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Innovating data-sharing concept for industrial asset lifecycle: challenges and opportunities

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Abstract: This article aims to innovate a concept that promotes data sharing in industrial asset lifecycle management. The research identifies different actor roles and reveals data-sharing challenges and opportunities within the asset management ecosystem. A qualitative case study was conducted in the industrial asset management sector, based on semi-structured interviews with 23 representatives of seven companies. These companies are associated with industrial assets in the forestry sector and involve stakeholders responsible for the lifecycle management of these assets. The identified challenges related to data sharing include technical limitations, problems with data quality and security, inadequate organizational models and lack of understanding of the value of data. The opportunities range from process improvements and asset maintenance to advances in sustainability and entirely new business prospects. The concept offers insights into innovations in industrial asset management and enhanced collaboration through data sharing.

Keywords: asset management; asset lifecycle; data utilisation; data economy; Colife concept

1 Introduction

Collaboration and data sharing among asset owners, operators and service providers are crucial for improving efficiency and creating value in capital-intensive industries such as forestry, process, mining and energy industries. These industries rely on complex

solutions with long lifecycles. In this context, there is a growing need for close, sustainable and fair collaboration and data sharing. Currently, only a few large organisations are able to share their production asset data with other organisations.

Asset management (AM) describes an organisation's coordinated activities to derive benefits from its assets. An asset is an item, thing or entity that has a potential or actual value to an organisation (ISO 55000, 2024). Implementing a data economy for AM and asset maintenance faces some challenges, including organisational complexities, financial concerns, security and privacy issues, regulatory compliance, customer expectations, digital talent acquisition, return on investment (ROI) assessment and environmental sustainability (Global Forum on Maintenance & Asset Management [GFMAM], 2024). However, common data sharing holds a lot of unlocking potential, such as improvements in processes and asset maintenance, advances in sustainability and completely new businesses for companies. Thus, there is a need to examine how companies could share and utilise their asset data for better value realisation. In this article, in addition to **identifying challenges and opportunities, we innovate, discuss and illustrate the common data-sharing concept for asset lifecycle management.** We present the asset lifecycle data-sharing ecosystem concept (referred to as the Colife concept in this paper), which fosters data sharing in collaborative AM, that is, in an organisation's coordinated activities to obtain maximum value from its assets.

2 Literature review

Innovating future asset lifecycle management

AM contributes to organizational objectives and sustainability by planning, creating and preserving value from the total asset lifecycle (ISO 55000, 2024). Its focus is broader than that of the traditional maintenance management process, where assets are mainly studied during the operational phase. AM concentrates on decision-making throughout the lifecycle of a physical asset, from its creation or acquisition to its use, maintenance and renewal or disposal (Parra et al., 2021). Due to the long lifecycle of a production asset, the various decisions related to it are also diverse, from investment decisions in the beginning of life (BoL) phase to reconfiguration decisions in the middle of life (MoL) phase and, finally, to reuse or refurbish decisions in the end of life (EoL) phase (Polenghi et al., 2019). Therefore, AM helps in orchestrating not just the maintenance and operation phases of the assets but also their design and commissioning/decommissioning (Polenghi et al., 2019).

In this paper, innovation can be viewed from two distinct perspectives. First, innovation can pertain directly to AM itself, including the advancement of industrial assets and their lifecycle management. Second, innovation can be observed from a collaborative standpoint, such as developing new data-sharing concepts, like the Colife concept in this paper, in conjunction with various stakeholders involved in the AM lifecycle.

There is less literature on innovation from the AM perspective. Extant articles do not necessarily address the management of innovations in industrial assets but use more of a handbook style, for example, focusing on maintenance management. Additionally, the literature on innovating data-sharing models in collaboration with several actors is

scarcely touches on the AM perspectives. Thus, there is a need to innovate AM practices, especially new data-sharing concepts that support all actors throughout the asset lifecycle.

