information or connectivity loop.

In Level 5, optimisation can be done in real time on factory or machine level. The deployment of digital platforms for manufacturing is situated on this level.

2.2.2 Product Service Factories of the Future

The collaborative product-service pathway is developed around the concept of servitisation. The pathway aims at capturing how the manufacturing company is progressively embracing a service-oriented business model without dropping the product-oriented business model. While big companies have already understood the product-service concept, SMEs have more difficulties to understand the association with services, in particular if they produce high-tech components. The danger for them is that they abandon their product after sales, while also missing the opportunity to create jobs in service and post-production jobs. This would also enable the shift of job profiles that are more associated to service-delivery.

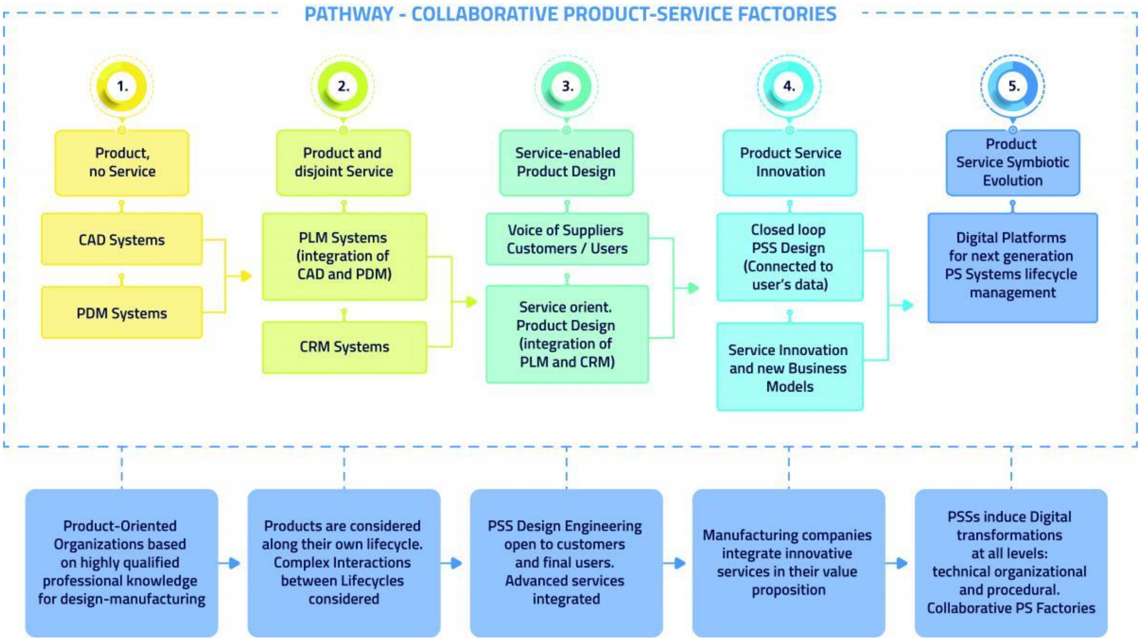


Figure 9 Product Service Factories Pathway

Level 1 is the situation where the full focus of the manufacturing company is on the product and where it does not or hardly address the services associated to that product.

Level 2 of the pathway implies that the manufacturing company has understood the opportunity for growth and job creation offered by associating services to their product in a structured way. This understanding is linked to the fact that products are seen within their full lifecycle and the complex interaction across different stages of their lifecycle. From the technological point of view this requires that the product can be tracked and traced remotely. A product lifecycle system (PLM) system should be able to manage this information and also provide insight into the evolution of the product, even to the stage of retro-fitting, re-use and recycling. The fact that a manufacturer does not lose the connection or even the control of the product along its lifecyle is a pre-condition for the structured development of services that are closely associated and integrated with the product.

In **level 3**, design and engineering processes of the product are opened to the requirements and needs from the different stakeholders along the whole life-cycle of the product: suppliers, business partners, customers. So level 3 is about creating a collaborative environment beyond the boundaries of the manufacturing company.(This involvement of users is different when the users are consumer or professional users).

Level 3 is a preparation phase in order to be able to integrate innovative services in the product (design for service) in level 4. It also assures that the design of new products are not taking place in a silo anymore. It assures also that products, such as machine tools, are engineered more specifically according to the needs of the use of the machine tool.

Level 4 is the further evolution of the process started in level 3, where innovative services are designed (in partnership with the different stakeholders) and delivered, sometimes in cooperation with specialised 'service' companies. For example, predictive maintenance services are offered in cooperation with specialised predictive maintenance services companies. This requires the sharing of data among the different parties and the conclusion of associated B2B agreements.

Level 5 is when the company has transformed it's business and product/services processes at all levels: embracing digital technologies (IoT, data analytics), integrating this with the hardware and manufacturing aspects (materials engineering, etc…), organisational aspects, where for instance sales people are both addressing the technical aspects as well as the business/service aspects.

In collaborative product service pathway, the link between the business objectives (shown in the bottom row of boxes) and the technological and digital aspect that enable to reach these business objectives, is less obvious that in the two previously presented pathway 'Autonomous Smart Factories' and 'Hyperconnected Factories'.

2.2.3 Hyperconnected Factories of the Future

The first levels of the Hyperconnected Factories pathway display similar levels as the Autonomous & Smart Factories pathway:

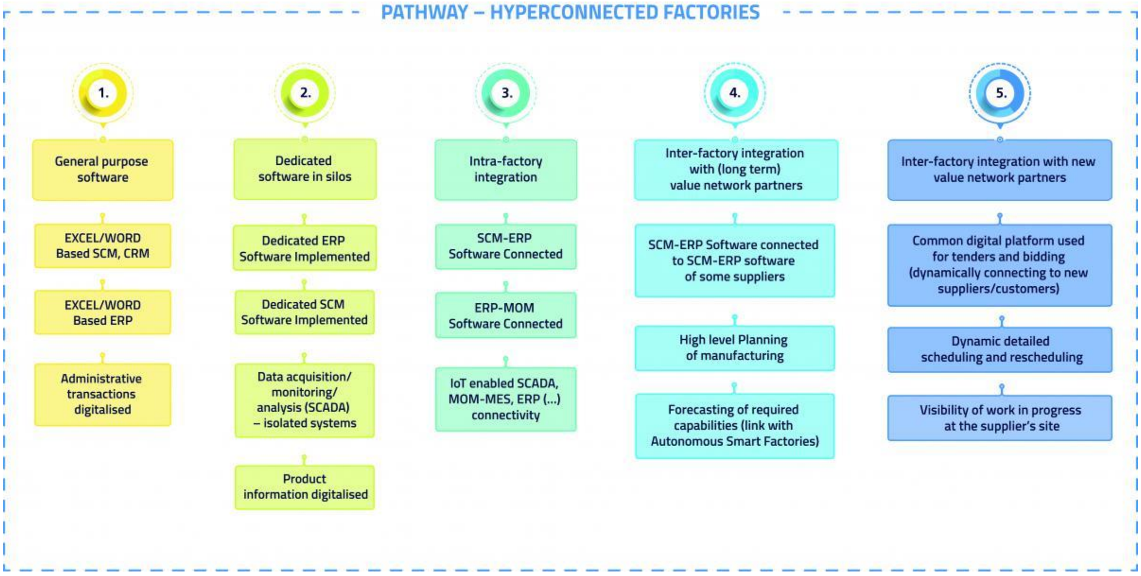


Figure 10. Smart Autonomous Factories Pathway

Multi-purpose digital tools are progressively implemented and complemented by dedicated tools that are operating in silos within the company.

Communication with other companies is primarily done by e-mails and attachments until reaching **Level 4**, where dedicated IT connections (such as private industrial networks) are established among a selection of long-term value chain partners.

Level 5 is a level where dynamic IT connection can be established with new business partners or suppliers.

2.3 Towards a common European Data Space: business models for Private Sector B2x

On April 25, 2018, the European Commission (EC) published a series of communications related to data trading and artificial intelligence. One of them called "Towards a Common European Data Space", came with a working document: "Guidance on Sharing Private Sector Data in the European Data Economy". Both the Communication and the guidance introduce two different sets of general principles addressing data sharing:

- contractual best practices for business-to-business (B2B)
- business- to-government (B2G) environments.

On the same day, the EC also published a legislative proposal to review the Public Sector (PSI) Directive. These two simultaneous actions are part of a major package of measures, which aim to facilitate the creation of a common data space in the EU and foster European Artificial Intelligence development.

The European data strategy aims to make the EU a leader in a data-driven society. Creating a single market for data will allow it to flow freely within the EU and across sectors for the benefit of businesses, researchers and public administrations.

The European Commission proposes a new European way of data governance to facilitate data sharing across sectors and Member States. It will create wealth for society, provide control to citizens and trust to companies.

A key pillar of the European strategy for data, the Data Governance Act seeks to increase trust in data sharing, strengthen mechanisms to increase data availability and overcome technical obstacles to the reuse of data. The Data Governance Act will also support the set-up and development of common European data spaces in strategic domains, involving both private and public players, in sectors such as health, environment, energy, agriculture, mobility, finance, manufacturing, public administration and skills. The Data Governance entered into force on 23 June 2022 and, following a 15-month grace period, is applicable from September 2023.

- Data-driven innovation will bring benefits for companies and individuals by making our lives and work more efficient through:
- Health data: improving personalised treatments, providing better healthcare, and helping cure rare or chronic diseases, saving approximately €120 billion a year in the EU health sector and providing a more effective and quicker response to the global COVID-19 health crisis;
- Mobility data: saving more than 27 million hours of public transport users' time and up to €20 billion a year in labour costs of car drivers thanks to real-time navigation;
- Environmental data: combatting climate change, reducing CO2 emissions and fighting emergencies, such as floods and wildfires;
- Agricultural data: developing precision farming, new products in the agri-food sector and new services in general in rural areas;
- Public administration data: delivering better and more reliable official statistics, and contributing to evidence-based decisions.

The initiative aims to make more data available and facilitate data sharing across sectors and EU countries in order to leverage the potential of data for the benefit of European citizens and businesses. For example:

- Good data management and data sharing will enable industries to develop innovative products and services, and will make many sectors of the economy more efficient and sustainable
- With more data available, the public sector can develop better policies, leading to more transparent governance and more efficient public services.

Four broad sets of measures are provided:

1. Mechanisms to facilitate the reuse of certain public sector data that cannot be made available as open data. For example, the reuse of health data could advance research to find cures for rare or chronic diseases.
2. Measures to ensure that data intermediaries will function as trustworthy organisers of data sharing or pooling within the common European data spaces.
3. Measures to make it easier for citizens and businesses to make their data available for the benefit of society.
4. Measures to facilitate data sharing, in particular to make it possible for data to be used across sectors and borders, and to enable the right data to be found for the right purpose.

The EU is creating a single market for data where:

- data can flow within the EU and across sectors, for the benefit of all
- European rules, in particular privacy and data protection, as well as competition law, are fully respected
- the rules for access and use of data are fair, practical and clear

The EU will become an attractive, secure and dynamic data economy by

- setting clear and fair rules on access and re-use of data
- investing in next generation tools and infrastructures to store and process data
- joining forces in European cloud capacity
- pooling European data in key sectors, with common and interoperable
- data spaces
- giving users rights, tools and skills to stay in full control of their data

With the European data act proposed in February 2022, the Commission aims to make more data available for use and set up rules on who can use and access what data for which purposes across all economic sectors in the EU.

The new rules are expected to create €270 billion of additional GDP for EU Member States by 2028 by addressing the legal, economic and technical issues that lead to data being underused.

Consumers and businesses generate data by using products and services. With the Data Act, they will benefit from:

- cheaper prices for aftermarket services and reparation of their connected objects

- new opportunities to use services relying on access to this data
- better access to data collected or produced by a device

By having more information, consumers and users such as farmers, airlines or construction companies will be in a position to take better decisions such as buying higher quality or more sustainable products and services, thereby contributing for example to the Green Deal objectives.

The Commission is looking to facilitate the sharing of data held by companies to improve public services and guide policy decisions.

Data-driven innovation is a key enabler of growth and jobs in Europe. As data is a non-rivalrous resource, it is possible for the same data to support the creation of several new products, services or methods of production. The same data can be used in different arrangements with other big companies, small and medium-sized enterprises (SMEs), startups or the public sector.

In order to ensure fair and competitive markets for the IoT objects and for products and services that rely on non-personal machine-generated data created by such objects, the following key principles should be respected in contractual agreements:

a) *Transparency*: The relevant contractual agreements should identify in a transparent and understandable manner (i) the persons or entities that will have access to the data that the product or service generates, the type of such data, and at which level of detail; and (ii) the purposes for using such data.

b) *Shared value creation*: The relevant contractual agreements should recognise that, where data is generated as a by-product of using a product or service, several parties have contributed to creating the data.

c) *Respect for each other's commercial interests*: The relevant contractual agreements should address the need to protect both the commercial interests and secrets of data holders and data users.

d) *Ensure undistorted competition*: The relevant contractual agreements should address the need to ensure undistorted competition when exchanging commercially sensitive data.

e) *Minimised data lock-in*: Companies offering a product or service that generates data as a by-product should allow and enable data portability as much as possible. They should also consider, where possible and in line with the characteristics of the market they operate on, offering the same product or service without or with only limited data transfers alongside products or services that include such data transfers.

As identified in the Communication 'Building a European data economy', manufacturers of IoT objects are usually in a privileged position to determine access to and reuse of non-personal and automatically generated data from IoT objects.

Depending on the market, these manufacturers may or may not grant access and usage rights to the user of the object, who may find themselves prevented from using data, the generation of which they triggered.

With this issue in mind, and as a follow-up to the stakeholder dialogue on the Communication 'Building a European data economy', the Commission outlined a set of principles in the

Communication 'Towards a common European data space' and its staff working document.

These principles should be respected in contractual agreements to ensure fair and competitive markets for IoT objects and for products and services that rely on non-personal machine-generated data created by such objects.

With the publication of these principles, the Commission launched a further consultation process with stakeholders. The Commission will continue to assess whether amended principles and possible codes of conduct are sufficient to maintain fair and open markets and will address the situation. If necessary, the Commission will take appropriate actions.

The underlying business models of data sharing can differ quite substantially, and it strongly depends on the type of data in question and the strategic business interest. They can range from an Open Data approach to exclusive data partnerships with only one party.

2.3.1 An Open Data approach

An Open Data approach, whereby the data in question are made available by the data supplier to an in principle open range of (re-)users with as few restrictions as possible and against either no or very limited remuneration, can be chosen when the data supplier has a strong interest in the data re-use. Examples are providers of services that would like to make use of an ecosystem of third-party application developers in order to reach the final customers.

2.3.2 Data monetisation on a data marketplace

Intangible assets, such as human capital, product-specific and process-related knowledge and the quality of customer relationships increasingly determine the competitiveness of companies, and even data and its use are now also classified as intangible assets. A greater understanding of the added value of data also increases its genuine value. This makes it possible to monetize data assets on data marketplaces or in direct exchange with interested organizations.

Data monetisation or trading can take place through a data marketplace as an intermediary on the basis of bilateral contracts against remuneration. This can be interesting for companies that do not know potential re-users for their data and aim at engaging in one-off data monetisation efforts:

a) there are limited risks of illicit use of the data in question,

b) the data supplier has grounds to trusts the (re-)user, or

c) the data supplier has technical mechanisms to prevent or identify illicit use.

2.3.3 Data exchange in a closed platform

Data exchange may take place in a closed platform, either set up by one core player in a data sharing environment or by an independent intermediary. The data in this case may be supplied against monetary remuneration or against added-value services, provided (inside the platform). This solution allows offering added-value services and thus provides for a more comprehensive solution for more stable data partnerships and allows for more mechanisms of control on the usage made of the data; model contract terms can lower the costs of drawing up data usage agreements. Where the data sharing is exclusive, it would need to comply with the competition rules.

Variations and combinations of these models are possible and need to be adapted to each concrete business need.

2.4 Data Spaces for manufacturing in EU Projects (H2020 DEP HEP)

By crossing CF I 2030 scenarios (§2.2) with the Business Models of the EU Data Strategy for the private sector, we have elaborated a matrix which could be useful to classify EU Projects. This matrix has been shown during the preparation events for the DEP deployment actions (SM4RTENANCE and UNDERPIN).

Figure 11. Data Spaces for manufacturing in EU Projects

2.4.1 Open Data Repositories

In this first category, we have included the projects which addressed how to network Data Spaces generated by Teaching-Learning-Didactic Factories, with a special future perspective on TEF (Testing and Experimentation Facilities). Three examples represent this category.

AI REGIO H2020 I4MS Phase IV Innovation Action "Regions and Digital Innovation Hubs alliance for AI-driven digital transformation of European Manufacturing SMEs" aims to build a one-stop-shop platform that enables access to resources for AI-based solutions in efficient and sustainable manufacturing, with particular emphasis on resources that can lower the AI adoption barriers for SMEs. Its network of 20+ Didactic Factories encompasses more than 150 SME-oriented services classified according to the DR BEST taxonomy (Data Remotisation Business Ecosystem Skills Technology) allows the Sharing of Data Assets, Digital Twins, Simulations, Tele-operations in so-called Virtual Factories which are able to interoperate assets and services physically located in different DFs. For this, it is an expression of Smart Autonomous factories.

DIMOFAC H2020 Innovation Action focusses more on the manufacturing of new Product and Services according to the Plug & Produce paradigm also implemented in its network of nine Didactic Factories in Italy, Spain, Switzerland, France, Germany and the Netherlands.

AI REDGIO 5.0 HORIZON EUROPE I4MS2 Innovation Action extends the AI REGIO network with sustainable value chains 5.0 by emphasizing the concept of TERESA (TEchnology and REgulatory SAndboxes) and the implementation of Industry 5.0 new WISE workspaces, respecting Wellbeing, Inclusiveness, Safety and Ergonomics of Workers 5.0.

2.4.2 Data and Model Marketplaces

In the second category we find projects which emphasizes the valorisation of the Data Sets to be exchanges, giving source to first examples of Data Marketplaces in manufacturing. Three selected examples are:

WeldGalaxy aims to deliver a secure and scalable B2B online platform that connects global buyers with the EU sellers of welding equipment and consumables. The platform with its integrated KBE tool aims to provide innovative web based services.

VIMMP (the Virtual Materials Marketplace) facilitates and promotes the exchange between all materials modelling stakeholders for the benefit of increased innovation in the European manufacturing industry. Materials modelling knowledge and service are of fundamental relevance to create new products and services according to circular and sustainable principles

MARKET4.0 (the Manufacturing marketplace Connect & Produce) develops an open multi-sided digital platform for enabling production equipment and service providers to connect and work together with manufacturing companies. It creates technical and financial trust to prove payment, delivery and anonymized feedback in manufacturing B2B collaboration. The project addresses the whole value chain of manufacturing equipment, by offering pre- and post-sales services, anticipating this way the vision of Manufacturing as a Service.

2.4.3 Trusted Data Networks

The third category of projects addresses trusted data networks of manufacturing companies (and SMEs) according to both hierarchical (led by a Large Manufacturer) and non-hierarchical (peer to peer network of production capacity) business models. Here we have selected six representative projects, two for each category.

RE4DY (manufacturing data networks) and AIDEAS (Industrial equipment platform) both addresses vertical (edge to cloud) and horizontal (supply chain) trusted data networks originated by Smart and Autonomous Factories, including Smart Systems and Industrial IoT.

Circular TwAIn (HORIZON Europe Innovation Action for Circular Economy and AI) and CIRPASS (DIGITAL Europe preparatory action in the domain of Digital Product Passports) focus on the product life cycle and on the need to integrate B2B Data Spaces with product traceability and certification of origin, for the benefit of EU consumers and under the control of EU Governmental agencies such as Customs and the Market Surveillance authorities.

AI SOV (EIT Manufacturing innovation Activity) aims at this project aims at creating a real reusable, sustainable industrial data space ecosystem based on industrial platforms that are supporting the European industries to faster exchange AI results, (such as spare parts production and forecast and predictive maintenance data, or data-driven new business opportunities throughout the value-chain) along with the whole industrial and supply/value chain stakeholders. AI.Sov it is an example of hierarchical trusted data networks.

CLARUS (Optimizing Production And Logistic Resources In The Time-Critical Bio Production Industries In Europe) enables AI-based energy and material resource consumption assessment, traceability, and optimization for food industry processes. CLARUS platform integrates advanced communications, data processing capabilities, AI, as well as standardized open protocols to achieve higher levels of sustainability in the critical bio production sector in a typical non-hierarchical value chain.

2.5 DS4.0 Analysis on Data Spaces in Manufacturing

Our analysis of Data Spaces in manufacturing follows a conceptual model which is a derivation of what described in the previous §2.4 paragraph. We identified three main categories of projects which are reported in the columns:

1. Industrial Data Spaces, which mostly focus on FAIR high-value datasets and how to achieve cross-organizational interoperability
2. Industrial Data Platforms, which mostly focus on Digital Manufacturing Platforms (marketplaces) of data-related services, including Data Sovereignty and Data Sharing
3. Industrial Circular Networks, which mostly focus on the multi-stakeholders agreements (access usage rights) to be put in place in complex value networks, both at the suppliers' and at the customers' sides, in order to achieve sustainability and circularity in a Green Deal perspective.

In the following matrix we have crossed the above three categories of projects with the basic three scenarios for implementing Data Spaces in Manufacturing, identifying nine distinct cases where to test and validate our methods and tools for data maturity assessment in industrial pilots (see Chapter 5 for a complete description of the method.

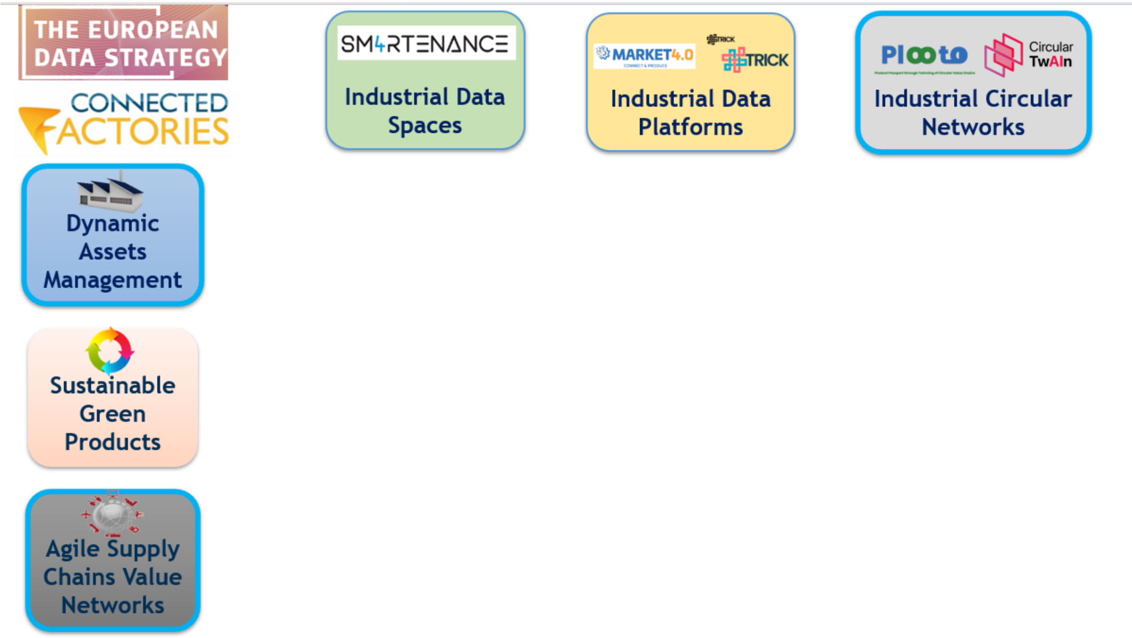


Figure 12. Data Spaces for manufacturing

2.6 Data Space Maturity Models in Manufacturing

Defining and developing a method and a set of tools to assess the Maturity of a Data Space is one of the most ambitious challenges for current research in Data Spaces. During the Connected Factories II CSA

2.6.1 The Connected Factories II Data Space Pathway 2030

The CF2 project (https://www.connectedfactories.eu) developed pathways that support manufacturing companies when navigating through the digital opportunities and challenges, i.e. the transformation of European Manufacturing Industry. The CF2 pathways focus on data, Artificial Intelligence and Circularity, the key aspects and enables of the twin transition of manufacturing. The pathways are divided to five steps that describe the development (maturity).

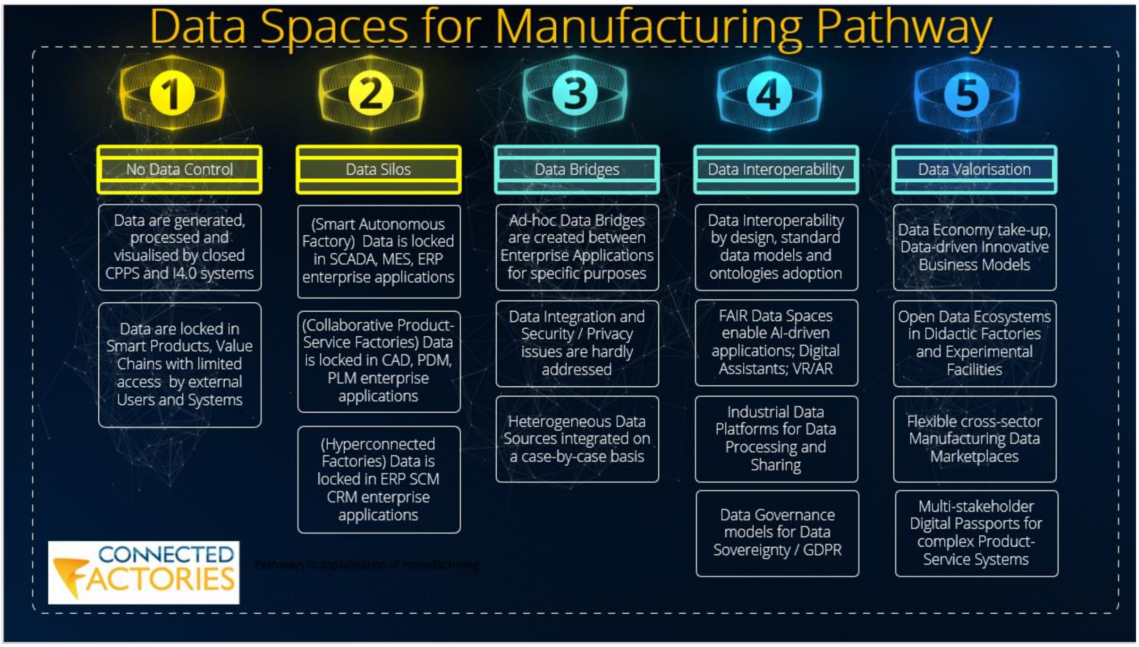


Figure 13. Data Spaces for Manufacturing Pathway

The Data Space pathway of the Connected Factories project provides a conceptual and operational framework where manufacturing companies could position themselves and their industrial cases with respect to a more mature and aware take-up and exploitation of the Data they produce.

