COLIFE –
Data economy in collaborative asset lifecycle solutions

Colife Playbook

BF diary number, 6064/31/2023, VTT
BF diary number, 214/31/2024, LUT

VTT

LUT University

seed FOREST

Colife vision

“Business partners collaborate equally in and over phases of the lifecycle of an industrial plant. They promote common benefits including environmental, social, and economic factors. This is facilitated by fair data sharing and new operating practices.”

The Colife research focused on Data Economy, Digitalisation, and Asset Management, exploring the business potential when combining these competencies.

This material presents the results of the COLIFE Co-Research project. Through close collaboration between industry and research partners, COLIFE established practical foundations for data sharing, collaborative asset management, and data-driven value creation. The authors sincerely thank all participating organizations, particularly Business Finland, for their valuable contributions and support.

seed FOREST

You will find this in the Playbook

Summary
Playbook purpose and key takeaways

Review the basics
Collaborative asset management (Co-AM) terminology, background concepts and related standards

Towards Co-AM environment
Co-AM concept, stakeholders, and principal elements

Examine Co-AM in your context
Opportunities and challenges, and Co-AM checklists

Identify your business opportunities
Business potential of data and its value co-creation opportunities within a collaborative asset management setting

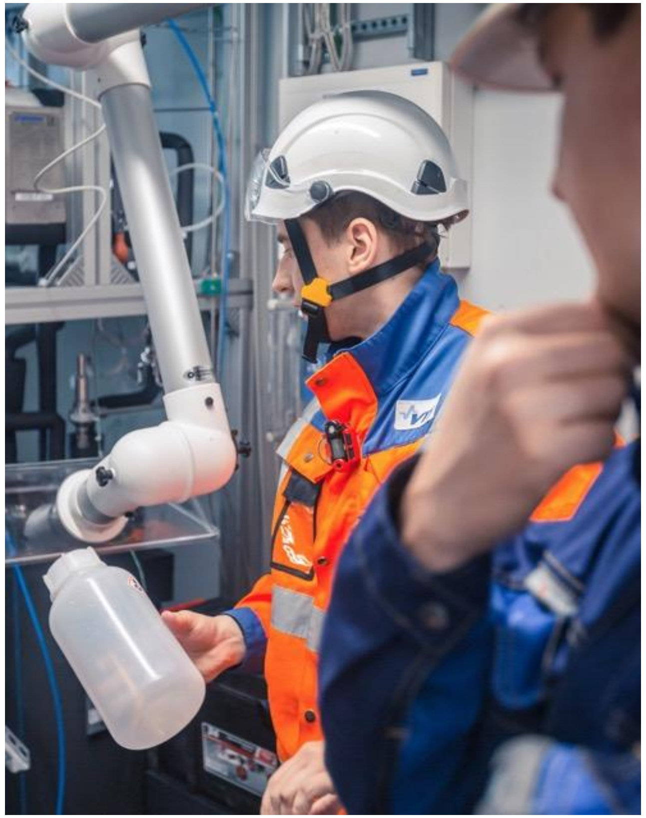
Develop your data governance capabilities
Governance, quality and interoperability, data and technologies

Examine examples
Upgrade and Federated learning cases

What is the Colife playbook?

A practical guide to understanding collaborative asset management (Co-AM) and using asset lifecycle data for shared value creation.

This playbook is intended for organizations and people responsible for managing production assets and their lifecycle, and for exchanging asset-related data with relevant stakeholders.



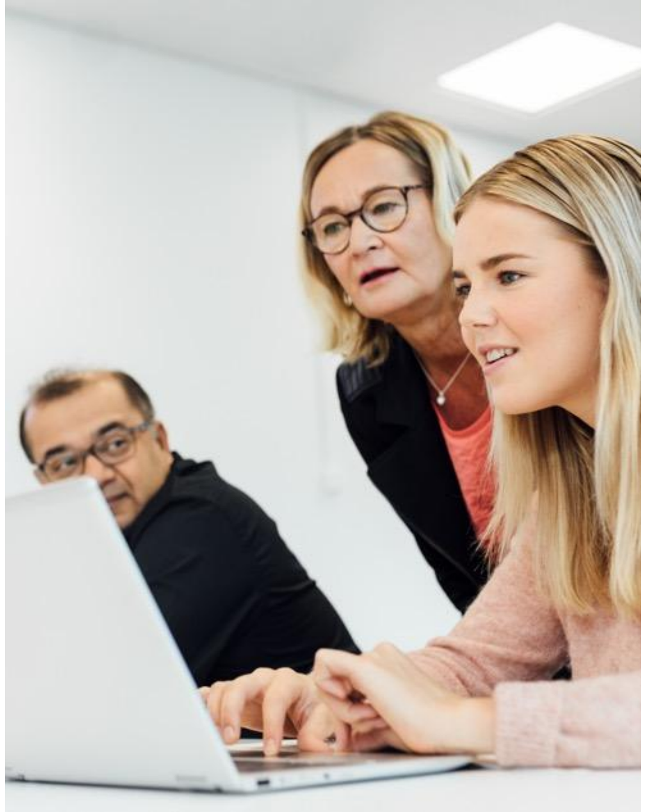
The Colife playbook helps industrial companies to:

- understand what is collaborative asset management and what that could offer them,
- why traditional asset management is no longer enough (changing mindset), and
- provide guidance how to mobilise asset data for collaborative win-win production asset management.

Key takeaways – Review the basics

1. This Playbook first establishes a common understanding of collaborative asset management (Co-AM) so that all actors (asset owners, OEMs, service providers, etc.) operate with aligned terminology, logic, and expectations.

- A **common conceptual foundation** is essential for Co-AM
- Value creation depends on understanding assets and data across the **full lifecycle and system hierarchy**
- Effective AM increasingly depends on **different types of shared lifecycle data**
- **Standards** provide the common reference needed for interoperability and trust.



Key takeaways – Towards Co-AM environment

2. The playbook introduces the concept and main principles of Co-AM, and what changes when transitioning towards Co-AM.

- AM shifts from single-organization to **ecosystem-level coordination**
- Successful **Co-AM requires** aligned asset management systems, shared governance, interoperable data, common risks and KPIs, and coordinated lifecycle responsibilities
- Compared with traditional AM, **more collaboration** is required for value creation in Co-AM
- AM ecosystem involves **diverse stakeholders**, such as asset owners, OEMs, maintenance providers, technology partners, service providers and ecosystem coordinators
- **Principal elements of Co-AM** include data availability and quality, systems interoperability, data security and trust, people and culture, value creation from data, and business renewal

Key takeaways – Examine Co-AM in your context

3. The Playbook assesses how Co-AM applies to your organization by identifying context-specific opportunities, challenges, and readiness using structured elements and checklists.

- Co-AM should be evaluated **in your own operational and ecosystem context**, it is not universally applicable for all contexts
- Context analysis is systematic and based on **defined dimensions and structured reflection**
- Understanding Co-AM is not enough, you should identify **gaps between potential and current capabilities**
- Co-AM should be evaluated holistically from the perspectives of **business value, governance and data quality and interoperability**
- The checklist acts as a practical tool for **assessing readiness and guiding next steps.**

Key takeaways – Identify your business opportunities

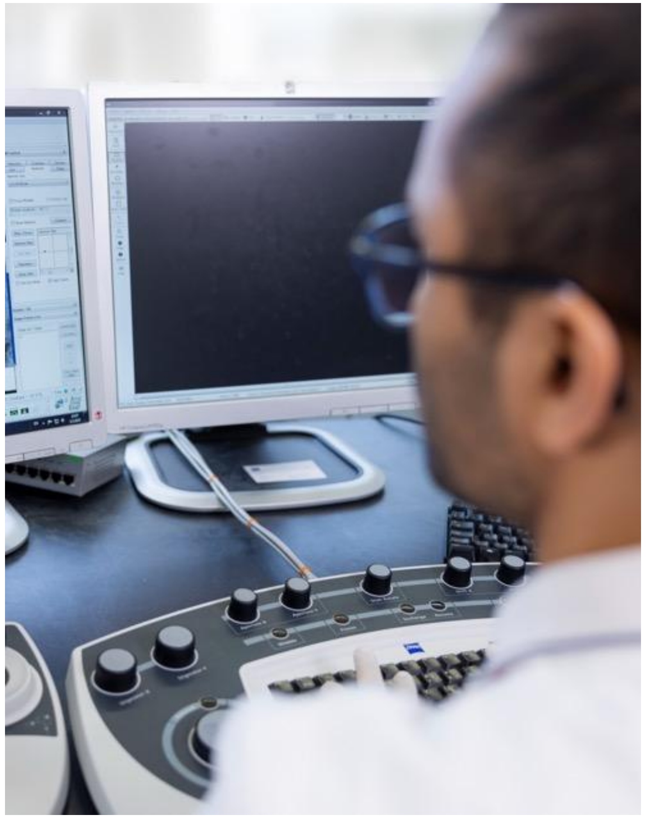
4. Translate shared asset data and collaboration into concrete value creation opportunities in your business

- Data alone does not create value → value emerges when data is **linked with decisions, operations and offering**
- Sustainable data-driven business demands the **alignment of organizational readiness and ecosystem dynamics**
- Focus on **specific use cases** instead of just data-sharing
- Define a **clear value proposition and ecosystem logic**, not just internal benefits
- Business opportunities must be **viable for multiple actors** or collaboration may fail

Key takeaways – Develop your data governance capabilities

5. Build the governance, quality/interoperability, and technological capabilities required to securely and effectively share and utilize data across stakeholders.

- Governance is essential for **trust and collaboration**
- Data ownership and rights must be **explicitly** defined
- Effective ecosystems require **common data-sharing rules and agreed practices**
- Data sharing requires sufficient **inter-organizational trust**
- Governance models must be **scalable**
- Contracts should enable **value creation,** not only risk minimization
- Governance is tightly linked to **business and data capabilities**



Key takeaways – Examine examples summary

6. Learn from practical cases (e.g., upgrade project, federated learning) to understand how Co-AM can be implemented in real-world settings.

- Successful Co-AM in the upgrade project requires **shared project data environment and standardized data practices**
- In the upgrade project case, success depends on strong stakeholder involvement, shared platforms, standardization, and trust-based collaboration, and overcoming structural challenges such as data quality, inconsistent identifiers, outdated baseline data, integration gaps, and late data delivery
- Federated Learning (FL) enables collaboration **without sharing raw data and is** well suited for distributed asset lifecycle ecosystems, enabling **learning from fragmented data sources**
- It supports **privacy-preserving collaboration**. However, does not eliminate privacy, security, or compliance issues
- FL feasibility depends on **clear joint value from shared learning** (Business), agreements on **model ownership, roles, liabilities** (Governance), **harmonized identifiers, usable data** (Data quality & interoperability) and **local compute, secure communication, orchestration** (Technical)

Review the basics

seed FOREST

Introduction

This section establishes a shared foundation for Collaborative Asset Management (Co-AM)

- Core asset management terminology
- How assets, activities and AMS link to objectives
- Standards related to Co-AM

ISO 55000:2024 (2024) Asset management — Vocabulary, overview and principles.

Asset management terminology

Asset

Item, thing or entity that has potential or actual value to an organization. Assets can be physical or non-physical. A grouping of assets referred to as an asset system can also be considered as an asset. E.g. a pump, a valve, control software, a router, a production line, a wrapping system, or an automation system. .

Asset management (AM)

"Coordinated activity of an organization to realize value from assets". Realization of value normally involves a balancing of costs, risks, opportunities and performance benefits. The term "activity" has a broad meaning and can include, for example, the approach, planning and plans, and their implementation.

Collaborative asset management (Co-AM)

The coordinated activities of an ecosystem to realize value from its assets. Collaborative Asset Management (Co-AM) enables *ecosystem-level coordination, shared use of asset lifecycle data, and collective value creation across organizational boundaries.*

Strategic asset management plan (SAMP)

Documented information that contains and aligns asset management policy, objectives, strategies and approaches for developing and managing the *asset portfolio and the asset management system.*

Asset management system (AMS)

Set of interrelated or interacting elements to establish AM policy, AM objectives and processes to achieve those objectives. AMS can be organized in different ways, either informally or with a more formal structure, depending on the organization's specific needs and operational complexity. Many organizations incorporate AMS requirements into their overall management system.

Asset management plan (AMP)

Documented information that specifies the activities, resources, costs and timescales required for *an individual asset, or a grouping of assets*, to achieve an organization's asset management objectives.

ISO 55000:2024 (2024) Asset management — Vocabulary, overview and principles.

Asset management terminology

Governance

Governance involves all the strategies, policies, procedures, roles, responsibilities and control over the management of the data and members in an ecosystem context.

AM ecosystem

A collaborative organization where stakeholders cooperate and coordinate their activities to co-create value for the industrial customer and all members of the ecosystem in the context production assets.

Business model

Describes how an organization creates, delivers, and captures value for customers while generating profit. It typically identifies a company's products or services, target customers, revenue sources, and cost structure.

Federated learning

A collaborative machine learning approach that enables multiple stakeholders to learn from distributed asset lifecycle data without sharing raw data, supporting ecosystem-level collaboration and value creation while maintaining local data control.

Data economy Korolainen & Ojanen (2026)

An area of the economy where ecosystem partners and actors share data and make it accessible and usable for others in order to create new business opportunities in data economy ecosystems.

Asset data ISO 55013 (2025)

"Data that lists and describes an asset". Asset data can exist in different formats. Asset data can support AM decision-making.

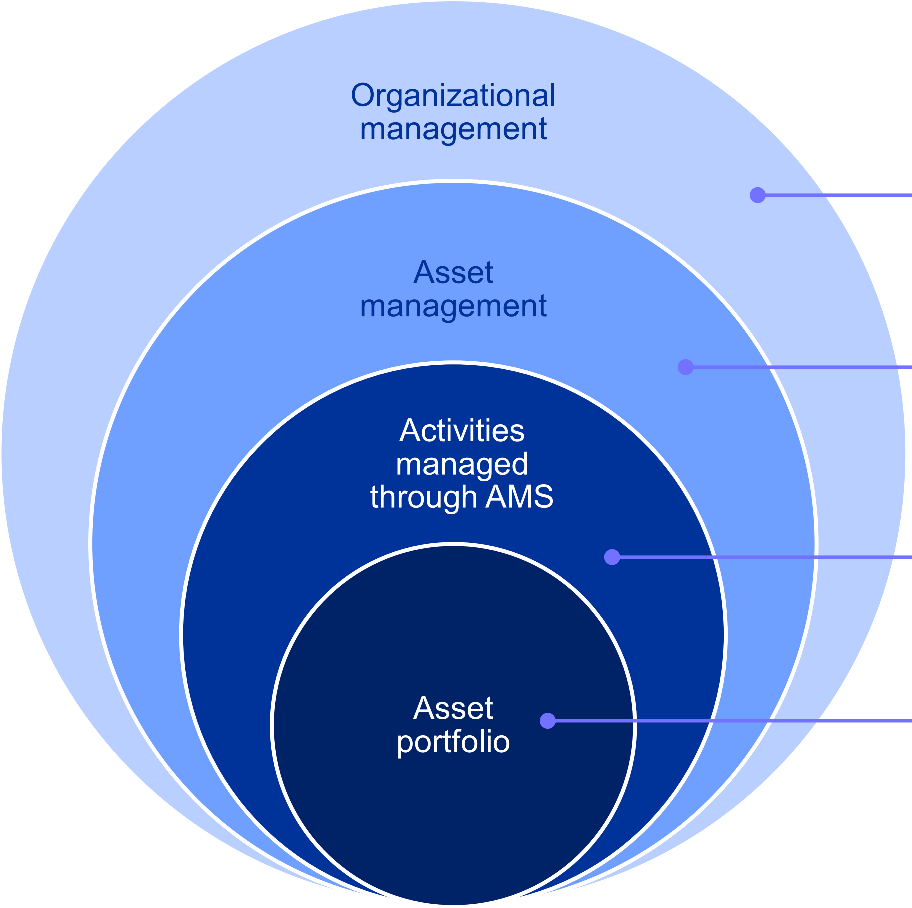
Data asset ISO 55013 (2025)

Data that has the properties of an asset and can be managed as an asset.