Innovating future asset lifecycle management demands a multifaceted approach that integrates data-driven foresight, circular economy principles and immersive technologies (Table 1). The GFMAM publishes insights on the international situation of for utilising new technologies in the AM field. The GFMAM's (2024) report emphasises maximising an asset's value throughout its lifecycle by evaluating performance, cost and risk. The report highlights the role of emerging technologies, for instance, digital twins (DTs) and artificial intelligence (AI), in enhancing AM. Sustainable practices integrating economic, environmental and social governance are also encouraged. Furthermore, continuous improvement through ongoing analysis and adaptability is promoted. Configuration management ensures consistency and effective change management (GFMAM, 2024). Scheuffele et al. (2024) stress the importance of predictive analytics and data mining in strengthening decision-making, while Koumou and Isafiade (2024) note the transformative potential of immersive technologies such as augmented reality (AR), virtual reality (VR) and extended reality (XR) in real-time data visualisation and interaction. The integration of circular economy principles into AM is becoming increasingly vital (Winterhalter et al., 2023). For example, data-driven maintenance decisions to boost coordination and collaboration across functional responsibilities could improve asset lifecycle management (Hinrichs et al., 2024). Adopting these innovative practices and balancing them with risk management strategies, as Beedles (2020) suggests, will make future asset lifecycle management more efficient, reliable and intelligent.

Innovation in collaboration for data-sharing models has been researched (see, e.g., Adner, 2017; Jacobides et al., 2018). Companies need collaboration to co-develop data-sharing models by aligning their activities and positions within the ecosystem (Adner, 2017). Focusing on mutual agreement regarding data flows and the roles played by each partner is crucial. This collaboration ensures all parties' satisfaction with their positions and the overall structure of data sharing (Adner, 2017). Jacobides et al. (2018) identify modularity as a key enabler of ecosystem emergence, allowing distinct yet interdependent organisations to coordinate without hierarchical control. The cited authors highlight the importance of non-generic complementarities and the creation of roles that face similar rules. Ecosystems add value by enabling managers to coordinate multilateral dependencies through structured roles, avoiding the need for customised contractual agreements (Jacobides et al., 2018).

Table 1 Literature on innovating future perspectives on asset management (AM).

Reference	*Focus of innovation in AM*	*Future perspectives on AM*
Scheuffele et al., 2024 ("Data-Driven Foresight in Lifecycle Management: An Interview Study")	Integration of data-driven methods into lifecycle management to enhance decision-making; focus is more general than only AM	Predictive analytics and data mining will improve efficiency and proactivity.
Hinrichs et al., 2024 ("Data-Driven Decision-Making in Maintenance	Data-driven maintenance decisions to improve the performance of production	Data-driven collaborative solutions can support maintenance, production and

Management and Coordination Throughout the Asset Lifecycle: An Empirical Study")	systems by supporting material, maintenance, asset and production planning to coordinate and collaborate on cross-functional responsibilities	logistics. Internal goal synchronisation, information systems' harmonisation and information visualisation enable data-driven decision-making.
Winterhalter et al., 2023 (*German Standardization Roadmap Circular Economy*)	Circular economy principles and their standardisation perspectives	Integrating circular economy principles into lifecycle management should be considered.
Beedles, 2020 ("Reducing the Risks of Innovation in Asset Management")	Mitigating risks associated with implementing innovative practices	A balanced approach combining innovation with risk management ensures stability and reliability.
Koumou and Isafiade, 2024 ("Asset Management Trends in Diverse Settings Involving Immersive Technology: A Systematic Literature Review")	Exploring the integration of immersive technologies, such as augmented reality (AR), virtual reality (VR), mixed reality (MR) and extended reality (XR), in AM across diverse settings	Increasing integration of immersive technologies such as AR, VR and XR will enhance real-time data visualisation and interaction. The adoption of artificial intelligence (AI) and the Internet of Things (IoT) will drive predictive maintenance and optimise asset utilisation, leading to more efficient and intelligent AM systems.
GFMAM, 2024 (*Digital Transformation in Maintenance and Asset Management)*	Maximising asset value through lifecycle management, leveraging emerging technologies, promoting sustainability and ensuring continuous improvement	Adapting AM practices to address climate change and integrate sustainable development is crucial, while leveraging emerging technologies such as digital twins (DTs) and AI for data-driven decision-making. Continuous improvement and adaptability to evolving organisational environments and stakeholder needs are also essential.
ISO 55000, 2024 (*Asset Management*)	Provides an overview of AM, its principles, and the outcomes and expected benefits of its adoption; introduces the AM system and relevant terminology	Future impacts, risks, uncertainties and opportunities are considered to realise value.
Adner, 2017 ("Ecosystem as Structure: An Actionable Construct for Strategy")	Understanding how ecosystems structure the interactions and roles of different actors to deliver specific value propositions	Structuring ecosystems to facilitate effective collaboration and value co-creation among different actors is important. This process involves aligning activities and roles within the ecosystem to ensure seamless data flows and mutual satisfaction.