The Data Space pathway is composed of 5 levels, characterised by increasing maturity degrees of the manufacturing company / industrial case towards a full exploitation of Data Economy in Manufacturing.

At Level I, data remain trapped inside the systems and is practically not available to Manufacturing Industry end users and further elaborations.

At Level II, traditional Enterprise Systems (SCADA MES ERP PLM SCM) are able to capture most of the data produced, but owing to scarce adoption of open standards, data silos are created so that processing and analytics is just possible from inside such applications.

At Level III, ad-hoc data integration bridges are created among systems and their repositories, but every integration project remains isolated and needs to start from scratch.

We start speaking of Data Spaces at Level IV of the pathway's scale, named Interoperability. At this level, the Technology perspective to Data Spaces is addressed. As an integral part of common unified Industrial Architecture Models (like the OPC Unified Architecture), Findable Accessible Interoperable and Re-usable Data Sets are implemented thanks to open standard data models (like the RAMI Asset Administration Shell) and semantic interoperability (like the Industrial Ontology Foundry);

Industrial Data Platforms are able to integrate, process, analyse, visualise and share the data in secure and trusted manner Advanced rule- and AI-based decision support systems implement the business and governance agreements and let the ecosystem work and evolve along time.

In conjunction with the Level IV Technical approach, Level V of the Data Spaces pathway addresses the Business challenges implied by the implementation of Data Spaces. Three main Business Models are enabled: Open Data, Data Marketplace and Trusted Network.

The evolution of Data Aggregation, Data Anonymisation and above all synthetic Data Generation techniques as well as the flourishing of open innovation business models is opening new interesting perspectives for Manufacturing Open Data development.

Data Spaces represent one of the fundamental enablers, allowing the full exploitation of Data Economy business models of Open Data, Data Marketplaces and Trusted Data Ecosystems.

For instance, in a Smart Autonomous Factories scenario, Data Spaces support dynamic multi-stakeholder industrial assets monitoring and control, enabling predictive maintenance and substantial reduction of environmental footprint. In a Collaborative Product-Service scenario, Data Spaces (often associated to Digital Product Passports) are able to collect, integrate and harmonise highly distributed datasets, in space and in time, along the whole lifecycle of the product, enabling new service-oriented business. In a Hyperconnected Factories scenario, Data Spaces are able to model heterogeneous, complex and dynamic supply and delivery business ecosystems by adopting common standard data models and business processes, finally enabling order-capacity matchmaking and One-of-a-Kind production.

Three pathways for the above particular scenarios within the overal context of manufacturing have been developed during the Connected Factories project.

The pathways enhance the awareness among different stakeholders about the actual and future use of digital technologies in manufacturing and facilitate the migration from legacy situations towards innovative approaches.

2.6.2 The DSSC Maturity Model for Data Spaces

The DSSC Maturity Model for Data Spaces, as described in section 2.6.2, is an important framework for understanding and evaluating the development and evolution of data space initiatives. This section introduces the a maturity model that is crucial for writing about topics related to the creation, maintenance, and progression of a data space initiative.

The primary focus of the DSSC Maturity Model is to provide guidance on the deployment and maintenance of a specific data space, as well as the development of use cases and pilot projects within that data space. The model aims to help organizations assess and improve the maturity of their data space initiatives over time.

In this section, it's important to note that the terminology presented may not be as stable or universally accepted as other terms in the glossary. This is because the field of data spaces and related technologies is evolving rapidly, and new concepts and approaches continue to emerge.

The terminology presented may not be as stable or universally accepted, bu the inclusion of this section in draft format is deliberate, as it encourages discussion and collaboration among stakeholders involved in data space initiatives. The different life cycle stages of data space initiatives, as outlined in the DSSC Maturity Model, serve as a starting point for such discussions. These discussions can help refine and expand the terminology and concepts associated with data spaces as the field matures.

Overall, the DSSC Maturity Model for Data Spaces is a valuable resource for organizations and individuals working in the realm of data management and data space initiatives. It provides a structured framework for assessing and improving the maturity of these initiatives and fosters ongoing dialogue about the terminology and stages of development within the field.

4. Evolution of data space initiatives - Glossary - Data Spaces Support Centre (dssc.eu)

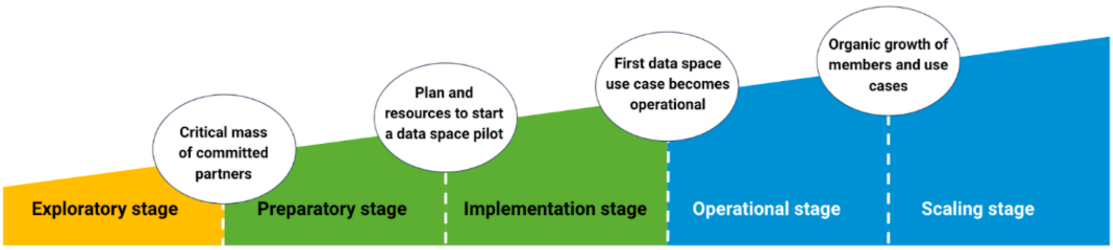


Figure 14. Evolution of data space initiatives

The Development cycle is the sequence of stages that a data space initiative passes through during its progress and growth. In each stage, the initiative faces distinct needs and challenges, evolving in terms of knowledge, skills, and capabilities.

Exploratory stage: This marks the initial phase of a data space initiative, where a group of individuals begins exploring the interest, potential, and viability of the data space. Activities during this stage typically include identifying and engaging stakeholders, gathering requirements, discussing potential use cases, and reviewing existing conventions or standards.

Preparatory stage: As the initiative gains momentum and garners commitment from partners, the preparatory stage commences. Here, the initiative has a critical mass of dedicated partners who collectively develop use cases and prepare for the actual implementation of the data space.

Implementation stage: Progressing further, the initiative enters the implementation stage, characterized by a detailed project plan, milestones, and adequate resources (including funding). This stage focuses on building the governance framework and infrastructure needed for a data space pilot, with clear identification of involved parties and the intended value for each.

Operational stage: When the initiative successfully implements infrastructure and governance frameworks and achieves operational use cases (with data flowing between providers and recipients, delivering the intended value), it enters the operational stage. This stage often involves ongoing changes to both governance and technical aspects of the data space.

Scaling stage: The scaling stage begins when the data space initiative consistently attracts new participants and accommodates new use cases in an organic manner. At this point, the data space becomes financially and operationally sustainable, capable of adapting to market changes, and poised for gradual growth over time.

3 Business Modelling for Data Spaces in Manufacturing

3.1 Business Stakeholders in Manufacturing Data Spaces

Companies are showing a growing interest in digital sovereignty, because of the importance for the business to retaining control over their digital business assets or the digitized business model itself. This pursuit of digital sovereignty not only unlocks a realm of new business opportunities but also paves the way for entirely novel markets. Additionally, it facilitates and expedites the evolution of existing markets through the incorporation of data sovereignty services.

The diversity of enabled business models, as previously mentioned, is a crucial aspect. These models intricately interconnect within a data-driven ecosystem, fundamentally grounded in the principles of data sovereignty.

The IDS-RAM introduces a set of fundamental roles organized into business roles, designed to serve various business purposes.

Data Supplier

A data supplier is an entity that generates or possesses data intended for use within the IDS ecosystem. Depending on the prevailing business and operational framework, the fundamental roles undertaken by a data supplier typically include that of a data creator, data owner, and data provider.

1. Value Proposition: The core offering revolves around providing valuable data, ensuring data quality, completeness, aggregation, specialized data evaluations, and more.
2. Customers: The recipients of this data encompass a spectrum of roles, including data owners, data consumers, brokers, clearing houses, identity providers, service providers, app providers, app stores, vocabulary providers, and evaluation facilities.

In the specific use case of enhancing transparency in automotive supply chains, both Volkswagen and Thyssenkrupp engage in the exchange of relatively sensitive data. This collaborative data sharing aims to boost the efficiency of the entire supply chain, leading to faster reactions, reduced inventory, and decreased reliance on express transportation.

Data Intermediary

Functioning as a reliable data intermediary, this entity oversees data exchange within data ecosystems. The data intermediary possesses knowledge of the participants, assumes common roles, directs data flow, accommodates data storage requests, and manages both metadata and available data sources in the ecosystem. An organization serving as a data broker may concurrently undertake multiple intermediary roles, involving additional tasks and responsibilities. However, a crucial aspect remains unchanged: a data intermediary guides the data without utilizing or analyzing it, maintaining the role of a trusted intermediary.

1. Value Proposition: Serving as an interface for data suppliers, the data intermediary facilitates the availability of metadata for data customers. This includes providing overviews, structuring data, categorizing information, offering a search engine, ensuring quality, and providing recommendations. The intermediary is acquainted with trusted suppliers and customers, potentially assuming a platform role that fosters exponential growth for all participants

2. Customers: The clientele encompasses various data suppliers, data customers, identity providers, service providers, and evaluation facilities.

The Meta Data Broker Data Intelligence Hub, Deutsche Telekom and the Smart Connected Supplier Network by TNO are good examples of manufacturing related data intermediaries.

The product Data Intelligence Hub manages metadata describing the data sets of B2B data suppliers. It provides secure storage of metadata and provides it on a data marketplace. Smart Connected Supplier Network is an initiative of manufacturing companies and their IT-suppliers in the high-tech manufacturing supply chain. The aim is to facilitate cross-factory communication to ensure supply chain transparency and interoperability. Manufacturing companies can use a single SCSN connection to exchange purchase-to-pay information with all their suppliers and customers. This reduces administrative efforts and human errors while increasing the supply chain agility.

Service Provider

In the realm of IDS, services encompass a spectrum of functions, including data analysis, data integration, data cleansing, and semantic enrichment of data. The service intermediary, serving as a platform operator, delivers services (e.g., an app with computing time as a trustee), metadata about services, or a combination of both.

1. Value Proposition: The core offering revolves around the provision of valuable services, ensuring service quality, offering support, maintaining a hotline, ensuring service availability, optimizing service performance, and providing a diverse range of payment methods.

2. Customers: The clientele spans data owners, data providers, data consumers, data users, brokers, app providers, app stores, and vocabulary providers.

Collaborative warranty and quality management, SAP and Fraunhofer use case. In a multi-tier supply chain, SAP aims to address delayed quality data sharing using IDS concepts. The "collaborative warranty and quality management apps" incentivize repair shops to share vehicle quality data throughout the manufacturing supply chain, overcoming delays and lack of incentives. This facilitates timely visibility into quality issues for suppliers at any tier, enabling proactive identification and resolution. The system promotes efficient root-cause analysis by integrating downstream or upstream quality and usage data, governed by usage policies for secure information exchange. Overall, this collaborative approach enhances the efficiency of manufacturing processes.

Service Intermediary

The service intermediary ensures the prompt and efficient delivery of services within the IDS, functioning as a kind of "Yellow Pages" for services. It oversees metadata for both new and established services, offering a platform for data providers to present metadata for their respective services.

1. Value Proposition: Summary, framework, classifications, search functionality, quality assurance, and recommendations.
2. Customer Segments: Data providers, data consumers, identity providers, service providers, and evaluation facilities.

Smart Connected Supplier Network (SCSN) by TNO streamlines communication in high-tech manufacturing. It enables manufacturing companies to effortlessly exchange purchase-to-pay information with all suppliers and customers through a single SCSN connection. This minimizes administrative efforts, reduces errors, and enhances supply chain agility.

Vocabulary Publisher and Provider

Vocabularies serve to annotate and describe data assets. A vocabulary intermediary technically oversees and provides vocabularies, including ontologies, reference data models, and metadata elements. These vocabularies are owned and governed by the relevant standardization organizations. The vocabulary intermediary typically takes on the fundamental roles of a vocabulary publisher and a vocabulary provider.

1. Value Proposition: Terminology, ontologies, homogenous wording, …
2. Customers: Data owner, data provider, data consumer, data user, clearing house, service provider, app store

UMATI, led by VDMA, is creating an OPC Companion Specification for a common machine vocabulary across manufacturers, facilitating seamless data exchange. VDMA, with T-Systems, runs a 24x7 demonstrator for member self-onboarding globally. Future plans include enhanced data control. Domain-specific vocabularies, like 'Gene Ontology' and 'GAO,' are critical, managed by organizations like Odette for automotive supply chains. Vocabularies also define legal terms, like data usage policies using ODRL in the IDS information model. Specific IDS communities may introduce additional vocabularies, e.g., for Incoterms or iShare references.

Clearing House

A functional entity within the IDS, the Clearing House validates financial and data-based transactions, overseeing both data exchange and monetary transactions. It plays a neutral role in managing transactional metadata.

1. Value Proposition: Facilitates secure payments and ensures transactional transparency.
2. Customers: Data owner, data provider, data consumer, data user, identity provider, app provider, app store, vocabulary provider, evaluation facility.

Clearing House within the Smart Connected Supplier Network (SCSN), TNO:

SCSN is used to send purchase-to-pay information in a business-to-business scenario, which means that billing and payment information is exchanged. This information can be highly confidential and at the same time it is mission-critical for the connected companies, as it directly affects their day-to-day business. If dispute arises (e.g., a seller claims to receive a different order then the receiver claims to have provided), the clearing house is used as trusted third party to resolve this issue by comparing the fingerprint of the messages and identifying the error.

Identity Authority

The Identity Authority provides a service for creating, maintaining, managing, monitoring, and validating identity information for IDS participants. This service is crucial for the secure operation of IDS, preventing unauthorized access to data. Every participant in the IDS ecosystem must possess and utilize an identity for authentication. The Identity Authority is an indispensable component that can be offered by a single company to all participants, enabling sovereign data exchange within the IDS ecosystem.

1. Value Proposition: Security, certification, handling of identities (directory)
2. Customers: Applies to all the IDS-Roles

PKI service, Deutsche Telekom:

The Deutsche Telekom Trust Center, operated by Deutsche Telekom Security GmbH, provides a Public-Key-Infrastructure (PKI) service that supports automated issuance of machine certificates to computers, servers, VoIP systems, printers and IoT / M2M devices. This ensures that each IDS participant can be definitively identified.

In order to determine certificate validity, the certificate's status can be queried using the Online Certificate Status Protocol (OSCP). Access to the services is supported by a wide range of standard protocols. In order to live up to the importance of identity services in IDS, the PKI services are operated to a high standard of availability and performance, fulfilling a wide range of security requirements.

Software Developer

A software developer can act as an app developer or connector developer in IDS. An app developer creates data apps for IDS participants, assuming roles like app creator and owner. Connector developers provide software components for essential IDS functions. Unlike data apps, IDS Connectors aren't from the app store but are distributed through standard channels with individual agreements between the connector developer and users (e.g., data customer, supplier). Notably, agreements like licenses for deploying and using IDS Connectors are beyond the scope of IDS

1. Value Proposition: Offering valuable services/apps, service quality, support, hotline, service availability, service performance, wide range of payment methods
2. Customers: Data owner, data provider, data consumer, data user, clearing house, service provider, app provider, vocabulary provider

Certification Body and Evaluation Facilities

Certification in the IDS ecosystem builds trust by ensuring a standardized level of security for all participants. It involves certifying the operational environment and components, carried out by the certification body and an evaluation facility. The evaluation facility conducts testing, while the certification body oversees the process, manages quality assurance, and provides guidance. These roles ensure access is granted only to IDS-compliant organizations. The certification body sets up the certification scheme, approves evaluation facilities, and currently, the IDSA head office serves as the initial certification body.

1. Value Proposition: IDS security, proven authenticated identities, interoperability, access control
2. Customers: All IDS roles

The SQS Testing & Evaluation Facility delivers assurance evaluation services for industrial data sharing components, platforms, equipment, and infrastructures. These services adhere to DIN 27070 security profiles and the IDSA Reference Architecture.

The facility provides independent validation services for various commercial IDSA components, supporting developers and European companies in service certification across sectors like logistics, transport, and medical and pharmaceutical product development. Additionally, it prepares evaluation reports for IDSA certification. Fees may apply based on the specific service required.

3.2 DSSC Business Models Framework and Manufacturing Industry

The DSSC blueprint covers the business, governance and legal building blocks of data spaces – collectively, these are called organisational and business building blocks. The organisational and business building blocks form a reference for data space initiatives to develop business, governance and legal capabilities within data spaces. Data space organisational and business building blocks are components that can be implemented and combined with other building blocks to achieve the functionality of a data space.

The organizational and business building blocks describe at the system-level the desired behaviors of data space participants and determine data space participants' intentions, positions and operations. This chapter is about the business building block category and introduces crucial concepts for the business modeling of a data space. In the context of data spaces, it is imperative to distinguish between:

1. The Business Model of the Data Space Infrastructure that can supports multiple use cases within the data space.
2. Business Models of Individual Data Space Participants that engaged in one or more data space use cases.

Both the data space and its participants are integral parts of data ecosystems. The analogy of ecosystems from biology, where equilibrium is reached without central planning, applies to the business realm. Despite individual participants having their own business models without central coordination, the overall data ecosystem, supported by data spaces, should find equilibrium.

This business building block category comprises the following components:

Business Model Development:

- Aids a data space in developing its business model by identifying key elements and considerations for the governance authority.
- The data space business model represents the logic behind sustaining and developing operations and governance.
- It defines how the data space creates and delivers value for participants while ensuring sustainability over time.
- For sustainability, a value capture mechanism, such as a usage fee, is needed unless the data space is continuously publicly funded.

Use Case Development:

- A strategic approach to enhance the value of a data space by fostering the creation, support, and scaling of use cases.
- Use cases rely on the data space to address business challenges or create value for participants, generating demand and potential customers.
- Financial sustainability requires attracting use cases that generate income through usage fees, with costs lower than total revenue.
- Interconnected use cases create synergies between participants and data products, contributing to the data space's overall success.

Data Product Development:

- Considers data product templates for providers, governance rules, and network effects between data providers and users.
- Data products serve as fundamental units of data space use cases, and network effects play a crucial role in attracting users and providers.

Data Space Intermediaries:

- Supports decision-making on business and governance aspects related to intermediaries providing enabling services.
- Enabling services include identity, observability, catalogue, and connector services, which can be outsourced to external intermediaries specializing in delivering these services to multiple data spaces.

Catena-X Your Automotive Network

Catena-X Operating Model

The Catena-X Operating Model is an example of how to define the business operational model and processes required in the Catena-X ecosystem. The operation of Catena-X data space consists of three main areas: (1) Core Services, (2) Enablement Services and (3) Business Applications as shown in figure below:

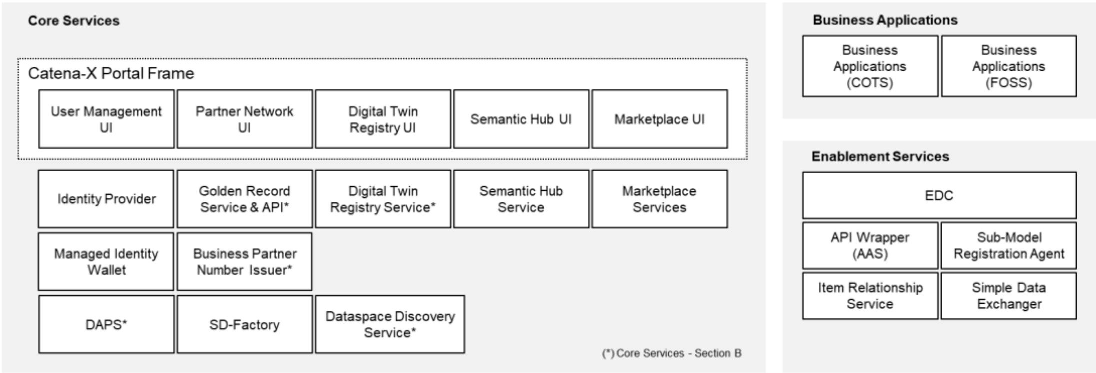


Figure 15. Catena-X Operating Model

- Core Services:

Facilitate fundamental functions within the Catena-X ecosystem, including identity and data discovery at the data space level. Some of these services are executed once in the data space. The Catena-X portal frame is a single management interface for customers. Customers can, for example, register their organizations, manage their organization and user data, manage their technical integration (e.g., IdP or Connector).

- Enablement Services:

Can be self-managed by participants or delegated to an Enablement Service provider, utilizing the Eclipse Dataspace Connector (EDC). Integration of EDC extensions or backend data services is feasible based on use cases and legacy systems.

- Business Applications:

Address specific business challenges like demand and capacity management, circular economy. Span from extensive enterprise solutions to specialized options for small and medium-sized enterprises.

Operators play a pivotal role in "bringing the data ecosystem to life." The Catena-X data ecosystem's future involves decentralized implementation by various operators. These operators will separately implement services in the three areas, adhering to standards and norms specified by Catena-X Automotive Network e.V. Each operator has the flexibility to assume one or more roles. More information about of Catena X operation model can be found on the Catena X website.

3.3 DSSC Governance Building Blocks and Manufacturing Industry

The fundamental elements of governance focus primarily on overseeing the dynamics of the data space. Governance within data spaces must evolve in tandem with the changes in the data environment. This necessitates collaborative and strategic efforts among data space participants to ensure effective governance.

This category of governance building blocks encompasses the following components:

Organisational Governance:

- Guides the establishment of the data space governance authority by identifying crucial decision points.
- Offers options for inclusive governance and transparent rules and roles.
- Organisational governance is essential within a data space to assist participants in organizing and achieving their goals.
- Key decision points include defining the scope of the data space, determining its position in the ecosystem, establishing openness for participants, providing support, and implementing principles (e.g., democratic).
- Decisions may vary between data spaces, but the aim is to foster collaborative, multi-stakeholder governance for effective data space operation.

Data Sharing Governance:

- Supports the governance authority in establishing common rules to facilitate effective and reliable data sharing processes.
- Introduces various ways to organize data transactions within a data space.
- Governs how data transactions are facilitated, with the authority mandating rules and standards for security, performance, interoperability, and observability.
- Clear data sharing rules are crucial for building trust among data space participants and directly impact the functionality of the data space.
- Strategic choices regarding rule enforcement affect entry barriers and challenges related to implementing new use cases.
- Decisions also involve enabling services like identity and catalogue services.

This building block forms the foundation for efficient data sharing processes, ensuring reliable and observable data transactions through defined rules and services.

Catena-X
Your Automotive Network

Governance Framework for Data Space Operations

https://catena-x.net/fileadmin/_online_media_/231006_Whitepaper_DataSpaceGovernance.pdf.

The governance framework of Catena-X revolves around the core principles of providing a reliable, trustworthy, and transparent ecosystem, with trust as the cornerstone for successful supply chain collaboration. Scalability is a key goal, both within Catena-X and beyond its data space boundaries, to attract more participants and extend the adoption of Catena-X. Strategic partnerships with neutral, independent entities are instrumental in achieving these objectives. The governance units include:

- Identity: Collaborating with Gaia-X to establish an overarching Trust Framework.

- Data Exchange: Partnering with the International Data Space Association (IDSA) to create an industry-agnostic foundation for sovereign data exchange.
- Development: Forming a partnership with the Eclipse Foundation to leverage proven software development processes, best practices, and the management of repositories in open source.
- Industry-specific logic: Teaming up with the Catena-X Association to drive standards addressing common business needs within the automotive industry.

These partnerships ensure the adherence to fundamental principles and the effective governance of the Catena-X initiative.

To foster trust, Catena-X incorporates the Gaia-X Digital Clearing House (GXDCH) into its onboarding process. The GXDCH ensures adherence to Gaia-X rules by conducting a veracity check during participant onboarding. New participants validate their company information, which is then sent to the GXDCH for verification against publicly available data. If the check is positive, the GXDCH issues a signed Participant Self-Description (Gaia-X Credential), stored in the participant's SSI wallet and accessible to the network via the company registration service. This integration exemplifies the commitment to trust-building through a transparent and verifiable onboarding process.

The aim is to empower participants to choose to publish their services' Gaia-X Credential in the Gaia-X registry for a broader audience.

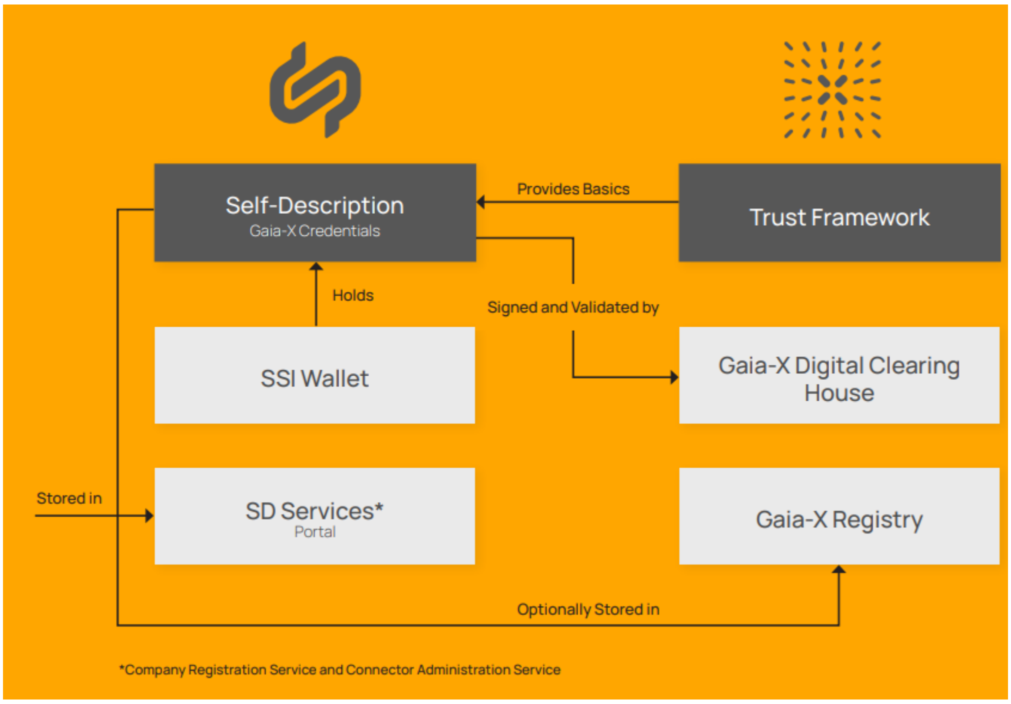


Figure 16. Governance Framework for Data Space Operations

To create the base for sovereign data exchange and interoperable solutions, the IDSA data-space protocol forms the foundation for sovereign data exchange and interoperable solutions. The Eclipse Dataspace Connector (EDC) serves as a reference implementation of this protocol, allowing data providers to systematically describe their data assets. Through access policies, providers can control who can view and consume their data, while usage policies set conditions for consumption. Although not technically enforceable, the dataspace protocol and EDC establish a robust foundation for data sovereignty, with legal binding ensuring that data consumers must adhere to the usage policies as if they were formally signed contracts.