Asset data management Based on ISO 55013 (2025)

AM relies on effective decision-making which relies on data and information. Asset data used to inform decision-making requires effective management. Asset data management can be defined as coordinated management of asset-related data and information across the asset lifecycle to ensure data quality, accessibility, interoperability, and effective use in AM activities, enabling realization of value from assets.

Asset management fundamentals – linking assets to organisational objectives



In organisational contexts, assets, asset management activities and the asset management system are structured in a nested manner, linking assets to organisational objectives.

Activities to deliver organizational objectives

Coordinated activity of an organization to realize value from assets

Set of interrelated or interacting elements to establish AM policy, AM objectives and processes to achieve those objectives

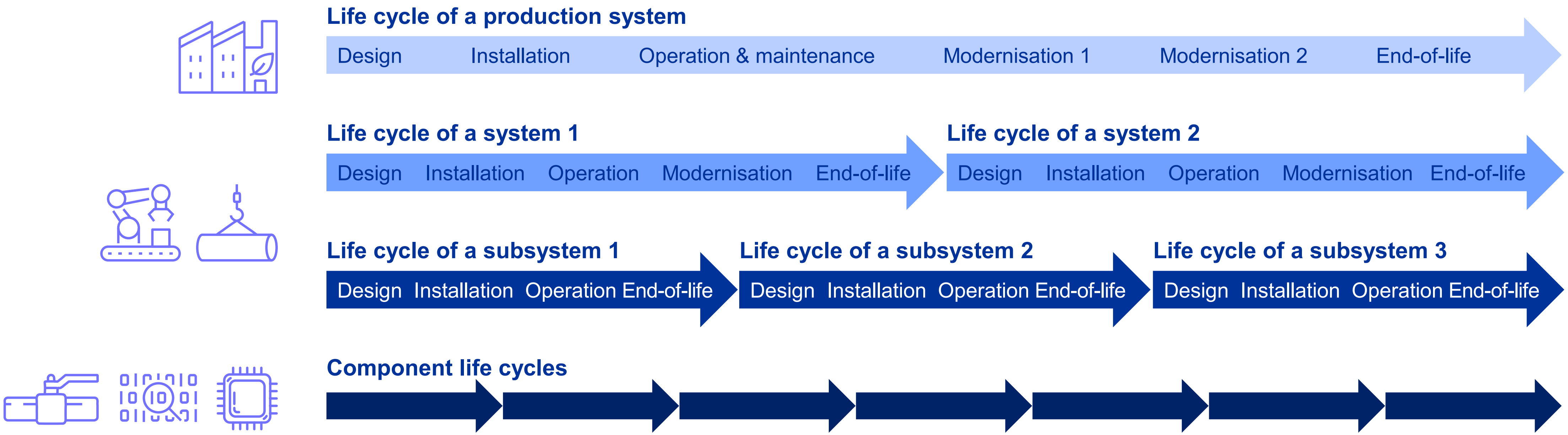
Asset within scope of AMS

ISO 55000:2024 (2024) Asset management — Vocabulary, overview and principles.

seed FOREST

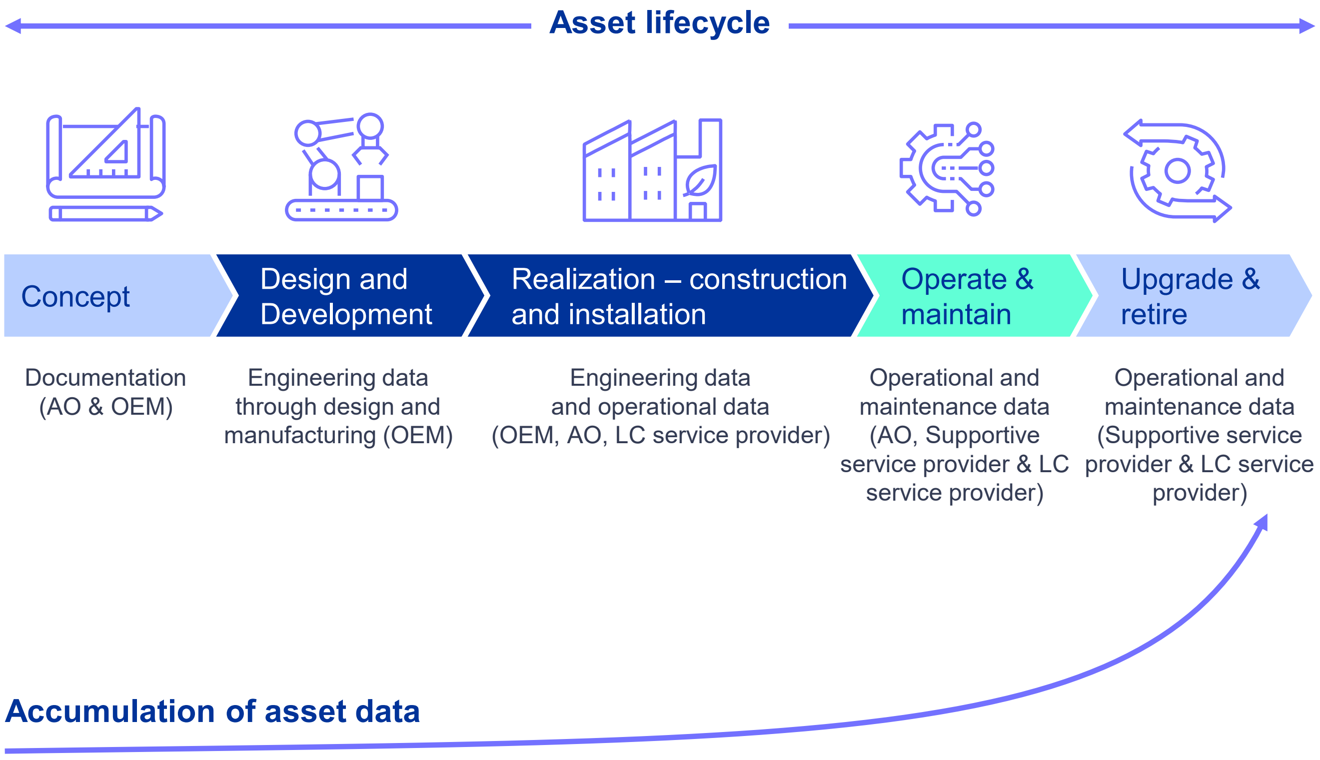
Asset management fundamentals – structured lifecycle of asset data

Lifecycle complexity emerges from system hierarchy. Multiple lifecycles exist at different system levels (figure below). Complexity arises from keeping lifecycle information consistent across levels.



Based on Hanski et al. 2012 https://publications.vtt.fi/pdf/technology/2012/T21.pdf

Asset data evolves throughout the lifecycle



AO = Asset Owner
OEM = Original Equipment Manufacturer
LC = Lifecycle

Asset data is created, accumulated and refined throughout the lifecycle of a production asset.

During the concept and design stages, the available information mainly describes requirements, assumptions, intended functions and planned solutions.

Construction and installation add detailed information about the asset as realized, while operation and maintenance generate data on actual performance, condition, interventions and changes.

Upgrades and retirement further modify and complement the asset record.

As a result, asset data develops from an initially abstract description into an increasingly detailed representation of the physical asset and its lifecycle history.

Data as a strategic asset

Data asset = data that has the properties of an asset

Data is a key enabler of collaborative asset management ecosystems

However, it is often scattered in several information systems. This fragmentation often makes it difficult to utilize the information

Managing life cycle of production assets requires:

- Access to a wide range of information types and systematic data management practices
- Reliable and high-quality data to support design, installation, use and end of life phases

ISO 55013: 2025 Kortelainen et al. 2023

Asset data types

Asset management is supported by various types of data that is stored in asset register:

- Asset creation
- Service strategy
- Asset strategy
- Maintenance history
- Maintenance planning
- Operations
- Reporting
- Capital works
- Asset disposal
- Condition assessment

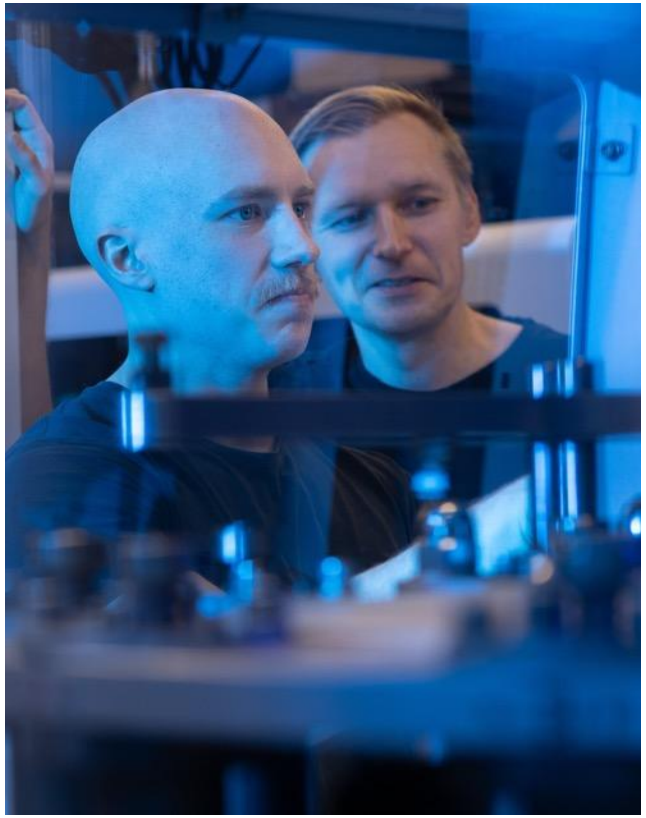
Asset history information

- Design information
- Operating manuals
- Metadata
- Documented information (e.g. reports)
- Images and multimedia
- Work orders

Market data

Customer data

Other data (e.g. weather data)



ISO 55013: 2025

Collaborative AM related standards – Asset management standards

ISO 55000:2024: Asset management — Vocabulary, overview and principles

- defines terms and establishes principles and outcomes for asset management

ISO 55001:2024 Asset management — Asset management system — Requirements

- specifies requirements for an asset management system

ISO 55002:2018 Asset management — Management systems — Guidelines for the application of ISO 55001

- guidelines for the application of an asset management system, in accordance with the requirements of ISO 55001

ISO/TS 55010:2024 Asset management — Guidance on the alignment of financial and non-financial functions in asset management

- guidance on the alignment between financial and non-financial asset management functions, to improve internal controls as part of an organization's management system

ISO 55012:2025 Asset management — Guidance on people involvement and competence

- guidance on enhancing the involvement and commitment of personnel within an asset management system to improve the overall efficiency of translation of asset management objectives into results

ISO 55013:2025 Asset management — Guidance on the management of data assets

- guidance on managing data to support an organization in meeting its asset management objectives and by extension its organizational objectives

Collaborative AM related standards – Maintenance and asset management standards

EN 16646:2015 Maintenance. Maintenance within physical asset management

1. introduces physical asset management as a framework for maintenance activities,
2. introduces the relationship between organizational strategic plan and maintenance management system and
3. describes the interrelations between maintenance process and all the other physical asset management processes

EN 17666:2022 Maintenance. Maintenance engineering. Requirements

1. specifies the maintenance engineering discipline throughout the entire life cycle and
2. gives guidance on how maintenance engineering can contribute to the assurance of required dependability to achieve a sustainable balance between performance, risk and costs.

EN 17485:2021 Maintenance. Maintenance within physical asset management. Framework for improving the value of the physical assets through their whole life cycle

1. specifies methods and procedures when applying physical asset management as a framework to take maintenance into account as an influencing factor within an organizations' strategic and tactical decisions on its physical assets, and when applying physical asset management as a framework to maintenance activities,
2. specifies the relationship between organizational strategic plan and the maintenance management system at a methodological level and
3. describes the interrelations between maintenance process and all the other physical asset management processes at a procedural level.

Collaborative AM related standards – Maintenance management and reliability standards (examples):

EN 17007:2017 Maintenance process and associated indicators

1. generic description of the maintenance process,
2. specifies the characteristics of all the processes, parts of maintenance process, and
3. establishes a maintenance model to gives guidelines for defining indicators

EN 13460:2009 Maintenance. Documentation for maintenance

- general guidelines for: the technical documentation to be supplied with an item, at the latest before it is ready to be put into service, in order to support its maintenance

ISO 14224:2016 Petroleum, petrochemical and natural gas industries. Collection and exchange of reliability and maintenance data for equipment

1. comprehensive basis for the collection of reliability and maintenance (RM) data in a standard format for equipment in all facilities and operations within the petroleum, natural gas and petrochemical industries during the operational life cycle of equipment,
2. describes data collection principles and associated terms and definitions that constitute a "reliability language" that can be useful for communicating operational experience

SFS-EN IEC 60300-1:2024 Dependability management - Part 1: Managing dependability (IEC 60300 series)

1. guidance on the meaning and significance of dependability from a business, technical and financial perspective,
2. achieving dependability through suitable adaptation of organizational management systems (e.g. ISO 55000),
3. the activities that are integrated into management systems and life cycle processes in order to achieve dependable systems, products and services,
4. planning and implementing dependability activities throughout the life cycle to achieve and assure required outcomes.

Collaborative AM related standards – IT/OT integration, interoperability, data and collaboration standards (examples):

IEC 62541-1:2026 OPC unified architecture - Part 1: Overview and concepts (IEC 62541 series)

- the concepts and overview of the OPC Unified Architecture (OPC UA). Reading this document is helpful to understand the remaining parts of the IEC 62541 series

ISO 8000-1:2022 Data quality — Part 1: Overview (ISO 8000 series)

1. establishing the principles of information and data quality and
2. describing the path to data quality

ISO 10303-1:2024 Industrial automation systems and integration — Product data representation and exchange — Part 1: Overview and fundamental principles (ISO 10301 series)

1. defines the architectural principles of product information representation and exchange used in the ISO 10303 series,
2. specifies the characteristics of the various sets of parts in the ISO 10303 series and the relationships among them

SFS-ISO 44001:2017 Collaborative business relationship management systems — Requirements and framework

- specifies requirements for the effective identification, development and management of collaborative business relationships within or between organizations.