Jacobides et al., 2018 ("Towards a Theory of Ecosystems")	Recognising modularity as a crucial factor for the development of ecosystems, enabling different organisations to collaborate without centralised control and establishing defined roles to handle complex interdependencies	Future perspectives emphasise the importance of modularity in enabling ecosystems, allowing distinct organisations' coordination without hierarchical control. Creating structured roles to manage multilateral dependencies and enhance value co-creation is crucial.

Challenges and opportunities of data sharing in asset lifecycle management

AM is one discipline where advances in digitalisation, including the Internet of Things (IoT) and DTs, have brought many opportunities (e.g., Macchi et al., 2018; Moreno et al., 2023; Niskanen, 2022; Polenghi et al., 2019). In their study, Macchi et al. (2018) conclude that DTs can inform AM decision-making throughout the lifecycle of a production asset, for example, regarding designs and configuration options; therefore, DTs can be considered a concept with high potential for AM. Polenghi et al. (2019) highlight the IoT as a necessary foundation for advancing the AM practice. The IoT enables gathering data from different sensors and controllers and passing these to AM operations. This consideration should take into account the fact that data comprise values and observations from selected variables and need to be transformed into information or knowledge that can be utilised (Valkokari et al., 2019). Data are collected from the assets on the shop floor, transformed into relevant information and managed and shared through integrations into the different enterprise-wide solutions. However, this easier collection and utilisation of data enabled by new technologies also brings challenges to AM. Polenghi et al. (2019) emphasise analysing the right data to make the right decisions. It is important to guarantee data quality to avoid passing misleading data that will subsequently be transformed into indicators for decision-making (Polenghi et al., 2019). Hanski (2018) identifies three different decision-making levels for strategic AM - simple, complicated, complex and uncertain - including strategic decision support methods for each level. Complex and uncertain AM decision-making require e.g. analysing risks, benchmarking, scenario building and other advanced analytics to succeed (Hanski, 2018).

In their study of production asset master data management in the pulp and paper industry, Pakkala et al. (2024) report that AM benefits of good quality asset-related data include increased asset availability, more robust performance and decreased costs. Therefore, it is essential for users to rely on the information received from maintenance management systems. High-quality master data are perceived as significant enablers in planning criticality-based maintenance tasks, based on an understanding of failure behaviour and system criticality, and spare parts are managed accordingly (Pakkala et al., 2024).

In practice, factories have systems and production assets; some are newer, while others are older. Thus, legacy systems in factories may limit the possibilities of digitalisation. Schlemitz and Mezhuyev (2024) recommend analysing the current state of production and manufacturing equipment, as well as the interconnectivity of available infrastructure. They point out that the number of legacy systems that need to be integrated should not be underestimated. The business incentives of different suppliers

must also be considered. Some suppliers push their communication protocols as standards to ensure a closed ecosystem and customer retention, which once again hinders interoperability (Schlemitz and Mezhuyev, 2024).

Production AM takes place in a network (ecosystem) formed by various stakeholders, such as industrial customers, asset manufacturers, maintenance service providers and support service providers (Pakkala et al., 2024). For effective AM, data sharing should be smooth among different stakeholders in such an environment, but it faces problems (Metso and Kans, 2017). Metso and Kans (2017) identify an unclear view of the data-sharing process and difficulties in recognising its benefits as barriers to data sharing. When operating in a multistakeholder environment, data security, ownership and sovereignty are issues that may hinder data sharing (Jurmu et al., 2023; Moreno et al., 2023; Niskanen, 2022). This raises the question of establishing secure data streams between the manufacturing shop floor and digital data-driven service providers (Moreno et al., 2023). Interesting international efforts to support this endevour have been the data space approaches (Jurmu et al., 2023). Niskanen (2022) presents the International Data Spaces (IDS) in an experiment to enable secure exchange of data among heterogeneous production machines. Since connectivity on the shop floor is a crucial element in this context, the authors developed the so-called Open Platform Communications Unified Architecture (OPC UA) -compatible IDS connector to enable the link to the production assets. Moreno et al. (2023) examined and piloted the provision of digital data-based services in industry using the DT and data space approaches. They employed a data space solution to implement secure data exchange, allowing the machine manufacturer to sell and provide data-based services in addition to selling the machine, which could generate additional revenue.