More information:

https://catena-x.net/fileadmin/_online_media_/231006_Whitepaper_DataSpaceGovernance.pdf

3.4 JRC Emerging Models and Data Intermediaries

Mapping the landscape of data intermediaries. Emerging models for more inclusive data governance report (JRC science for policy report), this paper provides a landscape analysis of key emerging types of data intermediaries. It reviews and syntheses current academic and policy literature, with the goal of identifying shared elements and definitions. An overall objective is to contribute to establishing a common vocabulary among EU policy makers, experts, and practitioners. Six types are presented in detail: personal information management systems (PIMS), data cooperatives, data trusts, data unions, data marketplaces, and data sharing pools.

Data intermediaries range from individualistic and business-oriented types to more collective and inclusive models that support greater engagement in data governance, while certain types do aim at facilitating economic transactions between data holders and users, others mainly seek to produce collective benefits or public value.

This report examines the concept of business models in relation to data intermediaries, taking in consideration that the economic sustainability is the major challenges for data intermediaries.

A business model as ‘the principles and mechanisms according to which an organisation creates and delivers value to stakeholders while ensuring the conditions of its own long-term reproduction (Coriat, 2022). The term value includes aspects such as monetary return or an increase in productivity,

Table with the overview of the Six types of data Intermediaries covered by the JRC report:

Table 2. Overview of the six types of data intermediaries covered in this report

Type	Main goals	Key stakeholders	Value proposition / business models considerations?	Type of approach	Distinguishing factors*
PIMS	Provide tools to individuals to take control over their personal data	Individual data subjects	Finding alternative revenue streams to user payments (e.g. data-driven services)	Individual	Technologies for individuals to manage the use of their personal data
Data cooperatives	• Establish a bottom-up democratic governance structure • Produce benefits for the members of a community	• Communities • Members of cooperatives • Individual data subjects • Individual data holders	Providing incentives for individuals to devote time to the different tasks they carry out	Collective	• For specific purposes or groups, not for universal scaling. Based on democratic principles through the production and management of common pools of data
Data trusts	Establish responsible data management through independent decision processes in the interest of data subjects/holders	Individual data subjects	Focusing on increasing uptake in order to generate sustainable revenue streams	Individual	For delegating the management of rights over personal data to a trusted entity
Data unions	Establish collective bargaining on rights to personal data generated through platforms	Individual data subjects belonging to the same social group category (digital workers, platform users)	Providing incentives for individuals to devote time to the different tasks they carry out	Collective	For increasing bargaining power of platform users and digital workers, based on democratic principles and workers' dignity
Data marketplaces	Match data supply and demand	Business data holders	Reducing search costs and facilitating data exchange initiation between supply and demand.	Business oriented	Match supply and demand among data holder companies or entities
Data sharing pools	Leverage data synergies among stakeholders with complementary datasets	• Business data holders • Organisations	Improving data products and services, creating new business opportunities, and tapping unexploited data value.	Business oriented	Create common pools of data among data holders often creating partnerships among multiple partners

Source: JRC own elaboration with contribution of Viivi Lähteenoja

Figure 17 Six types of data Intermediaries covered by the JRC report

Personal Information Management Systems (PIMS)

Personal Information Management Systems (PIMS) encompass a set of technologies designed to empower individuals in controlling the processing of their data. These systems offer an alternative approach to data processing by enhancing individuals' ability to manage and direct how their data is handled. PIMS, often referred to as Personal Data Spaces (PDS), are emerging as promising platforms that grant data subjects, such as consumers, increased control over their personal data. This shift aims to restore user agency, particularly in the context of the Internet of Things.

Key initiatives related to PIMS include MyData Global and ANewGovernance. In essence, the technology underlying PIMS involves providing individuals (PIMS users) with a dedicated device for managing their data. This device serves as a technical environment where the user's personal data is stored, offering mechanisms for the user to control both incoming and outgoing data flows.

Illustrative examples include the CozyCollect application, which presents users with a catalog of data holders from whom they can retrieve various types of personal data, including financial (e.g., Paypal or bank transactions), administrative (e.g., electricity consumption history, insurance contracts), music (e.g., Spotify, YouTube), fitness (e.g., Fitbit, Garmin, Google Fit), and social media data (e.g., Facebook, Instagram, Twitter). Another example is JoinData, a Dutch PIMS specifically designed for farmers, enabling them to manage all permissions related to their company data through a unified platform.

PIMS can contribute significantly to manufacturing data spaces by providing a robust framework for individuals and organizations to manage, control, and share their data effectively. The features of PIMS align well with the needs of manufacturing, where data governance, security, and interoperability are vital for optimizing processes and fostering innovation.

Some examples of prominent manufacturing use cases that involve personal data are:

- Worker Performance and Safety Monitoring: In smart manufacturing environments, wearable devices and sensors are often used to monitor worker performance and ensure safety. PIMS can enable workers to have control over access to their performance data, fostering a balance between performance monitoring and individual privacy.
- Health and Well-being Monitoring: Personal data related to the health and well-being of workers, such as biometric information and health metrics, are crucial for ensuring a safe and productive work environment. PIMS can empower individuals to manage and control access to their health-related data within the manufacturing data space.

Data cooperatives

Data cooperatives empower data subjects and holders by providing greater control over their information, allowing them to exercise their rights, make informed choices, and guide the processing of data based on their motivations, preferences, and concerns. What sets data cooperatives apart from other data intermediaries is their emphasis on democratic governance. The sharing, processing, and use of data within these cooperatives are determined through agreements among members.

Various stakeholders, including individuals, communities, civil society organizations, small and medium-sized enterprises (SMEs), research institutions, and NGOs, can lead data cooperatives. These cooperatives offer tools that enable direct control over both personal and non-personal data, active participation in cooperative governance, and the pursuit of collective benefits. In essence, cooperatives embody a communal approach to data sharing, emphasizing a decentralized model where the entire community engages in decision-making, akin to managing data as a commons. The benefits derived from cooperative data contribute to the interests shared by the community members.

Examples of data cooperatives include Salus.Coop, a not-for-profit citizen-led data cooperative dedicated to promoting innovation and research in healthcare. Salus.Coop establishes a collaborative governance model for health data management, allowing members to decide which research initiatives they want to support and empowering them as managers of their own data. Another illustration is the MIDATA cooperative, which operates as a not-for-profit entity facilitating access to data for public interest purposes, particularly in supporting medical research projects. These examples showcase the potential of data cooperatives in fostering democratic governance, individual empowerment, and collective benefits in the realm of data management and utilization.

Data cooperatives can play a pivotal role in manufacturing industries by fostering democratic governance, granting greater control over data, promoting a communal approach to data sharing, and providing tools for collaborative decision-making. But it is important to tailor their structure to the unique needs and characteristics of the manufacturing sector.

Data Trusts

A data trust, typically defined by a legalistic approach, involves the establishment of specific legal mechanisms to ensure responsible and independent data stewardship. It operates through a relationship between two entities: the trustee (intermediary) and the beneficiary (data rights holder). The trustee assumes responsibility for stewarding the beneficiary's data or data rights. This legal mechanism, rooted in trust law, enables data rights holders to delegate control of their data to a trustee, allowing for pooled rights and determining data use terms in the suppliers' interests.

Data trusts leverage existing legal governance structures, such as trustees' fiduciary duty, to enhance public protection against privacy violations and unethical data collection and use. While some definitions rely on trust law, others may involve contractual or statutory legal obligations. Data trusts are expected to be independent, avoiding conflicts of interest and upholding a duty of care to clients.

In the absence of trust law in certain jurisdictions, institutions may establish a board of trustees to achieve similar goals. The overarching goal of a data trust is to balance risks and responsibilities with opportunities for data reuse. While concrete cases of implemented data trusts are limited, the concept envisions an ecosystem where various data trusts offer individuals choices based on their privacy preferences and values, allowing them to select and switch between trusts to meet their specific needs.

The Data Trusts Initiative (www.datatrusts.uk) has implemented pilot projects to explore the potential of data trusts: (1) Brixham Environmental Stewardship Data Trust: Focuses on environmental stewardship in the small fishing town of Brixham, UK. (2) NHS Longitudinal Study Data Trust: Offers an alternative consent route for women in an NHS longitudinal study in Scotland. (3) Opt-Out Reconsideration Data Trust: Targets one million individuals who opted out of sharing NHS primary care data in 2022.

These projects showcase the versatility of data trusts in community-focused environmental efforts, healthcare studies, and reconsidering data-sharing options for individuals. The initiative aims to assess the effectiveness of data trusts in diverse scenarios.

Data trusts offer manufacturing industries a framework for responsible and collaborative data governance. By fostering trust, enabling secure data sharing, and supporting innovation, data trusts contribute to the overall efficiency, competitiveness, and sustainability of the manufacturing sector.

Data unions

Data unions, grounded in democratic principles, aim to safeguard and negotiate rights over personal data generated by individuals in digital practices, including users of Big Tech platforms and platform workers. Positioned as intermediaries, these unions operate on a simple mechanism: data subjects grant them the exclusive right to use the data. Platforms, such as Facebook or Airbnb, must then negotiate with the data union to collect, use, and commercially exploit the data of data subjects. This arrangement establishes a protective layer for individuals and empowers data unions to advocate for fair terms between their members and platforms.

Worker Info Exchange is a data union specifically targeted at platform workers (like Uber drivers or Deliveroo riders). It is a not-for-profit organisation that aims at helping digital workers in accessing and gaining insights from the data that are collected about them at work.

Data unions in the manufacturing sector can act as advocates for workers, ensuring their rights are protected, and simultaneously facilitating responsible and ethical data practices within the industry.

Data marketplaces.

Data marketplaces serve as platforms facilitating the matching of data supply and demand. Positioned as neutral intermediaries, they do not actively intervene in data value chains but focus on connecting data providers with data consumers. These marketplaces adhere to open data intermediation services accessible to any third party complying with established terms, conditions, and legal frameworks.

Key characteristics of data marketplaces include: (1) Establishment of standardized licensing models and rules for data access and use. (2) Lowering barriers to finding and accessing data assets, promoting data-driven innovation. (3) Potential enhancement of transparency in bargaining conditions between data suppliers and users.

Data marketplaces exhibit diverse governance structures, differing in value proposition, access mode, domain specificity, architecture, pricing models, and revenue models, as outlined by Spiekermann (2019). The variety in these aspects allows for flexibility and adaptability in catering to the specific needs of different stakeholders within the data marketplace ecosystem.

CARUSO is a collaborative platform co-owned by various automotive industry companies. It functions as a neutral intermediary, collecting and harmonizing in-vehicle data from different manufacturers. This harmonized data is then made available to various stakeholders in the mobility sector, such as insurance companies, car-sharing platforms, and apps enabling drivers to locate and book electric charging stations. The platform aims to provide a standardized and accessible source of multi-brand in-vehicle data for enhanced services and innovations within the broader mobility ecosystem.

Data marketplaces support the manufacturing industry by providing a collaborative platform for accessing, sharing, and utilizing diverse datasets. This facilitates innovation, informed decision-making, and operational excellence, contributing to the overall competitiveness and sustainability of manufacturing operations.

IDSA has published the Impulse Paper *"Reflections on the DGA and Data Intermediaries ",* October 2023. It aims to contribute to the discussion about the Data Governance Act (DGA) regulations on "data intermediation services" and the role of data intermediaries in data spaces.

The Data Governance Act (DGA) regulations on data intermediation services might become relevant for data spaces considering that the generic concept of data intermediaries already exists and is widely used in data spaces. Even more, it is one of the key instruments to enable data sharing and re-use. That is also the reason why the DGA mentions the importance of data spaces for the enabling of data sharing and at least refers to data spaces in the context for "data sharing ecosystems that are open to all interested parties".

The paper form IDSA emphasizes that the current lack of clarity in the DGA's definition of data intermediaries within data spaces necessitates further investigation and guidance. One notable challenge highlighted in the paper is the existing diversity in the definitions and roles of data intermediaries across various frameworks and models. For instance, the IDS

Reference Architecture Model (RAM) distinguishes between data intermediaries and service intermediaries, and these distinctions do not align seamlessly with the DGA's definition. The text calls for a common understanding and alignment between co-existing concepts and the DGA framework, emphasizing the need for clarity in roles and responsibilities.

The European Commission's Joint Research Centre's (JRC) report is cited as a valuable resource, providing a landscape analysis of data intermediaries. This report identifies six types of intermediaries as explained before, including Personal Information Management Systems (PIMS), data cooperatives, data trusts, data unions, data marketplaces, and data sharing pools. The paper suggests viewing the DGA's concept of data intermediaries as a specific addition to this existing landscape.

Furthermore, the IDSA document raises a critical business design question for data spaces – whether to mandate DGA compliance for data intermediation services within the space. It speculates on the success and adoption of DGA-compliant services, noting that services not regulated by the DGA will likely continue to operate within data spaces. The evolving landscape of data intermediaries in data spaces will likely depend on legal precedents, and the text underscores the importance of clarifying the relationship between different data intermediary concepts and the DGA framework for effective governance and compliance.

Role of data intermediaries in manufacturing data spaces
The role of data intermediaries in the context of manufacturing data spaces is crucial, particularly considering the DGA regulations on data intermediation services. In manufacturing data spaces, where diverse sources of data need to be seamlessly integrated and exchanged, data intermediaries act as facilitators, connecting producers and consumers of data. The generic concept of data intermediaries is already widely utilized in manufacturing data spaces, playing a key role in enabling data sharing and re-use. However, certain uncertainties and challenges specific to manufacturing data spaces. It points out that the DGA's definition of data intermediation services within data spaces requires further investigation and guidance. The existing diversity in definitions and business models of data intermediaries, as outlined in the IDS Reference Architecture Model (RAM), adds complexity to the manufacturing data space ecosystem. The need for clarification and alignment between regulatory frameworks is emphasized, underscoring the importance of addressing the unique requirements and characteristics of manufacturing data spaces. It is important to highlight the evolving landscape of data intermediaries in manufacturing, as identified by the European Commission's Joint Research Centre (JRC), which includes various types of intermediaries like data cooperatives and data marketplaces explained before. As legal precedents on data intermediaries in manufacturing data spaces are awaited, the text raises a critical business design question for manufacturing data spaces. It prompts consideration of whether to mandate DGA-compliant services within the manufacturing data space context or allow the provision of services not explicitly regulated by the DGA. The success of DGA-compliant services in manufacturing data spaces remains uncertain, reflecting the ongoing evolution of this sector within the broader data ecosystem.

4 Business Model Assessment for Manufacturing Data Spaces

Business models play a pivotal role in the development and implementation of European dataspaces for manufacturing. These innovative models serve as the framework through which data sharing, collaboration, and value creation are facilitated. One significant aspect of these business models is the promotion of data sharing and exchange within the manufacturing ecosystem.

By defining the terms, conditions, and incentives for data sharing among various stakeholders, these models encourage collaboration and knowledge sharing. This, in turn, fosters a more interconnected and efficient manufacturing sector in Europe, enabling data-driven decision-making and innovation.

Moreover, these business models are instrumental in ensuring sustainability and economic viability. European data spaces for manufacturing often encompass vast and complex infrastructures, requiring substantial investments. By establishing monetization strategies, business models enable organizations to sustain these initiatives.

Through subscription-based models, pay-per-use arrangements, or other innovative monetization mechanisms, manufacturers can not only cover their operational costs but also generate revenues. This financial sustainability is crucial for the continued growth and expansion of data spaces in Europe, further supporting the region's manufacturing sector's digital transformation and competitiveness.

This chapter provides the results of the work done regarding development of a business model framework for manufacturing dataspaces and provides details about different building blocks of such a model along with specific characteristics tailored to manufacturing sector.

4.1 Data Spaces Business Model Framework

According to Paul Bulcke & U. Mark Schneider, Chairman & Chief Executive Officer, at Nestlé, the Swiss multinational food and drink processing company “Data and technology are an essential source of competitive advantage” nowadays.

Data is a critical asset for organizations allowing them to make informed decisions, optimize operations, understand their customers, stay competitive, innovate, and manage risks effectively. Companies that are able to leverage the power of data to innovate their business models are better positioned to succeed. Traditionally, a business model represents how a company creates, delivers, and captures value from its operations and activities.

A business model comprises several building blocks that can be visualized in Osterwalder's traditional business model canvas, a strategic management template. The template particularly highlights nine critical components of a business model, from the value proposition to customers and partner relationships to the key resources and activities. However, new data-driven business models are not entirely represented by traditional value chains frameworks.

On the opposite, the increasingly interconnected world is leading to the creations of data-driven ecosystem business models, where the shared value is created by the sharing and combination of different data and resources among different actors for the achievement of a common goal.

As a result, for the development of the manufacturing data-spaces business model framework on top of Osterwalder's business model canvas, two additional frameworks have been considered: the Service-Dominant Business Model Radar (Turetken and Grefen 2017) and the St. Gallen Business Model Navigator (O Gassmann, K Frankenberger, M Csik. 2013)

The framework developed shown in Figure 18. The Data Space Business Model Radar consists therefore of:

- Outer layers, identify the key partners of the data space, the key benefits each single participant get and the resources with which they contribute to the data space, and the specific activities each partner carries out within the data space
- Internal layers, focus on the shared value and resources. These layers include the value proposition, that is the north star, the "why" driving the activities of the data space. It also includes the shared infrastructure and data platform supporting data collection and exchange as well as the benefits and resources that are shared among participants.

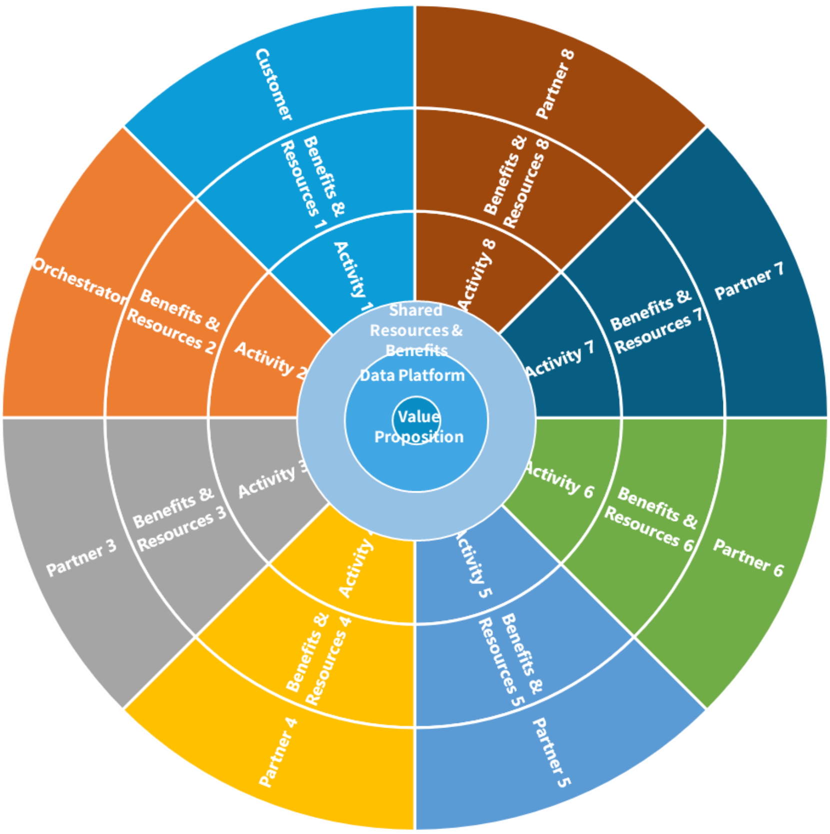


Figure 18. The Data Space Business Model Radar

4.2 Data Spaces Attributes and KPIs

4.2.1 Data Spaces Attributes

Data spaces can be defined according to some common attributes that make these types of ecosystems unique. These characteristics include:

- **Shared Business Value.** Within data spaces the relationships between participants, assets, resources and data lead to co-creation of value that is shared among participants. The value generated can be tangible (e.g. new revenue streams, productivity gains) or intangible (e.g. linked to the achievement of societal goals such as ESG – Environment, Social, Governance targets). Within the data space, the shared value can only be achieved by working together, manufacturers- participating into it cannot achieve the same on their own.
- **Stakeholders Interconnectedness,** in a data space ecosystem all stakeholders are interconnected in terms of processes, activities, resources and value generated. It is important to have defined roles and clear value chain relationships and dependance
- **Interdependent Operating Model,** with multiple stakeholders processes along the data space value chain are interrelated and dependent on one another
- **Data flows,** key characteristic of the data spaces is that data are at the heart of the value generation process, flowing across partners, applications and externally with customers and external partners
- **Shared Resources,** the co-creation of shared business value is connected with the availability and reliance of a set of resources that are shared within the ecosystem. This allows the access to relevant skills, assets and tools for carrying out data space activities
- **Shared Technology Architecture,** the underlying infrastructure supporting data collection, exchange and usage. This infrastructure should be open, flexible, modular, cloud-driven, and secure
- **Governance,** this relates to the development of clear policies and guardrails for the responsible use of data, transparency and audit mechanisms for compliance with existing regulations, the set up of proper contracts for IP rights ownership and also ethical use of tech.

	Attribute	Definition	Trait of Mature Data Spaces
1	Shared business value	▪ Value propositions ▪ Participants' benefits	▪ Co-creation and digital revenue generation ▪ Member/participant success ▪ Focus on Purpose beyond financials (e.g. ESG goals)
2	Stakeholders Interconnectedness	▪ Multiplicity of stakeholders ▪ Different roles	▪ Defined roles and engagement
3	Interdependent Operating Model	▪ Processes ▪ Value chains	▪ Interconnected End-to-End ▪ Automated when applicable
4	Data Flows	▪ Between stakeholders & applications ▪ With customers	▪ Real-time, valuable, accessible
5	Shared Resources	▪ Skills, tools & assets	▪ Access to relevant skills, assets & tools ▪ Multiplier effect
6	Shared Technology/Data Architecture	▪ Underlying tech architecture components	▪ Open, flexible, modular, cloud driven, intelligent & trusted platform
7	Governance	▪ Rules and regulations ▪ Contracts and IP rights ▪ Ethics	▪ Ethical sourcing & use of technology ▪ 360-degree trust ▪ Clear participants roles ▪ Data handling, access & usage policies and clear IP rights

Figure 19 Attributes and KPIs of Data Spaces

4.2.2 Data Spaces KPIs

For each dimension of the data spaces a series of KPIs can be identified to assess data space maturity, measure performance and track progress. By defining and monitoring KPIs, organizations can ensure that their data spaces are effective, efficient, and aligned with their strategic direction, ultimately driving better business outcomes. Here below are some examples of KPIs to be measured across the different dimensions of the data spaces.

Shared Value KPIs

To ensure that data spaces operate sustainably from an economic and societal perspective, it's important to focus on metrics that reflect the shared value generated by the data space. These include KPIs that focus on innovation rate, disruptive potential and new revenue generation as well as ESG KPIs that reflect the environmental, social, and governance impacts specific to data management and infrastructure.

Innovation and Revenue Generation KPIs, such as:

- Digital Revenue Growth: Measures the increase in revenue generated from digital products and services
- Innovation Rate: Assesses the number of new ideas or products developed through the data space.
- Time to Market: Evaluates the speed at which new offerings are brought to market.

Environmental KPIs:

- Energy Efficiency: Measures the energy consumption of data centers and efforts to improve energy efficiency.
- Carbon Emissions: Tracks the carbon footprint associated with data storage and processing.
- Water Usage: Monitors water consumption in cooling systems for data centers.

Social KPIs

- Data Privacy and Security: Evaluates the measures in place to protect user data and prevent breaches.
- Community Impact: Measures the involvement of data centers in local community initiatives and their impact.

Stakeholder Interconnectedness KPIs

These KPIs help organizations understand the effectiveness of their partnerships and the level of interconnectedness within their data spaces, some examples include:

- Partner Engagement Rate: Measures the level of engagement and participation from partners in data spaces activities.
- Number of Active Partnerships: Tracks the total number of active partnerships within the data space.
- Data Exchange Volume: Measures the amount of data exchanged between partners.
- Partner Satisfaction: Assesses the satisfaction levels of partners with the interconnectedness and collaboration within the data space.

Interdependent Operating Model KPIs

These KPIs help organizations ensure that their data value chains are efficient, reliable, and compliant, ultimately enhancing the overall performance and value derived from their data spaces. Some examples are:

- Operational Efficiency: Assesses the overall efficiency of operations within the value chain, including resource utilization and process optimization
- Integration Success Rate: Evaluates the success rate of integrating data from various sources within the value chain

Data flows KPIs

These KPIs help organizations ensure data usage and sharing within their data spaces is trusted and efficient to drive business outcomes.

- Data Flow Efficiency: Measures the speed and accuracy of data transfer between different partners of the data space.
- Data Quality: Assesses the accuracy, completeness, and reliability of data as it moves through the value chain
- Latency: Tracks the time delay in data processing and transfer across the data space
- Data Availability: Measures the uptime and accessibility of data for users and systems
- Data Utilization Rate: Measures how effectively data is being used

Shared Resources KPIs

These KPIs help organizations ensure that the data space has access to the right skills, tools, and resources to effectively support its goals. These include:

- Resource Allocation Efficiency: Measures how efficiently resources (e.g., hardware, software, personnel) are allocated and utilized.
- Employee Engagement: Evaluates the level of employee engagement through surveys and participation rates.
- Skill Development Rate: Evaluates the rate at which employees acquire new skills through training and development programs.
- Skill Gap Analysis: Assesses the difference between the skills required and the skills available within the team.
- Budget Adherence: Tracks how well the project stays within the allocated budget for resources.

Shared Technology Architecture KPIs

These KPIs help organizations ensure that their technology architecture is solid, open, flexible and agile to support their data space needs. Here some examples.

- Scalability: Evaluates the ability of the data architecture to handle increasing amounts of data and users without performance degradation
- Cost Efficiency: Tracks the cost-effectiveness of maintaining and operating the data architecture

- Security Incidents: Monitors the number and severity of security breaches or incidents within the data architecture
- API Usage: Measures the number of API calls and the extent of API integration with external systems.
- Interoperability: Assesses the ability of the architecture to work seamlessly with different systems and technologies.
- Deployment Frequency: Measures how often new features or updates are deployed to production.
- Lead Time for Changes: Tracks the time taken from code commit to deployment in production.
- Change Failure Rate: Assesses the percentage of changes that result in failures or require remediation.
- Time to Recovery: Measures the time taken to recover from a failure or incident.