Towards Co-AM environment

seed FOREST

1. Collaborative AM (Co-AM) explained
2. Co-AM stakeholders
3. Principal elements of Co-AM

Previous page

Next page

Introduction

This section establishes practical steps for Collaborative Asset Management (Co-AM)

- Transition from asset owner-centric AM to ecosystem-level collaboration (Co-AM)
- Co-AM stakeholders, roles and relationships across the lifecycle
- Principal elements of Co-AM

ISO 55000:2024 (2024) Asset management — Vocabulary, overview and principles.

Collaborative asset management (Co-AM) – How does it change the operation?

While traditional asset management focuses on optimizing assets within a single organization, Collaborative Asset Management (Co-AM) enables ecosystem-level coordination, shared use of asset lifecycle data, and collective value creation across organizational boundaries.

What is changing?

- Shift AM from asset owner perspective towards ecosystem-based model
- Value is created collectively
- Organizations in the ecosystem may operate their own AMS. However, collaborative AM requires these AMS to be aligned with the asset owners' AM objectives to ensure coherence in planning, execution, and performance evaluation

Characteristics of Co-AM:

- Multiple organizations and stakeholders
- Collaborative operation, maintaining and improving assets throughout their life cycle
- Enabled by shared data, aligned asset management system and coordinated responsibilities

Traditional owner-centric AM vs. Co-AM

While traditional AM focuses on optimizing assets within a single organization, Co-AM emphasizes ecosystem-level coordination (trust, rules), shared data, and joint value creation throughout the asset lifecycle.

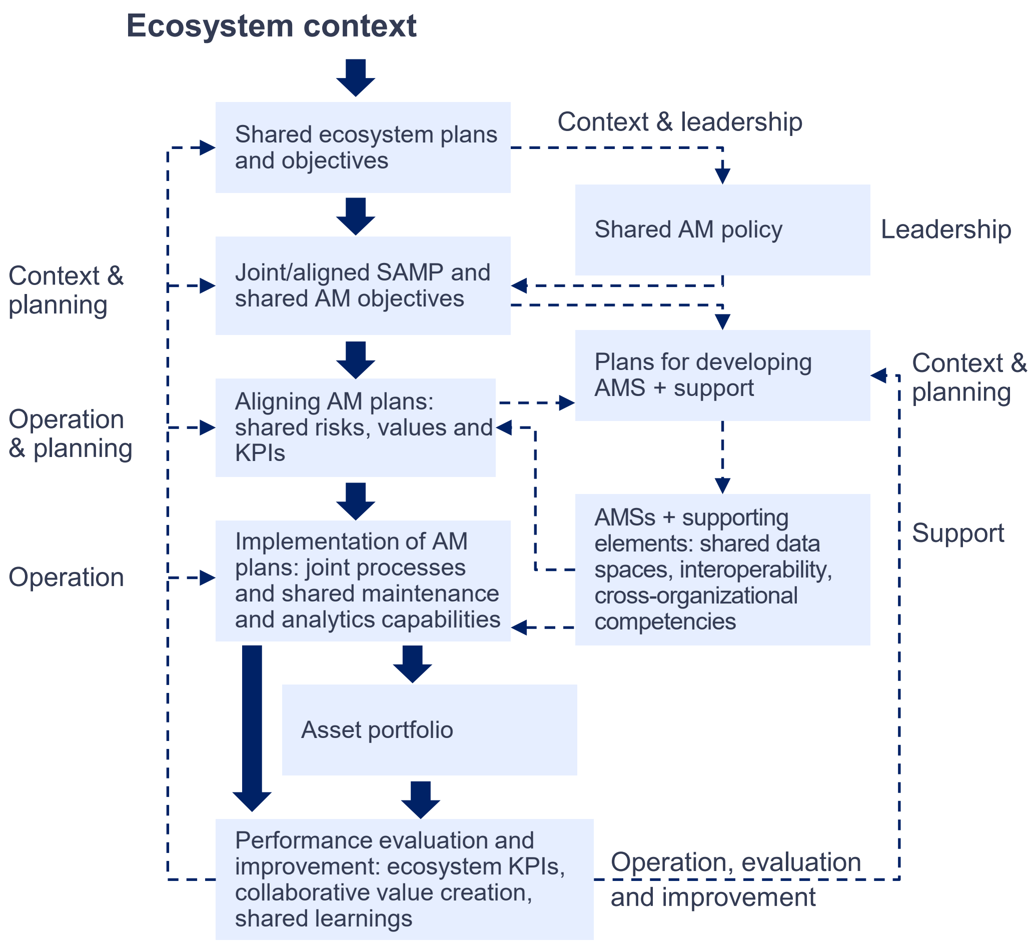
Aspect	Traditional AM	Collaborative AM (Co-AM)
Governance	Owner-centric governance	Ecosystem-centric, shared governance
Stakeholders	Single dominant owner	Multi-stakeholder cooperation
Data	Siloed data, proprietary	Shared data, interoperability
AMS	One AMS per owner	Multiple aligned AMS across organizations
Lifecycle	Owner responsible for lifecycle management	Joint lifecycle management with shared responsibilities
Business Models	Transactional, cost-driven	Value-sharing, new service models
Culture	Low transparency	Trust, collaboration, shared rules, transparent

Asset management in ISO 55000 context – Traditional asset management

Based on ISO 55000 (2024)

ISO 55000	Traditional AM
Context	Internal, owner-centric
Leadership	Centralized governance
Planning	One SAMP, owner-led
Support	Siloed data, internal competencies
Operation	Owner-run lifecycle processes
Evaluation	Internal KPIs
Improvement	Internal continuous improvement

Colife-compliant Asset Management – Collaborative asset management



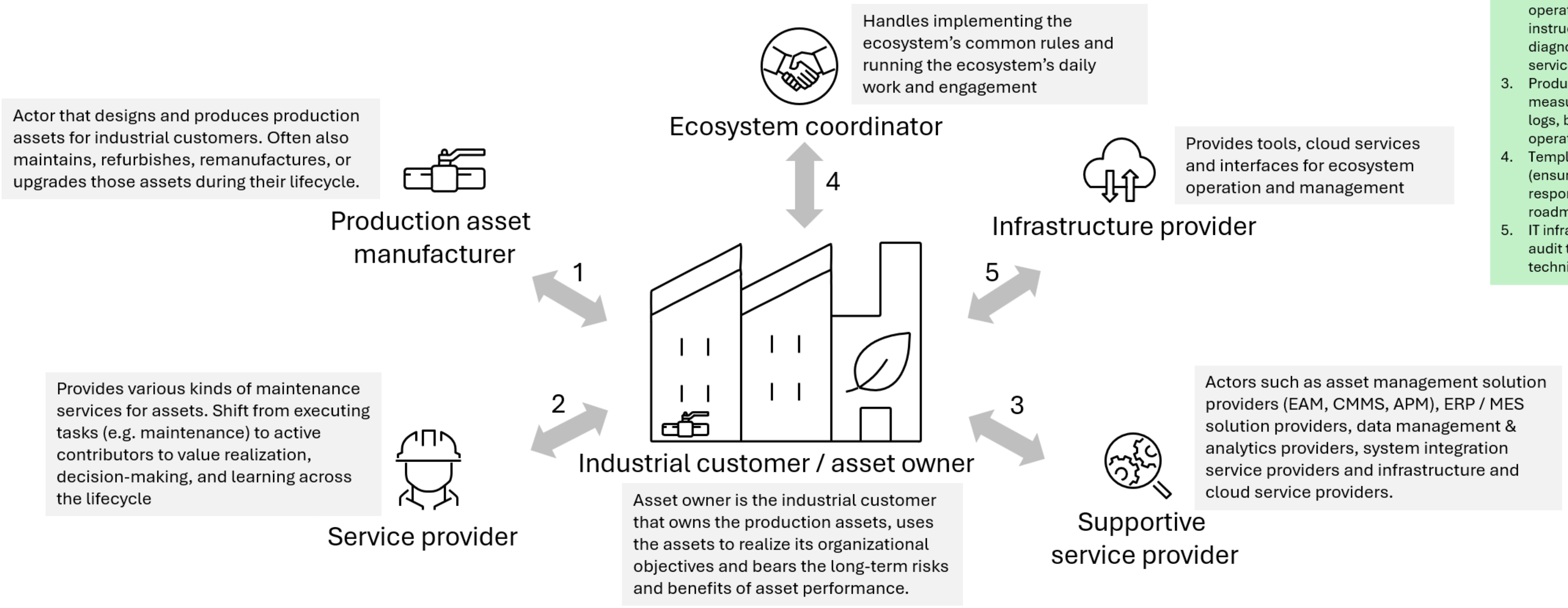
ISO 55000	Collaborative AM
Context	Network/ecosystem context with multi-party dependencies
Leadership	Shared governance, trust frameworks
Planning	Multi-AMS alignment; shared risks, values, KPIs
Support	Shared data spaces, interoperability, cross-organizational competences
Operation	Joint lifecycle processes, shared maintenance & predictive capabilities
Evaluation	Ecosystem KPIs, collaborative value realization
Improvement	Multi-party improvement cycles, shared learnings

Stakeholder description – multi-stakeholder ecosystem

A brief overview of the various actors typically involved in a networked production asset lifecycle management environment.

Role type	Role	Description (role in ecosystem)
Industrial customer	Capital intensive industrial company	Uses and manages production assets in their production sites.
Production asset manufacturer	Production asset manufacturer	Produces (and usually also maintains, remanufacture, refurbish) production assets for industrial customer.
	Production asset component provider	Produces (and usually also maintains, remanufacture, refurbish) production asset components for industrial customer.
Lifecycle (maintenance) service provider	Maintenance service provider	Provides different types of maintenance services for industrial customer.
Supportive service provider	Asset mgm solution provider	Provides solutions for ecosystem's asset management.
	Inspections services	Providers inspection services for production mills.
	Logistics provider	Provides delivery (or reverse) logistics for assets / spare parts etc.
	Engineering & consulting	Provides engineering services.
	ERP/MES solution provider	Provides ERP/MES solutions for industrial customer.
	Data management & analytics	Provides data related services.
	EOL & recycling partner	Materials recycling, component / spare part recycling.
	System integration service provider	Company providing integration services for IT and industrial systems.
Ecosystem and infrastructure provider	Ecosystem coordinator	Daily ecosystem activities. Communicates ecosystem and engages new partners.
	Infrastructure service providers	Provides tools, cloud services and interfaces for ecosystem operation and management.

Co-AM ecosystem stakeholders



Asset management related data examples:

1. Produces and uses asset's product data, device-level sensor data (e.g. diagnostics)
2. Produces and uses asset product data and operation data (logs, spares/configuration, instructions), maintenance data (history, diagnoses, RUL, hours, tacit knowledge, service quality).
3. Produces and uses audit/validation data, measurement data (history), inspection report, logs, best practices / experiences, operation/process data.
4. Templates/standards/conventions for data (ensuring data quality), ecosystem rules & responsibilities, enter/exit criteria, KPIs, roadmaps.
5. IT infra performance data, authentication logs, audit trails, ecosystem data models and technical rules, role-based access definitions.

Principal elements of Co-AM – Business value from shared asset data

Data Availability and Quality

The effectiveness of asset lifecycle activities depends on how well reliable data can be obtained from equipment and processes. Colife emphasizes the importance of a unified data ecosystem in which high-quality data is easily accessible and can be effectively utilized in asset lifecycle decision-making.

Systems Interoperability

In many organizations, legacy systems and fragmented data hinder the formation of a comprehensive overview. Colife promotes interoperability, enabling the integration of data from different systems and data sources to support lifecycle activities.

Data Security and Trust

From an asset lifecycle management perspective, it is essential that data can be used securely and under clear data ownership practices. Colife builds trust between stakeholders and supports secure data management without compromising privacy.

People and Culture

Alongside technology, an organizational culture is needed in which personnel are committed to using and developing data-driven practices. Colife supports a collaborative operating model where knowledge and expertise are shared openly. Data sharing is viewed as a beneficial win–win practice among different actors.

Value Creation from Data

Collecting data alone is not sufficient—it must enable improved predictive maintenance, reduced downtime, and optimized maintenance actions. Colife supports the use of analytics and decision-support tools to increase the value derived from data.

Business Renewal

The role of asset lifecycle management changes when data is used strategically. Colife enables the development of new service models and operational practices that can create added value for the entire ecosystem.

Data quality and interoperability | Governance | Business

Valkokari, P., & Kääriäinen, J. (2025). Colife konseptin elementtien tunnistaminen teollisuuden omaisuudenhallinnassa (Identifying elements of the Colife concept in industrial asset management). Promaint, (4/2025), 44. https://www.promaintlehti.fi/lehtiarkisto/?issue=339

Examine Co-AM in your context

seed FOREST

Introduction

This chapter introduces Co-AM opportunities and challenges to your organization, then use the checklist to reflect your organization’s practices from business, governance, and data perspectives.

This chapter answers to the following questions:

- Which opportunities or challenges make cross-organizational asset lifecycle data sharing worth exploring?
- Where could shared data create concrete value — better performance, new services, lower costs or sustainability gains?
- Can partners agree on data rights, responsibilities, secure use and fair benefit sharing?
- Is the required data usable, interoperable and able to flow across systems and organizations?