3 Research question and methodology

In this paper, we aim to understand the future AM operating environment. Our research questions are as follows: *What kind of future AM operating concept could be envisioned? What kinds of opportunities and challenges can be associated with promoting collaborative production asset data sharing?*

To address these questions, we conducted a qualitative case study by interviewing company representatives. This methodology is suitable for examining complex situations with multiple variables and processes (Yin, 2014). Between October and December 2024, we gathered qualitative data from interviews with 23 representatives from seven companies in the industrial AM sector (Table 2). The companies are associated with industrial asset ecosystem in the forestry sector and involve stakeholders responsible for the lifecycle management of these assets. We selected a diverse group of companies to ensure a comprehensive understanding of the AM landscape.

The scope of the interviews included not only the industrial AM operating environment but also a broader understanding of the companies' businesses, challenges, opportunities and future perspectives. The interviews were recorded, and the interviewers took detailed notes. Lasting approximately 1.5 hours, each interview was conducted by 3–5 interviewers.

Most of the interviewed company representatives completed a questionnaire with open questions regarding their viewpoints on the industrial asset lifecycle management and the common data-sharing concept (actors involved, challenges, opportunities, etc.).

The qualitative interviews allowed us to capture in-depth insights and nuanced perspectives from industry experts. Additionally, the questionnaire responses provided a greater understanding of asset lifecycle management from different actors' perspectives and innovated the Colife concept to complement the interview findings. The combination of interviews and questionnaires helped triangulate the data, enhancing the validity of our study.

The purpose of the study is to understand different actors in the asset lifecycle and their viewpoints and develop a first version of the Colife concept. The future research objective is to innovate the content of the Colife concept collaboratively further.

Table 2 Interviewed representatives of seven companies, their main products and services, number of interviewees and interview dates.

Company	*Industry/main products/services*	*Number of interviewees*	*Interview date*
A	Forest industry	5	8.10.2024
B	Telecommunications	2	11.10.2024
		2	23.10.2024
C	Digital solutions	2	23.10.2024
D	Material handling equipment	1	23.10.2024
		1	6.11.2024
E	Engineering and consulting	5	24.10.2024
F	Inspections, engineering consulting	2	25.10.2024
G	Software	3	19.12.2024

4 Results

Asset lifecycle data-sharing ecosystem

As a result of our study, in this paper, we present the asset lifecycle data-sharing ecosystem concept (Colife concept), consisting of two layers, as shown in Figure 1. The outside rim represents the whole system where different actors of the asset lifecycle data-sharing ecosystem operate. Inside the frame is the industrial system where the customer operates and the physical assets are located. The concept image forms a comprehensive visualisation of the actors in collaborative asset lifecycle management. The participating actors and their roles face potential barriers and challenges related to collaborative asset data sharing, but they also create new opportunities and value in the process.

The Colife ecosystem comprises different actors that have their specific roles and tasks in asset lifecycle management. The Colife actors and their roles are the results of our research and data acquisition during the project. The industrial customer as an asset owner is in the centre of the ecosystem as it uses and manages the physical production assets. The production asset manufacturer not only produces assets and components but can also maintain, remanufacture and refurbish them. The lifecycle service provider is

responsible for maintaining the lifecycle of the assets and offers different types of maintenance services. The ecosystem actors that also participate a lot in the industrial system are the supportive service providers.

Data management and use extend to the ecosystem level and beyond, where the infrastructure provider supplies the tools, cloud services and interfaces for ecosystem operation and management. The ecosystem coordinator engages new partners, communicates with them through the ecosystem and coordinates its activities. It can provide solutions for the ecosystem's AM, inspection services and delivery (or reverse) logistics for assets or spare parts. It also offers engineering and data-related services, as well as enterprise resource planning (ERP) and manufacturing execution system (MES) solutions for the industrial customer. Especially in the context of extending the asset lifecycle and promoting sustainable actions, material and component recycling becomes increasingly important, and different supportive service providers can manage it.

An interviewee states their expectations and hopes regarding the Colife concept:

> "Personally, I'm hoping to explore the Colife concept by practical case examples. It would be intriguing to theorise how the data economy should be set up, for example, in a maintenance shutdown project, which typically involves multiple participants simultaneously. It would also be interesting to speculate how our current inspection activities/services would change if such a data ecosystem would be in place."

The arrows in Figure 1 represent the data flows between the different actors in the Colife ecosystem. The current challenges related to this ecosystem's implementation are presented on the left side of the concept image. The possible opportunities from the ecosystem are shown on the right side of the image.