Governance KPIs

These KPIs help organizations ensure that their security measures are effective and that the right governance practices are in place. Some examples are:

- Compliance with Regulations: Monitors adherence to data protection regulations and standards.
- Transparency in Data Practices: Evaluates the transparency of data handling and processing practices.
- Responsible Data Use: Tracks policies and practices related to the responsible use of data.
- Transparency in Reporting: Measures the transparency and accuracy of reporting on security and governance issues
- Employee Training: Tracks the training programs for employees on data security and privacy.

The above mentioned KPIs can be used by entities involved in data spaces to assess the attributes of data spaces business model. The presented business model radar, has been validated through four cases studies (see Chapter 6). The validation methodology has been a qualitative one since the case studies have been at the early stages of development of data spaces, thus a quantitative assessment has not been feasible due to lack of data. However, while the data spaces will be at a more mature level at the deployment phase, a quantitative assessment can be done through implementation of the proposed KPIs.

4.3 Manufacturing Data Spaces Roles

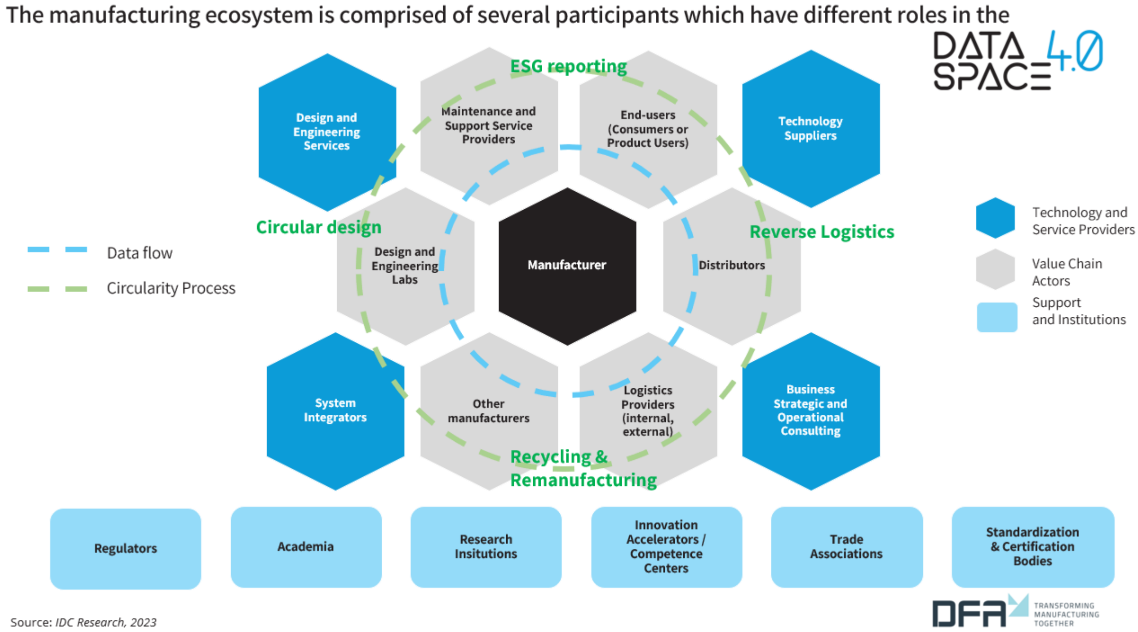


Figure 20 The Manufacturing Ecosystem

The data space constitutes the foundation for a thriving manufacturing ecosystem with several participants assuming different roles. The goal of the manufacturing data space is to provide support to both the day-to-day operations and strategic organizational decision-making processes, by leveraging various types of data that are shared among these ecosystem participants.

This constant data exchange plays a crucial role. At the core there is the manufacturer, which interacts with different value chain actors such as other manufacturers (i.e. suppliers), design and engineering firms, maintenance and support service providers, distributors, logistics providers, and final product end users. Examples of data exchanged are production and performance data, inventory data, prototypes and design specifications, maintenance and repair records, distribution and sales data, and customer feedback.

In the context of a data space, technology suppliers and system integrators also play a crucial role in providing the infrastructure to efficiently capture, manage, and share data to enable collaboration. This allows different actors to capture and leverage data to effectively support their individual and collective goals. Strategic and operational consulting firms also provide guidance in identifying the most suitable technology solutions, devising data management and governance frameworks and strategies, as well as support in developing and executing data-driven business models and transformation initiatives.

Beyond the operational interaction within the value chain, a thriving data space requires the support of a wider network of participants comprising regulators, academia, research institutions, innovation accelerators and competence centers, trade associations, standardization and certification bodies. Regulators or governments provide legal frameworks that govern the use and sharing of data and the necessary rule enforcement when needed. In the same way, standardization and certification bodies provide the guidelines and validations to promote interoperability, security, privacy, and trust within a data space.

This interconnectedness and interplay among different actors also enable new business cases and strategic targets such as the creation of a circular economy. For instance, data sharing can support environmental, social and governance (ESG) reporting by providing visibility and transparency on an organization's sustainability performance. It can also support circular design, which involves the creation of innovative product designs that maximize the lifespan with less resources and environmental impact. Data sharing and collaboration can also enable reverse logistics, which involves the efficient management of product returns and recycling, as well as in remanufacturing and recycling processes. This means that the circular economy is very closely linked to the data economy, and the data economy is key to enabling various initiatives that drive sustainability such as EU CSRD reporting (particularly for SCOPE 3), digital product passports, process sustainability digital twins, CO2 trading, and circularity-driven business models.

4.4 Value Proposition of Manufacturing Data Spaces

There are different value propositions that Manufacturing data spaces can pursue. We identified three macro areas of shared objectives that can drive ecosystem activities:

New revenue generation: this value proposition drives all those manufacturing ecosystem set up with the goal to generate new revenue streams through the launch of new products and services codeveloped by the ecosystem leveraging shared data, or new monetization models implemented for example by monetizing the data of the ecosystem through a marketplace model, as well as the incubation of new businesses such as startups for subsequent market launch.

Operations Optimization and Productivity: companies can also decide to join manufacturing data spaces with the objective to improve productivity, optimize internal processes and operations and achieve efficiencies, for example by leveraging automation or IoT technologies. Additional business outcomes in this group include having greater product quality, by leveraging simulation and digital twin tech for example, improving predictability of product demand and supply leveraging real time data along the supply chains as well as the sharing of costs among ecosystem participants.

Collaboration for Industry & Societal Goals: this third group includes non-tangible benefits, which sometimes manufacturing data spaces are designed for. These benefits include for example responding to ESG (environment, social, governance) requirements, understand and adapt new protocols and regulations (e.g. Digital Product Passport), foster research within the industry leveraging industry specific expertise and data.

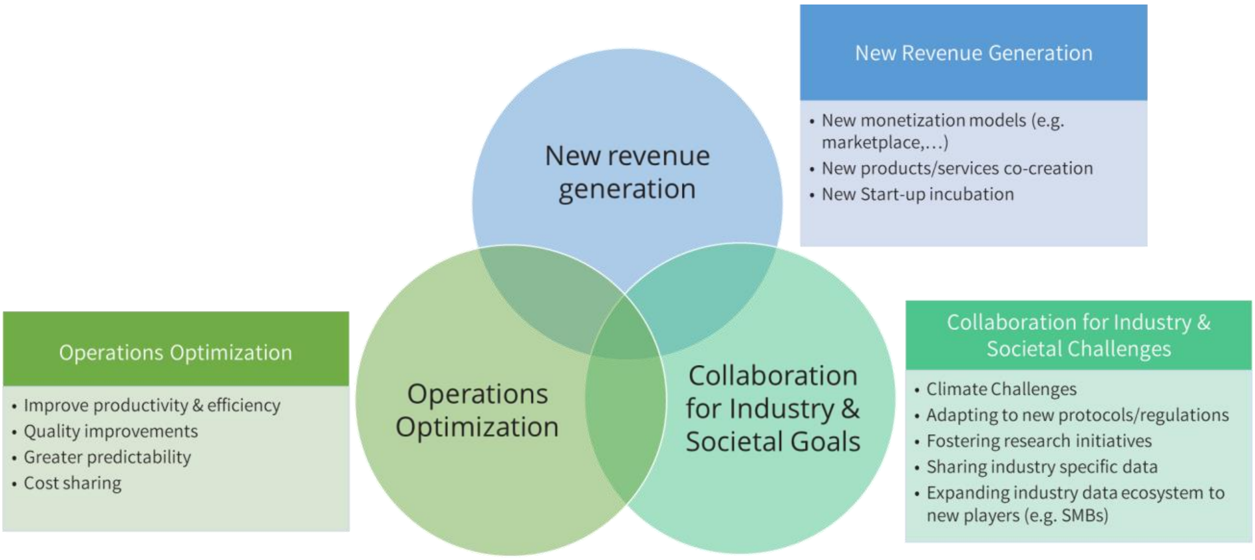


Figure 21 Value Proposition of Manufacturing Data Spaces

4.4.1 New Revenue generation Models

80% of CEOs of Manufacturing organizations in EMEA are under pressure to deliver financial results from digital business models. Manufacturing digital ecosystem, among which data spaces, are among the most relevant digital business models for manufacturers, with 82% of them currently leveraging or considering adopting them, however only for 9% of those organizations participating in digital ecosystem has a relevant impact on the topline, producing more than 10% of their revenues (IDC EMEA, Digital Executive Sentiment Survey, October 2023, 104 Manufacturing organizations) How can data spaces generate new revenue streams for participants? The IDC's Monetization Cube, showing the monetization opportunities that manufacturing data spaces can pursue.

The cube highlights three main axes data spaces can act upon to generate new revenue streams:

- Monetize through new channels. For example, through
    - Marketplace. This allows easy access to partners' and 3rd party data that are made available to ecosystem participants and to external players through this 2-multi sided platform matching and connecting different parties. A key characteristic of the marketplace is the network effect – which means that the value of the service increases with the number of users. Catena-X for example is a collaborative data space for the automotive industry to boost business processes using data driven value chains. The data space offers access to the **Catena-X Marketplace** where organizations can get access to business applications as well as network-enabling services developed within the data space.
- Monetize new assets. Assets that could be monetized include:
    - IoT and Asset data. In 2021 for example the Space Data Marketplace project was launched to facilitate access to space data and monetize them. Supported by the French Recovery Plan and the French space government agency CNES, the development of Space Data Marketplace has been driven by a consortium led by Dawex and including Airbus Defence and Space, Dassault Systèmes, Thales Alenia

Space, Geoflex, VisioTerra, namR, Altametris, Murmuration and Occitanie Data leveraging improved capabilities for accessing and distributing data and services on the platform.

  - Customer data. For example, in the automotive subindustry new opportunities are linked to monetization of data used or derived by a vehicle passenger or driver of vehicle itself. These data can be monetized with other ecosystem players (retail, insurance and so on) for providing personalized services to passenger including fleet management, remote services, road side and emergency assistance, usage-based insurance and infotainment services. Within the Mobility Data Space initiative, Mercedes-Benz provides anonymised data of connected vehicles on the Mercedes-Benz dashboard and via Mercedes-Benz OneAPI. This information can be used to optimize parking space search and planning, improve traffic management, get fuel or electric charge recommendations and discounts, and provide additional road assistance and management services.
  - IP software. Monetization of IP rights and software solutions or "softwarization". This Includes also APIs as a service (offering business functionalities and capabilities to 3° party developers). E.g. a data space has learnt how to automate some specific processes through software, it packages that software and then offers it on a subscription basis to other organizations.
  - Smart products and assets. This includes the monetization of new connected and smart products and assets both B2B and B2C.
- Monetize in new ways. This includes the shift from a product centered strategy to new servitization models, where in addition to physical products or equipment, manufacturers can sell data-driven services to customers. The servitization of physical products can happen through:
  - Pay per use/recurring subscription services, here the customer pays to use the product on demand, or on a regular (monthly, annual) basis. Still for example is one of Europe's leading suppliers of industrial trucks. Traditionally the company has been selling upfront or leasing forklifts to logistic players. They added to their traditional model, a new one leveraging IoT modules embedded in forklifts. Data collected were aggregated in a cloud dashboard and used to provide an add-on digital fleet management service paid on a subscription basis.
  - Outcome-based models, manufacturers can charge customers based on the outcomes that they achieve through the usage of their products. For example, an industrial valves manufacturer charges its customers based on volume of liquid processed by the valves

An organization can mix multiple monetization opportunities in a hybrid way, leveraging different revenue models.

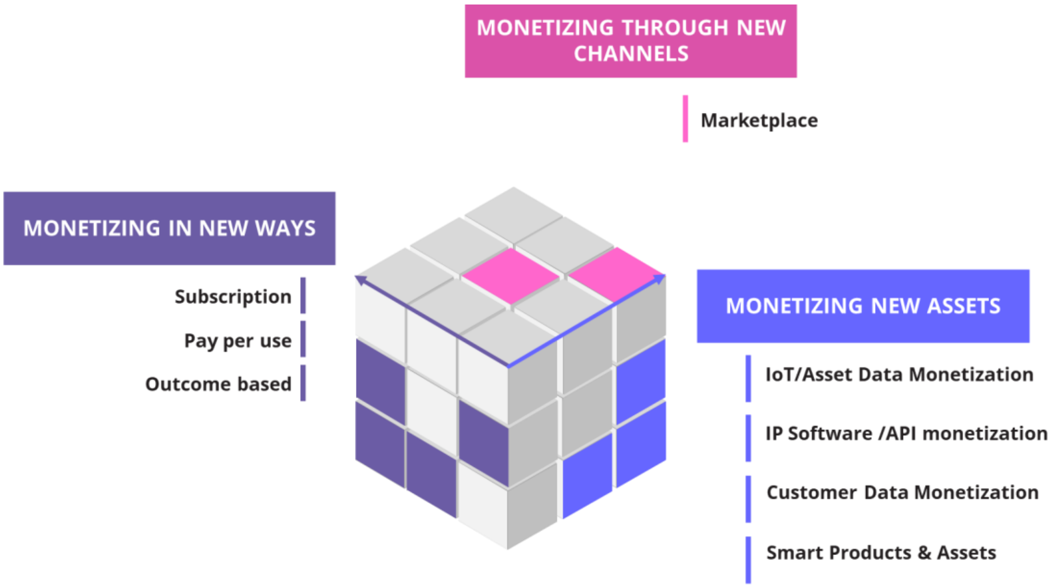


Figure 22 The Monetization Cube for Manufacturing Data Spaces

4.4.2 Operations Optimization Models

Data spaces can also have the key objective to help participants optimize processes and achieve cost efficiencies. By participating in these data spaces, companies can achieve:

- Greater productivity & efficiency. As an example the BMW Open Manufacturing Platform, is an open industrial IoT platform to accelerate production and logistics optimization efforts. It allows industrial manufacturers to work together to break down data silos and overcome the challenges of complex, propriety systems that slow down production optimization.
- Quality improvements. Leveraging product data, artificial intelligence and digital twin technologies to optimize product life cycle and minimize product defects.
- Greater predictability, of supply and demand but also on asset performance and maintenance
- Improved traceability, thanks to the sharing and collection of data along the supply chain
- Cost sharing, by minimizing transaction costs for participants to get access to the relevant data and shared resources

4.4.3 Collaboration Models for Industry & Societal Goals

Third, manufacturing data spaces can also target the achievement of the greater good, by sharing data and working together to address major industry and societal challenges. This includes, for example:

- Data spaces that promote adherence to regulations or development of new standards. For example, the International Data Space (IDS) aims at defining data standards and data governance frameworks to be used in collaborative data sharing environments.

  Similarly, the OPC-Foundation was founded to develop and maintain the interoperability standard for the secure and reliable exchange of data between industrial automation devices from multiple vendors. OPC stands for Open Platform Communications and the so called OPC Unified Architecture (UA), which was released in 2008, is a platform independent service-oriented architecture that integrates all the functionality of the individual OPC Classic specifications into one extensible framework.

- Tackling ESG (Environment, Social, Governance) challenges. Data spaces can also be built around the need to tackle social challenges that would be hard to be addressed by single companies.

  For example, the EU-funded Plooto project will develop a Circular and Resilient Information System (CRIS) to support manufacturers in their green, digital and circular transition. The aim of the CRIS is to enable waste reduction, end-to-end traceability of secondary raw materials and the development of Digital Product Passport (DPP) requirements.

4.5 Data flow scenarios

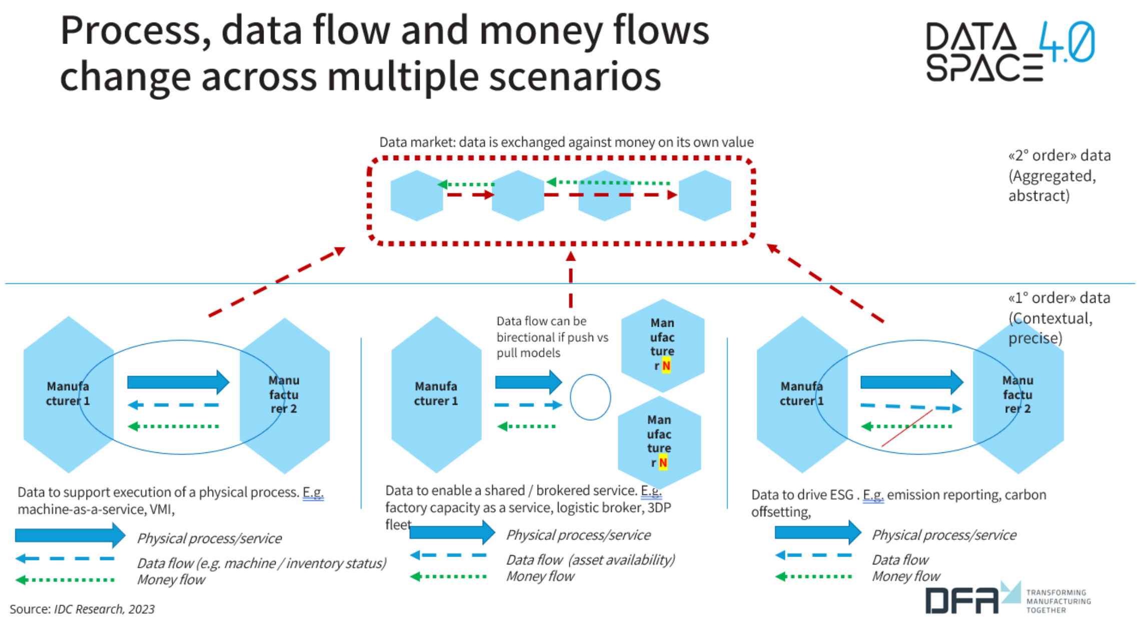


Figure 23 Data Flow Scenarios

While data is utilized and shared in several ways, there are 3 typical scenarios for data sharing in the context of manufacturing.

1. Data to support execution of a physical process. In this scenario, a manufacturer provides a product or service to another manufacturer in exchange for a fee. To execute the service, the service provider tracks data on product usage. A machine-as-a-service model is a typical example which involves renting out equipment and providing real time monitoring and data analytics as well as maintenance, repairs, or other services in exchange for periodic fees. This optimizes production and ensures continuity in production. Similarly, in a vendor managed inventory, the buyer (consignee) shares inventory data so that the vendor (consignor) knows the right time and products to replenish inventories with.

2. Data to enable a shared / brokered service. In this scenario, a manufacturer shares data to other organizations about excess capacity or asset availability to fulfill the latter's needs. Similarly, manufacturers can share unfulfilled requirements to potential providers. This is typical in a factory-as-a-service model where manufacturers can outsource production activities to a capable provider in exchange for fees. Similarly, in a logistics brokerage, brokers receive availability information from carriers as well as manufacturing clients' requirements, acting as a point of contact for transporting goods. The same applies for owners of 3D printing fleets that can be shared across an ecosystem of remotely connected companies.
3. Data to drive ESG. Manufacturers can build business value by merely exchanging data with other organizations. For example, to drive joint ESG goals, suppliers provide data on raw material provenience, sustainability practices and credentials, and adherence to ESG regulations. This sustainability-related information is often required in requests for proposals (RFP). More importantly, this allows manufacturers to accurately report on their emissions impact and take measures to offset their carbon footprint.

Aggregated and abstract data from the preceding scenarios are shared in a data market where data is exchanged on its own value. This enables manufacturers and other organizations to obtain valuable insights and make data-driven decisions.

5 Maturity Assessment of Data Spaces for Manufacturing

The developments in recent years of Data and AI solutions available on the market, facilitated by the availability of big data, digitisation, access to efficient and cost-effective computing capabilities and development of new algorithms that are increasingly within reach of non-expert users (so revolutionising the ways in which society functions and is opening up new business opportunities for companies), have made it essential for organisations to understand their possibilities to benefit from Data and AI.

Following this evolution, FPM has decided to develop an AI and Data maturity assessment tool, to investigate how companies, and in particular SMEs, relate to the issues of digitization, Industry 4.0, Data and AI and with which tools. The model described here below develops previous work by the FPM and POLIMI themselves in the area of digital maturity assessments, and in particular a tool called the 6Ps Digital Transformation Assessment Model, which is described below in its Data and AI instantiation.

5.1 Technology Maturity Assessment for Manufacturing Data Spaces

The 6Ps Migration Model is a tool to support manufacturing companies to assess their current and expected level of Digitization, along 6 dimensions, and to track a Digital Transformation roadmap.

Unlike other strategical tools, 6P has a more tactical approach, meaning that the company already has in mind its gaps, but it needs an effective set of actions to fill them. This set of actions is the Digital Transformation roadmap. When we say that the company has already in mind its gaps, we mean either that the company has a project to improve some aspects of its approach to digitization (in which case the roadmap to the implementation of digital solutions is implicitly defined by the project, and the 6P helps measure where progresses take place and how large they are), or that the company has identified some digitization gaps and wants to fill them (in this case, 6P provides a support to focus on the potential areas of improvement, and as an “inspirational” tool, suggesting concrete ideas of actions to implement digital solutions that may add to the company’s ideas).

The 6Ps methodology is a tool conceived to support enterprises along their digital transformation journey, by providing a complete analysis of the main six pillars that characterize the production process. It is based on the assumption that, to succeed in a digital transformation process, it is important to boost not only the technical dimensions, but also the so called “socio-business” dimensions.

The six Pillars of analysis (from which, the name “6Ps”) are: Product, Process, Platform, People, Partnership and Performance, grouped in three “technical” and three “socio-business” pillars.

Each pillar is composed of at least six different dimensions of analysis, typical of Industry 4.0, and each analysis dimension is broken down into five sequential development stages, from the least to the most advanced one with respect to Industry 4.0, Data and AI adoption.

In the present instantiation, the reference levels were taken from the work carried out within the Connected Factories project, in which increasing levels of evolution of Data Spaces (No data Control, Data Silos, Data Bridges, Data Interoperability, Data Valorisation) and increasing levels of autonomy with respect to AI (Human Control, AI Assistance, AI Recommendation, Collaborative AI and AI in control) were identified; this classification was referred to in the elaboration of the 5 increasing degrees of response to each question.

5.1.1 The Product Dimension

6Ps' PRODUCT pillar has the objective of evaluating in a quantified way to which extent the manufacturing company is digitally mature in terms of Product or Product-Service System that it offers to the market. This is the first dimension analysed, as the product constitutes the direct link that manufacturing companies have with their customers, thus significantly affecting the overall performances of the firm.

The six different fields of analysis are related to: Sensors and actuators (to understand how the product is equipped); Communication and Connectivity (to measure how the product is able to communicate with external devices); Storage and Exchange of information (to measure if the product is able to storage data); Monitoring (to assess if the product is able to self-monitor its status thanks to AI-based tools); Product-related IT services (to measure the level of service related to the product); Business Models enable by the product (how the digital maturity of the product impacts on the company's business model).

5.1.2 The Process Dimension

6Ps' PROCESS pillar has the main objective of assessing the level of digital maturity in the production processes of a manufacturing company.

The six analysis fields are: Design & Engineering (to evaluate how these processes are enabled by Data and AI); Production Management (use of I4.0 systems like SCADA, MES; ERP); Quality Management (how quality is managed by QMS and other SWs); Maintenance Management (to measure how much AI and X-AI characterize maintenance activities); Logistics Management (to assess the adoption of AGV and AI-based tools); Supply Chain Management (to evaluate to which extent Data and AI technologies are exploited).

5.1.3 The Platform Dimension

The PLATFORM pillar suggests migration pathways towards Digital Platforms supporting vertical integration (from the shop floor to the enterprise level), and horizontal integration along the value chain and end-to-end engineering.

In this respect, six technological fields of analysis are considered: CPS and embedded systems (to measure how much the firm is able to use the data collected from the field, with the support of AI in their elaboration); Industrial Internet of Things (ability in using and integrate IoT devices); Industrial Internet (IT-OT integration, use of edge and cloud); Industrial analytics (to evaluate the capacity of the company in exploiting analytics, also with the support of M/L); Vertical interoperability of data and events (integration across the automation pyramid) and Horizontal interoperability of data and services (to measure the capabilities of manufacturing companies in collecting, manipulate and manage data that are necessarily heterogenous in an integrated way).

5.2 Socio-Business Maturity Assessment for Manufacturing Data Spaces

5.2.1 The People Dimension

6Ps' People pillar aims at assessing the skills owned or to be owned among staff.

A digital transformation process cannot ignore the involvement of staff. Actually, staff, with their expertise, are the real drivers of digital transformation. When operating a digital transformation process, staff skills, training and involvement are the real heart of the change.

For this reason, to this pillar we have dedicated 10 questions, instead of 6.

Because of the high variance in the roles operating in the sector, this pillar has been at first divided into 4 macro-professions, namely: Managers & C-Levels, Digital Transformation Professional, I4.0 Professional and Operators I4.0, and then several fields of interest have been identified as well: Data Strategy, Smart Operations, Smart Supply Chain, Smart Product-Service Engineering, Industry 4.0 Infrastructure, Big Data, AI-based operations, AI autonomy, AI Explainability.

5.2.2 The Partnership Dimension

The Partnership pillar relates to the identification of the partners needed for digitalization and to achieve the desired business goals. It describes workflows whose purpose is to support the transition towards more collaborative relationships with key stakeholders in the digital ecosystem, in order to create strong and collaborative partnerships.

Accordingly, potential partners included in the dimensions are: DIHs, Research and Innovation, Education and Training Providers, IT Solution Providers, Suppliers and Customers.

5.2.3 The Performance Dimension

6Ps' Performance pillar aims at investigating the way the indicators of the manufacturing companies are defined, measured and monitored. Unlike it may seem at a first glance, this pillar doesn’t assess if the value of an indicator will improve, but if the way the indicator is measured is expected to become more accurate.