Opportunities – identify which opportunities are relevant to your organization

Process improvement

- Data harmonization from the shop floor
- Operation cost savings
- Improvement in process efficiency; time, speed, material usage
- Preventive and more homogenous maintenance processes
- Assisting operators in their work

Improvements in asset design and maintenance

- Extended lifecycle of assets
- Better information on asset integrity to be used in follow-up actions
- Preventive measures
- Improved safety
- Digital twin and digital product passport

Collaboration between partners

- Platform for data sharing and asset collaboration
- Many-to-many relationships and more integrated ecosystem
- Enhanced overall efficiency
- Best practices, co-learning

Advancement in sustainability

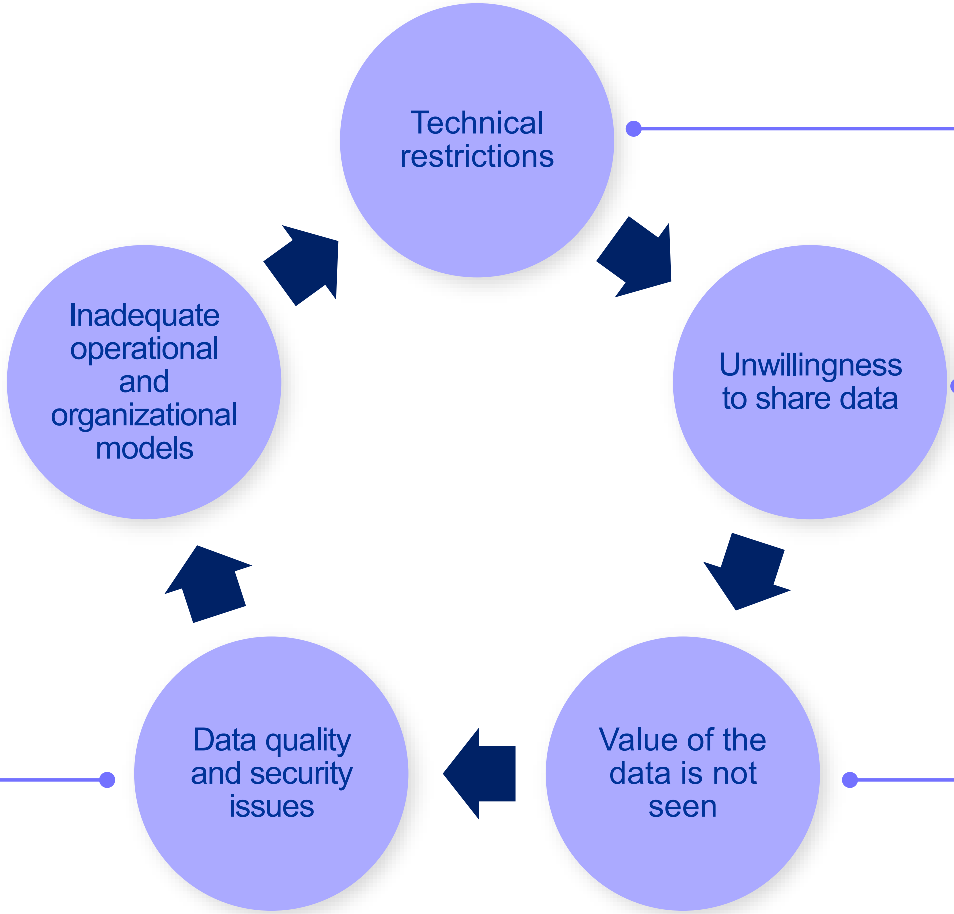
- Circular economy practices: reuse, remanufacturing, recycling
- Better understanding on sustainability status of companies
- Optimization of energy use and supply security
- Improved safety and efficiency while adhering sustainability goals

New business opportunities

- Asset data as a service
- Lifecycle and life extension services
- Further development of current solutions with open data and new technologies Utilization of process side streams
- Services for reuse and recycling

Rantala, T., Kääriäinen, J., Hatara, E., Valkokari, P., & Kokkonen, K. (2025). Innovating data-sharing concept for industrial asset lifecycle: challenges and opportunities. In I. Bitrain, S. Conn, A. Mitsis, P. Ritala, M. Torkkeli, & M. Trabelsi (Eds.), Proceedings of the XXXVI ISPIM Innovation Conference International Society for Professional Innovation Management ISPIM.

Challenges – identify what currently prevents you from realizing them



Technical restrictions

- Restrictions of old asset network and document management
- Deficiencies in data transformation and integrations
- Restricted availability of suitable data for AM
- Data privacy and protection laws
- Time-related constraints, e.g., in measurements and maintenance

Unwillingness to share data

- Poor commitment of people; no “data sharing atmosphere”
- Different organization cultures
- Protection of own business
- Protection of own expertise
- Fear of losing data in “wrong hands”

Value of the data is not seen

- The value of data is difficult to determine
- Uncertainty about what can be done with the data
- ROI in data driven business still difficult to see because of unorganized and inaccurate data
- ROI in data quality is not understood

Data quality and security issues

- The huge amount of data
- Lack of data standardization
- Poor data quality
- Weak comparability and consistency of data between different systems
- Relevant data is not available and/or up to date
- Company-level restrictions in data usage and contracts

Inadequate operational and organizational models

- Inadequate operational and governance models
- Silos inside and between companies
- Data management and collection is costly
- No clear overview what is done with the data
- The maturity levels of companies vary; the potential of technologies is not fully used

Rantala, T., Kääriäinen, J., Hatara, E., Valkokari, P., & Kokkonen, K. (2025). Innovating data-sharing concept for industrial asset lifecycle: challenges and opportunities. In I. Bitrain, S. Conn, A. Mitsis, P. Ritala, M. Torkkeli, & M. Trabelsi (Eds.), Proceedings of the XXXVI ISPIM Innovation Conference International Society for Professional Innovation Management ISPIM.

seed FOREST

Exploring your starting point – Reflecting on Co-AM in your own context

The questions on the following slides are not meant as a formal assessment, but as a structured way to reflect on your current practices. They **help you explore your situation from different viewpoints and consider the relevance of Co-AM in your organisation and ecosystem.**

Business:

These questions help you reflect on whether shared asset lifecycle data could create concrete business value, new services, or improved performance in your context.

Governance:

These questions help you examine whether data sharing and collaboration can be governed in a fair, trusted, and scalable way across organisational boundaries.

Data quality and interoperability:

These questions help you examine whether your data can actually flow across organisations.

Business – Why would data sharing be worthwhile?

Consider the following questions. If they sparked your thoughts, dive into our more detailed methods

- **Have you identified what kind of lifecycle data of production assets you or your partners own** that could create value if it were shared or combined across organizational boundaries?
- **Do you face challenges related to production asset performance, availability, lifecycle costs, or sustainability** that cannot be solved by a single organization alone?
- **Could shared data enable new or improved services,** such as lifecycle services, optimization, predictive maintenance, reporting, or compliance?
- **Is the value creation logic of shared data clearly defined,** or is data being collected without a clear connection to business benefits?
- **Do you see genuine win–win opportunities in data sharing for multiple parties,** or is data still primarily viewed as a competitive asset that must be protected?

Develop your business opportunities

Governance – Can data be shared fairly and securely?

Consider the following questions. If they sparked your thoughts, dive into our more detailed methods

- **Are data ownership, usage rights, and responsibilities clearly defined** when collaborating with partners during the asset lifecycle?
- **Do you have jointly agreed principles or rules for data sharing,** beyond individual contracts (e.g. what data is shared, with whom, and for what purpose)?
- **Is the level of trust between partners sufficient for data sharing,** or do legal, organizational, or cultural uncertainties hinder collaboration?
- **Are the governance and operating models related to data management and sharing scalable,** or are decisions based on case-by-case or partner-specific negotiations and personal relationships?
- **Do contracts support collaboration and win–win opportunities**, or do they primarily focus on risk minimization and data protection?

Develop your data governance capabilities

Data Quality and interoperability – Can data actually flow and be utilized?

Consider the following questions. If they sparked your thoughts, dive into our more detailed methods

- **Is the necessary production asset lifecycle data available in a digital and usable form,** covering the required lifecycle phases such as design, operation, maintenance, and end-of-life?
- **Is the data quality sufficient for shared use,** or is its value limited by incomplete, inconsistent, or outdated data?
- **Are data formats, interfaces, and concepts interoperable across organizations,** or does interoperability require significant manual effort?
- **Is it technically and organizationally defined how data flows between different parties,** or does information exchange take place in an ad hoc manner?
- **Do you know which data must be kept local and which data can be shared safely with other partners,** for example through aggregation, abstraction, or privacy-preserving methods?

Develop your quality and interoperability practices

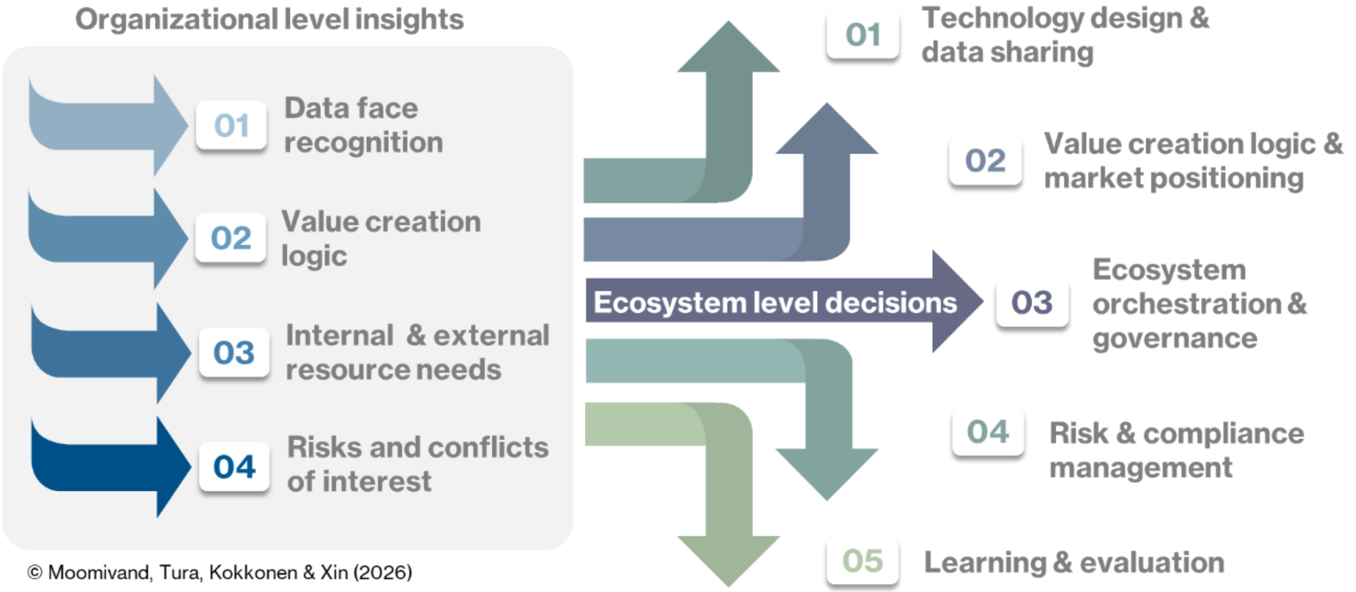
seed FOREST

Identify your business opportunities

Introduction

This part of the Colife playbook helps your company to recognize the business potential of data and its value co-creation opportunities within a collaborative asset management setting

- A practical framework for business model design guides you through relevant questions and key design choices at different stages of data-enabled business development
- The framework is built in two layers, forming a continuum from organizational readiness to ecosystem level key design choices



© Moomivand, Tura, Kokkonen & Xin (2026)

How to work with the tool

Two-level logic: from inside out: The tool progresses from organizational readiness to ecosystem-level value creation as a continuous process

Build a strong foundation within the organization
Understand your data, value creation logic, resources, and risks before engaging in broader collaboration

Identify and resolve critical uncertainties
Unclear areas at the organizational level guide development and determine readiness to move forward

Expand the analysis to ecosystem-level dynamics
Examine data sharing, value flows, roles, governance, and collaboration rules within the network

Align internal readiness with external collaboration
Sustainable data-driven business emerges when organizational capabilities and ecosystem structures support each other

Organizational level

Is your company ready for developing business within a collaborative asset management setting?

- Know your data, recognize the value creation logic, find the needed resources and ponder the possible risks and conflicts

The first layer of the framework guides you through a set of questions that your company needs to solve before targeting towards ecosystem level value co-creation.

In this first phase, you will assess your firm's status through question sets under each of the four dimensions. This assessment reveals the overall readiness level for each theme and provides recommendations for progressing toward a data-driven business in a collaborative setting.

Reflect on Your Data-driven Business Opportunity

Understand your idea

Review 14 reflection questions and assess clarity:

- Across four themes: data, value creation, resources, risks & conflicts
- Mark each answer: clear, partially clear, or unclear

Identify the gaps

You receive:

- Overview of the firm's readiness (Strong, Developing, Weak)
- Simple interpretation of maturity
- Diagnostic insight into strengths and gaps

Take the next steps

How to proceed:

- You will receive guidance on each theme according to its readiness status
- Progression plan towards data-driven business

Knowing your data – What data matters, what value it creates

		CLEAR	PARTIALLY CLEAR	UNCLEAR
Data Value	**Where does data create real value for us?**	☐ We know data is linked to certain improvements in decisions, operations, or offerings.	☐ Data seems valuable, but the specific impact is not yet focused.	☐ Data is present, but its contribution to value creation is vague.
Data Assets	**What data do we control or access?**	☐ We know what data we generate, its availability, and usefulness.	☐ Some important data is visible in our business, but access and quality are uneven.	☐ Our database is too fragmented or uncertain.
Data Exchange	**Can sharing our data create value for others?**	☐ There is a credible case for how our data could benefit partners or customers.	☐ External value is possible, but the use case or recipient is not well defined.	☐ We cannot yet see a convincing reason why others would value our data.
Data Needs	**What data do we need from whom?**	☐ The missing data and likely sources are specific enough to shape collaboration choices.	☐ We sense important data gaps, but not clearly enough to act on them.	☐ The needed data and relevant providers are still undefined.

Knowing your data – status overview and guidance for progression

Focus on improving how your firm recognizes and leverages its data assets.

WEAK

Start using data as a tool for decision-making:

Identify and map the main data sources in your organization.

Connect these to specific operational or managerial decisions.

Establish basic data reporting, dashboards, or analytics to support planning, monitoring, and problem-solving.

DEVELOPING

Develop data as an organizational practice:

Integrate data into workflows, experimentation, and improvement processes.

Use analytics to support innovation, product or service development, and organizational learning.

Build routines where data continuously informs actions and improvements.

STRONG

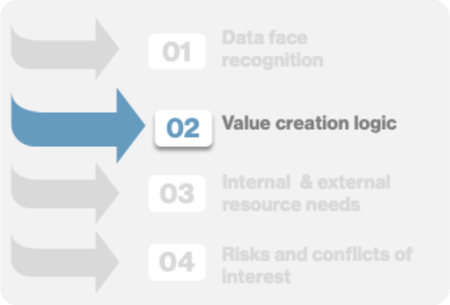
Leverage data as a commodity or algorithmic intelligence:

Explore opportunities to share, exchange, or monetize data with partners.

Develop advanced analytics or AI capabilities to automate insights and decision processes and participate in data-driven value co-creation within ecosystems.

Adopted from Xu et al. (2024)

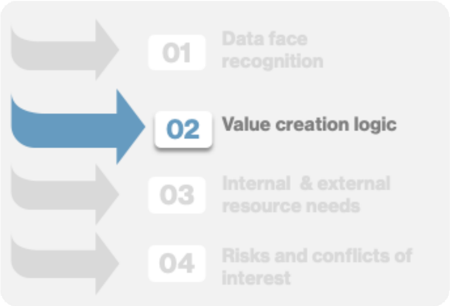
Value Creation Logic – What problem we solve, for whom, with whom



		CLEAR	PARTIALLY CLEAR	UNCLEAR
Data-related Problem	**What problem do we want to, or could we solve?**	☐ We identified a specific problem that is worth solving.	☐ The problem is visible, but we have not yet sharply defined it.	☐ We have not identified a specific problem, or it is too broad.
Customer	**Who is the customer of our data or data-based offering?**	☐ The customer is clearly identified.	☐ Customers are visible, but their use case is not fully clear.	☐ The customer is not defined.
Offering	**What does our product or service help the customer achieve?**	☐ The offering solves an important problem for a specific customer.	☐ We think the offering is useful, but its distinct value is not yet sharp.	☐ The link between the offering and customer benefit is not identified.
Co-creation	**With whom is the value created?**	☐ We know the key actors and their roles in creating value.	☐ Some actors are known for us, but their contribution is not clear.	☐ We have no explicit idea about collaborative value creation.