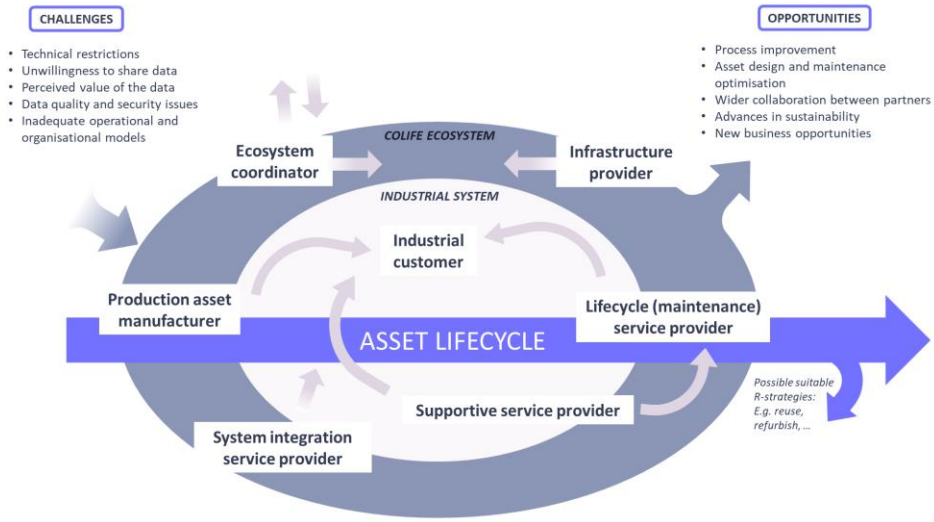

Figure 1 The Colife concept, asset lifecycle data-sharing ecosystem, and related actors, challenges and opportunities.

Challenges related to promoting collaborative production asset data sharing

Some challenges in the context of data sharing and AM are identified, based on stakeholder interviews conducted during the project. These challenges are categorised into five main areas and described in detail in Table 3.

First, the interviewees recognise several *Technical restrictions* related to common data sharing. For example, the legacy systems can pose significant limitations, hindering the effective transformation and integration of data. The availability of suitable data for AM is often restricted, undermining the overall efficiency of data utilisation. Moreover, companies often have multiple document management systems without a master system, leading to inconsistencies across units and countries.

The second category is *Unwillingness to share data*. There is a lack of commitment to data sharing within organisations, influenced by their varying organisational cultures. The companies are concerned about protecting their business interests and areas of expertise, fearing that shared data might fall into the hands of competitors; especially, if information sharing affects a company's business model, it is unlikely to be shared. The companies also fear losing control over the data if these are stored in the cloud. An interviewee clarifies the customer's unwillingness to share data:

> "One important goal is to somehow define how we can get to the data from the customer because that has always been difficult in the past to be let into their system, so to say, and they have been quite reluctant to share data with providers."

The third challenge is related to the *Perceived value of data*. Evaluating the intrinsic value of data presents a significant obstacle introducing uncertainty regarding its potential applications. The interviewees also argue that it is problematic to demonstrate the benefits of data since people are often unsure what they are allowed to do with the data. The difficulty in measuring the ROI in data-driven solutions arises, partly due to disorganised and inaccurate data.

The fourth category is *Data quality and security issues*. Managing the huge amount of raw data and ensuring data security are among the major concerns of the interviewees. They state that the lack of standardisation leads to disorganised and unreliable data, complicating efforts to compare data from different sources. Poor data quality is also a significant obstacle to AI development. Moreover, data privacy and intellectual property rights (IPRs) to sensitive data must be carefully managed. One interviewee gives the following example:

> "Indeed, it would require standardisation to determine what e.g. maintenance actually requires. Because it cannot be the case that the buyer and the supplier speak slightly different languages. The supplier naturally wants to protect their own intellectual property rights (IPR), and the buyer would like to obtain all possible data. Such situations have arisen, and it is not a realistic demand. Therefore, these requirements for information exchange and communication between companies should be set realistically to serve both perspectives."

The last category is *Inadequate operational and organisational models*, which are not deemed to support data-sharing activities. Separate services and project organisations within companies could benefit from documentation during the project phase, but this is

often overlooked. There are uncertainties about data ownership, and inadequate tools in data analytics prevent gaining insights from shared data. Silos within and between companies also seem to exist, preventing effective knowledge and data sharing. According to an interviewee, digital transformation has made companies rely heavily on technology, and organisational practices have often been neglected:

> "Bad quality data results from poor practices. Ultimately, data governance is about fixing those practices, and in doing so, we are deeply involved in the company's change management issues."

Additionally, a company's maturity is determinative; it may have the available advanced technologies but lack the knowledge of how to use them.

Table 3 Identified challenges of common data sharing.