The dimension is divided into 6 areas, namely: Operational/Technical (to monitor the performances of machines and production activities, such as OEE); Economic (KPIs focused on economic and financial results, such as ROI); Environmental and Social (to measure these performances and covering all the aspects of the triple bottom line); Product-Service Lifecycle (to assess how, to which extent and according to which criteria the Product-Service System is assessed); Supply Chain (modalities through which the company measures the overall performances of their entire Supply Chain). In this pillar, the answers also take into account the respondent company's propensity to adopt circular economy practices.

5.3 The Portability Dimension in Manufacturing Data Spaces

The 6Ps Methodology has been refined and extended with a new dimension of analysis: Portability as the combination of Replicability and Scalability capacities, to analyze the replicability and the scalability of R&I project platforms to other industrial domains or larger scale.

Replicability refers to the ability of a system to be repeated consistently and reliably, to serve multiple purposes.

Scalability is a characteristic of a system to cope and perform well under an increased workload or scope. A system that scales well will be able to maintain or even increase its level of performance or efficiency even as it is tested by larger and larger operational demands.

Among Replicability and Scalability enablers in an Industry 4.0 environment, that should be taken into account when designing a new R&D pilot, we can mention: Modularity; Standardization of API and Data modelling; Openness of components; Platforms interoperability; Compatibility with legacy infrastructure and equipment; Data quality, security and protection; Human-Machine Interfaces; Regulations Compliance, Design/usability of Human-Machine Interfaces, User experience, Operators training and re-skilling, Instructions and documentation.

To maintain consistency with the structure of the other pillars of the 6Ps, this 7th, added, pillar includes questions on scalability and replicability referring to the 6 pillars Product, Process, Platform, People, Partnership and Performance.

5.3.1 Replicability aspects

As said, Replicability refers to the ability of a system to be repeated consistently and reliably, to serve multiple purposes.

In the case of smart products or services, we mean the ability to be replicated and sold and delivered consistently and reliably – with the necessary adaptations - so as to serve multiple markets.

In the case of smart processes, it deals with being replicated consistently and reliably to other environments – with the necessary adaptations.

In the platform, replicability refers to the ability of a platform in an IoT ecosystem to be replicated consistently and reliably to other environments – with the necessary adaptations.

5.3.2 Scalability aspects

Scalability is a characteristic of a system to cope and perform well under an increased workload or scope. A system that scales well will be able to maintain or even increase its level of performance or efficiency even as it is tested by larger and larger operational demands.

In a smart product or service, by scalability we expect the capacity to increase its output or its number of features or its number of services offered.

In a process, scalability is the ability to increase the output, eventually adapting to changing needs.

In a platform, scalability refers to the ability to increase the output of a platform (in terms of users, features, services…) in an IoT ecosystem, eventually adapting to changing needs.

5.4 A Maturity Model for Data Economy

The digital transformation framework allows to assess the current level of digital maturity regarding Data Space of Application Cases (AS-IS), quantify the desired level of digital maturity that these latter aim at achieving (TO-BE) and design a specific action plan to allow the transition needed to fill the gaps identified.

Each dimension is analyzed according to 5 main levels of Maturity:

a. INITIAL: The process is poorly controlled or not controlled at all

b. MANAGED: The process is partially planned and implemented.

c. DEFINED: The process is defined with the planning and the implementation of good practices and management procedures.

d. INTEGRATED: The process is built on information exchange, integration, and interoperability across applications; and it is fully planned and implemented.

e. EXPLOITED: the process is digitally-oriented and is based on a solid technology infrastructure and on a high potential growth organization, which supports the decision making.

To identify and assess the current profile of the pilots and definition of the future target profile, an on-line survey has been developed and then refined with interviews. In the end, a comparative analysis has been conducted and some recommendations and success cases identified.

5.5 Future Outlook of the Maturity Model

The Data-AI 6Ps Digital Transformation Assessment Model is a very versatile and quickly applicable tool,

As written above, it has to be understood as a tactical tool, in the sense that it is mainly applied to SMEs that have underway an experiment or a pilot, of which they want to measure the impact on their organization. In this perspective, the 6Ps offers to the project managers an additional point of view about the expected and the actual impact of the experiment, that they can match with their understanding and expectations.

Furthermore, the representation of the outcome in the familiar form of radar charts and the defined and uniform methodology of Q&A allows for an easy benchmark analysis between different use cases. It is possible to aggregate results at different levels (such as clusters of experiments within a project, or at the level of different projects) and compare the impacts at aggregate levels. The aggregate analysis allows the project managers to deepen - and possibly call into question - their own ratings in relation to the others, striving to find similarities and/or understanding the reasons for differences.

For all these reasons, as well as for the simplicity of compilation, the 6Ps Transformation Assessment Model lends itself to being adopted in impact assessments within European projects where experiments or use cases are planned. To mention a few, the 6Ps was used (although - sometimes - in instantiations other than Data/AI) in the projects AI REGIO, CAPRI, DIH4AI, OPEN DEI, XMANAI, FlexiNDT, CTwAIn, AI REDGIO 5.0....

Normally, the assessment is delivered in two iterations, one at the beginning of the experiment and one at the end. In the first iteration, the SME answers about the maturity levels before the experiment ('AS-IS') and those expected at the end of the experiment ('Expected TO-BE'); in the second iteration, the SME indicates what results and progress were actually achieved ('Actual TO-BE').

This approach is very useful and effective to:

- measure the real impact of the experiments on the company; where the progress was, why, how it was achieved;
- assess the vision and planning capacity of the experiment leaders: goals achieved, deviations from expected results, possible corrective actions;
- understand who has performed better in terms of actual results compared to expected results, attempting to analyze and explain the reasons in relation to the experiment typical characteristics.

Another very important phase, typical of the delivery of the tool, is the interview with POLIMI, that can take place along or after the compilation. Conducting the interviews helps to establish a proper interpretive framework with respect to the experiment. Some experiments, in fact, lend themselves to more than one possible interpretation about what the definitions in the different pillars should refer to; for example, this may happen when the experiment is aimed at developing a system to improve the performance of a more complex system, which includes it; in this case, it is important to define what the respondent's point of view is and then carry out the entire questionnaire according to the decision made. One of the main purposes of the interviews is, therefore, to help the respondents to correctly define the interpretive perspective and achieve greater awareness in compiling the questionnaire and in interpreting its results; consequently, a greater homogeneity of responses among the different questionnaires is obtained, thus making them comparable, groupable, classifiable.

The interview also enables the SME to identify priorities among the actions to be undertaken and to define its step-by-step improvements to achieve the expected levels.

5.5.1 Portability

The Portability analysis serves a different purpose. As explained in Chapter 5.3, the Replicability and Scalability questions are an appendix of 6 questions to the 6Ps. The purpose of these 6 questions is to assess how well the SME has prepared its pilot for its scale-up to business exploitation level in case of success. Therefore, questions and answers are more typical of a pure assessment than of a transformation pathway,

- The Portability questionnaire has several purposes (common to the basic version of the 6Ps):to understand how far the SME will be able to exploit at industrial level what was developed during the European project, at both strategic and implementation level
- create benchmarks for comparison between pilots or between projects
- suggest paths for a real exploitation of results

We would like to draw attention to the last one in particular: the questions and answers that the questionnaires propose are intended to stimulate interest and knowledge in the SMEs that fill them; in fact, SMEs are often busy with day-to-day operations, and it is not possible for them to concentrate on aspects outside the business (but which could be of major impact for them!). With this tool, we aimed not only at asking SMEs for answers, but, in turn, to offer SMEs a legacy of knowledge and information in view of a concrete exploitation of the results achieved within the European project.

6 Conclusions, Lessons Learned and Recommendations

D3.2 Business Model (BM) navigator and data space 4.0 maturity assessment model is the second deliverable of WP3 after D3.1 the Industrial Agreements catalogue. The Business part of a Data Space requires not just to have all the stakeholders (economic operators in the DPP jargon) aligned and agreeing on the basic principles of their collaborative data exchange, but also they need to agree on a common Business Model and on a common Business Maturity target to achieve together.

Firstly, D3.2 analyses some embryonic Data Spaces in the Manufacturing domain currently present and described together with their development stage (Lead-in, Committed, Pilot, Live cases) and extracts commonalities and lessons learned during their implementation.

Moreover, D3.2 introduces the methods and tools to define a DS for Manufacturing Business Model and a Maturity Assessment Model. Several methods have been analysed specifically coming from EU projects and EU tenders and a specific methodology selected.

Finally, D3.2 validates such methods and tools through a series of DS for Manufacturing Industrial Pilots coming from H2020, Horizon Europe and Digital Europe programs.

- In the Industrial Data Spaces category we included cases especially focusing on high value FAIR data sharing, including standard common data models and semantic interoperability. The aim here is to have a highly decentralized pool of data, commonly described by standard models and ontologies and implementing Data Sovereignty rules between Data Providers and Data Consumers.
- In the Industrial Data Platforms category we included cases where the underlying digital platform is playing a fundamental role, for instance when managing and governing a non-hierarchical network of suppliers or when aiming for demonstrating a worldwide certification of origin for a high-quality product.
- In the Sustainable Green Products category we put cases specifically addressing green and circular economy challenges, using Digital Product Passports for critical raw materials tracking and tracing (Polymers, Magnets, Batteries)

In Chapter 2 we have seen how the International Data Spaces RADAR platform facilitates the discovery and development of IDS-based solutions applied to real-life challenges. Thanks to its tracking system that monitors companies developing data spaces (based on the IDS standard) it is possible to categorize companies by domain and solution maturity and find viable solutions at all maturity levels. Consequently, we have seen examples of effective implementation in Lead-In cases (2 examples), Committed cases (3), Pilot cases (3) and Live cases (2), and for each of these levels we have described their challenges, success and benefits.

Then, we have seen a new type of business model evaluation framework for manufacturing data spaces, that takes from traditional business models, like the Osterwalder's business model canvas, with the addition of frameworks more tailorable to Data Spaces, such as the Service-Dominant Business Model Radar and the St. Gallen Business Model Navigator. The result is an original work, able to consider the specific aspects of Data Spaces, that we have validated with 7 industrial pilots. This new tool has proven able to highlight the key factors in the Value Proposition, the Data Platform role, the Governance and the Partners for each case, along with Operations optimization and Monetization aspects.

Regarding the maturity assessment conducted using the 6Ps - Digital Transformation Assessment Model methodology on nine cases (results have been summarized in §7.1 above and are detailed in ANNEX III), the assessments aimed at evaluating the impact of Data Spaces implementation projects among the described champions. From the assessments emerged that companies implementing Data Spaces benefit of increased operational efficiency, reduced costs, and tangible productivity gains; they are more able to strategically position themselves for future innovation, scalability, and strengthened competitiveness in their respective markets. While awareness-raising has short-to-medium-term effects, the 6Ps Digital Transformation Pathway suggests actions for long-term impact, providing a solid foundation for organizational success. Different companies show diverse orientations for improvement, focusing on different pillars, although technical pillars are normally of prominent interest, reflecting the technical nature of the projects.

D3.2 concludes its journey by listing some lessons learned and recommendations for the deployment actions SM4RTENANCE and UNDERPIN developed in the first wave call (Dynamic Assets Management and Predictive / Prescriptive Maintenance) and for the additional initiative to be funded in the Agile Supply Chain domain.

6.1 Final Analysis and Summary of the Findings

In manufacturing, Data Spaces facilitate seamless engineering, planning, operations, and after-sales services. The manufacturing ecosystem relies heavily on constant data exchange between participants in the value chain, including suppliers, design and engineering firms, logistics providers, and end customers. Access to accurate, real-time data on production performance, inventory levels, and customer feedback is crucial not only for daily operations but also for strategic planning.

D3.2 examines existing embryonic Data Spaces in manufacturing, describing their current developmental stages. Additionally, it introduces methodologies and tools for defining Data Spaces tailored to manufacturing business models and includes a maturity assessment model to evaluate the digitization levels of SMEs, particularly regarding the integration of Data and AI into their operations. The report validates these tools through industrial pilots originating from H2020, Horizon Europe, and Digital Europe programs.

Three main categories of Data Spaces have emerged.

- First, the Industrial Data Spaces focus on high-value FAIR data sharing: these cases emphasize the use of standard common data models and semantic interoperability to establish a decentralized pool of data governed by data sovereignty rules.
- Second, the Industrial Data Platforms involve scenarios where digital platforms manage and govern non-hierarchical networks of suppliers or provide worldwide certification of high-quality product origins.
- Third, the Sustainable Green Products category addresses green and circular economy challenges, utilizing Digital Product Passports for tracking critical raw materials.

These examples illustrate the diverse applications of Data Spaces in addressing industry-specific needs and advancing digital transformation.

A key component of a Data Space is its business foundation. Successful implementation requires stakeholders to align and agree on collaborative data exchange principles, common business models, and shared maturity targets. Chapter 2 of the present study highlights how the International Data Spaces RADAR platform supports the discovery and development of IDS-based solutions for real-world challenges. By tracking companies engaged in Data Spaces, the RADAR platform categorizes solutions by domain and maturity level, presenting effective examples from Lead-In cases to Live cases. For each maturity level, challenges, successes, and benefits are documented, offering valuable insights for replication and scaling.

A new framework for evaluating business models within manufacturing Data Spaces builds on traditional tools, such as Osterwalder's Business Model Canvas, while integrating specific adaptations like the Service-Dominant Business Model Radar and the St. Gallen Business Model Navigator. Validated through seven industrial pilots, this framework identifies critical factors in value proposition, data platform roles, governance, partnerships, operations optimization, and monetization. These tools provide a nuanced understanding of the interplay between technical and business dimensions in Data Spaces.

Maturity assessments conducted using the 6Ps Digital Transformation Assessment Model evaluated the impact of Data Spaces on nine cases. The findings revealed that companies implementing Data Spaces achieve significant operational efficiency, reduced costs, and tangible productivity gains. These organizations also position themselves strategically for future innovations, scalability, and enhanced market competitiveness. While short-term effects stem from awareness initiatives, the 6Ps Digital Transformation Pathway suggests long-term actions for sustainable success. Companies' improvement efforts often focus on technical pillars, reflecting the inherent technicality of Data Space projects.

The integration and continuity enabled by Data Spaces aim to produce actionable business intelligence (BI). BI initiatives empower businesses to derive insights from extensive transactional, product, inventory, customer, competitor, and industry data generated by enterprise-wide applications. Companies engaged in Data Spaces realize significant benefits, including cost savings from operational efficiency, reduced energy consumption, fewer errors, better market scouting, faster product development, and higher sales growth. These advantages underscore the transformative potential of Data Spaces as foundational tools for innovation and collaboration in the digital age.

Data Spaces represent not merely technological advancements but pillars of systemic change. Through secure and transparent data sharing, they optimize resource use, minimize waste, and promote responsible production models. By tackling challenges such as standardization, trust, and scalability, and embracing trends like sector-specific ecosystems and emerging technologies, Europe can solidify its leadership in the global data economy. Continued investment, collaboration, and regulatory alignment will ensure that Data Spaces drive innovation, competitiveness, and sustainability.

ANNEX I Manufacturing Data Spaces Business Models: Questionnaire

Q1. What are the main objectives of your data space and its ecosystem? Select top 3

a. Monetize data generated in operations (i.e. production process, product performance, customers)
b. Create new value propositions based on shared and digital services
c. Evolve product and service innovation processes with collaboration and risk/cost sharing in the ecosystem
d. Increase supply-chain agility
e. Incubate new startups
f. Improve productivity and efficiency in operational processes
g. Improve the quality of products
h. Improve the execution of services on installed products
i. Improve the quality/availability of data for production planning and demand forecasting
j. Enhance supply chain visibility via collaboration with trading partners
k. Increase product traceability throughout the value chain
l. Tackling ESG challenges relevant to the ecosystem (i.e. Scope 3 emissions, circularity, material sourcing, and labor practices)
m. Leverage the ecosystem to better understand and adapt to new protocols and regulations
n. Expand industry data ecosystem
o. Improve collaboration around asset availability and performance
p. Improve asset maintenance through prescriptive and predictive analytics
q. Other

Q2. Which type of data is shared within the data space and its ecosystem? Multiple Response

a. Process data
b. Product-related data
c. Customer data
d. Supply-chain data
e. Asset-related data
f. Other (please specify)

Q3. Does your data space and its ecosystem have the objective of commercializing data, or a digital product/service based on ecosystem data? Yes/No

Q4. If Q3=Yes, Which products/services is your data space and its ecosystem providing? Multiple options, Please specify

a. Proprietary Software/APIs (i.e. remote asset monitoring and diagnostics, production analytics, energy management)

b. New digitally-enabled business services (i.e. remanufacturing and recycling, asset service and management, engineering services)
c. Data management, trading, and monetization (i.e. machine and asset performance, demand, capacity, inventory data)
d. Other

Q5. If Q3=Yes, which industries is your ecosystem targeting for commercializing data/digital products or services? Multiple response

Answer Options	Mouse-over Definition
1. Construction	Buildings, industrial facilities, transportation infrastructure, utility projects, etc.
2. Manufacturing — Discrete	Automotive, high tech, IT hardware and telecom equipment vendors, consumer goods, industrial machinery, domestic appliances)
3. Manufacturing — Process	Food, beverages, tobacco, basic metals, plastic, etc.
4. Oil and Gas	Extraction of crude oil & natural gas, oil & petroleum refinery, and service activities incidental to oil & gas extraction and refinery
5. Resource industries	Agriculture, forestry and logging, fishing, mining, and quarrying,
6. Retail trade	Food stores, clothing and footwear, accessories, consumer electronics stores, ecommerce, drug stores, furniture, DIY, gardening, etc.
7. Transport — freight transport and logistics	Logistics and supporting services, courier & postal services, etc.
8. Transport — passenger transport	Water, air, rail, and other land transport
9. Utilities	Gas, electricity, water, sanitation services, etc.
10. Wholesale distribution	Distribution and import & export
11. Other	All others not listed

Q6. If Q3= Yes Are you providing data/products as a service?

a. Yes, through subscriptions
b. Yer, through pay per use
c. Yes, based on demand models
d. Yes, based on the achievement of certain outcomes (cost saved, revenue generated)

Q7. How many partners are involved in the dataspace and its ecosystem?

a. 1-5 partners
b. 6-10 partners
c. More than 10 partners

Q8. In the table below please define for each partner, the industry, the role the partner has in the data space and its ecosystem, the specific benefits gained, and resources put at stake (add one row for each partner)

Industry	Key Role/Activities in the ecosystem (e.g. Orchestrator, data owner, asset manufacturer, …)	Resources invested/ shared in the ecosystem (business, technical and organizational resources, for example asset, funds, IP rights, technology platform, FTEs, and so on)	Benefits gained by each participant

Q9. How would describe the governance model of the data space and its ecosystem? Select one

a. Hierarchical governance model with a hierarchical centralized decision making and central governing partner that has control over data and sets rules for data governance, management and usage
b. Distributed governance model, where decision-making power is shared among multiple stakeholders involved in managing and utilizing data within the ecosystem

Other, please specify

Q10. Does the data space and its ecosystem has a formally recognized legal form? Yes (please specify), No

Q11. Does the data space and its ecosystem own IP (intellectual property) rights over the products and services it provides? Yes/No

Q12. If Q11=yes, who among the partners owns the IP right(s)? Multiple response

a. The technology provider
b. The orchestrator
c. The data owner
d. Another manufacturing partner of the ecosystem
e. Another partner of the ecosystem
f. Other

Q13. If existing, what is the revenue sharing mechanism across partners? Select one

a. Revenues are equally shared among partners
b. The partner who orchestrates that data space takes a larger share of revenues
c. The partner who provides the technology platform takes a larger share of revenues
d. Other, please specify

Q14. Who are the external partners and institutions you are collaborating with as part of your data space and its ecosystem's activities? Select all that apply

a. Regulators
b. Academia

c. Research Institutions
d. Innovation Accelerators/Competence Centers
e. Trade Associations
f. Standardization & Certification Bodies
g. Others

Q15. How would you describe the data platform model of your dataspace and its ecosystem? Select one

a. Open distributed technology platform among participants, with some application and data shared
b. Single proprietary ecosystem technology platform
c. Other (please specify)

Q16. Please explain response in Q14

Q17. Who owns the technology platform? Select one

a. A third-party external to the ecosystem
b. Tech provider that is part of the ecosystem
c. Another participant from the ecosystem
d. Other (please specify)

Q18. Is the technology platform commercialized/made available to other organizations external to the ecosystem/other ecosystems? Yes/No

Q19. What are the key technologies to enable ecosystem operating business model? Multiple choice

a. IoT
b. Connectivity and networking platform
c. Cloud infrastructure
d. Industry cloud dedicated platform
e. Ecosystem orchestration and management platforms (EOP)
f. Data management, governance, and exchange solutions
g. Application development
h. Data privacy, protection, and loss prevention solutions
i. Billing, contracts, transactions, and intellectual property tracking platforms
j. Digital marketplaces
k. Shared or open APIs
l. Other

Q20. How mature on a scale from 1=basic to 5=advanced is your data space and its ecosystem's governance model? This includes contracts, IP rights, data handling, access & usage policies definition, ethical use of technologies. Rate from 1 to 5

Q21. What are the key metrics you use to measure your data space and its ecosystem's success? Multiple Selection

a. Amount and strategic relevance of data exchanged
b. Digital revenue generated

c. Number of products or services launched
d. New skills and learnings in place
e. Environmental/sustainability-related performance
f. Value generated for customers
g. Number of new partners acquired
h. Level of digital maturity reached
i. Creation of new/alternative business models
j. Other, please specify

Q22. For metrics selected in Q21. What annual percentage change in the past 12 months did your ecosystem experience in the past 12 months? Insert %

Q23. What are the incentives for companies to participate in your data space and its ecosystem? Multiple response

a. Access to valuable data
b. Collaboration opportunities
c. Cost savings
d. Gaining competitive advantage
e. Fostering innovation and research
f. Improving data quality
g. Improving regulatory compliance
h. Other, please specify

Q24. What are the key challenges you are seeing for your data space and its ecosystem? Multiple response

a. Difficulties in exchanging data
b. Lack of skills
c. Lack of tools
d. Data protection concerns
e. Unclear contracts design
f. Unclear return on investment
g. Lack of clarity around participants' roles
h. Other, please specify

ANNEX II 6Ps Maturity Assessment of Data Spaces for Manufacturing: Questionnaire

1. PRODUCT

6P's Product dimension aims at investigating what is the current state and the desired level of digitalisation of your company's Product-Service System (PSS).

This part has the objective to define a tailored roadmap for the transition toward smart (digital, data and IoT featured) PSS offered to the market.

1.1 INTEGRATION OF SENSORS / ACTUATORS

To what extent are the products offered to your customers equipped with sensors and actuators?

1. INITIAL: The product does not use sensors or actuators

2. MANAGED: The product is provided with sensors but with limited, basic elaborations

3. DEFINED: The product internal sensors data are processed

4. INTEGRATED: Sensors and other data sources are analysed inside the product

5. EXPLOITED: The product independently responds based on the gained data and elaborates data to run AI model

1.2 COMMUNICATION/ CONNECTIVITY

Through which modalities are your products able to communicate, either send or receive information, with the external environment (other similar products, the overall system etc.)?

1. INITIAL: The product has no communication interfaces;

2. MANAGED: The product sends and manages hardwired Input/output signals or serial communication (e.g. fieldbus)

3. DEFINED: The product has Industrial Ethernet interfaces and proprietary LAN communication technologies

4. INTEGRATED: The product is connected with interoperable LAN communication technologies (e.g. OPC)

5. EXPLOITED: The product is securely connected to the Internet

1.3 DATA STORAGE AND EXCHANGE OF INFORMATION

What are the capabilities of your products to collect, store and share data?

1. INITIAL: The product does not have any functionality

2. MANAGED: The product has the possibility for individual identification

3. DEFINED: The product has the possibility to collect and elaborate data, but data remain locked in it

4. INTEGRATED: The product has the possibility to collect and elaborate data; product data can be transferred to other enterprise applications

5. EXPLOITED: Data and information exchange are integral part of the product features; the product is designed to allow interoperability since an interoperability communication protocol is adopted inside the company

1.4 MONITORING

To what extent is your product able to self-assess and record its conditions, also for self-correcting actions?

1. INITIAL: The product is not subject to condition monitoring

2. MANAGED: Monitoring is used just for detection of failures or malfunctions

3. DEFINED: The product records its operating conditions for diagnostic purposes and/or to improve its performances

4. INTEGRATED: The product records its operating conditions for prognostic purposes; the prognostic tools exploiting the accumulated data are based on internet AI tools

5. EXPLOITED: The product independently adopts control measures based on decisions and/or prescriptions (e.g. product self-configure, product self-healing, etc.), elaborated by internet AI tools and/or by AI tools embedded in the product

1.5 PRODUCT-RELATED IT SERVICES

To what extent is your product able to provide additional services based on data (in addition to its primary function)?

1. INITIAL: There are no IT services correlated to the product

2. MANAGED: There are product-related services that can be activated by the customer, e.g. via online portals.

3. DEFINED: There are product-related services that can be selected by the customer and that evolve dynamically based on market trends

4. INTEGRATED: Product-related services are customized on customers' needs thanks to data analysis supported by AI tools

5. EXPLOITED: The product is completely integrated into an ecosystem of product-service systems managed by Industrial Data Platforms for Data Processing and Sharing

1.6 BUSINESS MODELS ENABLED BY THE PRODUCT

How much is the revenue stream dependent on added services and on data rather than on the product itself?

1. INITIAL: The Business Model (BM) consists of selling standardized products, with no or little added services

2. MANAGED: The BM considers services as a decisive factor for the products sale's revenue stream

3. DEFINED: The BM consists of selling customized services after the product; services are a significant share of the revenue stream

4. INTEGRATED: The BM considers servitization as the main revenue stream; the data collected can be used to design new products and services for the same or other market segments

5. EXPLOITED: The BM considers servitization as the main revenue stream; products are designed to allow interoperability by design, so that new data-driven business models can leverage on an interoperable architecture, allowing an effective data valorisation.

2. PROCESS

6P's Process dimension aims at investigating what is the current state and the desired level of digitalisation of your company's processes.

This part has the objective to define a tailored roadmap for the transition towards smart, connected and circular processes taking place within your factory.

In particular, the areas assessed are: Design & Engineering, Production Management, Quality Management, Maintenance Management, Logistics Management and Supply Chain Management.

2.1 DESIGN & ENGINEERING

What is the option that better describes your Design and Engineering process?

1. INITIAL: No digital model of the process is present. There are only one-way exchanges between the functions of design and production.

2. MANAGED: Some preliminary digital models do exist as static representation of the process. Notifications between production and design functions are bidirectional and tracked in documents.

3. DEFINED: Simulations are developed and validated in a CAD environment and supported by digital models. Modifications are tracked and versioned in CAD. Production functions are involved in the design process.

4. INTEGRATED: Some Digital Twin simulations are used; digital models are compared versus physical prototypes. Modifications are automatically identified and managed in CAD. The Production function is involved in the design phase.