Value Creation Logic – status overview and guidance for progression

Focus on improving the clarity of your firm's value creation logic.

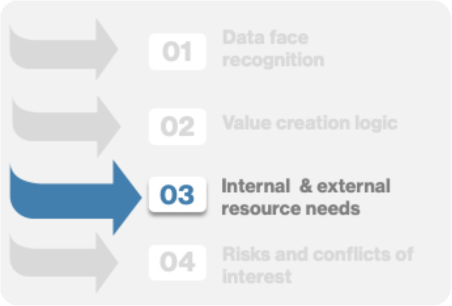


WEAK	DEVELOPING	STRONG
Clarify how data could create value: *Identify the problem your firm aims or is able to solve and explore how available data could support the solution.* *Define potential users or beneficiaries and articulate how data can contribute to improving decisions, services, or operations.*	**Strengthen data-driven value creation:** *Use data to refine the value proposition, support product or service improvement, and generate insights for customers and partners.* *Identify stakeholders who benefit from the data and explore opportunities for collaborative value creation.*	**Develop ecosystem-level data-driven value creation:** *Leverage data to enable new services, partnerships, and business models.* *Share or combine data with ecosystem actors to create economic, environmental, and social value across networks.*

Adopted from Manninen et al. (2024)

seed FOREST

Resource Needs – What resources we have and what we need from whom



		CLEAR	PARTIALLY CLEAR	UNCLEAR
Owned Resources	**What resources do we have that others need for value creation?**	☐ We know what resources we hold and where beyond our use are needed.	☐ We know our resource base, but its wider value potential is not recognized.	☐ We do not know what resources we can share for value co-creation.
Missing Resources	**What resources do we need, and from whom?**	☐ The missing resources for data-enabled solutions and providers are well recognized in our business.	☐ IImportant needs are visible but not clearly matched to actors.	☐ The needed resources and providers are undefined.

Resource needs – status overview and guidance for progression

Focus on strengthening the resources and capabilities needed to deliver your offering.

WEAK	DEVELOPING	STRONG
Identify the required capabilities: *Scan technologies, partners, and internal skills to understand what capabilities are needed to pursue the data-driven opportunity.* *Assess whether your organization currently possesses the necessary technological, analytical, and organizational resources.*	**Mobilize and align resources:** *Invest in developing or acquiring the required capabilities, such as data infrastructure, analytics skills, and partnerships.* *Align organizational processes, technologies, and complementary assets to support the data-driven opportunity.*	**Continuously reconfigure capabilities:** *Adapt and recombine internal and external resources as technologies and markets evolve.* *Coordinate capabilities across partners and ecosystems to sustain data-driven innovation and competitive advantage.*

Adopted from Teece (2007)

Risks & conflicts – Where do risks and conflicts arise and how to manage

		CLEAR	PARTIALLY CLEAR	UNCLEAR
Data risks	**What are the risks of sharing data for us?**	☐ The legal, strategic, operational, or relational risks are identified.	☐ Data sharing risks are not fully discovered.	☐ The risks of data sharing remain largely overlooked.
Conflicts of interest	**What conflicts and with whom could arise if we share our data?**	☐ Possible tensions between actors about the goals and incentives of data sharing are recognized.	☐ We know some conflicts might arise, but do not know where and when.	☐ Potential conflicts of interest are not understood.
Trade-offs	**What value may be sacrificed or destroyed if we share data?**	☐ We know the value we might lose if we share our data and what we can gain.	☐ Some trade-offs are recognized, but their consequences are not yet clear.	☐ The downside of collaboration or data sharing has not been assessed.
Conflict management	**How will the risks of data sharing and conflicts be managed?**	☐ We have a credible approach for risk and tension management.	☐ Some management ideas exist in our firm, but they are not implemented.	☐ We have no clear way to handle emerging risks or conflicts.

Risks & conflicts – status overview and guidance for progression

Focus on improving how risks, trade-offs, and conflicts are addressed.

WEAK

Identify potential risks and governance tensions:

Clarify possible conflicts related to data ownership, responsibilities, incentives, and value sharing among stakeholders.

DEVELOPING

Define governance rules and responsibilities:

Establish agreements on data access, roles, and decision rights.

Introduce mechanisms that coordinate stakeholders and reduce conflicts.

STRONG

Implement structured ecosystem governance:

Balance control rights and decision rights among actors to enable trusted collaboration and sustainable value creation across the ecosystem.

Adopted from Springer et al. (2025) and Tura et al. (2018)

Ecosystem level

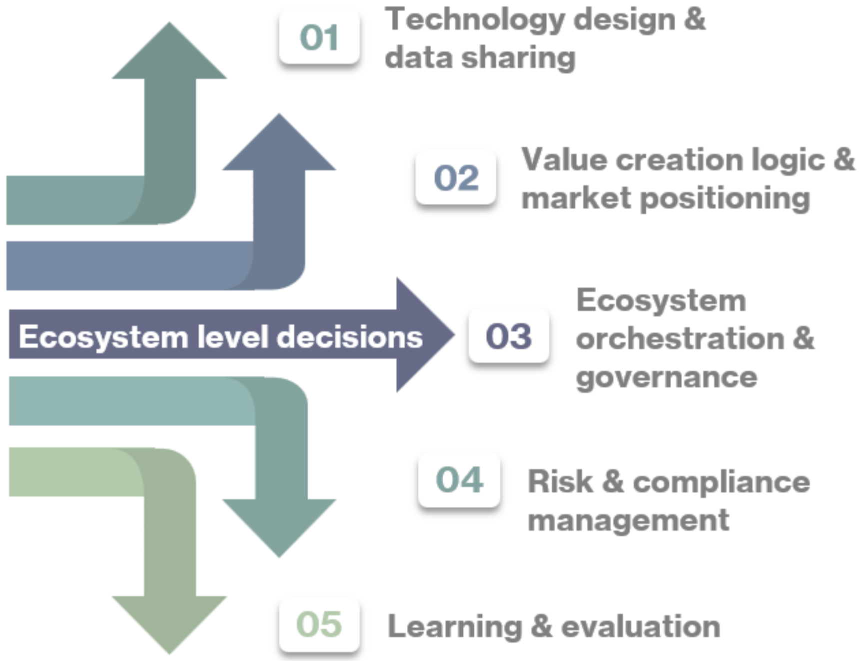
Reflect back to your organizational level results:

- What are your strengths?
- What are the biggest challenges?
- What are the most promising aspects?

► Be ready to transfer your organizational level results to ecosystem level discussion

The second layer of the framework guides you through a set of questions that your ecosystem needs to solve before targeting towards data-driven value co-creation.

In this second phase, you will assess your ecosystem's status through question sets under each of the five dimensions. This assessment reveals the overall readiness level for each theme and provides recommendations for progressing toward ecosystem level value co-creation.



Reflect on Your Readiness towards Ecosystem Level Value Co-creation

Understand your idea

Review 15 reflection questions and assess clarity:

- Across five themes: technology design & data sharing, value creation & market positioning, orchestration & governance, risks & compliance management, learning & evaluation
- Mark each answer: clear, partially clear, or unclear

Identify the gaps

You receive:

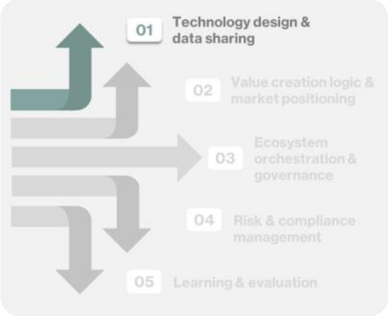
- Overview of the firm's readiness (Strong, Developing, Weak)
- Simple interpretation of maturity
- Diagnostic insight into strengths and gaps

Take the next steps

How to proceed:

- You will receive guidance on each theme according to its readiness status
- Progression plan towards eco-system level value co-creation

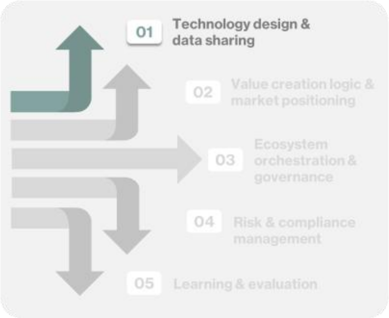
Technology design & data sharing – What data can be shared, combined, and used in a sound way?



		CLEAR	PARTIALLY CLEAR	UNCLEAR
Data Interoperability	**How can our data be combined and exchanged with our partners for joint use?**	☐ We know how data can be integrated and shared with our partners for joint use.	☐ Some integration or share options are known, but gaps remain.	☐ It is unclear how data can be combined or shared.
Data Usability	**How should data be designed to be usable by both us and our partners?**	☐ We know how data must be structured and documented for joint use.	☐ Some usability requirements are known, but not all.	☐ Data usability requirements are unclear.
Ethics & Legality	**What ethical and legal boundaries apply to data sharing?**	☐ Ethical and legal boundaries are clearly understood.	☐ Some boundaries are known, others are unclear.	☐ Ethical and legal boundaries need to be defined.

Technology design & data sharing – status overview and guidance for progression

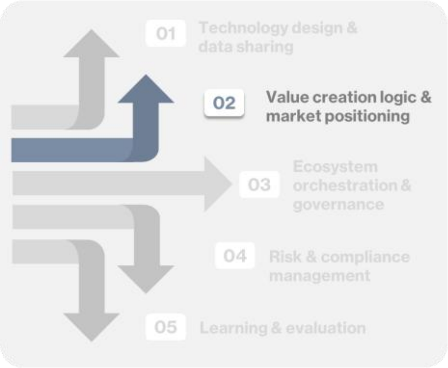
Focus on improving how your firm designs, integrates and shares data assets for joint use in the ecosystem.



WEAK	DEVELOPING	STRONG
Start clarifying basic interoperability and data sharing possibilities: *Identify what data can be technically shared and whether formats, standards, or systems allow integration with partners.* *Map key regulatory requirements that affect data sharing.*	**Enable structured data integration and improve data usability for joint use:** *Define shared data standards, interfaces, and governance mechanisms to support joint use.* *Align data formats, documentation and quality requirements among ecosystem partners.*	**Build ecosystem level data architectures and leverage data as a shared asset:** *Create interoperable platforms for smooth data exchange and joint analytics among ecosystem partners.* *Enable real-time, scalable, and secure data sharing.*

Adopted from Jacobides et al. (2018), Teece (2007); Xu et al. (2024)

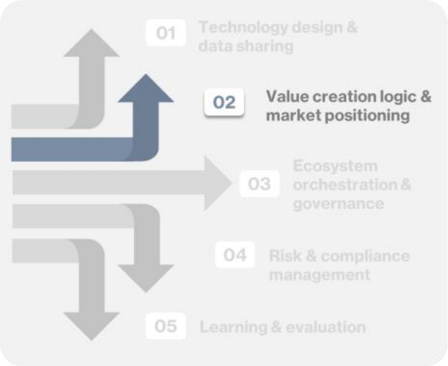
Value creation logic & market positioning – What value is created, for whom, and how it is shared and captured?



		CLEAR	PARTIALLY CLEAR	UNCLEAR
Value Flows	**What types of value flows exist across the ecosystem, and how does data support it?**	☐ We understand ecosystem value flows, how value is created, and the role of data.	☐ Some types of value flows and value sources can be identified.	☐ Value flows across the ecosystem are unclear.
Value Beneficiaries	**Who benefits from the ecosystem, and with whom is value created?**	☐ We know the beneficiaries and the co-creation relationships.	☐ Some beneficiaries or relationships are unclear.	☐ Beneficiaries and co-creation are unclear.
Value Capture & Share	**How is value captured and shared fairly among participants?**	☐ Value capture & share is fair, transparent, and supported by tools.	☐ Value capture & share exists but fairness and transparency is unclear.	☐ Value capture & share mechanisms are unclear.

Value Creation Logic & market positioning – status overview and guidance for progression

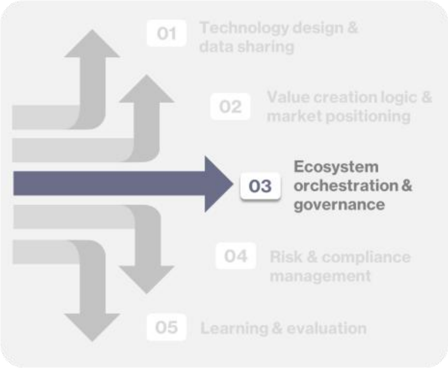
Focus on improving the clarity of your firm's value creation logic and market positioning considerations in the ecosystem.



WEAK	DEVELOPING	STRONG
Identify ecosystem-level value creation and recognize potential beneficiaries: *Identify how value is created beyond the firm, who are the actors involved, and who may gain benefit from data-driven offerings.*	**Map ecosystem value flows and position within the system:** *Analyze how value is co-created and exchanged among partners.* *Clarity the firm's own role and contribution to the system.*	**Design system-level value creation:** *Actively shape value creation logic in the ecosystem.* *Deliver sustainable value across stakeholders and over time.*

Adopted from Adner & Kapoor (2010); Dormeier et al. (2024); Manninen et al. (2024)

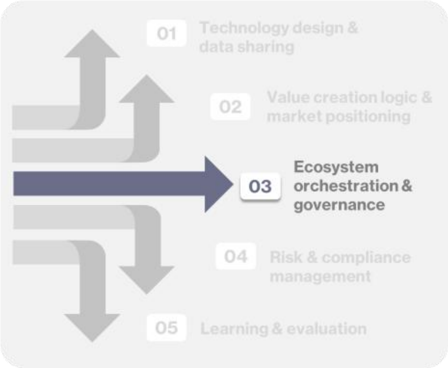
Ecosystem orchestration & governance – Who governs and how?



		CLEAR	PARTIALLY CLEAR	UNCLEAR
Roles & Commitment	**Who plays which role, what do they contribute, and how is commitment ensured?**	☐ We know the participants' roles, contributions, and commitment mechanisms.	☐ Some roles or commitments are still unclear.	☐ Roles and commitments are vague.
Leadership & Decisions	**Who leads the ecosystem and who makes which decisions?**	☐ Leadership and decision rights are clearly defined.	☐ Some leadership or decision rights need to be clarified.	☐ Leadership and decision-making are unclear.
Ownership	**Who owns the platform and who owns the data?**	☐ Platform and data ownership are clearly defined.	☐ Some ownership aspects are ambiguous.	☐ Ownership is unclear.
Ecosystem Rules	**What rules govern participation and how much autonomy do actors have?**	☐ Rules, permissions, and autonomy are clearly defined.	☐ Some rules or autonomy boundaries are unclear.	☐ Ecosystem rules are unclear.