Challenges of common data-sharing concept	
Technical restrictions	Old asset network limits possibilities for new solutions and data sharing
	Clear integrations for different data not yet established
	Good planning and implementation of data management in factory models not guaranteeing data quality over lifecycle if information not transferred during use phase
	Multiple document management systems without a master system; different units and countries use varying systems
	Measurement frequencies not ideal for creating optimal conclusions
	Restricted availability of suitable data for asset management
	Data privacy and protection laws of European Union (EU) must be considered. In some cases, organisational standards or policies must be taken into account.
	Difficulty in validating data source
	Time-related constraints – maintenance shutdown duration
Unwillingness to share data	Challenges in having people and organisations committed
	Everyone selling their own "closed" solutions – no willingness to openly share data
	Manufacturers rarely sharing their expertise with competitors, resulting in single-point models
	Different organisational cultures
	Data-sharing atmosphere not established over value chains
	Economic data challenging to share
	Danger of third-party data ending up in wrong hands
	Information sharing strongly affecting the business model of the company; information will not be shared
	Original Equipment Manufacturers (OEMs) protecting their spare parts business
	Data sharing is deemed to intrude on the privacy of people, trade and other secrets
	Sharing data with competitors is regarded as a risk; companies fear losing their data or their control of these if stored in the cloud
Perceived value of data	Determining data value challenging
	Asset owners not seeing return on investment (ROI) in data-driven business as data should first be organised and accurate
	Scepticism about data's value and demonstrating its concrete benefits
	People unsure about what they can do with the data
	Companies overlook the importance of data
	Intellectual property rights (IPRs) and value of data are muddy topics.
	ROI in data quality not understood

Challenges of common data-sharing concept

Data quality and security issues	Huge amount of raw data challenging to manage
	Data security issues
	Lack of data standardisation; disorganised, scattered and unreliable data
	Comparability challenges of data from different sources
	Defining relevant data
	False comfort regarding data, not based on realities
	Heterogeneity of data from various vendor devices, with only a small percentage supporting standard protocols, such as Open Platform Communications Unified Architecture (OPC UA)
	Company-level restrictions in data usage because of complying with contract terms and conditions as well as maintaining confidentiality
	Poor data quality one of the major obstacles to AI development
	Data privacy and IPR challenges related to sensitive data
Inadequate operational and organisational models	Inadequate operation models reducing data quality
	Silos within and between companies
	Hard to sell data management improvements even with verified savings
	Separate services and project organisations; services could benefit from documentation during the project phase
	Costly data management and collection
	No clear overview of data usage
	Questions on data ownership
	Inadequate data analytics tools preventing insights from shared data
	Data governance should include data quality process
	Some companies adhering to old/more convenient standards; common standards required for interoperability
	Inability to compare between own company and others
	Data must reach a certain level accuracy for data-based services
	Organisations' maturity is determinative; they may have technologies but lack knowledge on usage.

The challenges presented above highlight the complexities and barriers to effective data sharing and utilisation in industrial AM ecosystems. Addressing these issues is crucial for realising the full potential of data-driven strategies and improving overall AM practices.

Opportunities related to promoting collaborative production asset data sharing

Despite the challenges, the interviewees perceive the common data-sharing concept as providing some opportunities. These are also categorised into five main areas and presented in detail in Table 4.

The first category of opportunities deals with *Process improvement*. The interviewees recognise that shared data can, for example, enable aggregation and harmonisation of information from the shop floor, making it useful for asset lifecycle management applications. Shared data can also assist operators in their work by providing usage, maintenance and logistics data-based services. Moreover, production processes can be enhanced for higher efficiency in terms of time, speed, material usage and quality. Implementing preventive measures in operations extends the lifecycle of assets and increases safety. Shared data can also improve maintenance processes, making them more homogeneous and efficient. One interviewee identifies the possibility of

collaborative participants' value-sharing logic for process improvements, especially in maintenance shutdowns:

> "To properly motivate the participants, the value-sharing logic of actors should be tied to the reduced number of leaks and unplanned shutdowns, which pose significant financial and safety risks for paper and pulp mills. Being able to determine the necessary actions before the maintenance shutdowns reduces the need for unexpected work, which is more expensive for the asset owner. The reduction of unexpected work/maintenance shutdown costs could also be part of the value-sharing logic."