5. EXPLOITED: Full Digital Twin simulations developed in CAD environment are used. Different digital process options are managed and assessed in a single development environment, involving the Production function in the design phase.

2.2 PRODUCTION MANAGEMENT

What is the option that better describes your Production Management process?

1. INITIAL: Production processes are not automated, or they are partially automated but not connected, with significant human intervention.

2. MANAGED: Production processes are partially automated and connected via multiple system-to-system channels and protocols. Production data are generated, processed and visualised by CPPS and I4.0 systems (including e.g. SCADA, MES, ERP systems, etc.).

3. DEFINED: Production processes are automated and interoperable (i.e. SCADA, MES, ERP systems are in use within an interoperable architecture), in some cases with no human intervention.

4. INTEGRATED: Automated and interoperable production processes are reconfigurable through plug-and-play automation and capable of real-time communication. Industrial Data Platforms for Data Processing and Sharing are adopted, where data are standardized

and interoperable. There is some use of AI technologies (Big Data analytics, decision support systems, intelligent control systems, computer vision, image recognition…).

5. EXPLOITED: Flexible and interoperable production and support processes are capable of real-time communication, scalable and converged with enterprise and facility automation platforms to form highly autonomous networks. Data are standardized and interoperable. There is some use of AI technologies (Big Data analytics, decision support systems, intelligent control systems, computer vision, image recognition…).

2.3 QUALITY MANAGEMENT

What is the option that better describes your Quality Management process?

1. INITIAL: Quality processes are carried out through human inspections and simple systems (e.g. Excel control charts)

2. MANAGED: A QMS (Quality management system) is in use and is able to model correct quality patterns and identify deviations

3. DEFINED: Our Quality Management Systems is able to identify deviations and diagnose potential causes. Quality data are generated, processed and visualised by CPPS and I4.0 systems (including e.g. SCADA, MES, ERP systems, etc.).

4. INTEGRATED: A centralised and interoperable QMS is able to diagnose problems and predict future states of assets and systems. Industrial Data Platforms for Data Processing and Sharing are adopted to support QMS, where data are standardized and interoperable. There is some initial use of AI-based tools (Big Data analytics, decision support systems, intelligent control systems, computer vision, image recognition…).

5-AI. EXPLOITED: A centralised and interoperable QMS endowed of AI is able to diagnose problems, predict future states of assets and systems and autonomously suggest/execute decisions to adapt and implement RCA (Root Cause Analysis). Data are standardized and interoperable. Use of AI technologies (Big Data analytics, decision support systems, intelligent control systems, computer vision, image recognition…).

2.4 MAINTENANCE MANAGEMENT

What is the option that better describes your Maintenance Management process?

1. INITIAL: The company does not use any digital tool to track maintenance activities, and adopts a reactive approach.

2. MANAGED: The maintenance activities are tracked with simple tools (e.g. Excel sheets) and plans and procedures are loaded into CMMS/ERP. The company adopts inspection/monitoring plans but, at best, elaborates them only to detect on-going issues before the failure occurs.

3. DEFINED: The maintenance activities are tracked and analysed with simple tools (e.g. FMEA on Excel sheets) and reconfigurable plans and procedures are loaded into CMMS/ERP. The company adopts a diagnostic/predictive approach, enabling an adequate capability to assess the current health and prognosticate its future evolution, anticipating the failure occurrence.

4. INTEGRATED: Maintenance activities are traced and monitored through dedicated software (e.g. CMMS, SCADA, MES, etc.); procedures and plans are validated periodically. The company adopts a prescriptive approach supported by some initial use of AI-based tools (such as Big Data analytics; decision support systems; Digital Twins …).

5. EXPLOITED: Maintenance activities are traced and monitored through dedicated software (e.g. CMMS, SCADA, MES, etc.); procedures and plans validation is part of the maintenance activity. The company adopts a cognitive approach and a dynamic asset management supported by Explainable AI (XAI) technologies to help people to better understand AI decisions.

2.5 LOGISTICS MANAGEMENT

What is the option that better describes your management of your Internal Logistics processes?

1. INITIAL: Logistics processes are defined and executed by humans, with the support of analogue tools

2. MANAGED: Defined logistics processes are completed by humans with the support of digital tools. Data are generated, processed and visualised by CPPS and I4.0 systems (including e.g. SCADA, MES, ERP systems, etc.

3. DEFINED: Digitized logistics processes and systems are securely integrated across all hierarchical levels of the automation pyramid (i.e. SCADA, MES, ERP are in use)

4. INTEGRATED: Integrated logistics processes and systems are automated, with limited human intervention. There is some initial use of AI-based tools (Big Data analytics, decision support systems, intelligent control systems, computer vision, image recognition, Digital Twins…), possibly integrated with Autonomous Guided Vehicles (AGV)

5. EXPLOITED: Automated logistics processes and systems are actively analysing and reacting to data, supported by AI (Big Data analytics; decision support systems; intelligent control systems; computer vision; image recognition; Digital Twins …) with Explainable AI (XAI) features; AI tools are integrated with Autonomous Guided Vehicles (AGV)

2.6 SUPPLY CHAIN MANAGEMENT

What is the option that better describes your approach to Data in your Supply Chain (SC) Management process?

1. INITIAL: There is no software assisted integration within the organisation for internal logistics data exchange. The Supply Chain (SC) processes are lowly monitored, and managed on experience

2. MANAGED: Within the organisation, proprietary data are managed and integrated. The SC processes are monitored, with some use of good practices. No data bridges are implemented with suppliers and customers ("SC tiers")

3. DEFINED: Within the organisation, data are managed efficiently and effectively by means of a Sales & Operation Planning (S&OP) system. The SC processes are monitored, and partially integrated and automated by data bridges with suppliers and customers

4. INTEGRATED: The IT Systems of the organization are integrated and managed efficiently and effectively by an in-use S&OP, including an Industrial Data Platforms for Data Processing and Sharing. The SC processes are overall planned and monitored, and ad-hoc data bridges are created between Enterprise Applications for specific purposes

5. EXPLOITED: The IT Systems of the organization are integrated and managed efficiently and effectively by an in-use S&OP, including an Industrial Data Platforms for Data Processing

and Sharing. The S&OP is adopting AI tools to support our SC operations and decisions. The SC processes are systematically planned and monitored. Decentralised data spaces are utilised to interact with the supply chain stakeholders

3. PLATFORM

6P's Platform dimension aims at investigating what is the current state and the desired level of digitalisation of your company's Digital Platforms.

This part has the objective to define a tailored roadmap for the transition toward a Digital Platform able to support both vertical integration (from the shop floor to the enterprise level) and horizontal integration along the value chain and end-to-end engineering.

3.1 CYBER-PHYSICAL PRODUCTION SYSTEMS AND EMBEDDED SYSTEMS

To what extent is your facility able to integrate with sensors along the production line and exploit the collected information for supporting decisions?

1. INITIAL: There is no on-board intelligence

2. MANAGED: The system collects and store data and performs elementary elaboration

3. DEFINED: The system understands the environment and reacts correspondingly

4. INTEGRATED: The system has the ability to set up and manage M2M (Machine to Machine) and M2H (Machine to Human) interactions

5. EXPLOITED: The system uses the information to take decisions and behave autonomously thanks to the integration with an AI model

3.2 INDUSTRIAL IoT

How much are your physical resources connected through sensors and what functionalities are they able to perform?

1. INITIAL: The system has no capability to sense the environment

2. MANAGED: There are dumb sensors that only provide data

3. DEFINED: The sensors ecosystems are governed and controlled by dedicated hardware

4-AI. INTEGRATED: A computable model of the asset allows running simulations and forecasting on single assets

5. EXPLOITED: Ecosystems of smart objects are interoperable through open standards and AI, with limited human intervention

3.3 INDUSTRIAL INTERNET

To what extent is your Platform able to integrate IT with OT under an Industrial Internet paradigm?

1. INITIAL: Real World devices are controlled and managed by hard wired protocols

2. MANAGED: Real World devices are controlled and managed by multi-protocol gateways; data are in silos

3. DEFINED: Our platform supports data-bridges between enterprise applications; events gathered by gateways are processed and anomalous situations detected in real time; cybersecurity and data integrity are managed

4. INTEGRATED: An appropriate data infrastructure is adopted to allow data interoperability and data ownership; configurable rules can determine correct and anomalous patterns

5. EXPLOITED: An appropriate data infrastructure is adopted to allow data interoperability and data ownership; AI at edge determine correct and anomalous patterns also in terms of cybersecurity and data integrity

3.4 INDUSTRIAL ANALYTICS

To what extent is your company able to manage heterogeneous data coming from different sources (both internal and external) and exploit it for decision-making purposes?

1. INITIAL: No analytics functionality

2. MANAGED: Analytics techniques are used to filter and visualise data sets

3. DEFINED: Forecast/prediction models for instantiating “what-if analysis” are possible, relying on data ingestion and data storage; dynamic behavioural simulations & validation are possible

4. INTEGRATED: Forecast/prediction AI/ML models for instantiating “what-if analysis” are a common practice and rely on data ingestion and data storage; dynamic behavioural simulations based on models and on user-supervised “what-if” scenario exploration & validation are possible

5. EXPLOITED: Decision making process is fully assisted by an AI-based support system.

3.5 VERTICAL INTEROPERABILITY OF DATA AND EVENTS

To what extent is your Platform able to support a computational continuity between Physical Assets and Digital Cloud?

1. INITIAL: Data Events at Shopfloor are unexploited

2. MANAGED: Data generated by real world are collected by dedicated devices

3. DEFINED: Data generated by real world are stored into the cloud and processed into reliable metadata to help the user have at hand useful information

4. INTEGRATED: Data and metadata flows bidirectionally between the real world and the cloud

5. EXPLOITED: The configuration of the distributed architecture can be dynamically adapted

3.6 HORIZONTAL INTEROPERABILITY OF DATA AND SERVICES

How much data and services are managed, exchanged and used among different actors of your value creation process?

1. INITIAL: Data/Events are stored, managed and used in silos approach inside the organization

2. MANAGED: Data coming from different plants are stored into a unique repository;

there is no or very little access to the Value Chain Data by Users and Systems external to the organisation

3. DEFINED: Different data formats and protocols are managed and used together; there are some data bridges among enterprise applications of actors and stakeholders along the Value Chain

4. INTEGRATED: Different enterprise applications in different plants are integrated as a service; there are data bridges with enterprise applications of actors along the Value Chain, and AI tools to supervise the Value Chain processes

5. EXPLOITED: Collaborative business processes and workflows are used in the Value Chain through the use of decentralised and federated data spaces based on commonly agreed principles, where heterogeneous data can be integrated, and security and privacy policies are in place. AI tools supervise the Value Chain processes

4. PEOPLE

6P's People dimension aims at investigating what is the current state and the desired level of digital skills held by your company's employees (ranging from operators to top management).

This part has the objective to define a tailored roadmap for the transition toward a more digitally skilled organisation.

Managers & C Levels M1 DATA STRATEGY

How is the topic of Data Spaces part of your corporate strategy?

1. INITIAL: We have no/little data control and usage

2. MANAGED: We have Data Silos; Data are locked in their own Enterprise Applications (SCADA, MES, ERP, CRM, PDM…) with limited or no access by external Users and Systems

3. DEFINED: Ad-hoc Data Bridges are created between Enterprise Applications for specific purposes; Heterogeneous Data Sources can be integrated on a case-by-case basis

4. INTEGRATED: Our strategy considers at least some of the following approaches to Data: Data Interoperability by design; Industrial Data Platforms for Data Processing and Sharing; Data Integration and Security/Privacy issues

5. EXPLOITED: Our strategy considers at least some of the following approaches to Data: Data-driven Innovative Business Models; Data Governance models for Data Sovereignty/GDPR; Open Data Ecosystems; Multi-stakeholder Digital Passports for complex Product-Service Systems

I4.0 Professionals P1 SMART OPERATIONS

In the field of Operations, which option includes your most advanced achievements?

1. INITIAL: The company uses common software (e.g. Excel)

2. MANAGED: Use of Enterprise Systems (ERP, MES, PLM)

3. DEFINED: Data are systematically analysed and interpreted by means of Business Intelligence tools

4. INTEGRATED: Ability to plan, coordinate and optimise smart production systems

5. EXPLOITED: Proven abilities of redesigning processes in a I4.0 and AI perspective

I4.0 Professionals P2 SMART SUPPLY CHAIN

In the field of Supply Chain, which option includes your most advanced achievements?

1. INITIAL: The company uses common software (e.g. Excel)

2. MANAGED: The company adopts real-time dynamic management

3. DEFINED: Ability to collaborate with external actors and integrate them in the digital supply network

4. INTEGRATED: Ability to plan, coordinate and optimize the collaborative digital supply network

5. EXPLOITED: Analyse market demand, supply network data, social media and other data and predict future scenarios by using ML and/or other AI related technologies

I4.0 Professionals P3 SMART PRODUCT-SERVICE ENGINEERING

In the field of PSS Engineering, which option includes your most advanced achievements?

1. INITIAL: The company has a product-oriented organisation and business models

2. MANAGED: The company focuses on the whole lifecycle of the Product and support services

3. DEFINED: The company has availability of skills to design smart products customized with software user interface, services and integrations with the enterprise IT systems

4. INTEGRATED: The company focuses on the design, recycle and management of the P-S lifecycle and develops its Business Model around it

5. EXPLOITED: The company uses open innovation for smart and repurpose P-S lifecycle and a Business Model based on a digital ecosystem of partners

Professionals DT1 INDUSTRY 4.0 INFRASTRUCTURE (IT and OT)

What is the approach adopted by the company when it has to select and invest on technologies (OT and IT) both in terms of software and hardware?

1. INITIAL: The company contributes to the design and general functional specification and interfaces

2. MANAGED: The company can select sensors, software, protocols for its needs (including cybersecurity products)

3. DEFINED: The company uses modelling languages and programming tools besides selecting products from market

4. INTEGRATED: Specify, refine, update and make available a formal approach to implement solutions necessary to develop and operate the architecture oriented towards Data and AI

5. EXPLOITED: Investigating latest technologies and devising innovative solutions for integration of new technology into existing systems to meet future business Data and AI requirements

Professionals DT2 BIG DATA

How much is your company able to collect, manage and exploit data to run its business?

1. INITIAL: The company selects and collects useful data

2. MANAGED: The company is able to clean, organise and rationalise the data

3. DEFINED: The company is able to select and implement technology such as ML for analysing big data

4. INTEGRATED: Exploits Big Data automatically by ML and AI technologies

5. EXPLOITED: The company is able to exploit big data creatively and innovatively

Professionals DT3 AI-BASED OPERATIONS

Is your staff able to deal with AI Systems in order to optimize processes and workflows?

1. INITIAL: There is no use of AI

2. MANAGED: Workers are supported by AI apps; we have plans to adopt AI-based working methods to address specific issues in the company

3. DEFINED: We have adopted in the company AI-based tools to support operations (Digital Twins, Dynamic Simulations…)

4. INTEGRATED: We have adopted in the company AI-based tools to support operations; to improve/refine models and to maintain the existing ones, we have a dedicated department in the company or at least some professional roles with expertise in it

5. EXPLOITED: We have adopted in the company AI-based tools to support operations; we collaborate with our ICT providers in the research and development of AI tools, so reaching a high level of exploitation

Operator O1 SMART OPERATIONS

In the field of Operations, which option includes your most advanced achievements?

1. INITIAL: The company uses standard Human Machine Interfaces and common software

2. MANAGED: Use of wearable devices to monitor production

3. DEFINED: Analytical skills to interpret production data

4. INTEGRATED: Basic interactions with AI: Big Data analytics, decision support systems, intelligent control systems, computer vision, image recognition, Digital Twins…

5. EXPLOITED: Advanced interactions with AI (Big Data analytics, decision support systems, intelligent control systems, computer vision, image recognition, Digital Twins…) with Explainable AI (XAI) features.

Operator O2 AI AUTONOMY

In your operations, what is the level of autonomy of AI Systems?

1. INITIAL: No autonomy

2. MANAGED: Partial autonomy in some areas, human operators have responsibility and make all decisions

3. DEFINED: AI System warns if issues occur; human operators can confirm or change solutions recommended by the system

4. INTEGRATED: AI System functions autonomously and adaptively, humans can supervise or intervene in emergency situations; AI models have the full trust of human operators

5. EXPLOITED: Autonomous operations, including in cooperation; human presence is not always required; there is an experimentation culture towards the exploration and the development of AI use cases

Operator O3 AI EXPLAINABILITY

What is the level of transparency of the AI models, so that human users will be able to understand and trust decisions?

1. INITIAL: No use of AI/Use of black box systems

2. MANAGED: The AI systems support decisions, but without explanations

3. DEFINED: There are visualisation and debugging tools that allow to double-check the AI decisions and make them understandable

4. INTEGRATED: AI models provide an explanation of the results and offer different alternatives to the human decision maker

5. EXPLOITED: AI full explainability enables the interoperability with other automated systems that understand the decisions

5. PARTNERSHIP

6P's Partnership dimension aims at investigating what is the current and the desired level of engagement of your company's external stakeholders.

This part has the objective to define a tailored roadmap for the transition toward the identification of the partners needed for digitalization and for achieving the desired business goals and the creation of a more collaborative relationships with key stakeholders in the digital ecosystem, in order to create strong and collaborative partnerships.

5.1 DIGITAL INNOVATION HUBS

What kind of relationship does your company have with Digital Innovation Hubs?

1. INITIAL: There are not formal, nor informal relationships established

2. MANAGED: Only informal communication and one-off share of information is established

3. DEFINED: There are supportive relationships but no formal activities in place

4. INTEGRATED: DIHs are engaged in mutual projects and initiatives

5. EXPLOITED: There is a formal agreement in place

5.2 RESEARCH & INNOVATION

What kind of relationship does your company have with Research Institutes (e.g. Cefriel)?

1. INITIAL: There are not formal, nor informal relationships established

2. MANAGED: Participation to events and workshops oriented to research and innovation

3. DEFINED: There is active interest in Research & Innovation initiatives

4. INTEGRATED: There are occasional participation to R&I programs

5. EXPLOITED: There is a systematic Participation and common R&I programs

5.3 TRAINING & EDUCATION

What kind of relationship does your company have with Education and training institutions (e.g. Politecnico di Milano)?

1. INITIAL: No competence assessment and training programs on Data and AI are planned

2. MANAGED: Occasional competence assessment and training programs for a few roles

3. DEFINED: Competence assessment, training and education programs are done regularly

4. INTEGRATED: Technology-Enhanced Learning programs with educational institutions are planned.

5. EXPLOITED: There are widespread lifelong learning programs and collaborations with education institutions

5.4 IT SOLUTION PROVIDERS

What kind of relationship does your company have with its IT providers?

1. INITIAL: There are no continuative relationship established

2. MANAGED: IT partnership as a necessary provision of basic digitalisation services (suppliers)

3. DEFINED: IT partnership as a collaboration environment to develop together reliable solutions

4. INTEGRATED: IT providers as reliable partners in identification of new business opportunities

5. EXPLOITED: IT providers as offering game changing value and new business models

5.5 SUPPLIERS

What is the highest kind of relationship that your company has with its main suppliers?

1. INITIAL: Transaction relationship: partnership just related to the supply of goods/services

2. MANAGED: Cooperation relationship: partnership also related to the supply and usage of goods/services

3. DEFINED: Coordination relationship: partnership also related to whole ecosystem of goods/services suppliers

4. INTEGRATED: Collaboration relationship: partnership directed to a mutual but occasional business opportunity

5. EXPLOITED: Dynamic collaboration relationship: strategic long-term multi–dimensional partnership in a win-win situation

5.6 CUSTOMERS

What is the main level of involvement that your company establishes with its customer in the product development process/in the definition of the product to be delivered?

1. INITIAL: No partnership with Customers

2. MANAGED: Cosmetic customer partnership. Standard product is offered in different ways to different customers using special packaging, etc. Simple customization is defined by customer itself

3. DEFINED: Transparent Customer Partnership. Customization without direct interaction with customers

4. INTEGRATED: Adaptive Customer Partnership. Customer customizes the good or service as desired using customizable functionality embedded into the offer.

5. EXPLOITED: Collaborative Customer Partnership. Customers actively participate in Co-creation and co-production. AI-based model for recommendation

6. PERFORMANCE

6P's Performance dimension aims at investigating what is the current and the desired level of control over your company's processes and activities.

This part has the objective to define a tailored roadmap for the transition toward the definition of new KPIs to measure new Business Models based on the digital transformation of your industry.

6.1 OPERATIONAL/ TECHNICAL

What approach does your company adopt for measuring operational performances (e.g. OEE)?

1. INITIAL: Operational performance is often not measured or understood

2. MANAGED: Descriptive Performance - Measurement and analysis of business KPIs are largely retrospective

3. DEFINED: Diagnostic Performance - Measurement of KPIs is clear. Attempt to understand the causes that affects events and behaviours

4. INTEGRATED: Predictive Performance - Measurement of KPIs is prospective. Statistical models are used to forecast and to understand the KPIs predictions

5. EXPLOITED: Prescriptive Performance – future-oriented. Optimization and simulation to find the best course of action and operational KPIs measurement

course of action and operational KPIs measurement. AI/ML models are used to forecast and to understand the KPIs predictions

6.2 ECONOMIC

What approach does your company adopt for measuring economic performances (e.g. ROI)?

1. INITIAL: Economic performance is often not measured or understood

2. MANAGED: Descriptive – Measurement of economic KPIs is largely retrospective

3. DEFINED: Diagnostic - Measurement of economic KPIs is clear. Attempt to understand the causes of events and behaviours

4. INTEGRATED: Predictive - Measurement of economic KPIs is prospective. Statistical models and forecasts techniques to understand the KPIs predictions

5. EXPLOITED: Prescriptive Performance – future-oriented. An AI decision-making support system boosting optimization exploits simulation and allows to find the best course of actions and operational KPIs measurement

6.3 ENVIRONMENTAL

What approach does your company adopt for measuring environmental performances (e.g. water consumption per product, energy optimization)?

1. INITIAL: Environmental performance is often not measured or understood

2. MANAGED: Descriptive – Measurement of environmental KPIs is largely retrospective

3. DEFINED: Diagnostic - Measurement of environmental KPIs is clear. We attempt to understand the causes of events and behaviours

4. INTEGRATED: Predictive - Measurement of environmental KPIs is prospective. AI and/or statistical models are used to forecast environmental performances

5. EXPLOITED: Prescriptive – future-oriented. An AI decision-making support system boosting optimization exploits simulation and allows to find the best course of action and environmental KPIs measurement

6. SOCIAL

What approach does your company adopt for measuring social performances (e.g. welfare for employees)?

1. INITIAL: Social performance is often not measured or understood

2. MANAGED: Descriptive - Measurement of social KPIs is largely retrospective

3. DEFINED: Diagnostic - Measurement of social KPIs is clear. Attempt to understand the causes of events and behaviours

4. INTEGRATED: Predictive - Measurement of social KPIs is prospective. AI and/or statistical models are used to forecast social performances

5. EXPLOITED: Prescriptive – future-oriented. An AI decision-making support system boosting optimization exploits simulation and allows to find the best course of action and environmental KPIs measurement

6.5 PRODUCT-SERVICE LIFECYCLE

Which dimensions of analysis are taken into account in the assessment of lifecycle of the products/services offered to the customers?

1. INITIAL: No product lifecycle assessment

2. MANAGED: A few life-cycle aspects are included in some KPIs, but occasionally

3. DEFINED: Life Cycle Costing (LCC) towards recycling, re-use, de-re-manufacturing KPIs

4. INTEGRATED: Life Cycle Costing + Environmental LCA towards Circular Economy

5. EXPLOITED: Life Cycle Costing + Environmental LCA + Social LCA towards Sustainability and Green Deal

6.6 SUPPLY CHAIN

Which dimensions of analysis are taken into account for the overall evaluation of your company's supply chain?

1. INITIAL: The Supply Chain performances are lowly monitored/measured.

2. MANAGED: We measure only the most important physical performance of suppliers (e.g. punctuality, quality, operational flexibility)

3. DEFINED: We measure physical and economical performances (purchase price, non-quality costs, delivery delays, lack of flexibility, etc.).

4. INTEGRATED: We measure physical and economical performances, and sustainability indexes.

5. EXPLOITED: We measure physical and economical performances, sustainability indexes and cross-company value creation.

ANNEX III Business Impact Validation and Results

Business Model Impact Validation Methodology

In order to validate the Data Space Business Model Radar, a primary research was conducted between September and October 2023. The research was conducted with quantitative survey, developed by the partners of the projects, and carried out with our methodology. The questionnaire was designed to investigate all the dimensions of the Business Model Radar, from the single partners role to the shared value achieved with the objective to validate the framework and describe respondents according to the framework. The full questionnaire can be found in the Appendix.

For this assessment seven real case studies were analyzed.

Four case studies are from the industrial manufacturing industry (SM4RTENANCE project):

- Prima Power provides customers with targeted dynamic technologies that improve profitability in sheet metal working by designing integrated automated solutions and offering high-performance machines that guarantee flexible and precise execution. Prima Power's range of technologies is one of the widest in its sector: 2D and 3D laser machines for cutting, welding and drilling, punching machines, combined punching-laser and punching-shearing systems, press brakes, panelisers, robotic bending cells and flexible manufacturing systems.
- Fratelli Piacenza was founded in 1733 in the heart of the Biella textile district, an area with a high textile vocation, with the dream of creating and handing down the art of quality in wools. Lanificio Piacenza employs 300 people and pays special attention to sustainability and respect for ancient textile traditions. Its collections are created from carefully selected, traceable and natural raw materials, which the company processes in its weaving, dyeing and finishing departments.
- Fidia is an Italian manufacturer of CNC machines (and a leader in the construction of high-performance 5-axis milling systems), milling heads and related software, that has been on the market for over 40 years. Its product range includes milling machines, numerical controls and software modules, enabling Fidia to design, manufacture and service complex milling systems, customized to customer requirements. Continuous Research and Development activities allow Fidia to remain at the forefront of its sector
- Itema, with a tradition stretching back almost 200 years, is a global leader offering advanced weaving solutions, such as top-of-the-line looms, spare parts and integrated services, and it is the only manufacturer in the World able to offer the three top filling insertion systems: rapier, air and bullet. Thanks to its broad product portfolio, its presence with production facilities in Italy, Switzerland and China. and its commitment to continuous innovation and advanced technology in weaving machines, Itema is able to sell its looms in more than 100 countries worldwide, in sectors ranging from commodities to high fashion, industrial and technical textiles and many others.