Ecosystem orchestration & governance – status overview and guidance for progression

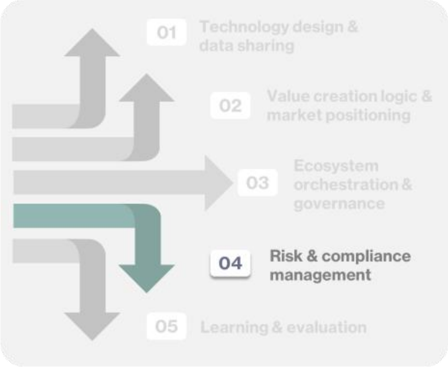
Focus on improving the recognition and capability of ecosystem governance.



WEAK	DEVELOPING	STRONG
Identify key actors and roles: *Recognize who is involved in the ecosystem and their possible contributions.* *Recognize who influences coordination and resource allocation.*	**Define governance structure and align incentives & commitments:** *Establish roles, responsibilities, and decision-making rights among ecosystem actors.* *Introduce mechanisms that support collaboration while reducing opportunistic behavior.*	**Orchestrate ecosystem interactions and balance control and autonomy:** *Actively coordinate actors, resources, and activities across the ecosystem.* *Design governance that promotes both coordination and innovation among participants.*

Adopted from Jacobides et al. (2018); Teece (2007); Tura et al. (2018)

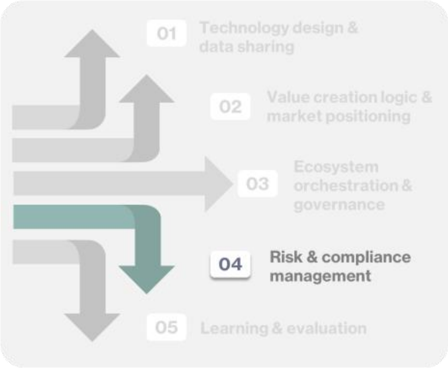
Risk & compliance management – Where do tensions arise and how to manage?



		CLEAR	PARTIALLY CLEAR	UNCLEAR
Goal Misalignment	**Do stakeholder goals or interests conflict, and how?**	☐ We know the goals conflicts and the reason for them.	☐ Some goal conflicts are known, but reason is unclear.	☐ Goal conflicts are unclear.
Value Contradiction	**How might long-term and short-term value contradict?**	☐ Contradictions between long-term and short-term value are well understood.	☐ Some contradictions are known.	☐ Contradictions between long-term and short-term value are unclear.
Conflict Management	**How can tensions and conflicts between ecosystem actors be managed?**	☐ Conflict management approaches are clearly defined.	☐ Some approaches exist but are incomplete.	☐ Conflict management approach is unclear.

Risks & compliance management – status overview and guidance for progression

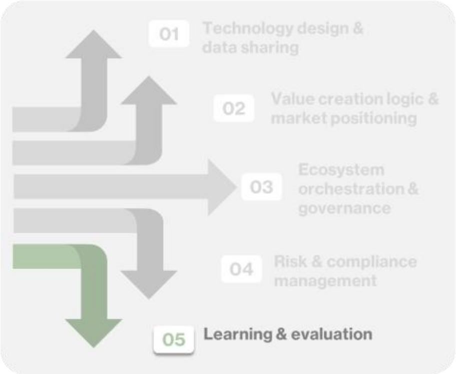
Focus on strengthening how tensions (e.g., goal misalignment, value contradiction) in the ecosystem are addressed.



WEAK	DEVELOPING	STRONG
Identify potential ecosystem risks and governance tensions:	**Analyze contradictions and establish risk mitigation mechanisms:**	**Manage risks & tensions and enable trust-based collaboration:**
Identify possible conflicts related to goals, data use, and value distribution.	*Evaluate short-term vs. long-term value conflicts and stakeholder misalignments.*	*Continuously balance competing interests among stakeholders and value dimensions.*
Map basic legal and regulatory risks associated with collaboration and data sharing.	*Implement contracts, governance rules, and monitoring mechanisms.*	*Develop transparent, fair, and adaptive mechanisms for conflict resolution and value sharing.*

Adopted from Hahn et al. (2014); Manninen et al. (2024)

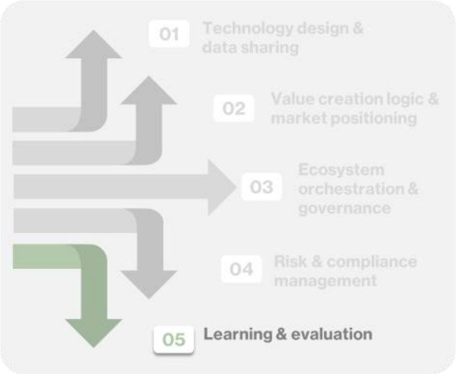
Learning & evaluation – How does the ecosystem evolve?



		CLEAR	PARTIALLY CLEAR	UNCLEAR
Adaptation	**How can the ecosystem business model align with the firm's long-term goals?**	☐ The business model can dynamically adapt to support our long-term goals.	☐ Adaptation is possible, but supporting long-term goals cannot be assured.	☐ It is challenging to adapt the business model.
Scaling	**When should a new partner join, and what value would they add?**	☐ We clearly understand when a new participant should be introduced and can assess their expected impact on the ecosystem.	☐ We have a general understanding of adding a new participant, but the criteria or prerequisites are not fully defined.	☐ We do not know when or why a new participant should be introduced.

Learning & evaluation – status overview and guidance for progression

Focus on improving the clarity of ecosystem evolvement.



WEAK	DEVELOPING	STRONG
Monitor basic ecosystem performance and recognize the need for adaptation:	**Introduce learning mechanisms and support adaptive business models:**	**Scale & renew the ecosystem and enable continuous ecosystem evolution:**
Track whether collaboration produces expected value. *Identify mismatches between ecosystem design and evolving goals.*	*Use data and stakeholder feedback to evaluate ecosystem performance.* *Adjust roles, partners, and value propositions based on learning*	*Dynamically reconfigure relationships, roles, and value structures.* *Integrate new actors and opportunities to sustain long-term value creation.*

Adopted from Adner (2017); Bocken et al. (2016); Teece (2007)

Governance, interoperability, quality, and technologies

Introduction

This part of the Colife playbook enables to identify the key issues related to data sharing from the viewpoint of your own company, and to select the best suitable ecosystem model that implements those issues.

In this part, the key questions related to data governance, quality, interoperability and technology should be thought and identify how those should be solved.

Four different solution alternatives for data sharing are presented, with the dimensions of centralization and decentralization of both governance and data, describing the power dynamics of data sharing.

How to select the most suitable ecosystem model

Review the questions under the themes of:

- Governance (data & member)
- Interoperability
- Quality
- Technologies

For each theme, detect how the questions are answered in different solution alternatives

A four-field model:

	Centralized data	Decentralized data
Centralized governance	“Star”	“Network”
Decentralized governance	“Vassal"	“Peer-to-peer"

Select the best suitable solution

Introduction of the four-field model

The four-field model describes **four different solution alternatives** for ecosystem data & governance.

Centralization/decentralization of data and governance affects:

- The control of the ecosystem members and data
- Members' trustworthiness and data quality verification
- Rules, roles and responsibilities
- The location of data
- Data access and interoperability
- Ecosystem maintenance and joining effort

	Centralized data	Decentralized data
Centralized governance		
Decentralized governance		

Introduction of the four-field model: governance

	Centralized data	Decentralized data
Centralized governance	Central entity is the owner of the use case and decides also who are participating into the data sharing. Central entity decides rules, interfaces and responsibilities.	Governance is centralized and common rules of data sharing is decided among the participants keeping the field more equal and fairer. Governance process is important to be transparent and predictable.
Decentralized governance	For example, there could be a joint entity that handles the data on behalf of the participants. Shared responsibility, but for customer it might appear unitary.	Approach is lightweight as it does not have oversight or rules, but the it may be chaotic and unable to scale. Governance is done case by case and different connections are maybe governed differently.

Introduction of the four-field model: governance

	Centralized data	Decentralized data
Centralized governance	Data is transferred to central entity which decides the use of the data. **Use case example:** Electronic Health Records	The data is kept within the hands of owner ensuring the data ownership and control. Data sovereignty **Use case example:** City data ecosystem
Decentralized governance	Centralizes the data but decentralizes the governance. **Use case example:** Co-operative electric car charger network.	The approach lets the participants create and tailor their own connections between the participants. **Use case example:** Sustainability data ecosystem

Governance – checklist questions

?

- Who owns the data?
- Are the member rights and responsibilities defined in the ecosystem?
- Are the stakeholders contractually related to each other or through a single main actor?
- Who gets to decide whether new parties can join or leave the ecosystem?
- Are there any criteria for joining the ecosystem and who decides on these criteria?
- How to ensure the trustworthiness of the ecosystem members?
- Who decides on the rules related to the operation and data processing of the ecosystem?
- What support/how much support does the ecosystem offer to its members (e.g. quality assurance services, data analysis services, ready-made contract templates, etc.)?
- How are the conflicts between ecosystem members solved?

Governance – the four-field model

	Centralized data	**Decentralized data**
Centralized governance	The main actor controls the ecosystem and decides the members. There may be strict rules or only recommendations for data management. Contracts between data providers and users describe users' rights and responsibilities with the data.	Roles and responsibilities in the ecosystem and with the data are strictly defined. Strict criteria for member acceptance and trustworthiness evaluation. Strict contracts between data providers and users. Support services may be provided for data management.
Decentralized governance	Key actors form the core of the ecosystem together and agree jointly the (loose) rules, practices and new members.	Close to common business-to-business data transfer. Terms and rules are agreed in the contract. Trust is often evaluated informally.

Interoperability – checklist questions

?

- Is there a specific format in which the data should be?
- Are there specific standards or rules to be followed?
- Is the metadata defined?

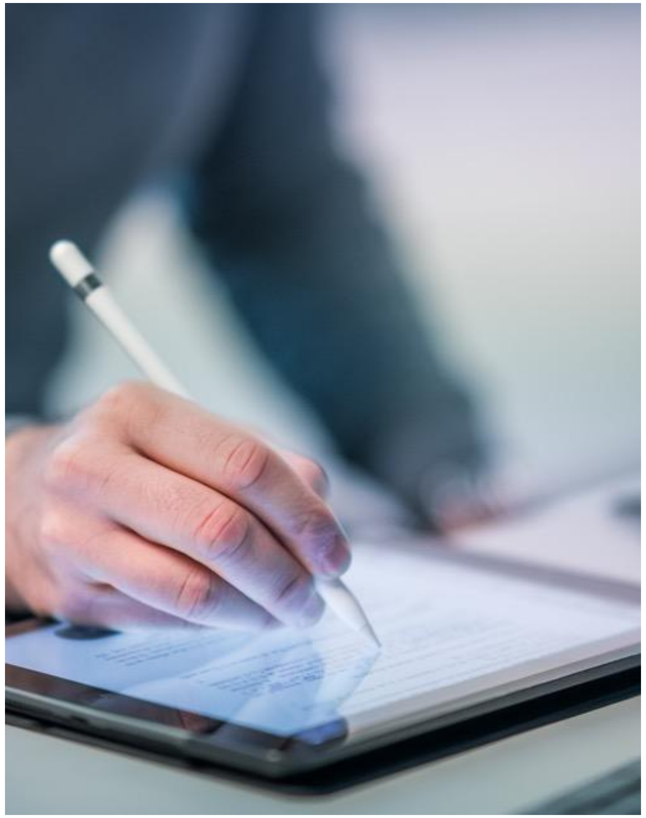
Interoperability – the four-field model

	Centralized data	**Decentralized data**
Centralized governance	Data controller decides the data formats, standards, metadata and practices, and the level of those. Others must follow these.	Jointly agreed, common data models, standards, etc. that all members are obligated to follow. Strict metadata procedures for the data.
Decentralized governance	Usually, the main organizations decide the data formats, standards, metadata, etc. but the practices may be flexible. The interoperability rules may be more informal.	Data provider and data user agree bilaterally about the data formats and standards. These are defined in the contract. Metadata may be considered unnecessary.

Quality – checklist questions

?

- Who is responsible of the data quality?
- Are there common policies for data quality description and evaluation?
- How to validate the quality of the content (data, metadata and measuring equipment)?
- Is the data transparent?



Quality – the four-field model

	Centralized data	Decentralized data
Centralized governance	The data quality is verified according to the defined practices of the main actor. It depends on the main actor at what level these are defined and implemented. Quality validation is the responsibility of the data providers.	There are common ecosystem policies for data quality description and validation. The data must be validated before it is brought to the ecosystem. There might be tools available for the validation. Metadata includes quality metadata.
Decentralized governance	The main organizations decide the how to ensure the data quality. These may be more informal and more trust-based.	Data quality is defined in the contract between the data provider and user, and both parties verify it on their own behalf according to their own practices.

Technologies – checklist questions

?

- Where is the data stored?
- Who is responsible for maintaining the master data?
- How is the data accessed (interfaces and protocols for data exchange)?
- Is the same data available to every member equally?
- Is there a need to limit data visibility in the data ecosystem?
- Who acts as the coordinator of the ecosystem?
- Who is responsible for choosing the standards to be used for data transfer?
- How are the security issues are solved in data transfer?
- How and by whom is the data privacy taken care of?
- What is the role of data infrastructure maintainer?

Technologies – the four-field model

	Centralized data	**Decentralized data**
Centralized governance	Central actor maintains the data storage, implements the interfaces and protocols for data exchange, and takes care of security processes. Other actors must conform to these.	Each actor has its own infrastructure and data storage and is responsible maintaining it. Data transfer protocol is decided by centralized governance body and actors are conforming to it, being responsible own their own behalf.
Decentralized governance	Actors maintain their own data but allow it to be aggregated at the central point which is for example a customer interface to make it show as a unitary service. Virtualization and APIs may be used.	Security issues are solved and protocols are agreed case-by-case. Interfaces between actors may be al different and data modelling is not dictated.