Second, several opportunities are identified as related to *Asset design and maintenance optimisation.* For instance, shared data can help in developing long-lasting machines with higher availability. It enables the creation of simulation and predictive models, improving the predictability of industrial asset integrity and extending the assets' remaining useful life and cost-effectiveness, as one interviewee states:

> "There is a business opportunity for … a supplier and for the end customer … designing and developing machines that are better, more durable and have higher availability. This can lead to increased profitability. Additionally, new services, such as remote monitoring of machines, can be offered. There are a lot of opportunities business-wise. Detecting the beginning of a fault in a machine part may make it easier to repair rather than replace it."

Better information about asset integrity can guide the necessary follow-up actions, both upstream and downstream. Additionally, shared data support the implementation of DTs and digital product passports, enhancing overall AM and operational efficiency.

The third category is *Wider collaboration between partners*. The creation of a platform for data sharing and collaboration will foster the development of many-to-many relationships and a more integrated ecosystem. In turn, this will enhance overall efficiency through broader collaboration and sharing of best practices. Additionally, it will facilitate co-learning among companies, leading to improved processes and innovations, as described by an interviewee:

> "The value is precisely that the best practices can be shared and thus a way to learn more quickly. When one company practises something, all others don't need to practise it separately."

Fourth, *Advancement in sustainability* is recognised as one of the most remarkable areas where common data-sharing practices will bring several opportunities for companies in the future. For instance, advancement is expected in circular economy practices, such as reusing, remanufacturing and recycling. Shared data can also lead to a better understanding of companies' sustainability status and optimisation of energy use and supply security. Additionally, improved safety and efficiency are achieved through adherence to sustainability goals. One interviewee identifies the benefits of data sharing from both business and sustainability perspectives:

> "The development of new solutions and services prolongs the remaining useful life of industrial assets, which has a net positive ecological impact as we get the most out of existing resources. Shared data also improve the working efficiency of suppliers and free up resources for less rudimentary activities."

Although all the above-mentioned categories provide opportunities to develop companies' business activities, *new business opportunities* from commonly shared data are also mentioned as a separate category, emphasising completely new opportunities based on new kind of AM data-sharing concept. For instance, the development of asset data as a service is essential for improving efficiency and sustainability. Introducing lifecycle or life extension services can significantly strengthen AM. Current solutions can be further developed with open data and new technologies to optimise processes. Utilising process side streams can lead to innovative solutions for operational enhancements. Furthermore, bolstering services for reusing and recycling contributes to both environmental and economic benefits.

Table 4. Identified opportunities for common data sharing

Opportunities of common data-sharing concept	
Process improvement	Aggregating and harmonising shop-floor data for asset lifecycle management applications
	Using digital twins (DTs) for maintenance optimisation
	Optimising asset lifecycle and reducing operating costs
	Assisting operators in their work (usage, maintenance, logistics data-based services)
	Enhancing production processes to be more efficient in time, speed, material usage and quality
	Implementing preventive measures in operations to extend asset lifecycle and improve safety
	Making maintenance processes more homogeneous and efficient
Asset design and maintenance optimisation	Developing long-lasting machines with higher availability
	Creating simulation/predictive models
	Improving predictability of industrial asset integrity, increasing remaining useful life and cost-effectiveness
	Providing better information about asset integrity for necessary follow-up actions in both directions (upstream and downstream)
	Implementing DTs and digital product passport
Wider collaboration between partners	Creating a platform for data collection
	Sharing best practices and co-learning
	Enabling many-to-many relationships with asset collaboration platform, enhancing overall efficiency
	Allowing operators to collaborate with multiple Original Equipment Manufacturers (OEMs) and service providers in an open network, creating a more integrated ecosystem
Advancement in sustainability	Implementing circular economy solutions (e.g., reuse)
	Understanding sustainability status of companies and ecosystems through modelling/data-based services
	Utilising data and data management to reach resource efficiency goals
	Optimising energy use and ensuring supply security
	Extending product lifecycles through circular economy practices such as reusing, remanufacturing and recycling
	Improving safety and operational efficiency while adhering to sustainable development goals
New business opportunities	Gathering expertise in constant asset maintenance
	Offering data as a service
	Providing contract-based lifecycle services
	Developing new business opportunities using shared data and cutting-edge technologies to improve existing services/solutions

Opportunities of common data-sharing concept
Providing after-sales services
Offering new services from installed base by OEMs
Selling information from assets/facilities and end customers in other regions
Utilising production side streams, such as those from pulp mills; repurposing these streams for internal use or selling to third parties
Providing life extension services for installed assets
Offering service packages for reusing and recycling, particularly in decommissioning stages and recycling construction materials

As noted from the above-mentioned results, common data sharing offers some opportunities, ranging from improvements in processes and asset maintenance to possibilities for added value generation via new business opportunities. Advances in sustainability also enable companies to respond to constantly increasing pressures for sustainable and greener operations. The empirical results indicate the need to further examine the opportunities for sharing data and utilising them for better value realisation.