In addition to that, the assessment includes among the respondents 3 pilots from the EU Plooto Project. The EU-funded Plooto project aims to deliver a Circular and Resilient Information System (CRIS) to support manufacturers in their green, digital and circular transition. CRIS enables waste reduction and end-to-end traceability of Secondary Raw Materials (SRM) through interconnected digital services for real-time decision-making, monitoring and certification of materials and products. The solution will be piloted in three different circular supply chains demonstrating waste reduction, reusability of scrap and production by-products, and operational improvement. Although not classified as data spaces, the data collection and sharing element is critical to these pilots, since one of the key objective of the project is to define Digital Product Passport (DPP) requirements for sustainable value chains, based on the parameters and information on products that need to be shared transparently at each node of the value chain:

- CFRP Waste for Drones, where partners are involved on the reusage of expired or uncured carbon fibres prepregs
- WEEE for Magnets, where pilot participants have the objective to optimize magnets extraction, qualification, and processing with a quality sufficiently high to avoid the addition of fresh raw material in the transformation stage – or at least to reduce at the minimum the requirements of these fresh raw materials.
  Citrus Processing Waste for Juice By-Products, the primary objective of this pilot is to refine the transformation process of by-products to produce cattle feed.

Manufacturing Data Spaces Business Models

PRIMA INDUSTRIE Data Space

Prima Industrie is the industrial innovation group focused on manufacturing automation since 1977. The Group operates in sheet metal working technologies through the Prima Power brand.

Business Model Radar key findings

PRIMA INDUSTRIE data space has among its primary objectives the improvement of internal operations as well as the generation of new revenue streams through continuous innovation and through the sell of proprietary software. The cloud platform supporting the data space is owned by Microsoft and is fed by data from PRIMA machines owned by customers. The software that analyzes machine data is developed by PRIMA. The Business Model Radar information on value proposition, data platform, governance and partners collected through the methodology described in §6.1 are reported in Figure 24. The data space includes 3 types of partners besides PRIMA it includes Microsoft as the Cloud Provider and PRIMA's customers that own the data and with which a legal agreement is in place related to data management and storage. Key success metrics for the data space includes the amount and strategic relevance of data exchanged, the value generated for customers and the number of new partners acquired.

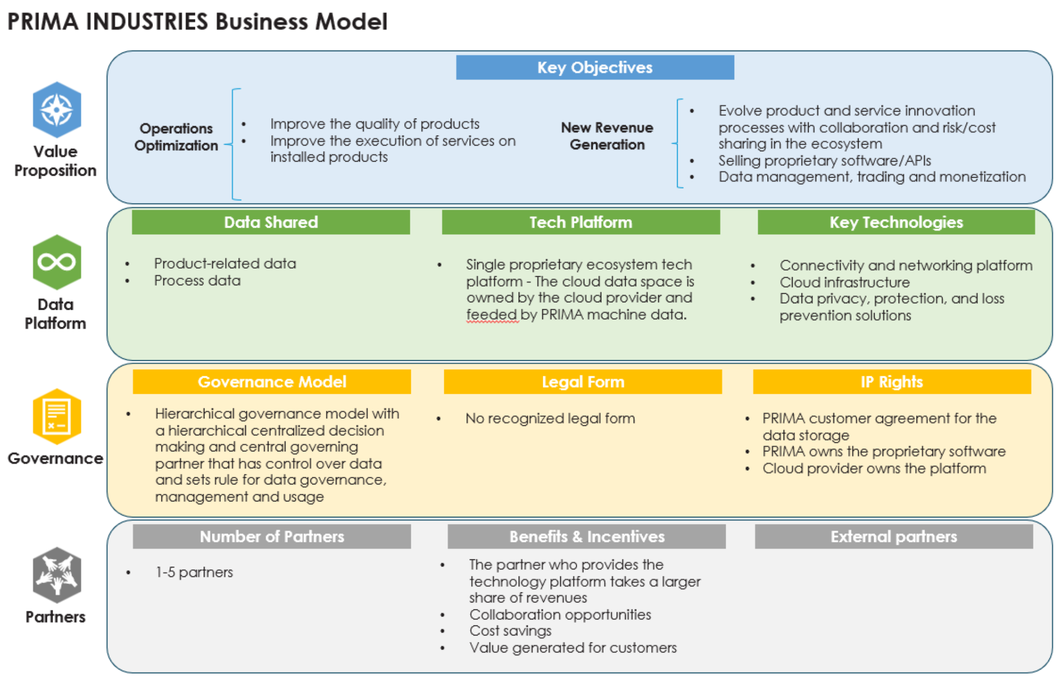


Figure 24 PRIMA INDUSTRIE Data Space Business Model

FRATELLI PIACENZA Data Space

Fratelli Piacenza is a historic textile manufacturer in northern Italy.

Business Model Radar key findings

The group has been focusing on digitizing the entire supply chain, leveraging also emerging technologies like blockchain, to improve operations, transparency and traceability of products and achieve ESG (Environment, Social, Governance) goals thanks to a better use of data and analytics. Within the data space Piacenza takes the role of the orchestrator providing the data platform to controlled companies, including Cerruti and Arte Tessile in the textile subindustry, and suppliers. The key metrics considered are aligned with the three groups of strategic priorities of the data space. KPIs include the amount and strategic relevance of data exchanged, the value generated for customers and environmental sustainability-related performance metrics, aligned with circularity goals. The Business Model Radar information on value proposition, data platform, governance and partners collected through the methodology described in 6.1 are reported in Figure 25.

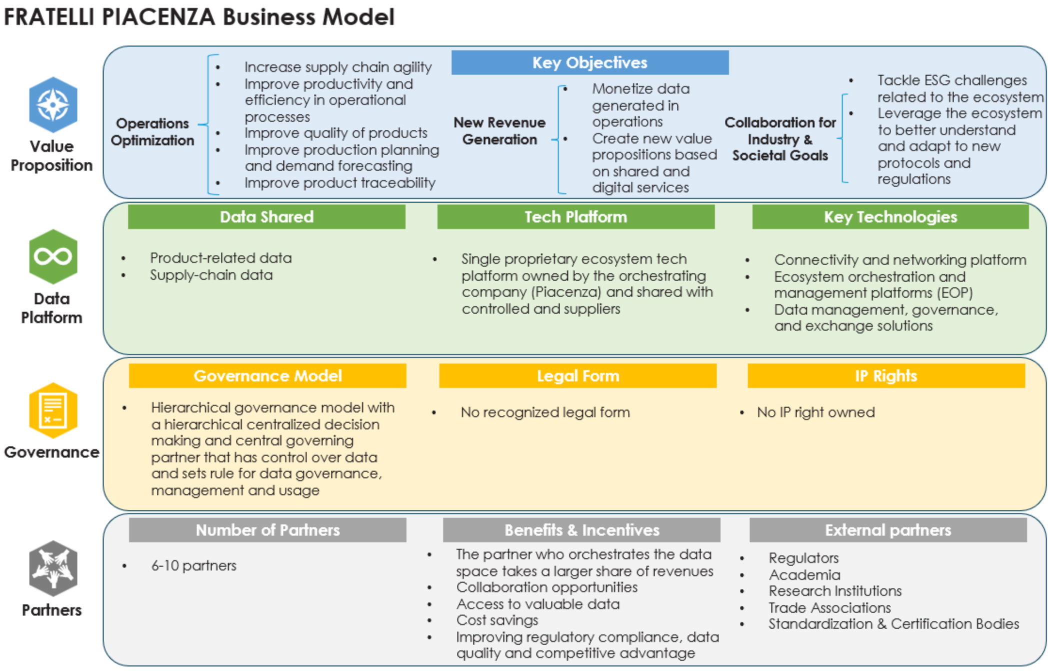


Figure 25 Fratelli Piacenza Data Space Business Model

FIDIA Data Space

Fidia is an Italian organization providing milling machines and numerical controls.

Business Model Radar key findings

Fidia's data space pursue multiple objectives from creating new value propositions through new digital services to optimizing operations, improving the execution of services as well as improving asset maintenance leveraging prescriptive and predictive analytics. The data space leverages a proprietary tech platform, the machine tool manufacturer owns the platform and the data shared. Digital revenue generated and value generated for customers are critical metrics used to measure data space and ecosystem's success.

More details on value proposition, data platform, governance and partners can be found in Figure 26.

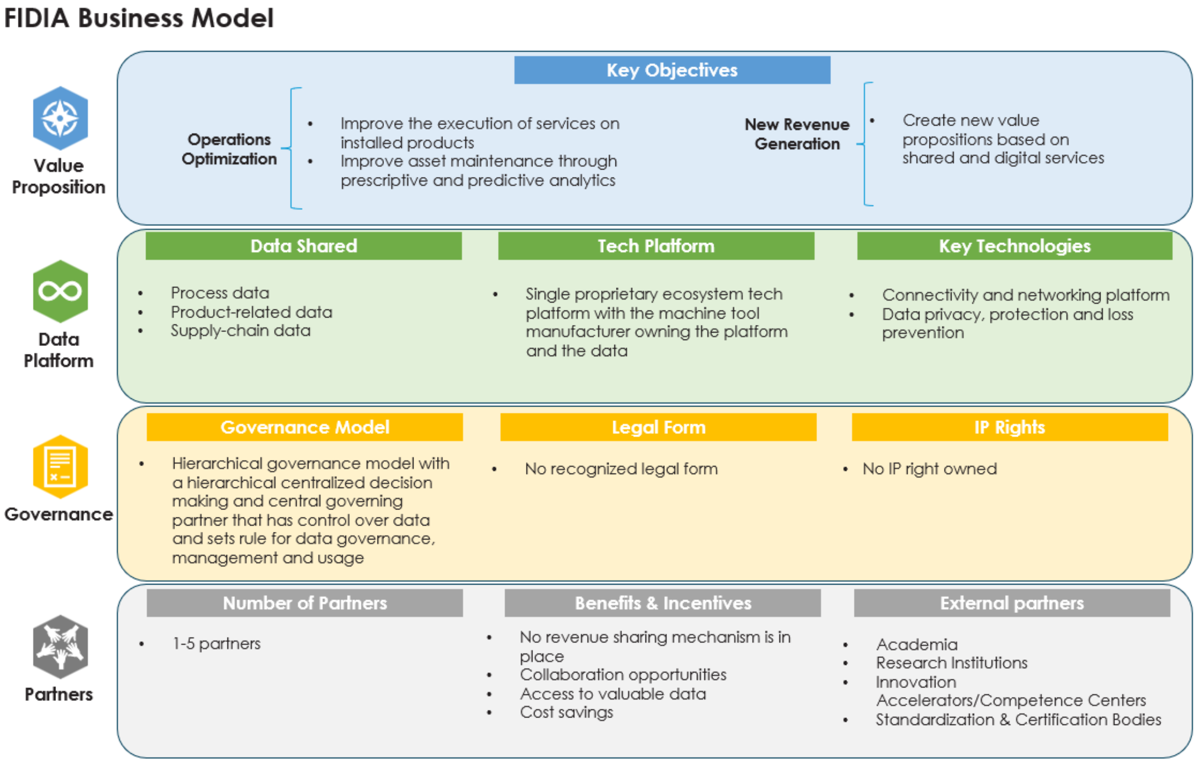


Figure 26 Fidia Data Space Business Model

ITEMA Data Space

ITEMA is a multinational Italian company that produces textile machinery for all types of weaving.

Business Model Radar key findings

Itema's data space is customer centric and focused on monetizing data, evolving product and service innovation and commercializing proprietary software. The underlying technology platform is a single unified architecture, owned by a third party external to the ecosystem. The revenue generated are equally shared among participants. On the top of that collaboration opportunities are the main incentive for organizations to participate in the data space. Full details on the data space value proposition, data platform, governance and partners can be found in Figure 27

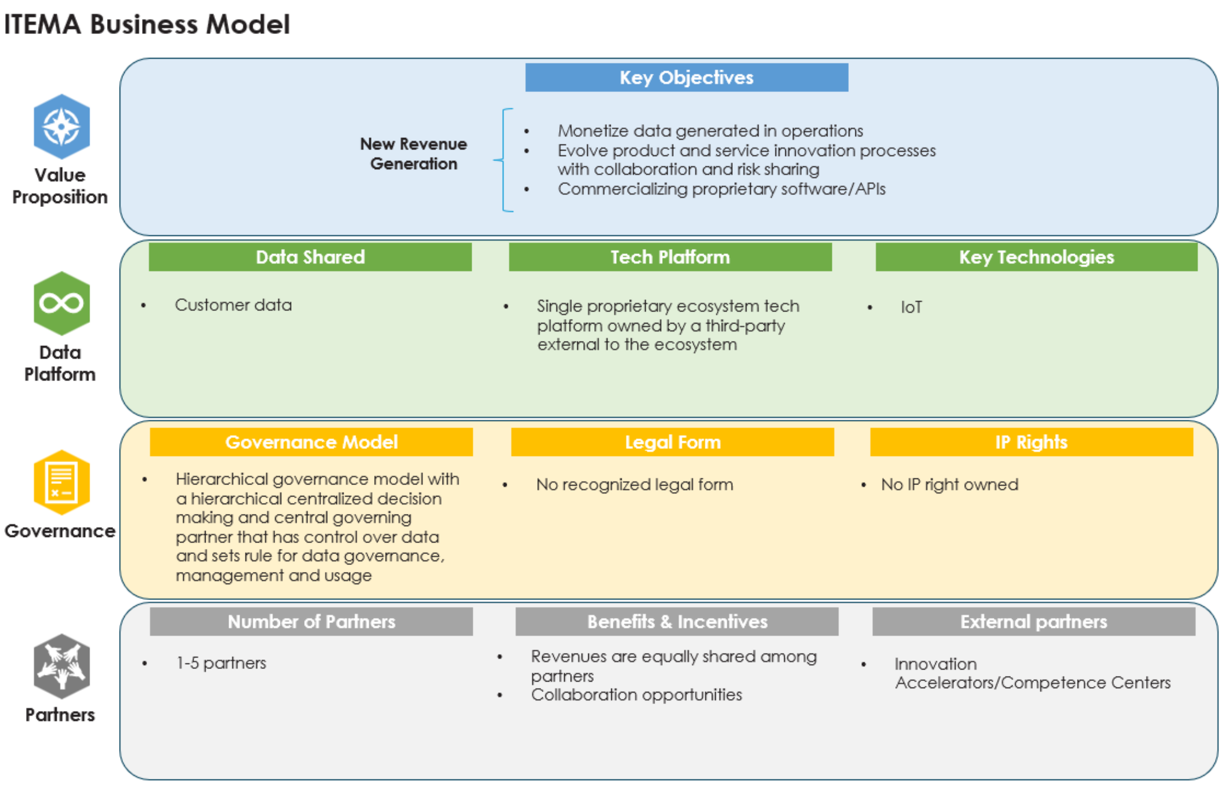


Figure 27 ITEMA Data Space Business Model

Circular Data Spaces Business Models

CFRP waste for Drones in PLOOTO HEP Innovation Action

This pilot within the Plooto project aims to increase the reuse of carbon fibre reinforced polymer CFRP composites and avoid the disposal of the waste for economic reasons and legislation restrictions.

Business Model Radar key findings

CFRP waste for Drones pilot is an example of data space with the primary objectives of achieving operational efficiencies for the partners and tackling broader ESG goals by fostering circularity through the reuse of critical materials. The Business Model Radar information on value proposition, data platform, governance and partners collected through the methodology described in §6.1 are reported in Figure 28.

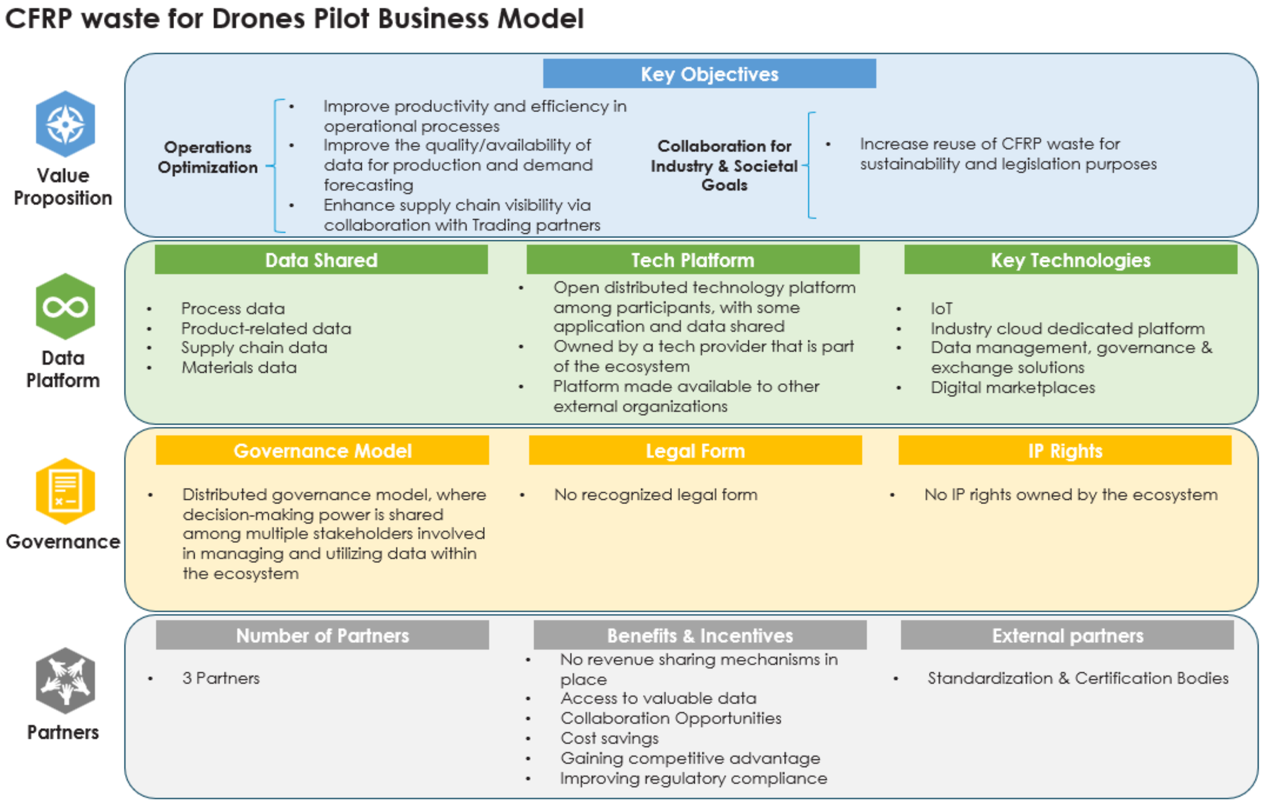


Figure 28 CFRP waste for Drones Pilot Business Model

The ecosystem consists of 3 partners from the manufacturing and professional services industry, involved in different activities of the circular value chain. Each of the stakeholders involved in the pilot's process have different requirements and clearly information requested varies depending on the tasks and operations carried out. Overall, the most important information and data that need to flow across actors of the full pilot are around technical and mechanical properties of the waste, such as thermal properties, rheological properties (e.g., viscosity in function of the temperature), mechanical properties (e.g., ILSS), and deviation of waste properties from the original material (just to name a few). Manufacturing cost reduction and waste reduction will be the most critical benefits gained by this pilot. Key metrics to measure pilot's success include among the others environmental-related performance, and new skills acquired.

WEEE for Magnets in PLOOTO HEP Innovation Action

This Plooto pilot focus on increasing the reuse of NdFeB and Strontium-ferrite (Sr-ferrite) permanent magnets (PMs) recovered by WEEE from magnet products. The possibility of recovering NdFeB PMs from WEEE brings many competitive advantages, such as a decreased dependency on third countries for the obtention of Nd (rare-earth element, i.e., critical raw material) to manufacture magnets in Europe, the obtention of a competitive secondary raw material source and the valorization and reduction of WEEE landfilled.

Business Model Radar key findings

The objectives of the WEEE for Magnets pilot are related to the improvement of operational processes and the achievement of circularity goals. The goals are achieved through the design a fully or semi-automated robotic process to extract magnets from disposed devices and machines, the optimization of the processes to prepare crushed magnets prior to re-enter the production process, and the design of a better process to remove the coating or the impurities created by polymers and resins in sintered Sr-ferrite magnets. The pilot, at this early stage, is still working on defining the right governance and tech architecture. The data collected and shared are mostly related to the type of material, the quantity and the origin of the magnets. The data exchange, specifically, relies on different proprietary systems. More details on the current business model can be found in Figure 29.

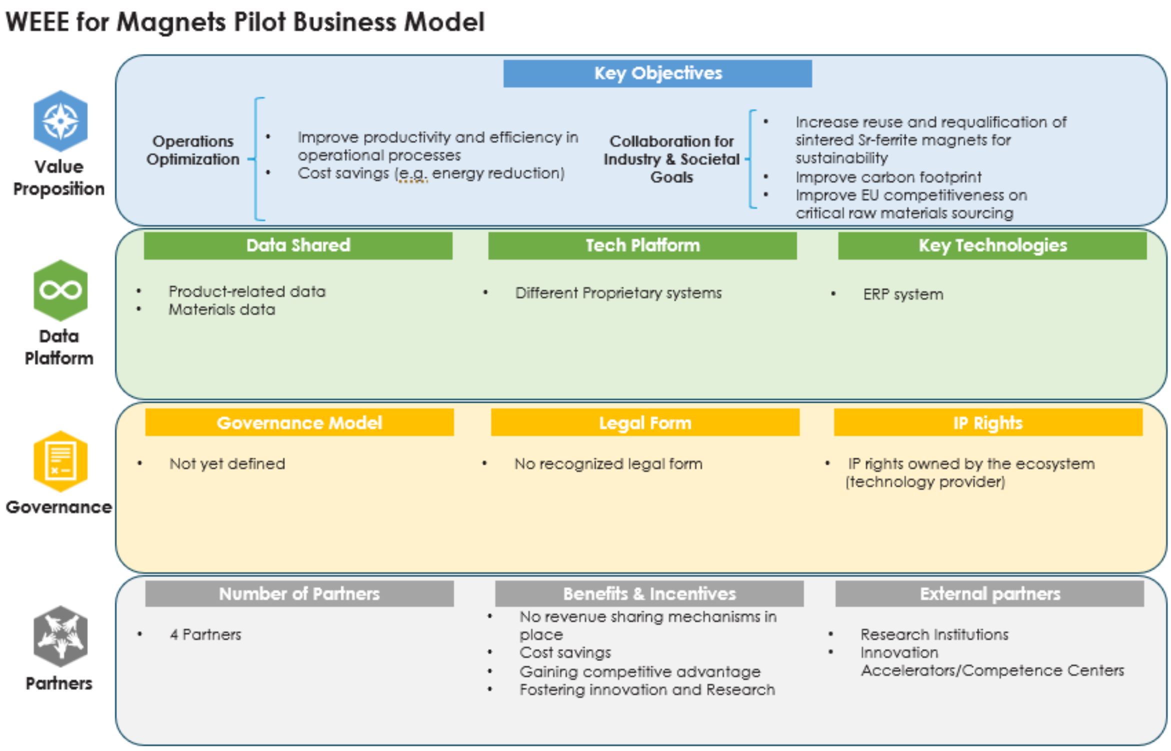


Figure 29 WEEE for Magnets Pilot Business Model

In the WEEE for Magnets pilot four stakeholders are involved from manufacturing and professional services industries. The benefits achieved are varied. It reduces the environmental impact through the conservation of resources and lowers energy consumption. Moreover, it diminishes the dependency on non-EU countries for critical raw materials, potentially leading to import tariff reductions. The added benefits of shortening the supply chain and reducing delivery times further enhance the appeal of opting for these types of magnets, that are sourced and produced locally – especially when the customer is based in Europe.

Citrus Processing Waste for juice by-products in PLOOTO HEP Innovation Action

This pilot focuses on reusing by-products (peels, pulp, wastewater) generated during the production of juice, in the production of animal feed - more precisely cattle feed. More details on the Pilot the business case and processes can be found in deliverable 1.1 “Plooto Methodological Approach and Business Cases Specifications V1”.

In addition to circularity goals, the objectives of the Citrus processing waste for juice by-products pilot are also related to the improvement of operational processes. The goals are achieved through the optimization of the process of the by-products, which allows for energy savings and produces certified higher quality cattle feed, compared to feed produced using chemical additives. The pilot is still at early stage when it comes to defining governance for the ecosystem. This is mostly hierarchical with centralized decision making and one partner ASPIS SA owning the underlying technology architecture. The data collection and share are mostly related to the production process and to the properties of the by-products (e.g., humidity, sugar concentration). More details on the current business model can be found in Figure 30.