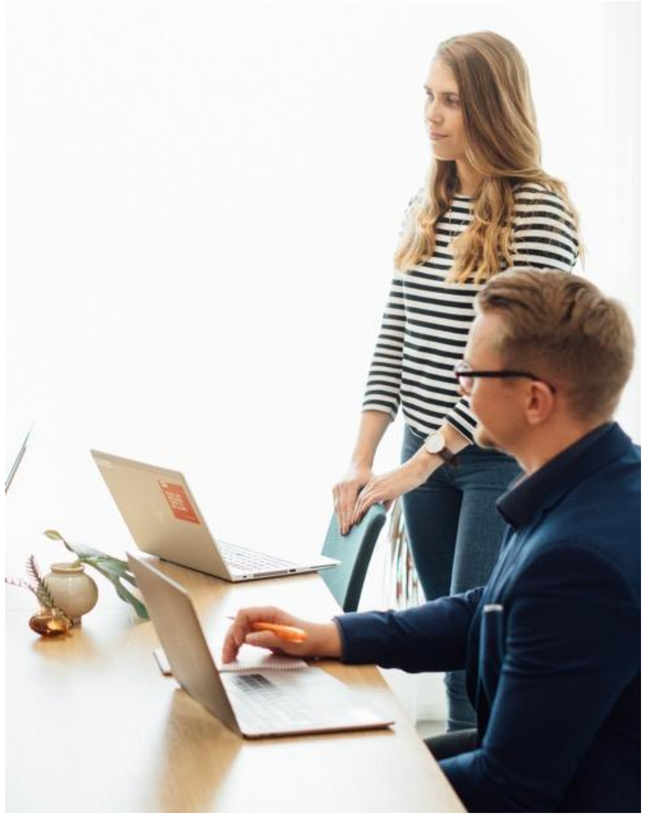
Applicable technologies for the solutions of the four-field model

	Centralized data	Decentralized data
Centralized governance	• Databases • Data lakes • Platforms • Common data repositories	• Data Spaces • Data Mesh
Decentralized governance	• Virtualization	• Blockchains • E-mails • Portals • Tailored APIs

seed FOREST

Positioning yourself according to results

- Building a multi-stakeholder data sharing ecosystem can be done with different amount of centralisation
- The main goal for the questions is guiding the user through right mindset by using the questionnaire and reveal details in data sharing.
    - What kind of characteristics, limits and environment exist and need to be taken into account?
- The centrality of data storage and governance is determined through results and positioning of current/possible approach to data sharing can be done
- Delving more into technologies that are described at identified approach is recommended



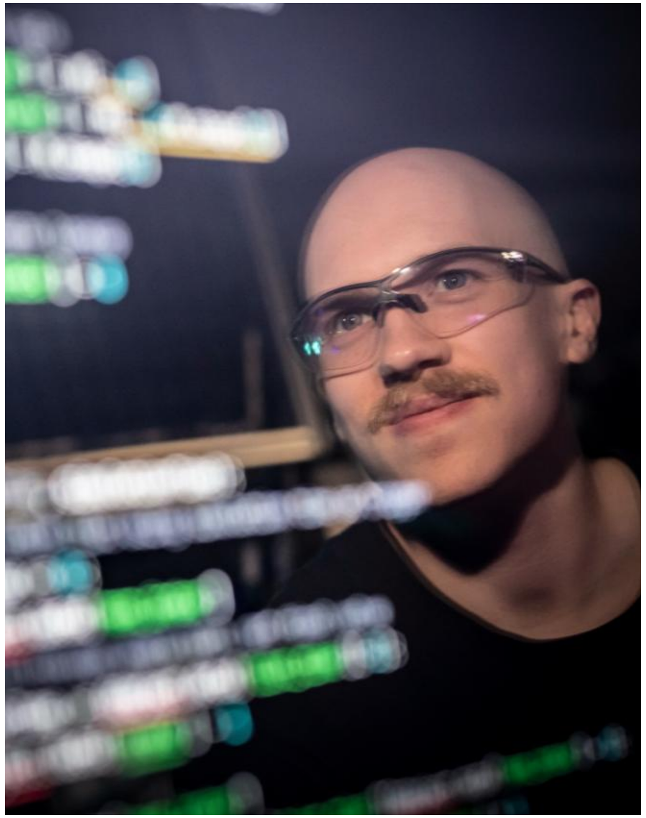
Summary

The division between centralization and decentralization has become apparent in both member and data governance in ecosystems.

The four-field model provides four different approaches to implement data and governance in ecosystem using the axes of centralization, consisting of a data and governance matrix.

The model

- enables to detect differences between the data sharing approaches,
- provides companies with guidance on selecting an appropriate model,
- manages the required properties related to governance, interoperability and quality for data sharing, and
- introduces technical data sharing implementations.



Examine examples - Upgrade project

seed FOREST

Previous page

Next page

Introduction

This chapter presents a practical case example of Co-AM:
asset lifecycle data management realized in a multi-stakeholder brownfield upgrade project in an industrial context.

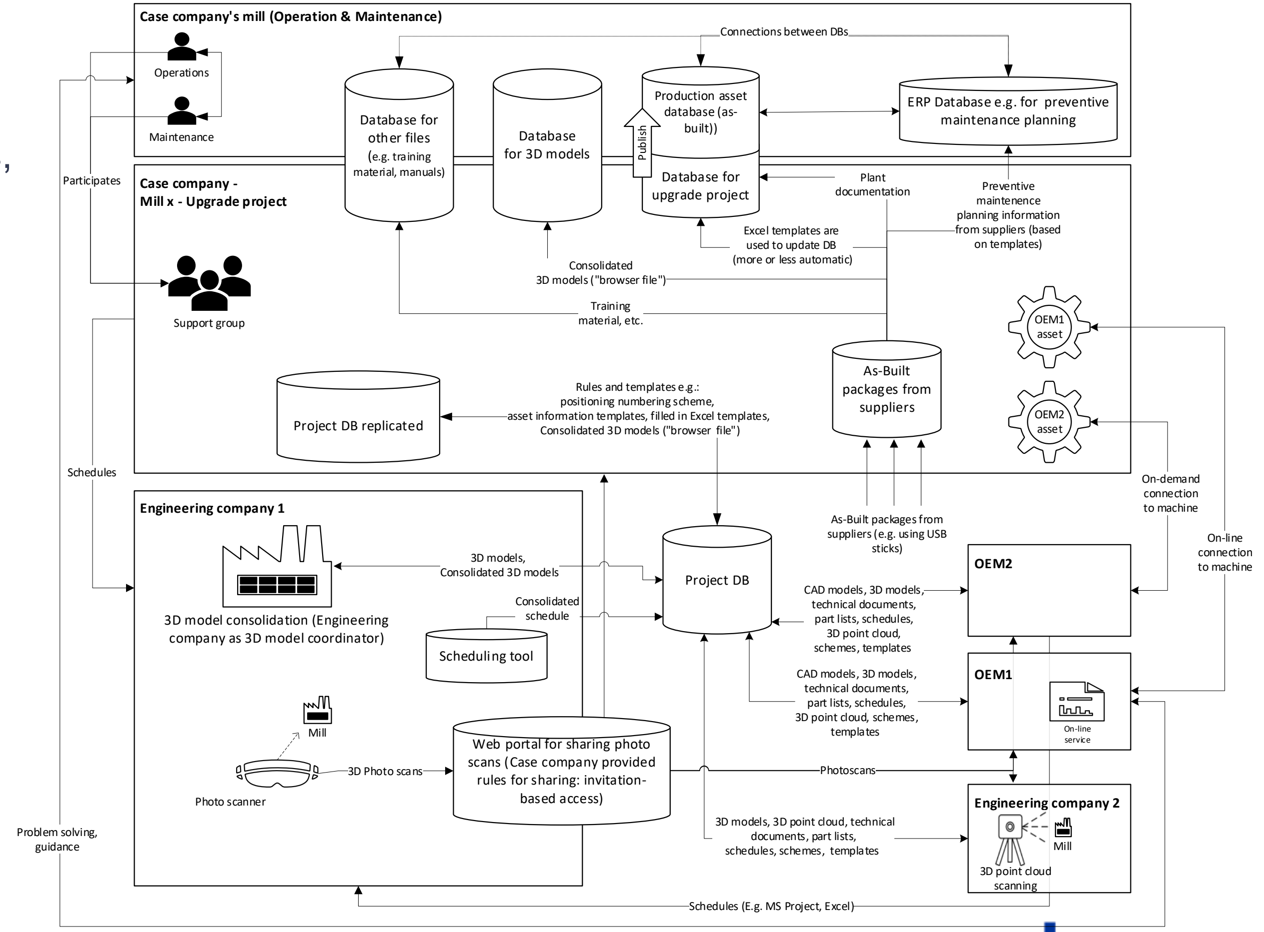
Motivation:
example describes identified best practices and structural challenges of Colife (Co-AM) aligned excellently performed modernization project.

The case example analyses:

- Realization of lifecycle data management in the upgrade project.
- Enabling and hindering factors for Co-AM.
- Business, governance, interoperability, quality and technology aspects related to the case.

Realization of lifecycle data management in the upgrade project

- Shared project data environment (Project DB) enables document management, data sharing and traceability.
- Use of multiple data types and tools: 3D models, point clouds, photoscans supporting collaboration and remote work.
- Structured data collection practices (templates, position numbering) to ensure consistency.
- Final data distributed across multiple systems (asset DB, ERP, DB for 3D models, …) → varying integration levels.



Kääriäinen et al. (2026)

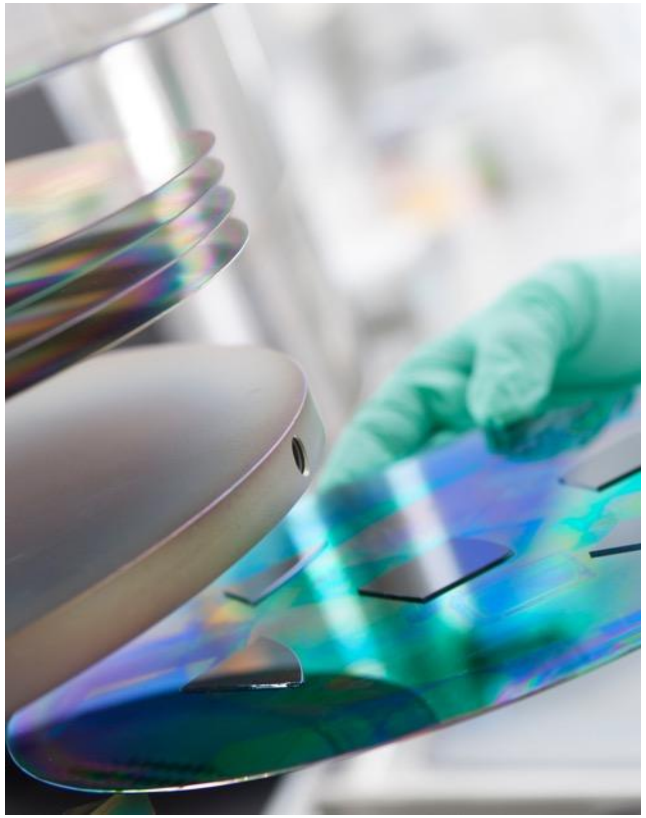
Enabling and hindering factors for Co-AM in the upgrade project

Enabling practices:

- Strong stakeholder involvement (incl. maintenance & operations early) and ”mirrored organizations”
- Shared platform and transparency → “one source of truth”
- Standardized asset identification & templates (position numbering)
- Trust, collaboration, and prior relationships
- Digital tools (e.g. photoscanning) improving collaboration and shared view

Structural challenges:

- Lack of up-to-date baseline data (e.g. outdated 3D models)
- System integration gaps → data silos (especially 3D data)
- Late and incomplete data delivery → high workload peaks
- Inconsistent use of identifiers (position numbers)
- Data quality and metadata issues → difficult to find and use data



Previous page

Next page

Key points related to business, data governance, quality and interoperability and technology in the upgrade project case

	Upgrade project
Business	• Significant increase in the annual capacity of the production line. • Smart automation across the factory's production environment, while also enhancing occupational safety. • Stakeholder mapping. • Data management concept.
Governance (& collaborative culture)	• Long history in collaboration. • Well-aligned working practices. • Ecosystem coordinator (Engineering company). • Participating companies to the upgrade project defined the contact persons for each organizational levels (mirroring organisations). • Contracts. • Strong stakeholder involvement and trust
Quality / interoperability	• Shared project database. • Standardized asset data templates. • Positioning numbering scheme. • Asset data database integration. • Connections to assets (on-line, on-demand).
Technical	• Shared digital practises. • Technical architecture presented in slide 80.

Examine examples – Federated learning in collaborative asset lifecycle management

What is federated learning

Collaborative training without data sharing

Federated learning enables multiple participants to train a shared machine learning model while keeping raw data local, enhancing privacy.

Model moves to data

Unlike centralized machine learning, federated learning moves the model to data locations, avoiding raw data transfer centrally.

Privacy and security nuances

Federated learning reduces raw data exposure but does not eliminate all privacy or security risks in collaborative AI.

Collective benefit vs coordination

Participants must weigh the benefits of joint machine learning model improvements against the effort and complexity of coordination.

How federated learning works

Initial model distribution

Federated learning begins with distributing a shared model to multiple participating nodes for local training.

Aggregation and redistribution

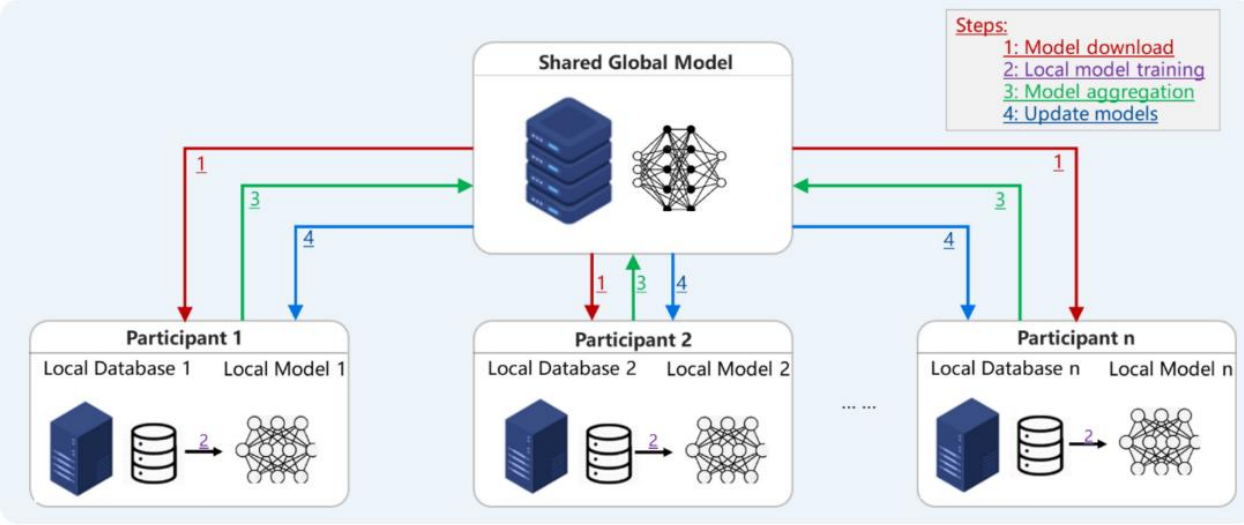
A central server aggregates updates into a global model and redistributes it to participants for the next training round.

Local training and update sharing

Participants train locally on their own data and send only model updates to a central coordinator, preserving data privacy.

Orchestration and challenges

Effective orchestration addresses communication frequency, participant selection, privacy, and resource constraints.



Key principle:

Collaboration happens through model training, not through raw-data pooling.