5 Discussion and conclusions

This article is the first step in envisioning the future concept of the asset lifecycle data-sharing ecosystem (Colife concept). The research goal is to gain an understanding of the challenges and opportunities that such an operating environment poses for AM ecosystem actors – especially from the data-sharing standpoint. The research reveals that a data-based, collaborative asset lifecycle management concept must tackle a wide range of issues during the lifecycle, but it may also enable opportunities such as operational efficiency, sustainability and even an entirely new business. The GFMAM (2024) report also states that maximising asset value during the whole lifecycle can give rise to new opportunities. This is understandable because AM covers the production asset's BoL phase, through the MoL phase, all the way to the reuse or refurbishment decisions in the EoL phase (Polenghi et al., 2019). We have identified a rich set of actors (e.g., industrial customer, production asset manufacturer, maintenance service provider) that participate in the AM activities during the asset lifecycle (cf. Pakkala et al., 2024). This actor network can be viewed from an ecosystem perspective (Metso and Kans, 2017) or from collaborating data-sharing models (Adner, 2017; Jacobides et al., 2018). These actors produce, share and use data related to production assets for a variety of tasks in this environment. However, smooth and value-creating sharing of data is not self-evident but needs to tackle several challenges in the industrial AM environment. To create such value, high-quality data must first be collected and shared in the AM ecosystem. These data can then drive decision-making that supports AM activities, such as maintenance (Hinrichs et al., 2024). However, data availability is affected by the diversity and limitations of legacy equipment and IT systems. This issue has also been noted by Schlemitz and Mezhuyev (2024), who state that when considering improvement actions, the current state of production and manufacturing equipment and the connectivity opportunities of the available infrastructure must be analysed first. The quality of the dataset itself must be excellent so that it can be reliably used for decision-making. The quality of the production asset data is also emphasised for operational effiency by Pakkala et al. (2024).

The challenges identified in our research are not only technical, but some organisational and individual aspects are also raised, such as unwillingness to share data, inadequate operational and organisational models, and companies' inability to recognise the value of the data. Ecosystem actors may have concerns and fears about losing control of their own data if these are shared in the AM ecosystem. This matter is related to building trust and mutual agreement in the ecosystem; distrust (Metso and Kans, 2017) and lack of mutual agreement (Adner, 2017) are huge barriers to sharing data with other actors. This relevant concern has been discussed a lot recently, resulting in the data space approach, which aims to provide mechanisms for data sovereignty (Jurmu et al., 2023; Moreno et al., 2023) – that is, organisations should have control over their data, how these are collected, stored, shared and used by others (International Data Spaces Association, 2025).

The opportunities offered by shared data in the AM ecosystem range from process improvements and asset maintenance to prospects for generating added value through new business opportunities. According to the interviews, if asset data are mobilised and managed, these can be utilised, for example, in DT solutions to support the maintenance of production assets. Such use of DT solutions has been perceived as a high-potential concept for industry (Macchi et al., 2018). Another important topic that emerged in the interviews is the potential for sustainability advancements in the AM ecosystem. These include aspects such as recycling, reusing and remanufacturing but require the collection and management of lifecycle data (Kortelainen et al., 2015) in the AM environment.

This article contributes to the research of innovation in data-sharing in AM ecosystem by innovating and presenting the first elaboration of the Colife concept, which fosters data sharing in collaborative asset lifecycle management. The concept identifies different actors and their roles and outlines the related challenges and opportunities. The research also provides insights into the current state of innovation in AM and the potential for improvements through enhanced collaboration and data sharing.

The practical implications of this research are significant for industries relying on complex production assets with long lifecycles. Such industries can leverage this study's results to understand the challenges and opportunities for collaborative asset lifecycle management and innovation of their own solutions as well as data-sharing practices.

This research is the first step towards the Colife concept, which will be refined in future research. The research focuses on the case of the forest industry. Thus, the results have not been applied to other industrial sectors, but it will be an interesting topic for further research. For example, what kinds of special issues does the industrial domain bring to the collaborative production asset lifecycle management?

By implementing the Colife concept, organisations can improve their operational efficiency and create added value through better collaboration and data sharing. In turn, all these can lead to increased asset availability, more robust performance and decreased costs. Finally, the research highlights the importance of high-quality master data and the need for secure data streams across stakeholders.

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