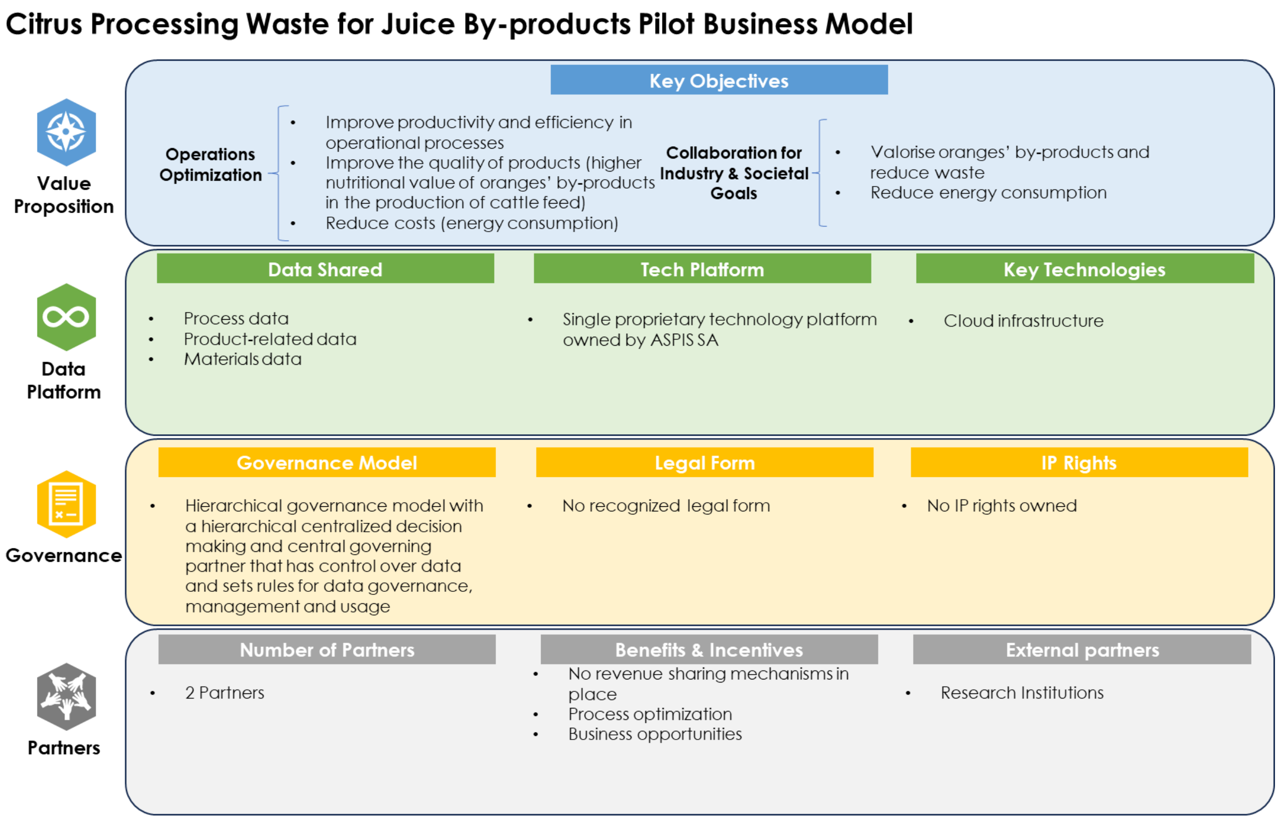


Figure 30 Citrus Processing Waste for Juice by-products Pilot Business Model

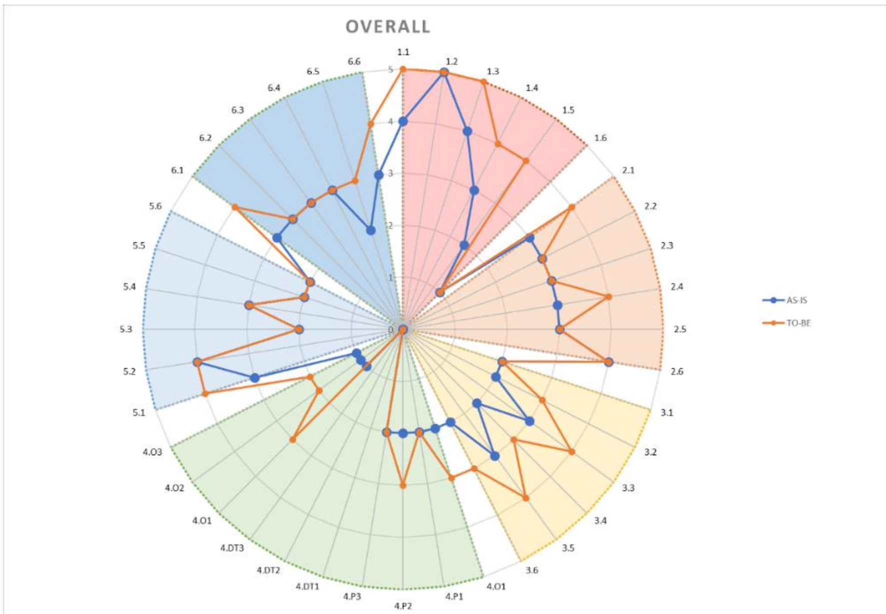
The pilot consists of two partners from the manufacturing and professional service industries. The benefits achieved for ASPIS (manufacturer) include enhanced product quality, which will be certified, resulting in greater customer value. Additionally, operational improvements and energy savings contribute to reduced costs. KPAD (professional services) benefits range from stronger partnerships in the industry to new business opportunities related with the replicability of the acquired know-how. KPIs are related to product quality, energy savings, new skills development and sustainability-related performance.

ANNEX IV Maturity Assessment validation and results

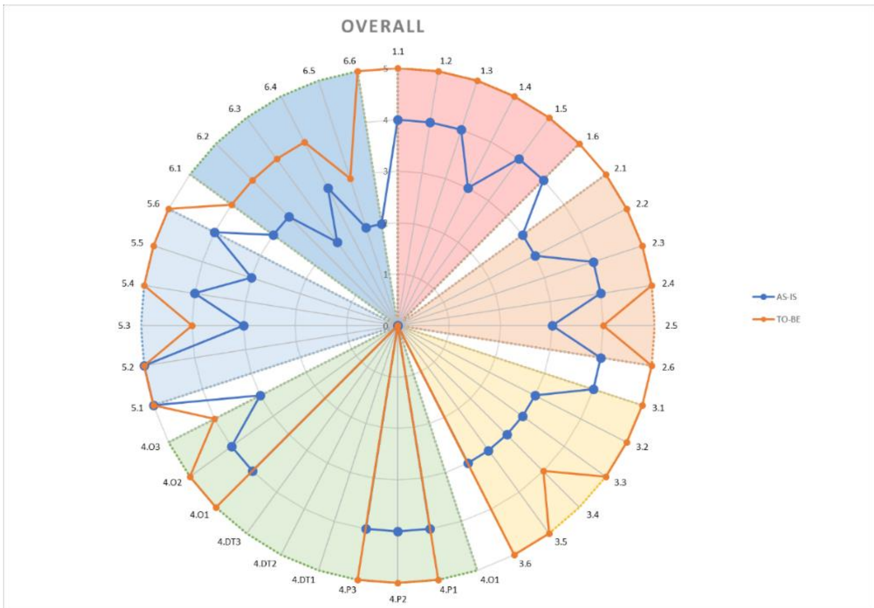
Industrial Cases and Validation Methodology

According to the matrix previously introduced in §2.5, we are now validating our Maturity assessment Model in nine industrial cases.

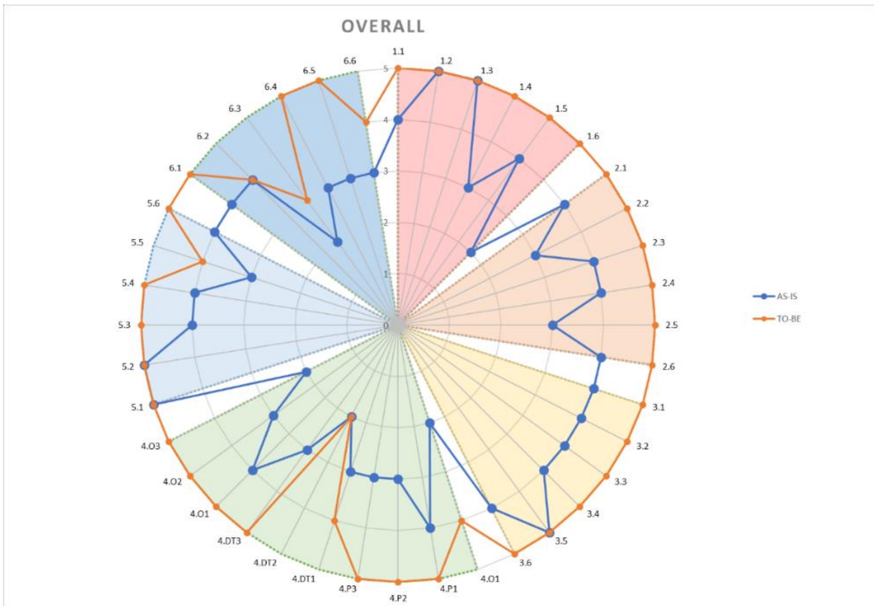
PRIMA INDUSTRIE (SM4RTENANCE) is a worldwide leader in the field of the laser machinery for the metal sheet cutting and welding applications in 2D and 3D. The 6Ps assessment has been compiled from the perspective of its use case, the introduction of predictive maintenance algorithms for the detection of anomalies and subsequent preventive correction actions, also with a focus on Agile Supply Chain Value Networks and on Industrial Data Spaces. As we can see in the graph below, the compilation of the 6Ps showed that all the 6 pillars of analysis were considered applicable, albeit with different intensities. The most attractive were the pillars PRODUCT (consistently with the product characteristics of PRIMA INDUSTRIE, CNC machines of very advanced technology), PROCESS and PLATFORM (consistently with the pilot scopes of Supply Chain and Industrial Data Spaces).



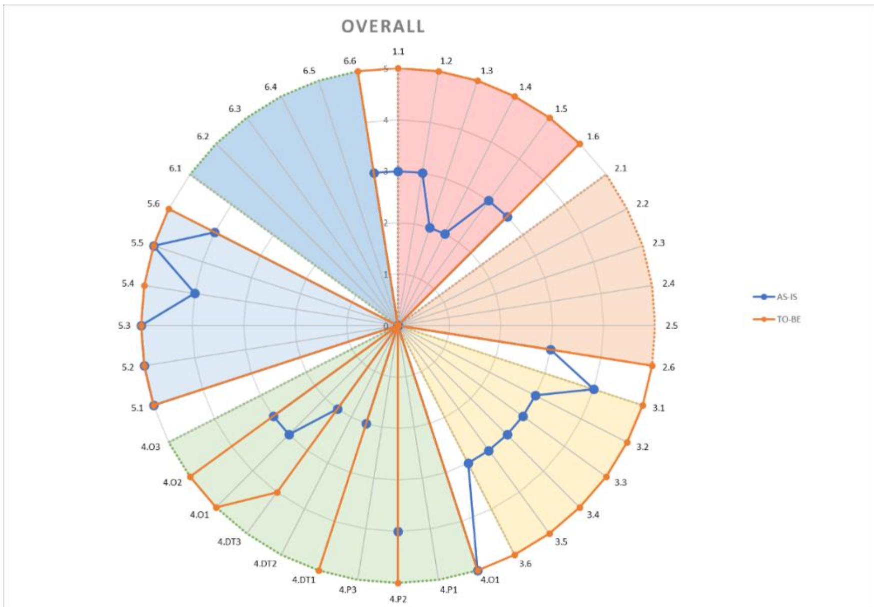
TRIMEK (SM4RTENANCE). The 6Ps assessment has been compiled by TRIMEK-INNOVALIA from the perspective of Trimek use case in SM4RTENANCE, where TRIMEK is bringing its metrology expertise and aiming towards big data connected factories 4.0 and data ecosystems, setting the pathway towards autonomous maintenance. The focus of the pilot was on Dynamic Assets Management and on Industrial Data Spaces The pilot had a major impact on TRIMEK's organization; starting (AS-IS) levels were already very advanced (average AS-IS 3.5, between DEFINED and INTEGRATED), and almost maximum exploitation levels were reached during the course of the project (TO-BE of 4.7, close to EXPLOITED). This progress benefited all the examined company's sectors, as evidenced by the graph below.



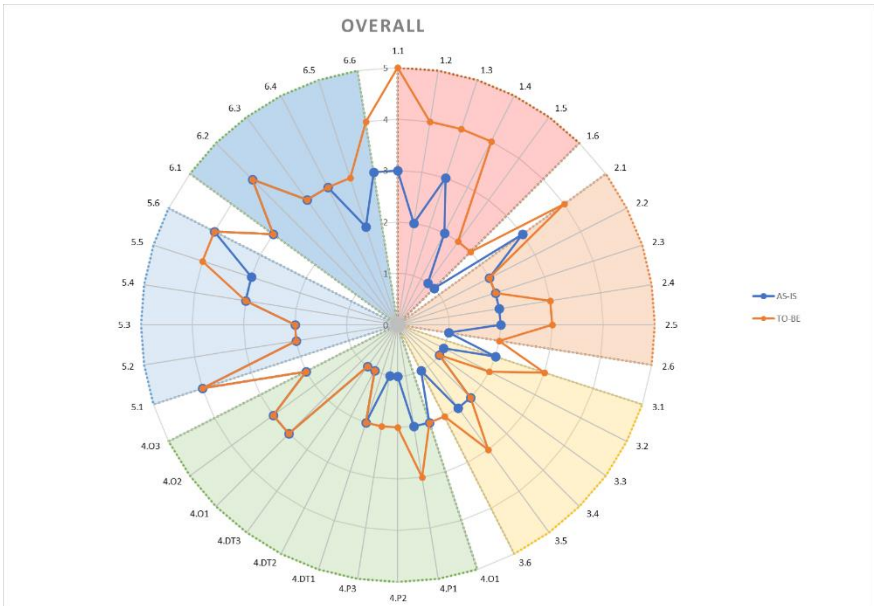
FILL (SM4RTENANCE) is a manufacturer of advanced automated machinery for different sectors and applications; the 6Ps assessment has been compiled by Fill from the perspective of its use case, aimed at providing the basis and knowledge for interconnections among ecosystems leveraging on data spaces, that can be put together by setting up a data-sharing approach, with a focus on Sustainable Green Products and on Industrial Data SpacesSame as in the case of TRIMEK, in Fill we can observe that considerable progress was made in all the pillars examined: Fill started from average values between DEFINED and INTEGRATED and, in the areas examined by the 6PS survey, achieved levels of excellence close to the full exploitation (average TO-BE of 4.8).



SCSN (MARKET4.0). The Smart Connected Supplier Network (SCSN) is one of the most promising use cases based on IDS components, and is aimed at increasing productivity in the supply chain. SCSN is led by Brainport Industries and supported by TNO. The pilot consisted in a technical infrastructure, in which it was agreed how the information can be shared in a safe and controlled manner, based on IDS, for the purpose of connecting an entire supply chain. Consequently, the main achievements have been in the PLATFORM pillar (highest levels of exploitation) and in some professional figures in the PEOPLE pillar, i.e., those able to operate what has been developed in the PLATFORM. Significant were also the responses obtained in the PARTNERHISP pillar, reflecting the wide predisposition to collaboration by the partners involved.



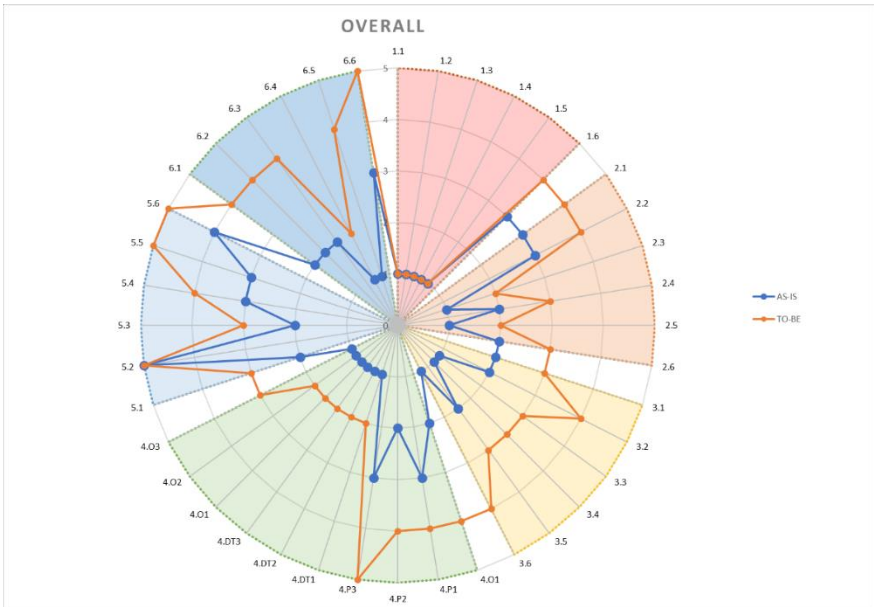
ITEMA (SM4RTENANCE) is one of the world's leading suppliers of quality, high-performance weaving machinery and support services to the industry. Itema's pilot leverages on the setting of Industrial Data Spaces to achieve a more effective participation of clients and suppliers to logistics and distribution operations thanks to data sharing. Predictive maintenance is also among the targets of the pilot.



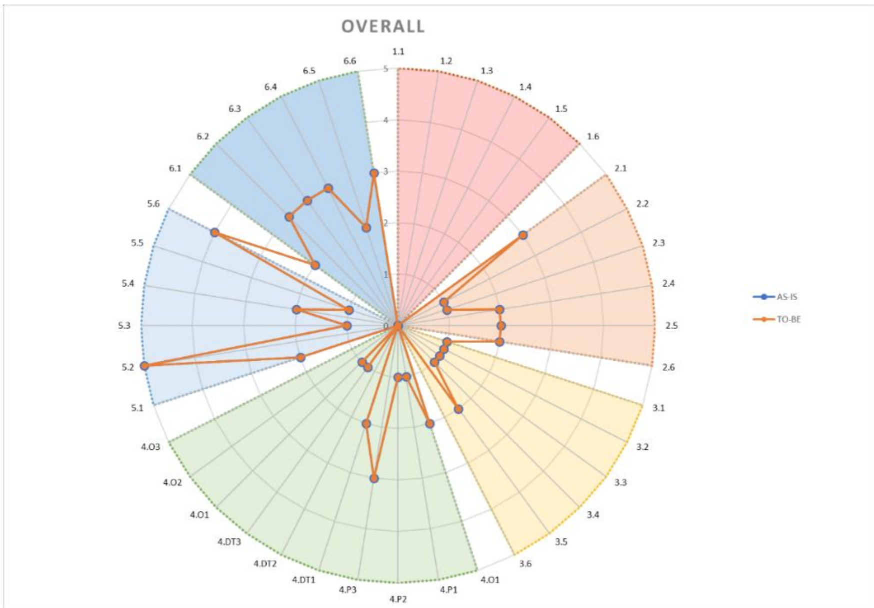
The company started from an average level of 2.2, slightly above MANAGED, and was able to reach an average TO-BE level lose to DEFINED (2.8).

Improvements were not homogeneous across the Ps: the main improvements have been achieved in the technical pillars: PRODUCT from 2.0 to 3.5, with a remarkable +1.5, PROCESS (from 2.0 to 2.7) and PLATFORM (from 1.5 to 2.2); minor improvements in the socio-business pillars

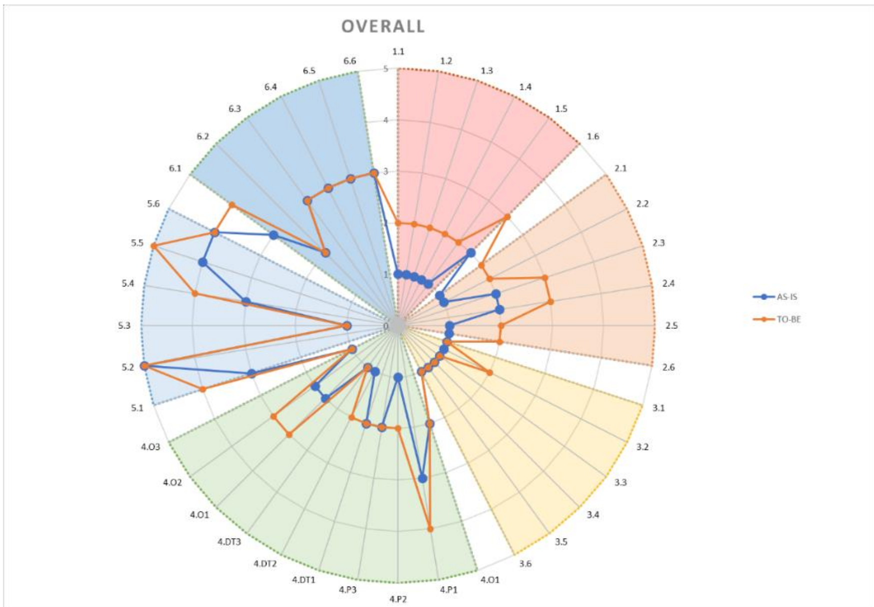
PIACENZA 1733 (TRICK) is a historic wool mill in northern Italy. The 6Ps assessment has been compiled by Piacenza from the perspective of its use case in the Trick project, with the scope of taking advantage of a circular economy platform, adopting blockchain technology, to achieve better monitoring of product and processes through data sharing, fostering traceability and recyclability, and supporting the transition to circular economy. It goes without saying that the focus is on Sustainable Green Products and on Industrial Data Platforms It is evident from the 6Ps that the pilot carried significant improvements in all pillars, except, of course, in the PRODUCT (which, being woollen fabrics, does not allow the incorporation of smart technologies). Relevant progress was made in PLATFORM and, consequently, in some professional figures (PEOPLE), consistent with the purpose of the pilot. Remarkable also the progress at the PARTNERSHIPS level and in the adoption of new PERFORMANCE indicators (KPIs).



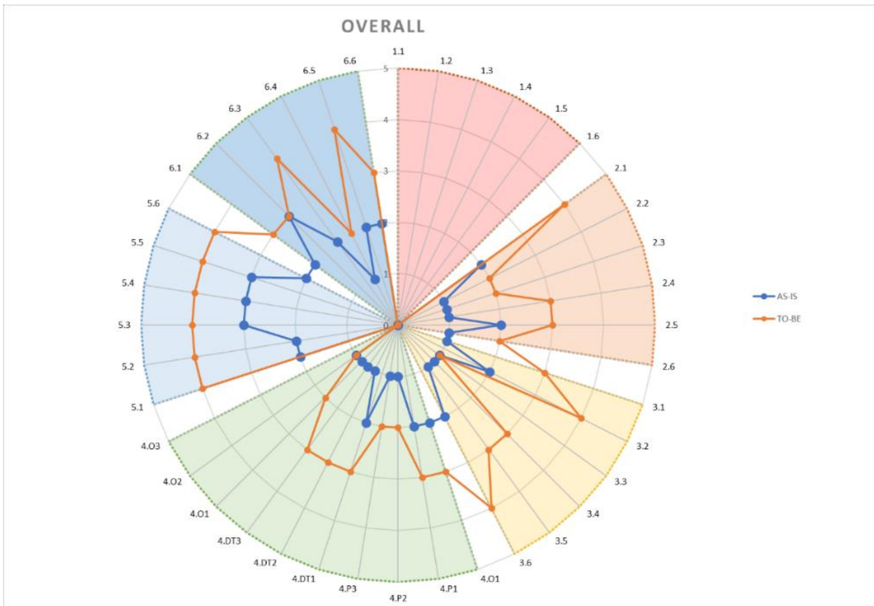
CFRP waste for Drones (PLOOTO). The 6Ps assessment has been compiled by Acceligence from the perspective of the use case of a drone manufacturing process that uses composite materials, that in turn are produced by uncured prepreg scraps, with a positive spin-off on performances, cost reduction and environmental impact. The focus of the pilot was especially on Dynamic Asset Management and on Industrial Circular Networks, with the collaboration of HPC, a world leader in the design and production of CFRP components for aerospace, automotive, motorsport, naval and so on. Although all pillars of the 6Ps survey were affected by the pilot activity, we observe that the main impacts occurred at the level of performance indicators. The PRODUCT was not compiled because, although it was the subject of the experiment to a significant extent, it did not lend itself to the incorporation of IT technologies.



WEEE for Magnets Pilot (PLOOTO). The questionnaire has been filled by IMA manufacturer and data owner of the pilot. The pilot aimed at setting processes for the recovery of magnetic materials from WEEE in order to re-use them in new products; this would bring competitive advantages, especially like the obtention of a secondary raw materials source and a wider range of suppliers. The 6Ps assessment has been compiled by IMA from the perspective of its use case, focused on Sustainable Green Products and on Industrial Circular Networks As visible in the chart below, the main impacts of the pilot were at the level of the so-called socio-business pillars (PEOPLE, PARTNERSHIP, PERFORMANCE), but there were also improvements at the PRODUCT and PROCESS levels. In detail, we see that among the highest scores there are the development of new business models and, consistently with the pilot scope, the ability to re-design smart operations.



COBAT (Circular TwAIn). The 6Ps assessment has been compiled by Cobat from the perspective of its use case, where the concept is to overcome the current value chain by integrating innovative circular economy nodes in a battery manufacturing system, re-designing the supply chain (hassle-free pickup, individual waste management, waste treatment…); the pilot focus is, in fact, on Agile Supply Chain and on Industrial Circular Networks. In this case, it was decided not to answer with respect to the PRODUCT characteristics, as the pilot was mainly focused on the management of the new Supply Chain and on the most suitable technologies to support it. Consequently, we see that the greatest progress has been made in the pillars PROCESS and PLATFORM; consistently, we observe an improvement in personnel skills (which must necessarily follow the progress in the technical pillars) and, in this case, also in RELATIONSHIPS, since the experience in the pilot has allowed COBAT to improve its relations with different institutional and commercial stakeholders.



The questionnaires used for this maturity assessment are reported in ANNEX II.

Industrial Maturity Assessment Outcomes

In this section we report the conclusions and observations regarding the Industrial Cases maturity assessment, while the full details of the analysis conducted on the 9 embryonic cases are reported in ANNEX III.

The conduct of the assessments according to the 6Ps - Digital Transformation Assessment Model methodology, aimed at assessing the impacts of the Data Spaces implementation projects among the nine champions described in Chapter 7, highlighted a number of benefits resulting from the project implementation, while providing an analysis of the organisation's current state of digital and Data Space usage maturity and an overview of specific opportunities for improvement.

In general, we observe that the implementation of Data Spaces results in increased operational efficiency, reduced costs and tangible productivity gains. These improvements are a function and a consequence of the level of skill and maturity in data management, but, in general, we observe that companies that have implemented Data Spaces have been able to place themselves in a strategic position to proactively prepare for future innovation, facilitating scalability and strengthening competitiveness in their respective market segments. Awareness-raising has mainly short-to-medium-term effects, but the benefits can be prolonged in the long term if the actions suggested by the 6Ps Digital Transformation Pathway (such as adopting certain technologies, focusing on emerging priorities, aligning with corporate goals, etc.) are then actually implemented; in this case, the impact analysis can help build a solid and lasting foundation for the organisation's future success.

From the analysis of the answers, a variety of starting states (AS-IS), arrival states (TO-BE), gaps and planned actions emerge. Depending on the companies, the sector and the strategies, different opportunities for improvement are identified: in some cases there is a greater orientation on the PRODUCT (FIRST, SCSN), in others on the PLATFORM (PIACENZA, SCSN), in others cross-wise on PRODUCT-PROCESS-PLATFORM (TRIMEK, FILL).

Generally speaking, the three so-called 'technical' pillars are the ones where the greatest interest is concentrated, as it was to be expected given the very technical nature of the related projects, and also because they are actually the pillars on which the company's attention is most focused. The PEOPLE pillar also sees significant interest (especially in the cases of FILL and PIACENZA; but not only there), and this is a consequence of the improvement actions at PRODUCT, PROCESS, PLATFORM level, which cannot be carried out without a consistent improvement of personnel skills.

Other aspects that emerged from the surveys are:

- The implementation of Data Spaces can lead to greater efficiency in managing and accessing data; measuring the level of digital maturity helps to understand how these improvements can translate into tangible benefits for day-to-day operations;
- An accurate analysis of digital maturity can reveal opportunities to reduce costs through process optimisation and automation;
- Improve data management: the assessment helped understand how data is currently managed within the organisations, and that the implementation of Data Spaces can improve data quality, security and accessibility, contributing to better management of information assets;
- Facilitate scalability, because an SME can grow more efficiently and sustainably if its digital infrastructure is ready for scalability;

- Prepare for Innovation: being ready to adopt emerging technologies helps maintain relevance in the changing business environment;
- Foster Sustainable Digital Transformation: implementing Data Spaces within a digital maturity framework helps ensure that digital technology adoption is aligned with business and environmental goals.