Leng, J. et al. (2025) "Federated learning-empowered smart manufacturing and product lifecycle management: A review," Advanced Engineering Informatics, 65, p. 103179. Available at: https://doi.org/10.1016/j.aei.2025.103179.

seed FOREST

Relevance for collaborative asset lifecycle solutions

Common features:

- data is distributed across multiple actors' sites, or systems
- no single party has the full picture
- joint learning could create more value than isolated local models
- raw-data sharing may be difficult or undesirable

Areas for federated learning:

- asset performance management
- smart manufacturing
- predictive maintenance
- product lifecycle management
- manufacturing supply chains

Where federated learning can create value

Quality related tasks

Defect prediction, defect detection, process quality modelling through diverse data across organizations.

Operation and maintenance

Machinery fault diagnostics, anomaly detection, predictive maintenance with distributed rare failure data.

Product lifecycle management

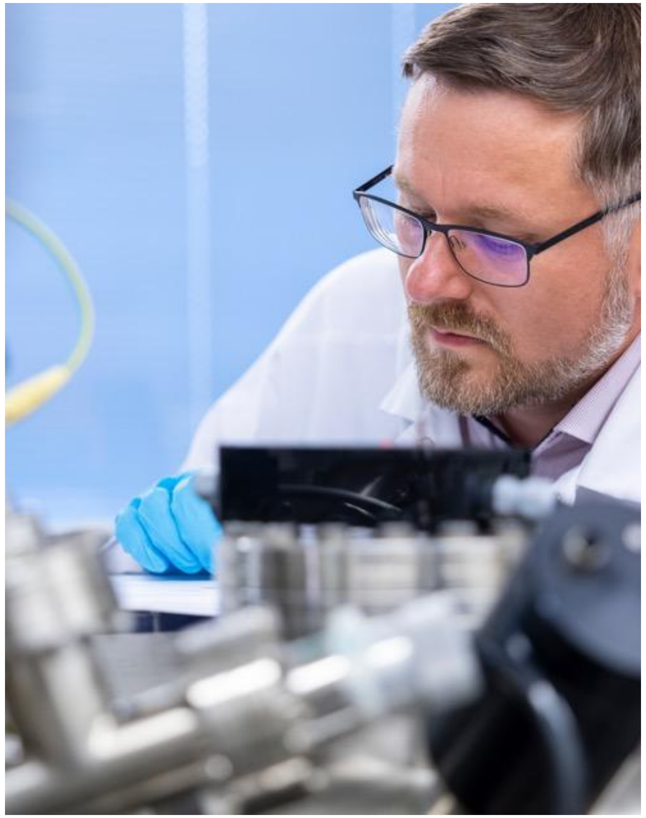
Demand forecasting, logistics, traceability, recycling and remanufacturing.

Collaborative data use

Stronger models by learning together without sharing raw data centrally.

Expected benefits

1. **Better models from distributed experience:** Multiple studies show FL can outperform isolated local models by learning across distributed sites, assets, or organizations.
2. **No need to pool raw operational data:** The core benefit across the studies is collaborative learning with local data remaining under the control of each participant.
3. **Potential to approach centralized-learning performance:** In the Bosch production-line case, FL and centralized learning were not significantly different on the studied evaluation settings.
4. **Can improve efficiency when well designed:** Aggregation design matters; improved methods reduced training iterations and improved performance in diagnosis studies.



Coordination needed

Federated learning does **not** remove the need for coordination.

It changes:

- **What** is shared
- **How** collaboration happens
- **Where** training takes place

It does not automatically solve:

- Governance
- Trust
- Compliance
- Data quality issues

Key limitations

Data heterogeneity is a major issue:

Clients may have different fault classes, different operating conditions, or different feature spaces; this can degrade FL aggregation.

Data quality and noise still matter:

Poor-quality or noisy local data can harm the shared model if aggregation is not robust.

Limited labels are common in industrial settings:

Rare failures and expensive labelling make pure supervised learning difficult; some studies addressed this with self-supervised or semi-supervised extensions.

FL does not remove governance and validation needs:

Coordination, trust, compliance, and validation remain important.

Is federated learning relevant in your ecosystem?

	Upgrade project
Business readiness	• Would joint learning create significantly better outcomes than isolated analytics? • Are rare failures distributed across multiple actors? • Could collaborative machine learning improve maintenance, quality or lifecycle optmisation? • What ecosystem-level value could shared intelligence bring? • Is there a coordinator actor? • Is there a common business objective? • Are incentives aligned?
Governance (& collaborative culture)	• Can partners agree on machine learning model governance? • Are responsibilities and liabilities defined? • Is trust sufficient for collaborative machine learning applications? • Can participation rules be agreed? • Is long-term collaboration realistic?
Quality / interoperability	• Is local data available in suitable format? • Are asset identifiers compatible? • Is metadata sufficiently harmonised? • Is data quality sufficient for analytics?
Technical	• Are local compute resources available? • Are secure interfaces available? • Can model updates be exchanged securely? • Is orchestration capability available?

References

Review the basics

- Hanski et al. (2012) Development of knowledge-intensive product-service systems https://publications.vtt.fi/pdf/technology/2012/T21.pdf
- ISO 55000:2024 (2024) Asset management — Vocabulary, overview and principles.
- ISO 55013:2025 (2025) Asset management — Guidance on the management of data assets.
- Korolainen, R. & Ojanen V. (2026) Unpacking the Concept of Data Economy. Proceedings of the XXXVII ISPIM Innovation Conference, Granada, Spain, Jun. 7–10, 2026.
- Kortelainen et al. (2023) Knowledge-Based Life Cycle Management. https://cris.vtt.fi/en/publications/knowledge-based-life-cycle-management-2/
- Kääriäinen et al. (2026) Collaborative lifecycle data management of production assets: a case study of an upgrade project from the forest industry. Presented at Euromaintenance conference in Luleå at 23.-25.6.2026.

Towards Co-AM environment

- ISO 55000:2024 (2024) Asset management — Vocabulary, overview and principles.
- Valkokari, P., & Kääriäinen, J. (2025). Colife konseptin elementtien tunnistaminen teollisuuden omaisuudenhallinnassa (Identifying elements of the Colife concept in industrial asset management). Promaint, (4/2025), 44. https://www.promaintlehti.fi/lehtiarkisto/?issue=339.

Examine Co-AM in your context

- Rantala, T., Kääriäinen, J., Hatara, E., Valkokari, P., & Kokkonen, K. (2025). Innovating data-sharing concept for industrial asset lifecycle: challenges and opportunities. In I. Bitrain, S. Conn, A. Mitsis, P. Ritala, M. Torkkeli, & M. Trabelsi (Eds.), Proceedings of the XXXVI ISPIM Innovation Conference International Society for Professional Innovation Management ISPIM.

Examine examples

- Kääriäinen et al. (2026) Collaborative lifecycle data management of production assets: a case study of an upgrade project from the forest industry. Presented at Euromaintenance conference in Luleå at 23.-25.6.2026.
- Leng, J. et al. (2025) “Federated learning-empowered smart manufacturing and product lifecycle management: A review,” Advanced Engineering Informatics, 65, p. 103179. Available at: https://doi.org/10.1016/j.aei.2025.103179.
- Ge, N. et al. (2022) “Failure prediction in production line based on federated learning: An empirical study,” Journal of Intelligent Manufacturing, 33(8), pp. 2277–2294. doi:10.1007/s10845-021-01775-2.
- Geng, D. et al. (2022) “Bearing fault diagnosis based on improved federated learning algorithm,” Computing, 104, pp. 1–19. doi:10.1007/s00607-021-01019-4.
- Jiang, G. et al. (2024) “A Federated Learning Framework for Cloud–Edge Collaborative Fault Diagnosis of Wind Turbines,” IEEE Internet of Things Journal, 11(13), pp. 23170–23185. doi:10.1109/JIOT.2024.3387417.
- Landau, D. et al. (2026) “Federated learning framework for collaborative remaining useful life prognostics: An aircraft engine case study,” Future Generation Computer Systems, 174, p. 107945. doi:10.1016/j.future.2025.107945.
- Zhang, W. et al. (2021) “Federated learning for machinery fault diagnosis with dynamic validation and self-supervision,” Knowledge-Based Systems, 213, p. 106679. doi:10.1016/j.knosys.2020.106679.

Identify your business opportunities

- Adner R & Kapoor R (2010) Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations. Strategic Management Journal 31(3): 306–333.
- Dormeier C, Mindt N, Niemeyer JF, Asghari R & Mennenga M (2024) Review and framework for the engineering of Business Models for Sustainability: A System of Systems perspective. Sustainable Production and Consumption 51: 1–22.
- Manninen K, Laukkanen M & Huiskonen J (2024) Framework for sustainable value creation: a synthesis of fragmented sustainable business model literature. Management Research News 47(1): 99–122.
- Jacobides MG, Cennamo C & Gawer A (2018) Towards a theory of ecosystems. Strategic Management Journal 39(8): 2255–2276.
- Springer V, Randhawa K, Jovanović M, Ritala P & Piller FT (2025) Platform design and governance in industrial markets: Charting the meta-organizational logic. Research Policy 54(6): 105236.
- Teece DJ (2007) Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strategic Management Journal 28(13): 1319–1350.
- Tura N, Kutvonen A & Ritala P (2018) Platform design framework: conceptualisation and application. Technology Analysis & Strategic Management 30(8): 881–894.
- Xu D, Indulska M, Asadi Someh I & Shanks G (2024) Time to reassess data value: The many faces of data in organizations. The Journal of Strategic Information Systems 33(4): 101863.
- Bocken, N.M.P., De Pauw I, Bakker C & Van Der Grinten B, (2016) Product Design and Business Model Strategies for a Circular Economy. : Informa UK Limited.
- Hahn, T. et al. (2014) Cognitive Frames in Corporate Sustainability: Managerial Sensemaking with Paradoxical and Business Case Frames. The Academy of Management review. [Online] 39 (4), 463–487.
- Adner R (2017) Ecosystem as Structure: An Actionable Construct for Strategy. Journal of Management 43(1): 39–58.

seed FOREST

Authors (1/2)

Jukka Kääriäinen is a senior research and development professional with a strong background in digitalisation, digital transformation, governance, configuration management and lifecycle management. Over his 27-year career at VTT, he has served as a researcher, coordinator, project manager and work package leader in numerous national and European R&D projects, including ITEA, ITEA2, EU, VN-TEAS, Artemis, Business Finland and ERDF initiatives. He holds a PhD (2011) and a Licentiate degree (2007) in Information Processing Science from the University of Oulu.

ORCID https://orcid.org/0000-0001-5611-1509
https://www.linkedin.com/in/jukka-kaariainen/

Jyri Hanski. D.Sc. (tech) Jyri Hanski is a senior scientist at VTT. He also holds the title of docent at LUT-University. His research focuses on sustainability related aspects including circular economy, economic sustainability assessment, critical raw materials, climate change adaptation and asset and lifecycle management. He has worked in and led various EU and nationally funded projects with manufacturing, process industry, ICT and infrastructure companies.

ORCID https://orcid.org/0000-0002-8146-280X
https://cris.vtt.fi/en/persons/jyri-hanski/

Ella Hatara. Ella Hatara is a research scientist at VTT. She uses a holistic approach to sustainability matters, including many aspects such as circular economy, emissions, design for sustainability and corporate responsibility. Her main goal is to pursue a systemic sustainability transformation with the help of data and digital solutions. One of the main focus areas of her research is to turn data into effective actions towards sustainability within the value chains.

ORCID 0009-0002-1394-7482
https://cris.vtt.fi/en/persons/ellahatara

Anne Immonen. Ph.D. Anne Immonen is a senior scientist at VTT. Over her 25-year career at VTT, she has worked in various EU and nationally funded projects and collaborated with companies from ICT, energy, logistics, forest industry and public sectors. Her main research interests include service and data ecosystems, data sharing, data quality evaluation, and data-based services.

ORCID https://orcid.org/0000-0003-2970-5859
https://cris.vtt.fi/en/persons/anne-immonen/

Kirsi Kokkonen is an Associate Professor at LUT University. Her research interests include e.g, data-driven industrial services, lifecycle business, value co-creation in networks and business ecosystems, and SME collaboration. She has experience as a researcher, project manager and principal investigator in several national and international research projects implemented in close collaboration with companies from manufacturing, forest and maritime sectors.

ORCID https://orcid.org/0000-0002-9240-9123
https://www.lut.fi/en/profiles/kirsi-kokkonen

Mehdi Moomivand is a doctoral researcher at LUT University, Finland. His work focuses on circular business models and sustainable innovation in industrial systems. He is involved in research projects examining business transformation in the context of the circular economy. His research interests include innovation management and sustainable value creation. Mehdi collaborates with academic and industry partners, contributing to applied research on advancing sustainability and innovation practices.

ORCID https://orcid.org/0009-0003-3959-6462
https://www.lut.fi/en/profiles/mehdi-moomivand

Authors (2/2)

Erkki Siira works as a Senior Scientist at the VTT Technical Research Centre of Finland. He comes from the strong ICT background. He has long experience in digitalization of different domains - especially in data sharing architectures. Domains include Smart cities, mobile work machines, water and forestry. His work is currently focusing on renewal of Finnish industry and how intraorganizational data sharing could create data economy and create new business and increase efficiency.

ORCID https://orcid.org/0000-0002-2127-9982
https://cris.vtt.fi/en/persons/erkki-siira/

Nina Tura is an Associate Professor at LUT University, Finland, holding a title of docent in Innovation Management and Sustainable Development. Her research focuses on sustainability-oriented innovation, ecosystems, circular economy, sustainable value creation, business models, and strategic management. Recently, her work has increasingly addressed sustainability leadership and twin transition. In addition to academic publishing, supervision, and editorial work, she collaborates actively with industry and serves as Head of the Master's Programme in Global Management of Innovation and Technology at LUT University.

ORCID https://orcid.org/0000-0002-0803-469X
https://www.lut.fi/en/profiles/nina-tura

Teuvo Uusitalo. Teuvo Uusitalo is a Senior Scientist at VTT specializing in circular economy, sustainability assessment, and data-enabled industrial transformation. His expertise includes impact assessment, techno-economic and sustainability evaluations, critical raw materials, and asset lifecycle management. He has extensive experience in European collaborative research projects developing data-driven solutions for sustainable value creation across industrial ecosystems.

ORCID https://orcid.org/0000-0001-5667-5777
https://cris.vtt.fi/en/persons/teuvo-uusitalo/

Pasi Valkokari. Pasi Valkokari is a Senior Scientist at VTT specializing in asset management, techno-economic risk management, industrial services development and industrial circular economy. His recent work experience has been gained from managing co-funded research projects, such as Solid Value of Digitalisation in Forest Industry - SEED, Hydrogen Underground - HUG and Data economy in collaborative asset lifecycle solutions - Colife.

https://cris.vtt.fi/en/persons/pasi-valkokari/

Yan Xin. Yan Xin is a post-doctoral researcher at LUT University. Her research focuses on knowledge management and sustainability, with particular emphasis on circular economy, product lifecycle management, business model development, and knowledge management in product–service systems. She has contributed to various projects in collaboration with manufacturing firms, ICT companies, and public service partners.

ORCID: https://orcid.org/0000-0003-1806-1904
https://www.lut.fi/en/profiles/yan-xin